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FUNCTIONAL CAPABILITY CRITERIA FOR ESSENTIAL MARK II PIPING

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NOMENCLATURE

B_1 = pressure loading index

B_2 = moment loading index

B_{2b} = moment loading index, moments applied to branch pipe

B_{2r} = moment loading index, moments traversing run pipe

C_{2b} = moment loading index, moments applied to branch, pipe, see Code Table NB-3682.2-1

C_{2r} = moment loading index, moments traversing run pipe, see Code Table NB-3682.2-1

D = mean diameter of pipe, of run pipe for branch connections and tees

D_o = outside diameter of pipe, of run pipe for branch connections and tees

d = mean diameter of branch pipe

h = $4tR/D^2$, elbow parameter

i = stress intensification factor, see Code Figure NC-3673.2(6)-1

K_d = S_m/S_y

K_β = S_h/S_y

M = moment

M^* = M_L/M_{C4}, M_{C4} calculated by equation 4 of NUREG/CR-0261

M_2 = test-determined limit moment at $\delta = 2\delta_c$

M_b = moment applied to branch, see footnote (5) to Code Table NB-3682.2-1

M_{C1} = code allowable moment, Class 1, Equation (9) of NB-3652 with right-hand-side limit of S_y

M_{C2} = code allowable moment, Class 2, Equation (9) of NC-3652.2 with right-hand-side limit of S_y

M_{f1} = functional capability antenna allowable moment, Class 1, with right-hand-side limit of S_y

M_{f2} = functional capability criteria allowable moment, Class 2/3, with right-hand-side limit of S_y

M_i = resultant moment (see Code definitions for details)

M_L = test-determined limit moment

M_{max} = maximum load applied during a test

M_x, M_y, M_z = set of moments applied on elbow, see Figure 9a of NUREG/CR-0261

M_{x3}, M_{y3}, M_{z3} = set of moments applied to branch pipe, see Table NB-3682.2-1

P = internal pressure, see pages 2 and 4 for criteria definition

R = bend radius of an elbow

R_m = mean radius of run pipe, see Figure NB-3686.1-1

NOMENCLATURE (Continued)

S_n = allowable stress, tabulated in Code Table I-7.0

S_m = allowable stress intensity, tabulated in Code Table J-1.0

S_y = yield strength of material.
In test evaluations, S_y is the actual yield strength of material used in the test specimens.

T = temperature (deg. F) in the criteria

T_r = wall thickness of run pipe, see Figure NB-3686.1-1

t = nominal wall thickness of pipe (branch pipe for branch connections and tees), see NB-3683.1

T_g = lesser of T_r or (i)(t)

Z = section modulus of pipe

α = multiplier of S_m to define right-hand-side of Equation (9) in NB-3652

α_o = arc angle (degrees) of an elbow

β = multiplier of S_n to define right-hand-side of Equation (9) in NC-3652.2

δ = displacement in test

δ_e = extrapolated elastic displacement in test

ABSTRACT

This report addresses the functional capability of essential piping. Functional capability criteria are presented. These criteria are based principally on data contained in NUREG/CR-0261. The criteria make use of equations and definitions given in the ASME Code but give limits in terms of material yield Strenght (S_y). The functional capability criteria presents combinations of limits, stress indices and stress intensification factors such that functional capability is assured. The criteria are supplimental requirements and are not intended to supersede ASME Code requirements.

SUMMARY

This document gives "Functional Capability Criteria" for the evaluation of piping in Mark II nuclear power plants. The criteria were selected to be conservative and yet avoid excess conservatism where possible to assist in assuring maximum reliability of piping considering all aspects of design, fabrication, in-service inspection and operation.

The criteria discussed in this document are structured to make maximum use of the equations and definitions contained in the Code.* However, the functional capability criteria are not intended to be substituted for or supercede any requirement of the Code.

These criteria are based mostly on the conservative approach contained in NUREG/CR-0261; i.e., on the single-hinge, limit moment concept with little or no consideration of strain hardening or dynamic effects. Recommendations or concepts given in NUREG/CR-0261 for B-indices are also used. For elbows with a $\alpha_o < 90^o$, excess conservatism has been avoided by using the recommendations given in Reference 2. The criteria uniformly uses a right-hand-side limit of $1.5S_y$ or $2.0S_y$ rather than the less-applicable factors on S_m or S_h as used in the Code for A, B, C, or D Limits.

For the ratio of $D_o/t > 50$, the allowable moments are decreased by increasing the B_2 indices and equivalents of (0.75i). This is based on test data on straight pipe of ferritic materials at room temperature with a temperature factor based on ratios of allowable longitudinal compressive stresses from Reference 3.

Dynamic effects may make the criteria very conservative when used for conditions where the loadings are dynamic in nature.

*The term "Code" used in this document is the ASME Boiler and Pressure Vessel Code, Section III, Division 1, "Nuclear Power Plant Components," 1977 Edition with Addenda up to and including Summary 1978. References to portions of the Code are indicated by identification used therein; e.g., NB-3652.

1. INTRODUCTION

Functional capability of piping is defined as its fluid-flow capability. The functional capability of piping may be impaired by large reductions in the cross-sectional flow area and the criteria given in this document were selected to assure that significant reductions in cross-sectional area do not occur.

The criteria given in this document were selected to be conservative* when used with an elastic analysis of piping systems. It may be possible to show that functional capability is assured by using more sophisticated analysis techniques, such as determining loads to produce a collapse mechanism, or by conducting an elastic plastic analysis. The criteria contained herein are not to be construed as prohibiting more sophisticated analysis methods.

The criteria identified in this document are listed in Section 2. The basis for the criteria is discussed in the remainder of this document.

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*The term "conservative" means more-than-adequate for the specific aspect of functional capability. However, excessive conservatism in any one aspect of designing a piping system (e.g., in postulation of loads, combination of loads, combinations of stress, etc.) does not necessarily mean that the piping system will be of optimum reliability. Excess conservatism may require unnecessary snubbers or supports, that must be attached to the pipe, with potential problems at the attachment points, reduced inspectibility and the possibility of additional loads due to malfunction of snubbers or to the mass of snubbers. Therefore, each aspect of design should be as accurate as possible so that the final design is of optimum reliability.

The criteria are structured to make maximum use of the equations and definitions contained in the Reference 1. However, the functional capability criteria given in this document are not intended to be substituted for or supercede any requirement of the Code. These criteria are for functional capability and do not depend upon Service Levels (i.e., A, B, C or D) used in the Code.

2. FUNCTIONAL CAPABILITY CRITERIA

2.1 CLASS 1 PIPING

Equation (9) of NB-3652 shall be satisfied with the following requirements:

a. The right-hand-side of Equation (9) shall be $1.5S_y$ for products other than branch connections or tees, and shall be $2.0S_y$ for branch con- nections or tees.

b. The B-indices shown in Table 1 shall be used.

c. For $D_o/t > 50$, B_2, B_{2b}, and B_{2r} shall be divided by;

$(1.3 - 0.006\ D_o/t)(1.033 - 0.00033T)$ for ferritic materials, and by $(1.3 - 0.006\ D_o/t)$ for other materials.

The indices are not applicable for $D_o/t > 100$.

Table 1

B-INDICES FOR FUNCTIONAL CAPABILITY EVALUATION, $D_o/t \leq 50$, FOR USE IN EQUATION (9) OF NB-3652, CLASS 1 PIPING

Piping Products or Joints	B_1	B_2
Straight Pipe[a]	0.5	1.0
Curved Pipe or butt-welding elbows per ANSI B16.9, ANSI B16.28, MSS SP-48 or MSS SP-87	(-0.1 + 0.4h), but not less than 0.0 or greater than 0.5. For B_2 = 1.0, B_1 = 0.5.	$\alpha_o \geq 90^o$, $1.3/h^{2/3}$ $\alpha_o = 45^o$, $1.17/h^{0.56}$ $\alpha_o = 0^o$, 1.0 } but not less than 1.0
Branch Connections per NB-3643	0.5 except if either B_{2b} or B_{2r} is 4/3, B_1 = 2/3	$B_{2b} = 0.50\ C_{2b}$, but not less than 4/3 $B_{2r} = 0.75\ C_{2r}$, but not less than 4/3
Butt-welding-tees per ANSI B16.9, MSS SP-48 or MSS SP-87	0.5 except if either B_{2b} or B_{2r} is 4/3, B_1 = 2/3	$B_{2b} = 0.40\ (R_m/T_r)^{2/3}$, but not less than 4/3 $B_{2r} = 0.50\ (R_m/T_r)^{2/3}$, but not less than 4/3
Butt-welding reducers per ANSI B16.9, MSS SP-48 or MSS SP-87	1.0	1.0
Girth fillet weld to socket weld fittings or valves, slip-on flanges, or socket welding flanges	0.50	1.0

[a] Applicable to all piping products/joints which have B_1 = 0.5, B_2 = 1.0 in Table NB-3682.2-1.

d. The definitions given in NB-3652 are applicable except that:

(1) P is the pressure coincident with the moments, and

(2) S_y is the yield strength of the product material at the metal temperature, T (deg. F), coincident with the occurrence of the loads; from Table I-2.

(3) α_o = arc angle (degrees) of an elbow

Table 2
VALUES TO BE USED IN PLACE OF (0.75i) FOR FUNCTIONAL CAPABILITY EVALUATION, $D_o/t \leq 50$, FOR USE IN EQUATION (9) OF NC-3652.2, CLASS 2 OR 3 PIPING

Description[a]	(0.75i)
Straight Pipe[b]	1.0
Welding elbow or pipe bend	$\alpha_o \geq 90^\circ$, $1.3/h^{2/3}$ } but not less than 1.0 $\alpha_o = 45^\circ$, $1.17/h^{0.56}$ } but not less than 1.0 $\alpha_o = 0^\circ$, 1.0 } but not less than 1.0 Interpolate linearly for other values of α_o.
Reinforced fabricated tee	0.75i, but not less than 1.0. Use i as defined in Figure NC-3673.2(b)-1
Unreinforced fabricated tee	0.75i, but not less than 1.0. Use i as defined in Figure NC-3673.2(b)-1
Welding tee per ANSI B16.9	0.90i, but not less than 1.0. Use i as defined in Figure NC-3673.2(b)-1
Fillet welded joint, socket welded flange, or single welded slip on flange	1.0
Brazed joint	1.0
Concentric reducer (ANSI B16.9 or MSS SP48)	0.75i, but not less than 1.0. Use i as defined in Figure NC-3673.2(b)-1

(a) Piping products included in Figure NC-3673.2(b)-1 but not covered by this criteria are: "Closely spaced miter bend;" "Widely spaced miter bend;" "branch connection," "threaded pipe joint or threaded flange" and "corrugated straight pipe or corrugated or creased bend." Functional capability of these piping products shall be demonstrated by appropriate methods. For "branch connection," the Class 1 criteria are applicable.

(b) Also applicable to "butt weld, $t_n > 3/16$ and $\delta/t_n \leq 0.1$;" "butt weld, $t_n \leq 3/16$ or $\delta/t_n > 0.1$;" "full fillet weld" and "30° tapered transition (ANSI B16.25)."

2.2 CLASS 2 OR 3 PIPING

Except as permitted in e. below, Equation (9) of NC-3652.2 shall be satisfied with the following requirements.

a. The right-hand-side of Equation (9) shall be $1.5S_y$

b. The values to be used in place of (0.75i) are shown in Table 2, except for "branch connection" where Class 1 criteria shall be used.

c. For $D_o/t > 50$, the values to be used in plate of (0.75i) shall be divided by:

$(1.3 - 0.006\ D_o/t)(1.033 - 00033T)$ for ferritic materials, and by $(1.3 - 0.006\ D_o/t)$ for other materials.

The values to be used in place of (0.75i) are not applicable for $D_o/t > 100$.

d. The definitions given in NC-3652 are applicable, except that:

(1) P_{max} is the pressure coincident with the moments, and

(2) S_y is the yield strength of the product material at the metal temperature, T, (deg. F) coincident with the occurrence of the loads; from Table I-2 or, if the material is not included in Table I-2, from other authoritative sources, adjusted to minimum expected yield strength like Table I-2 data.

(3) α_o = arc angle (degrees) of an elbow

e. Piping constructed in accordance with the code rules for Class 2 or 3 may be evaluated for functional capability using the criteria given herein for Class 1 piping. When using this alternative, S_y shall be established as in d.(2).

3. BASIS FOR THE CRITERIA

3.1 NUREG/CR-0261 REPORT

NUREG/CR-0261, (Reference 1) addresses the Code rules which are for pressure boundary integrity and not necessarily for functional capability. However, the report points out that if allowable moments are restricted to limit moments (defined as that moment of which $\delta = 2\delta_e$) then restrictions in flow area will be small (less than 5%) and functional capability will be assured. Test data from Reference 22 of NUREG/CR-0261 indicates that reduction in cross sectional area of elbows at the limit moment M_2 never exceeding 2%. Accordingly, the data and recommendations given in NUREG/CR-0261 are pertinent to and used as a main basis for the functional capability criteria.

At present (September 1978), the recommendations contained in NUREG/CR-0261 are being reviewed by the Code Committee, Working Group on Piping Design. However, any actions that may be taken are not directly relevant to the functional capability criteria given herein.

NUREG/CR-0261 addresses the adequacy of the Code criteria as judged by the existence of limit moment conditions at some point in the piping system that cause a single "hinge/." The report points out that for gross plastic deformation to occur, a "collapse mechanism" must be developed by occurrence of more than one "hinge"; and gives a simple example where the collapse-mechanism load is 33 percent higher than the load creating the first hinge. The report uses theory (for straight pipe) which ignores strengthening by strain hardening, and dynamic effects are not taken into account. As discussed at the end of this chapter, dynamic effects should make the criteria very conservative when used for conditions where loadings are dynamic in nature. Accordingly, NUREG/CR-0261 recommendations are based on conservative evaluations and the functional capability criteria share that conservatism. As additional data becomes available, the functional capability criteria should be reviewed and modified as appropriate to remove excess conservatism.

3.2 STRAIGHT PIPE

The criteria for Class 1 and Class 2 or 3 piping are identical. Both can be expressed as:

$$0.5 \frac{PD_o}{2t} + 1.0 \frac{M_i}{Z} \leq 1.5 S_y \qquad (1)$$

This criteria is deemed appropriate by NUREG/CR-0261; see Recommendation 4. However, for functional capability, we simply use the more significant limit of $1.5S_y$, rather than a constant times S_m or S_h as used in the Code. These are more restrictive criteria than Code C-Limits for SA312-TP304 above 100°F (Class 1) or above 500°F (Class 2 or 3).

3.3 CURVED PIPE OR BUTT-WELDING ELBOWS

The criteria for Class 1 and Class 2 or 3 piping are identical except for the coefficient of $PD_o/2t$, which varies from 0.0 to 0.5 for Class 1 and [because there is no equivalent of B_1 in Equation (9) of NC-3652.2] is 0.5 for Class 2 or 3 piping.

3.3.1 Pressure Term Index, B_1

As pointed out in Recommendation 5 of NUREG/CR-0261, internal pressure tends to increase the limit moment. These criteria implement the concept that B_1 can be small when the elbow behavior is predominant (which occurs when h is small), however, B_1 should be 0.5 the same as for straight pipe, when the elbow behavior is predominantly like straight pipe. The elbow behavior is characterized by the parameter $h = 4tR/D^2$, where t is the wall thickness, R is the bend radius and D are the cross section mean diameter. The criteria for B_1 is such that $B_1 = 0.0$ for $h \leq 0.25$ (at $h = 0.25$, $B_2 = 3.28$ for $\alpha_o = 90°$) and $B_1 = 0.5$ for $h = 1.5$ (at $h \geq 1.5$, $B_2 = 1.00$, the same as for straight pipe). Accordingly, the criteria for B_1 recognizes that pressure does not reduce functional capability when h is small but also recognizes that, when the elbow behaves like straight pipe, the limit moment may be reduced by pressure.

3.3.2 Moment Term Index and (0.75i) = B_2

The criteria for Class 1 and Class 2 or 3 piping are identical for the coefficient of M_i/Z. For $\alpha_o = 90^o$, Recommendation (6) of NUREG/CR-0261 has been used; i.e., $B_2 = 0.67C_2$ rather than $B_2 = 0.75C_2$. However, recognizing that α_o (the elbow arc angle) may be less than 90^o and to remove excess conservatism from this particular aspect of piping evaluation, the criteria makes use of recommendations given in Reference 2. This report gives the results of an extensive parametric study of calculated elastic stresses and shows that as α_o decreases below 90^o, the maximum calculated stress for an "in-plane" moment also decreases. ORNL/Sub-2913/7 recommends that the C_2 index, for in-plane moment (identified therein as C_{22}, see page 23 of Reference 2) be given by:

$$C_2 = 1.95/h^{2/3} \text{ for } \alpha_o \geq 90$$

$$C_2 = 1.75/h^{0.56} \text{ for } \alpha_o = 45^o$$

$$C_2 = 1.0 \text{ for } \alpha_o = 0$$

> Linear interpolation with α_o shall be used, but C_2 shall not be less than interpolated for $\alpha_o = 30^o$ and not less than 1.0 for any α_o.

The criteria uses this recommendation with $B_2 = 0.67C_2$, but not less than 1.0, except that the provision in Reference 2 that "C_2 shall not be less than ext lated for $\alpha_o = 30^o$" is not used in the functional capability criteria. Th is because the bound at $\alpha_o = 30^o$ was motivated by concern over possible int between two closely spaced welds from a fatigue standpoint and hence is not to functional capability.

The criteria are based on "in-plane" moment loading; this in-plane moment produces higher elastic stresses and lower limit moments than the other two moments making up M_i; i.e., out-of-plane and torsion. Accordingly, the criteria is conservative if all of M_i is in-plane moment and may be excessively conservative if M_i is mostly out-of-plane or torsional moments.

Unfortunately, this possible excess conservatism cannot be removed from the simplified approach used in this criteria, but could be used in more sophisticated analysis methods which are not prohibited by this criteria.

Test data on elbows from Table 4 of NUREG/CR-0261 are shown in Figure 1. The criteria, for $\alpha_o \geq 90^o$, $h \leq 0.25$, is:

$$B_2 \frac{M_{f1}}{(\pi/4)\, D^2 t} \leq 1.5 S_y$$

or, in terms of the parameters used in Figure 1, recalling that $B_2 = 1.3/h^{2/3}$,

$$\frac{M_{f1}}{D^2 t S_y} = \frac{(\pi/4) \times 1.5}{1.3} h^{2/3} = 0.906 h^{2/3} \qquad (2)$$

Equation 2 is plotted in Figur 1, providing a visual comparison of test data with the functional capability iteria for elbows. Variation in the test data with h by roughly $h^{2/3}$ as used in the criteria can be seen in Figure 1. Recalling that the theoretical limit moment for straight pipe is $M_2 = D^2 t S_y$, the fact that the test data $M/(D^2 t S_y)$ values are less an 1.0 indicates that elbows with $h < \sim 0.4$ are not as strong as straigh ver, the important aspect is that the criteria conservatively evalu ow-effect" for all but two points which are briefly discussed belc

One of the two points slightly (~10%) below the criteria is from Reference 23 of NUREG/CR-0261. The reference tests were different as $+M_z$ was applied first to a magnitude of about 1.3×10^6 in.-lb, then $-M_z$ was applied to about the same magnitude. This cycle was repeated approximately 10 times, and each time the maximum moment was increased. On the final cycle, the magnitude of $+M_z$ was 3.8×10^6 in.-lb (with load increasing with increasing deflection) and the magnitude of $-M_z$ was about 3.3×10^6 in.-lb (with load not increasing with increasing deflection indicating that the maximum $-M_z$ load had been reached). The maximum moment was therefore 3.3/1.5 times M_2 on the first half cycle. The maximum moment is indicated in Figure 1 by the leader to "M_{max}."

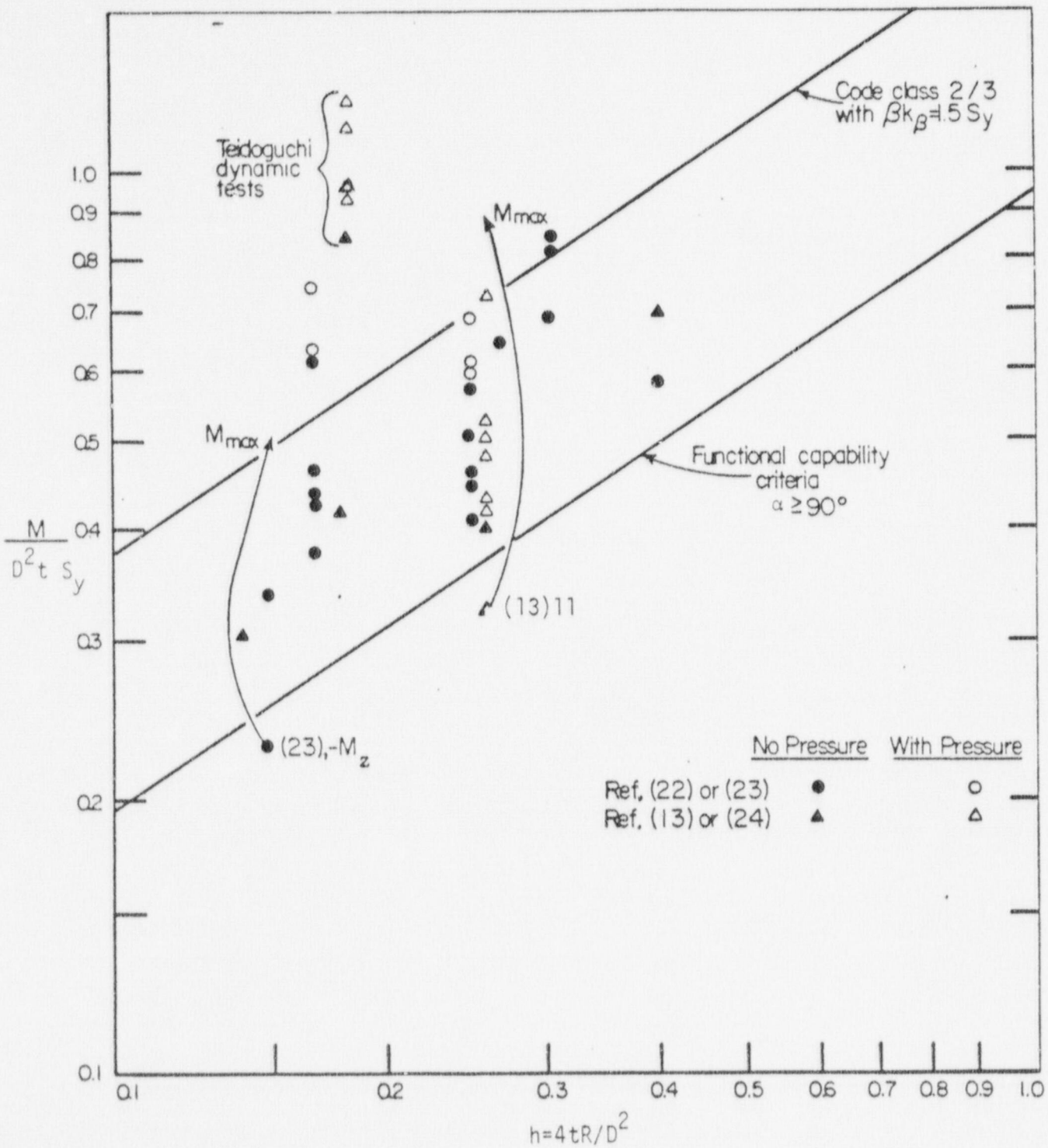

Figure 1. Test Data on Butt-welding Elbows with Arc Angle, α_o, of 90° or 180°, from Table 4 of NUREG/CR-0261

The other of the two points slightly (~14%) below the criteria, is the test identified as (13)11 in Table 9 of NUREG/CR-0261. This test is anomalous in that pressure decreased the limit moment, when compared to a presumably identical loading with P = 0; that being the test identified as (13)10. Data in Figure 2 shows the complete load versus deflection plots of these two tests. Unfortunately, the yield strengths of the materials in the elbows tested are not known; stainless steel elbows were assumed to have a yield strength of 30,000 psi. Accordingly, the seeming anomaly of pressure reducing M_2, as shown in Figure 2, may be due entirely to a higher yield strength in the elbow tested with P = 0. In any case, the substantial stiffening effect of internal pressure at high loads is apparent in Figure 2 and the maximum applied moment is indicated by Figure 2 by the leader to "M_{max}".

The criteria for Class 1 with P = 0, $\alpha_o = 90^o$ are more restrictive than the Code C-limits for SA-312 TP304 at temperatures above 100°F.

The criteria for Class 2/3 with $\alpha_o = 90^o$ are almost always significantly more restrictive than the Code C-limits. This because B_2 is larger than (0.75i); i.e.,

$$B_2 = 1.3/h^{2/3}$$

$$0.75i = 0.75 \times 0.9/h^{2/3} = 0.675/h^{2/3}$$

$$B_2/(0.75i) = 1.3/0.675 = 1.93$$

This aspect is shown in Figure 1 by the line identified as "Code Class 2/3 with $\beta_{K\beta} = 1.5S_y$." $\beta_{K\beta}$ is the right-hand-side limit of Equation (9) of NC-3652.2, and for SA312-TP304 at ~500°F, is equal to $1.5S_y$. This is one of the aspects where the Code rules are not supported on the basis of the conservative single-hinge, limit load concept used in NUREG/CR-0261. This is not to say that the Code rules are necessarily unconservative because a more sophisticated approach considering collapse mechanisms, strain hardening, dynamic effects, etc., might show the Code rules to be appropriate.

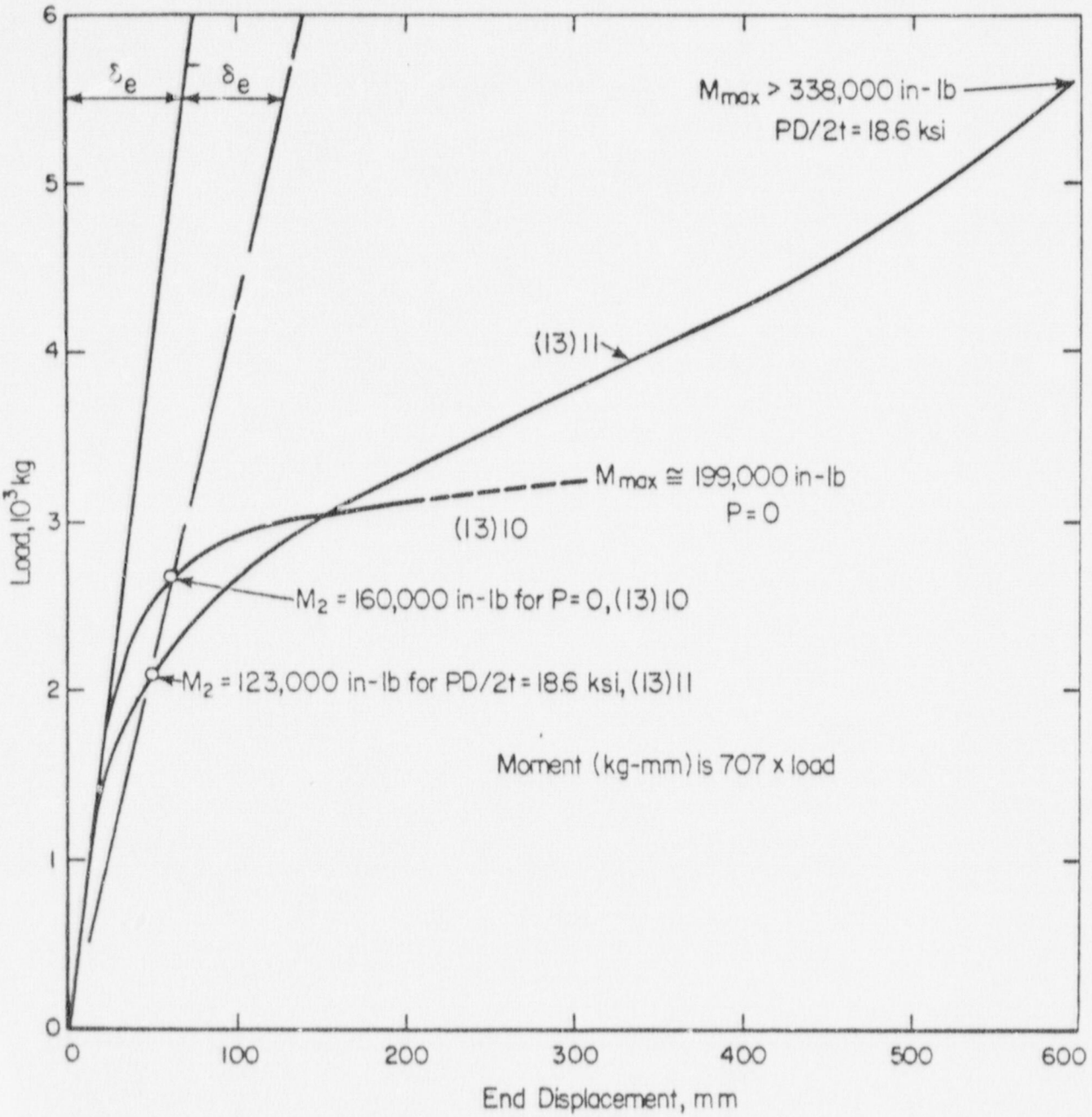

Figure 2. Load-Displacement Plots, Elbows Identified as (13)10 and (13)11 in NUREG/CR-0261

3.4 BRANCH CONNECTIONS AND TEES

For Class 1 rules, the equation to be satisfied is:

$$B_1 \frac{PD_o}{2t} + B_{2B} \frac{M_b}{Z_b} + B_{2R} \frac{M_r}{Z_r} < \alpha_{K\alpha}$$

Definitions of B_{2b}, M_b, Z_b, B_{2r}, M_r and Z_r are given in footnotes 5, 7 and 9 of Table NB-3682.2-1, and $\alpha_{K\alpha}$ represents the right-hand side limit of Equation (9) of NB-3652. The equation to be satisfied for Class 2/3 piping is:

$$\frac{PD_o}{4t} + (0.75i) \frac{M_i}{Z} < \beta_{K\beta}$$

For Class 2/3 piping, each end of the branch connection or tee is checked separately in accordance with NC-3652.4(c) or (d). For checking the run ends, Z is simply the section modulus of the run pipe, $A = (\pi/4)\, D^2 T_r$. For checking the branch end, however, Z is defined as $(\pi/4)\, d^2 t_s$, where t_s is the lesser of T_r or (i)(t).

3.4.1 Branch Connections, Class 1 Piping

Limit moment test data or branch connections are summarized in Table 9 of NUREG/CR-0261. Table 3 of this document is Table 9 of NUREG/CR-0261 with one additional column (the column headed M_L/M_{f1}) where M_{f1} is the moment permitted by the criteria given herein for Class 1 piping. The value M_L/M_{f1} is the ratio of test limit moment (essentially M_2) to the moment permitted by the criteria with the right-hand-side limit of Equation (9) of NB-3652 equal to S_y. The criteria set the right-hand-side limit as $2.0S_y$. Accordingly, to justify the criteria limit of $2.0S_y$, all values in the column of Table 3 headed M_L/M_{f1} should be 2.0 or higher. As shown in Table 3 this is the case, except for the test identified as (34)6, where $M_L/M_{f1} = 1.95$. In most tests, the criteria is very conservative ($M_L/M_{f1} >> 2$) but, as can be seen by comparing M_L/M_{f1} with M_L/M_{c1} not as excessively conservative as the present Code with a right-hand side-limit of the same value.

Table 3

SUMMARY OF LIMIT MOMENTS ON BRANCH CONNECTIONS

FROM TABLE 9 OF NUREG/CR-0261

Ref. No. (a)	$\frac{D}{T_r}$	$\frac{d}{D}$	$\frac{t}{T_r}$	$\frac{PD}{2T_r}$ (ksi)	Type of Moment	M* (b)	B_{2b} (c)	$\frac{M_L}{M_{c1}}$ (d)	$\frac{M_L}{M_{c2}}$ (e)	$\frac{M_L}{M_{f1}}$ (f)
(33)1	24	0.52	0.52	0	M_{z3}	0.91	4.25	4.9	2.1	3.3
2	25	0.75	0.75	0	M_{z3}	0.84	7.57	8.1*	2.9	5.4
3	25	1.00	1.00	0	M_{z3}	0.64	11.65	9.5*	3.0	6.3
4	25	0.75	0.75	12.5	M_{z3}	0.49	7.57	6.8*	2.0	3.6
5	27	1.00	1.00	6.8	M_{z3}	0.50	12.30	10.5*	2.8	5.9
(34)1	56.5	1.00	1.00	0	M_{z3}	0.50	20.51	13.1*	4.0	8.7
2	34.5	0.40	0.80	0	M_{z3}	0.70	7.18	6.4	3.2	4.3
(35)1	31.0	0.65	0.66	0	M_{z3}	0.66	7.21	6.1*	2.3	4.0
(36)1	30.1	0.79	0.79	0	M_{z3}	0.63	9.32	7.5*	2.6	5.0
2	30.0	1.00	1.00	0	M_{z3}	0.46	13.24	7.8*	2.4	5.2
(33)1	25	0.5	0.5	0	M_{x3}	0.72	4.12	3.8	1.7	2.5
2	34.5	0.7	1.27	0	M_{x3}	0.48U	15.16	9.3*	3.5	6.2
3	25	1.0	1.0	0	M_{x3}	0.59U	11.65	8.8*	2.7	5.8
4	42	1.0	1.0	0	M_{x3}	0.49U	16.73	10.4*	3.2	7.0
5	34.5	0.7	1.27	17.3	M_{x3}	0.33	15.16	14.0*	3.2	5.7
(34)1	34.5	0.4	0.8	0	M_{x3}	0.57U	7.18	5.2	2.6	3.5
2	34.5	0.6	1.2	0	M_{x3}	0.46U	13.20	7.7*	3.2	5.1
3	34.5	0.3	0.6	0	M_{x3}	0.75	4.67	4.5	2.6	3.0
4	34.5	0.8	1.6	0	M_{x3}	0.33U	20.32	8.5*	3.0	5.7
5	25.0	0.7	0.7	0	M_{x3}	0.70U	6.82	6.1*	2.3	4.0
6	34.7	0.2	0.4	0	M_{x3}	0.9	2.55	2.9	2.1	1.95
7	35.0	0.97	1.94	0	M_{x3}	0.27U	27.41	9.4*	3.0	6.3
8	45.0	0.4	1.33	0	M_{x3}	0.33U	14.05	6.9	3.0	3.9
9	45.0	0.6	2.00	0	M_{x3}	0.22U	25.86	7.2*	3.0	4.8

Table 3 (Continued)

Ref. No. (a)	$\frac{D}{T_r}$	$\frac{d}{D}$	$\frac{t}{T_r}$	$\frac{PD}{2T_r}$ (ksi)	Type of Moment	M* (b)	B_{2b} (c)	$\frac{M_L}{M_{c1}}$ (d)	$\frac{M_L}{M_{c2}}$ (e)	$\frac{M_L}{M_{f1}}$ (f)
(34)10	45.0	0.8	2.67	0	M_{x3}	0.16U	39.87	8.1*	2.9	5.4
11	45.0	0.96	3.2	0	M_{x3}	0.17U	52.34	11.3*	3.7	7.5
12	25.0	0.4	0.4	0	M_{x3}	1.0	2.95	3.8	1.9	2.5
13	25.0	0.6	0.6	0	M_{x3}	0.77	5.42	5.3*	2.1	3.5
14	45.0	0.2	0.67	0	M_{x3}	1.1	5.00	7.0	5.0	4.7
15	45.0	0.3	0.9	0	M_{x3}	0.62	8.29	6.5	3.8	4.4
(35)1	31.0	0.65	0.66	0	M_{x3}	0.50	7.21	4.6*	1.8	3.1
2	22.9	0.65	0.39	0	M_{x3}	0.84	3.50	3.7*	1.4	2.5
(36)1	30.0	0.6	0.59	0	M_{x3}	0.69	6.06	5.3*	2.1	3.5
2	29.7	0.79	0.77	0	M_{x3}	0.52	9.01	6.0*	2.1	4.0
3	30.0	1.0	1.0	0	M_{x3}	0.41	13.24	6.9*	2.1	4.6
4	30.0	0.6	0.61	10.5	M_{x3}	0.58	6.25	6.1*	2.1	3.4
5	30.0	0.8	0.79	12.0	M_{x3}	0.61	9.36	9.9*	2.8	5.5
6	30.0	1.0	1.0	12.0	M_{x3}	0.47	13.24	10.9*	2.8	6.0
(13)1	25.4	0.76	0.87	23.7	M_{x3}	0.97	7.5	24.*	5.1	8.0
2	25.4	0.45	0.70	23.7	M_{x3}	1.69	4.5	27.	7.4	9.0
3	25.4	0.76	0.87	23.7	M_{x3}	0.58	8.9	17.*	3.1	5.7
4	25.4	0.45	0.70	23.7	M_{x3}	1.36	5.4	26.	6.2	8.7
5	25.4	0.76	0.87	27.4	M_{x3}	0.67	7.5	56.	3.6	5.7
6	25.4	0.76	0.87	20.6	M_{x3}	0.69	8.9	22.*	3.7	6.8
7	25.4	0.45	0.70	27.4	M_{x3}	0.82	4.5	49.	4.2	5.0
8	25.4	0.45	0.70	20.6	M_{x3}	0.70	5.4	14.	3.2	4.5
9	25.4	0.76	0.87	23.7	M_{y3}	1.32	7.5	33.*	7.0	9.9
10	25.4	0.45	0.70	23.7	M_{y3}	1.07	4.5	17.	4.9	5.2
11	25.4	0.76	0.87	23.7	M_{y3}	1.24	8.9	36.*	6.5	11.0
12	25.4	0.45	0.70	23.7	M_{y3}	1.08	5.4	21.*	4.9	6.3
13	25.4	0.76	0.87	27.4	M_{y3}	0.82	7.5	68.*	4.4	6.3

Table 3 (Continued)

Ref. No. (a)	$\frac{D}{T_r}$	$\frac{d}{D}$	$\frac{t}{T_r}$	$\frac{PD}{2T_r}$ (ksi)	Type of Moment	M* (b)	B_{2b} (c)	$\frac{M_L}{M_{c1}}$ (d)	$\frac{M_L}{M_{c2}}$ (e)	$\frac{M_L}{M_{f1}}$ (f)
(13)14	25.4	0.76	0.87	20.6	M_{y3}	0.55	8.9	17.*	2.9	4.9
15	25.4	0.45	0.70	27.4	M_{y3}	0.91	4.5	54.	4.7	5.0
16	25.4	0.45	0.70	20.6	M_{y3}	0.85	5.4	17.	3.9	5.0
(13)17	25.4	0.76	0.87	27.4	M_{x3}/M_{y3}	0.76	7.5	65.*	4.8	6.2
18	25.4	0.76	0.87	20.6	M_{x3}/M_{y3}	0.63	8.9	20.*	4.0	6.1
19	25.4	0.45	0.70	27.4	M_{x3}/M_{y3}	0.67	4.5	42.	5.2	4.1
20	25.4	0.45	0.70	20.6	M_{x3}/M_{y3}	0.70	5.4	15.	4.8	4.5

(a)These are reference numbers in NUREG/CR-0261. Material is carbon steel except for Reference 13, Figures 5-8, 13-16, and 17-20, which were stainless steel like TP304. Construction was like Figure 14b in NUREG/CR-0261 except Reference 13, Figures 1, 2, 5, 7, 9, 10, 13, 15, 17 and 19, which are believed to be like Figure 14c in NUREG/CR-0261. (References and Figures are those of NUREG/CR-0261.)

(b)$M^* = M_L/M_{c4}$, where M_{c4} is calculated by equation 4 of NUREG/CR-0261
M_L is the experimental limit moment
Values followed by U" are deemed unstable by authors of sited references.

(c)B_{2b} = stress index calculated by Code rules.

(d)M_{c1} = allowable moment by Code Equation (9) with $\alpha K_\alpha = 1.0$, Class 1.
Values followed by * are tests with d/D larger than covered by B_{2b}.

(e)M_{c2} = allowable moment by Code Equation (9) with $\beta K_\beta = 1.0$, Class 2.

(f)M_{f1} = allowable moment by functional capability criteria with right-hand side limit of S_y

3.4.2 Reinforced and Unreinforced Fabricated Tees, Class 2/3 Piping

The column in Table 3 headed M_L/M_{c2} is the ratio of the test limit moment (essentially M_2) to the moment permitted by the criteria for Class 2/3 piping with the right-hand-side limit of Equation (9) of NC-3652.2 equal to S_y. The criteria set the right-hand-side limit as $1.5S_y$. Accordingly, to justify the criteria limit of $1.5S_y$, all values in the column of Table 3 headed M_L/M_{c2} should be 1.5 or higher. In Table 3, the ratio M_L/M_{c2} is greater than 1.5 except for the test identified as (35)2, M_{x3}, where $M_L/M_{c2} = 1.4$. In most tests, the criteria are very conservative ($M_L/M_{c2} >> 1.5$), although not as conservative as the criteria for Class 1 piping.

3.4.3 Butt-welding Tees, Class 1 Piping

Table 4 shows data from the insert table on page 49 of NUREG/CR-0261. The column headed M_L/M_{f1} is the ratio of the test limit moment to the moment permitted by the criteria for Class 1 piping with the right-hand-side limit of Equation (9) of NB-3652 equal to S_y. The criteria set the right-hand-side limit as $2.0S_y$. Accordingly, to justify the criteria limit of $2.0S_y$, all values of Table 4 in the column headed M_L/M_{f1} should be 2.0 or higher. Table 4 shows that this is essentially the case.

3.4.4 Butt-welding Tees, Class 2/3 Piping

The column headed M_L/M_{f2} in Table 4 is the ratio of the test limit moment to the moment permitted by the criteria for Class 2/3 piping with the right-hand-side limit of Equation (9) of NC-3652.2 equal to S_y. The criteria set the right-hand-side limit as $1.5S_y$. Accordingly, to justify the criteria limit of $1.5S_y$, all values in Table 4 in the column headed M_L/M_{f2} should be 1.5 or higher. Table 4 shows that this is essentially the case.

Table 1

TEST DATA ON BUTT-WELDING TEES[a], FROM NUREG/CR-0261

Spec. No.	M_L in.-lb (b)	S_y psi (c)	$\frac{M_L}{M_{c1}}$ (d)	$\frac{M_L}{M_{c2}}$ (d)	$\frac{M_L}{M_{f1}}$ (d)	$\frac{M_L}{M_{f2}}$ (d)
PT-1A	421,200	44,600	2.70	1.35	2.15	1.62
PT-1B	442,800	44,600	2.84	1.43	2.27	1.71
PT-1E	422,100	44,600	2.71	1.36	2.16	1.63
PT-2A	396,900	42,250	2.69	1.35	2.14	1.60
PT-2B	411,300	42,250	2.79	1.40	2.22	1.67
PT-2E	362,000	42,250	2.46	1.23	1.95	1.47

(a) 6x6, Sch. 40 (0.280 nom. wall), $D/T_r = 22.7$, $d/D = 1.0$; $t/T_r = 1.0$.

(b) M_L = limit moment. In first three tests, the branch pipe yielded without any visible plastic deformation of the tee. In the second three tests, the tees deformed appreciably while the branch pipe remained straight.

(c) Yield strength of tee material.

(d) M_{c1} = allowable moment by Code Class 1 with $1.0S_y$ limit
M_{c2} = allowable moment by Code Class 2 with $1.0S_y$ limit
M_{f1} = allowable moment by Functional Capability Criteria Class 1 with $1.0S_y$ limit
M_{f2} = allowable moment by Functional Capability Criteria Class 2/3 with $1.0S_y$ limit

3.5 OTHER PRODUCTS/JOINTS

The coverage of products/joints in the criteria is intended to be the same as the Code.

3.5.1 Class 1 Piping

Footnote (a) to Table 1 uses the concept given in NUREG/CR-0261, page 52, "Piping Products with $B_1 = 0.5$, $B_2 = 1.0$." For reducers, the criteria uses the B_1 and B_2 indices given in the Code. However, the $1.5S_y$ limit in the criteria provides additional conservatism as compared to Code rules where the limit exceeds $1.5S_y$; e.g., for Level C-Limits, SA312 TP304 above 100°F.

For girth fillet welds, the Code gives $B_1 = 0.75$, $B_2 = 1.50$ in piping, fillet welds which are used to join the pipe to socket welding fittings, socket welding valves, slip-on flanges or socket welding flanges. From a functional capability standpoint, the fitting, valve or flange reinforces the pipe at the weld so that the pipe cross section will not deform to the extent that straight pipe, remote from such reinforcing, would deform under the same loads. Accordingly, the criteria conservatively uses the same indices for fillet welds as for straight pipe; i.e., $B_1 = 0.5$, $B_2 = 1.0$. As discussed in Reference 5, pages 56 and 57, the Code B_1 and B_2 indices are higher than for straight pipe to encompass the possibility (albeit remote) that a full fillet weld (a weld with legs not less than 1.4 times the pipe wall thickness) may not be achieved with ANSI B16.11 socket welding fittings. However, this is an aspect related to pressure boundary integrity; not functional capability. It should be recalled that the functional capability criteria given herin are not intended to supercede any requirement of the Code.

3.5.2 Class 2/3 Piping

Although stated differently, footnote (b) to Table 2 uses the same concept as Footnote (a) to Table 1. Footnote (a) to Table 2, for completeness, recognizes that there are some products covered by Figure NC-3673.2(b)1 which are seldom used in Mark II piping systems. It also recognizes that, for "branch connections," the equation given in Figure NC-3673.2(b)1 is not appropriate and points out that Class 1 criteria may be used.

For concentric reducers, the criteria uses (0.75i) from Figure NC-3673.2(b)-1. However, the $1.5S_y$ limit in the criteria provides additional conservatism as compared to Code rules where the limit exceeds $1.5S_y$; e.g., for Level C-Limits, SA312 TP304 above 500°F.

For girth fillet welds and brazed joints, the criteria applies the same value of (0.75i) used for straight pipe; (0.75i) = 1.0. The bases for this is the same as discussed under Class 1 Piping; the presence of a fitting at a fillet welded or brazed joint increases the functional capability load capacity as compared to straight pipe remote from reinforcement, hence use of (0.75i) = 1.0 is conservative for functional capability.

3.6 LIMITS FOR $D_o/t > 50$

NUREG/CR-0261 points out that for D/t > 50, it is not prudent to assume that the limit load theory is an adequate assessment of the moment capacity of straight pipe.

Considerable test data on the moment capacity of straight pipe with D/t > 50 is included in Table 2 of NUREG/CR-0261. These data are plotted in Figure 3. An indication of relative moment capacity of pipe as a function of D/t can also be obtained from Paragraph UG-23(b) of Reference 3. This paragraph provides rules for establishing maximum allowable longitudinal compressive stresses on cylindrical shells. This is applicable for a uniform (around the circumference) longitudinal stress and hence is conservative for evaluating moment loadings, where the maximum compressive stress occurs at only one point around the circumference. Nevertheless, the relative values of allowable longitudinal stress as a function of D/t should be applicable to bending of straight pipe. The relative values, for carbon steel with specified minimum yield strength of 30 to 38 ksi at temperature up to 300°F are shown in Figure 3. Based on this data, a criteria factor for $D_o/t > 50$ has been established as indicated in Figure 3.

It may be noted that a few test points lie beneath the criteria line. Such data, of course, is expected to exhibit some scatter due to variations in test measurements, dimensions of test specimens and determination of material yield strength. It is significant to note that S_y, as used in the criteria, is the minimum specified yield strength at 100°F and is the minimum expected yield strength at higher temperature. Most piping materials will have yield strength well above the specified or expected minimums, hence there is a statistical margin-of-safety in the criteria.

3.6.1 Temperature Effect on Material Properties

All of the data in Figure 3 represent data from room temperature tests. At elevated temperatures, the allowable moment decreases because S_y decreases. To assess whether this is adequate to compensate for buckling, the data given in Paragraph UG-23(b) of Reference 3 were used. For austenitic stainless steel, the decrease in allowable longitudinal stress with increasing temperature is essentially proportional to the decrease in yield strength with temperature. However, for ferritic steels like SA106 Grade B, the decrease in allowable longitudinal stress with increasing temperature from 100 to 700°F is about 25% more than the decrease in yield strength with increasing temperature from 100 to 700°F. Accordingly, a factor of (1.033-0.00033T) has been used in the criteria for ferritic steels to account for the temperature effect on material properties.

3.6.2 Internal Pressure Effect

All of the data in Figure 3 represent tests with zero internal pressure. As discussed in NUREG/CR-0261 (pages 18 and 19, on "Buckling With Internal Pressure"), some test data indicate that internal pressure will increase the moment capacity of pipe with $D_o/t > 50$. However, these criteria take the conservative approach that internal pressure does not increase moment capacity; i.e., the B_1 indices are not a function of D_o/t.

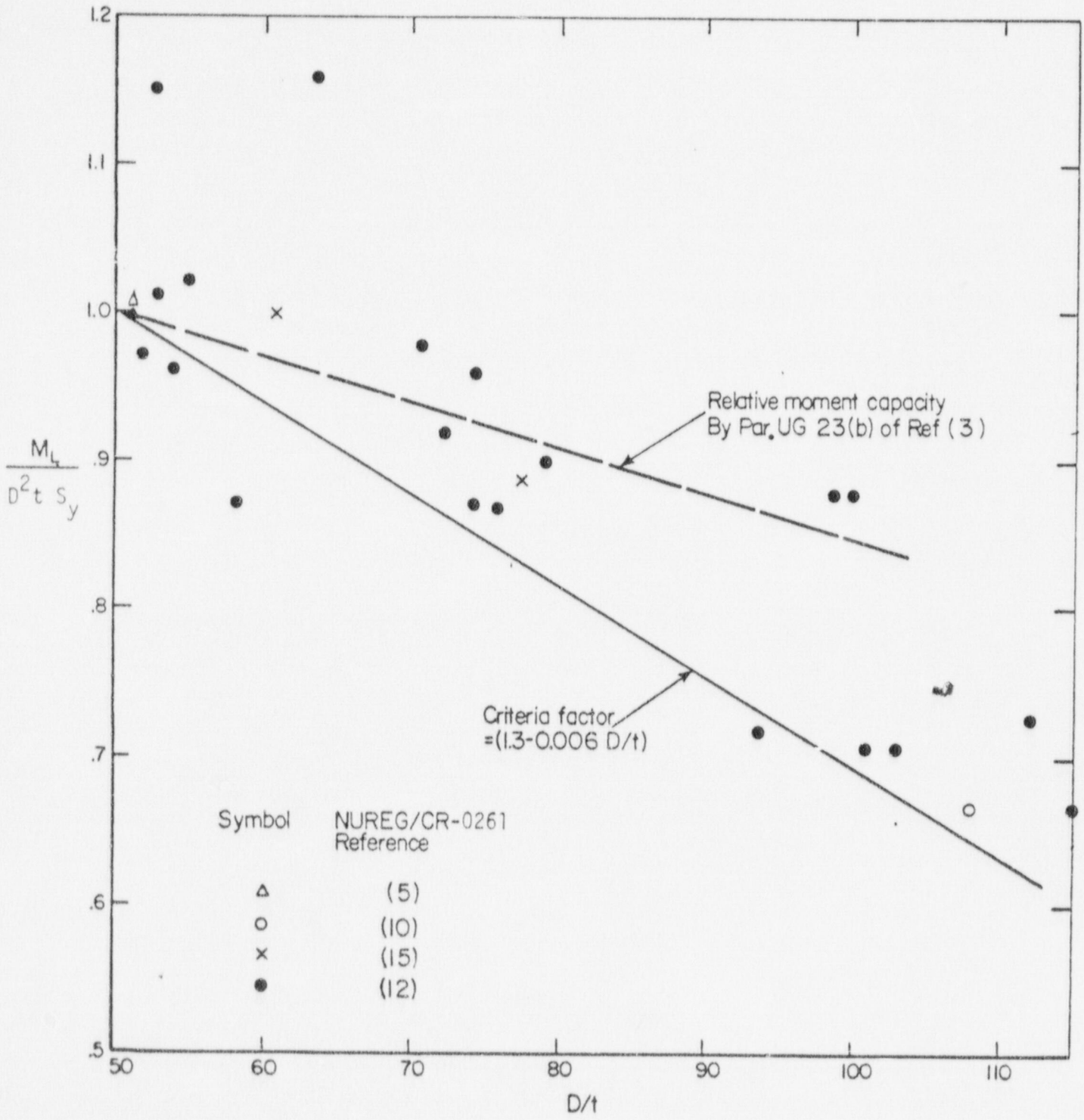

Figure 3. Test Data on Straight Pipe with D/t > 50, From Table 2 of NUREG/CR-0261

3.6.3 Products/Joints other than Straight Pipe

All available test data are on straight pipe; the data are deemed to be directly applicable to girth-butt welds and transition joints. For elbows with small h, the criteria are probably very conservative because the B_2 index for elbows reflects the tendency for the cross section to become out-of-round. However, in the absence of supporting data, these criteria apply the corrections for $D_o/t > 50$ to all products and joints.

3.7 DYNAMIC EFFECTS

In many nuclear power plant piping systems, the large and therefore design-controlling loads are caused by dynamic conditions such as steam hammer, relief valve transients, postulated earthquakes or pipe breaks. These have the characteristic of rapidly oscillating loads with relatively short total time duration. Some examples of the load characteristic are shown in Figures 4, 5, and 6 herein.

The test data cited in NUREG/CR-0261, with the exception of one set of data, represent tests in which loads were slowly applied. Tests in Figure 1 are the one exception. The five data points bracketed and identified as "Teidoguchi Dynamic Tests." These were tested under dynamic loadings (on a shake-table) at a frequency of about 3 Hertz. These test data, shown in Figure 1, are about a factor-of-two higher (stronger) than would be expected from the other static loading test data. The elbow did not lose functional capability during the tests, although fatigue failure was to be expected and did occur. This set of tests suggests that, under dynamic loading, the criteria given in this document may be excessively conservative but the single set of data is not sufficient to provide a more realistic basis over the parameter ranges covered by the criteria.

Water hammer occurs in industrial piping systems and for piping made of brittle material such as cast iron can cause failure of the piping. However, for piping made of ductile material, the ability of piping to absorb these dynamic loads without failure is impressive. Reference 4 gives a quantitization of a service occurrence which is relevant to dynamic effects and discussed below.

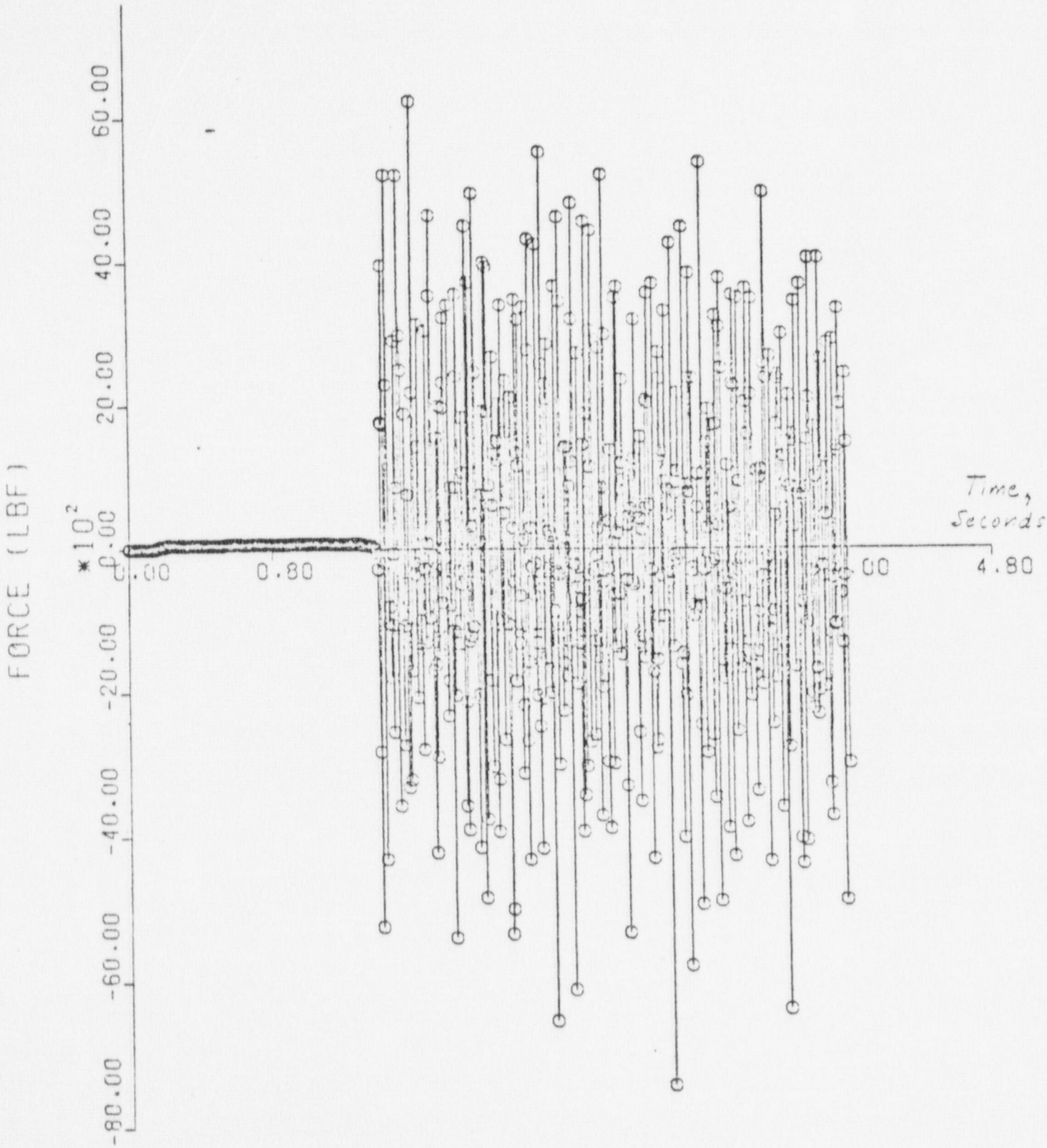

Figure 4. Typical Feedwater Fluid Transient Forces

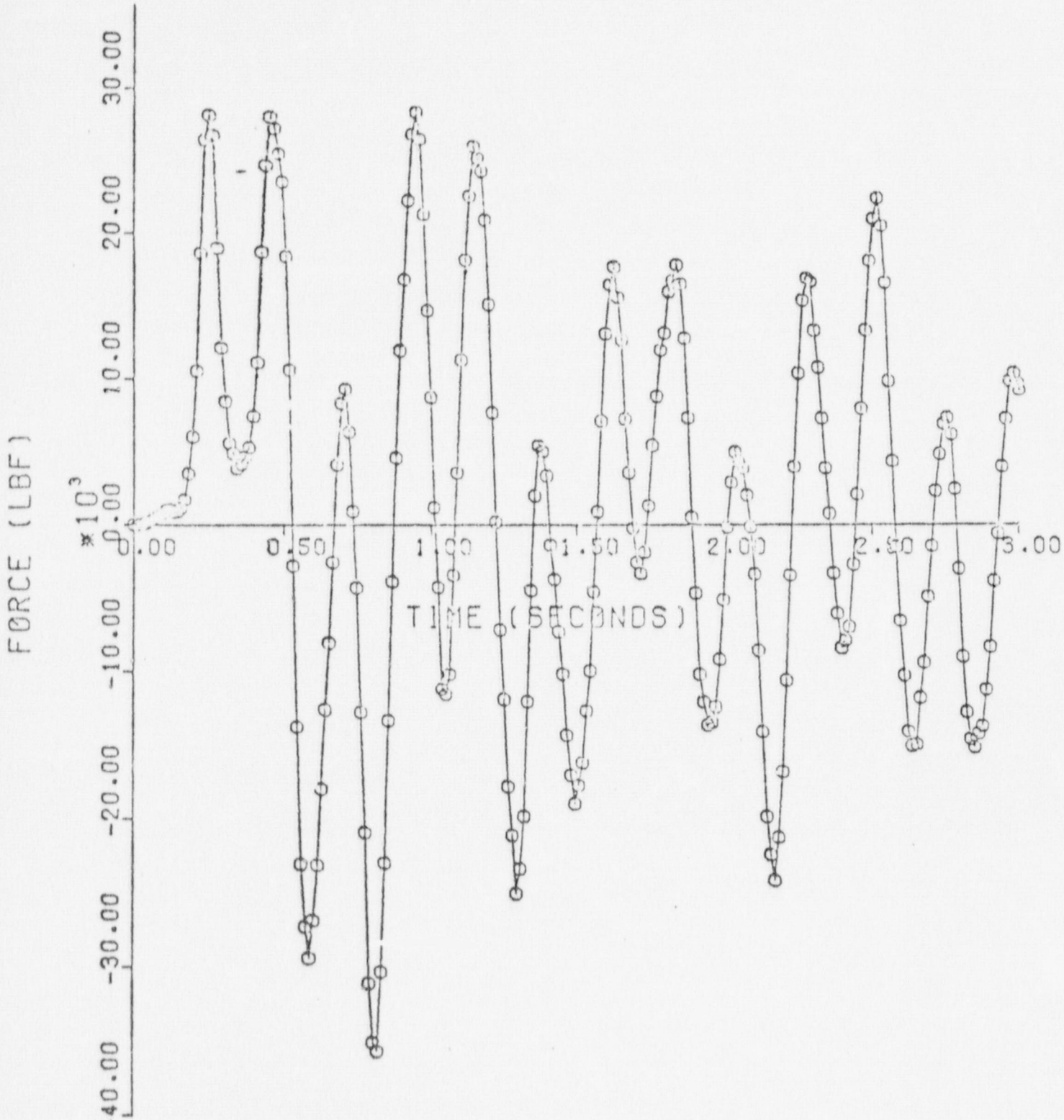

Figure 5. Typical Main Steam Transient Steam Hammer Forcing Function

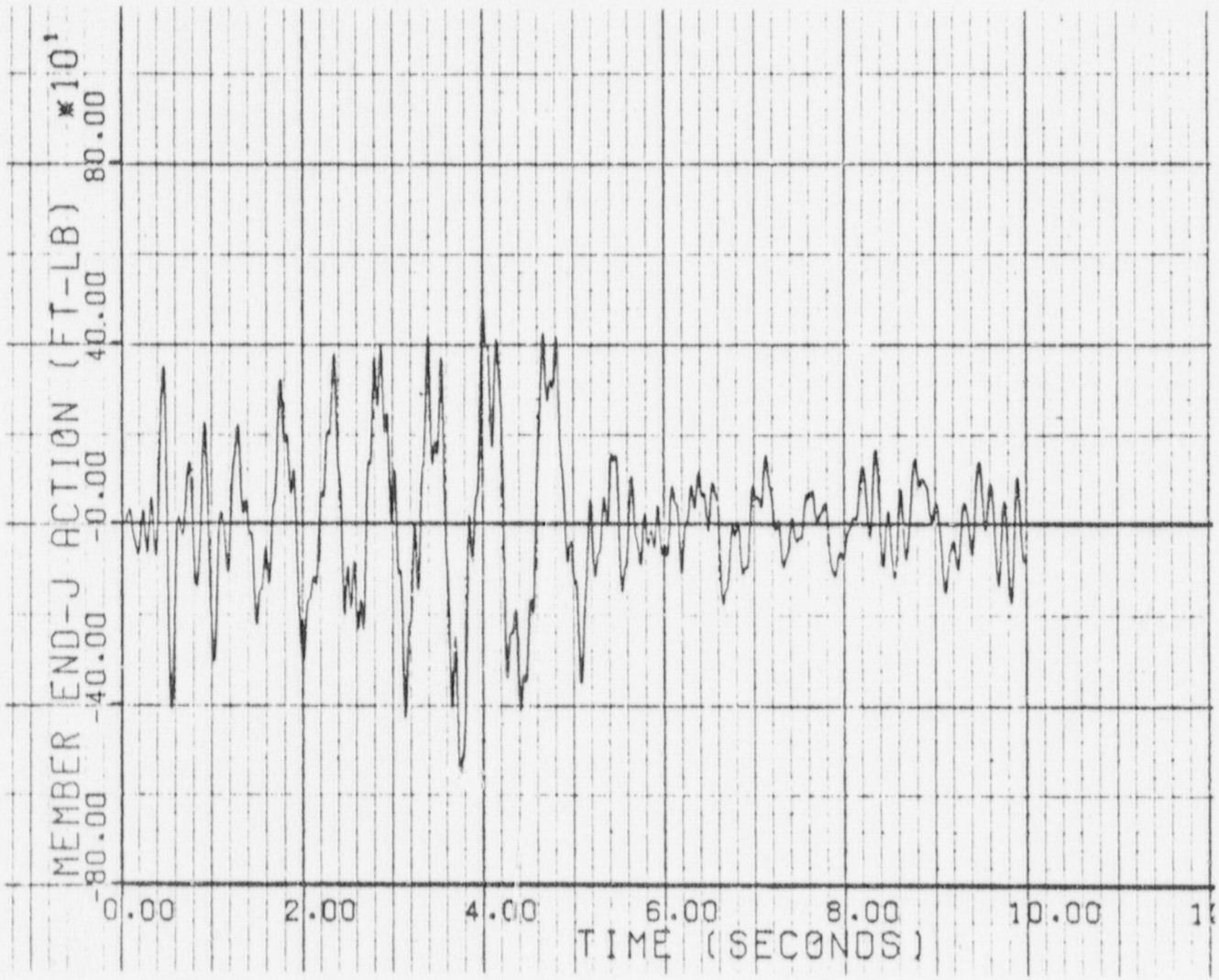

Figure 6. Typical Piping Elastic Response to OBE

Because of abnormal operation of a regulation valve, pressure transients occurred in the piping system shown in Figures 7 and 8. The location of the portion of piping shown in Figure 8 with respect to the entire piping system are shown by noting correspondence at Points 58 and 94 on the two figures. During shutdown following the incident, the piping system was examined for damage to the piping but none was found. Estimates were also made of the pipe movements as indicated by the physical evidence. These movements were then used as input data for static analysis of the piping system.

Several combinations of movements were evaluated, including the combination of interest identified in Reference 4 as Case I. A transient bending stress of $\pm$53,328 psi was calculated at point "X" as shown in Figure 8. While most of the piping in the system was 24-inch, Schedule 120 (1.812-in. wall), the U-shaped bypass shown in Figure 8 was 6-inch, Schedule 160 (0.718-in. nominal wall).

To evaluate this incident in terms of the criteria, note that:

a. P = operating pressure = 1250 psi

b. T = operating temperature = 340°F

c. Material was SA-106 Grade B, S_y = 30.5 ksi (at T = 340°F)

d. Point "X" in Figure 8 is "straight pipe"

e. The bending stress due to weight at Point "X" was 651 psi.

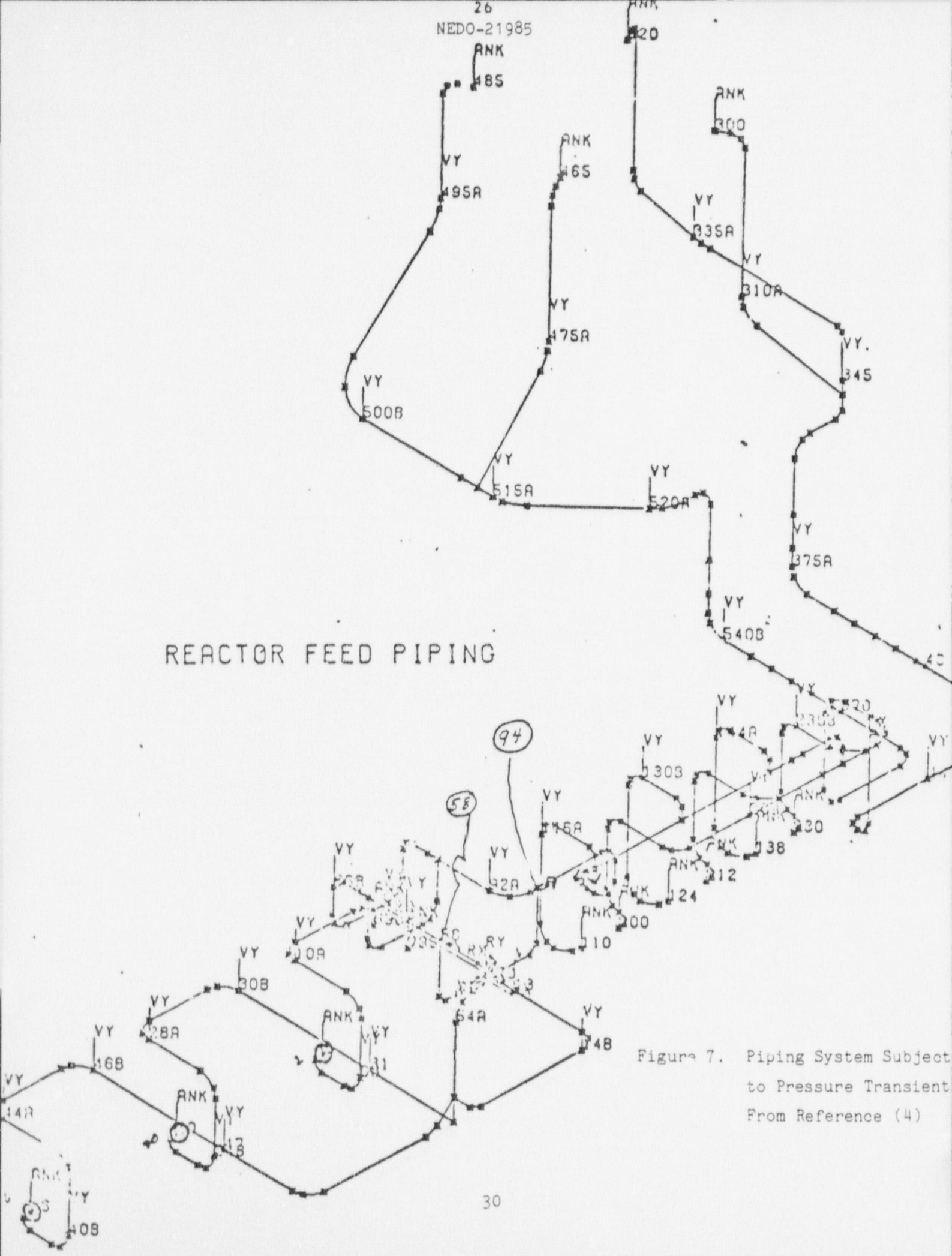

Figure 7. Piping System Subject to Pressure Transient From Reference (4)

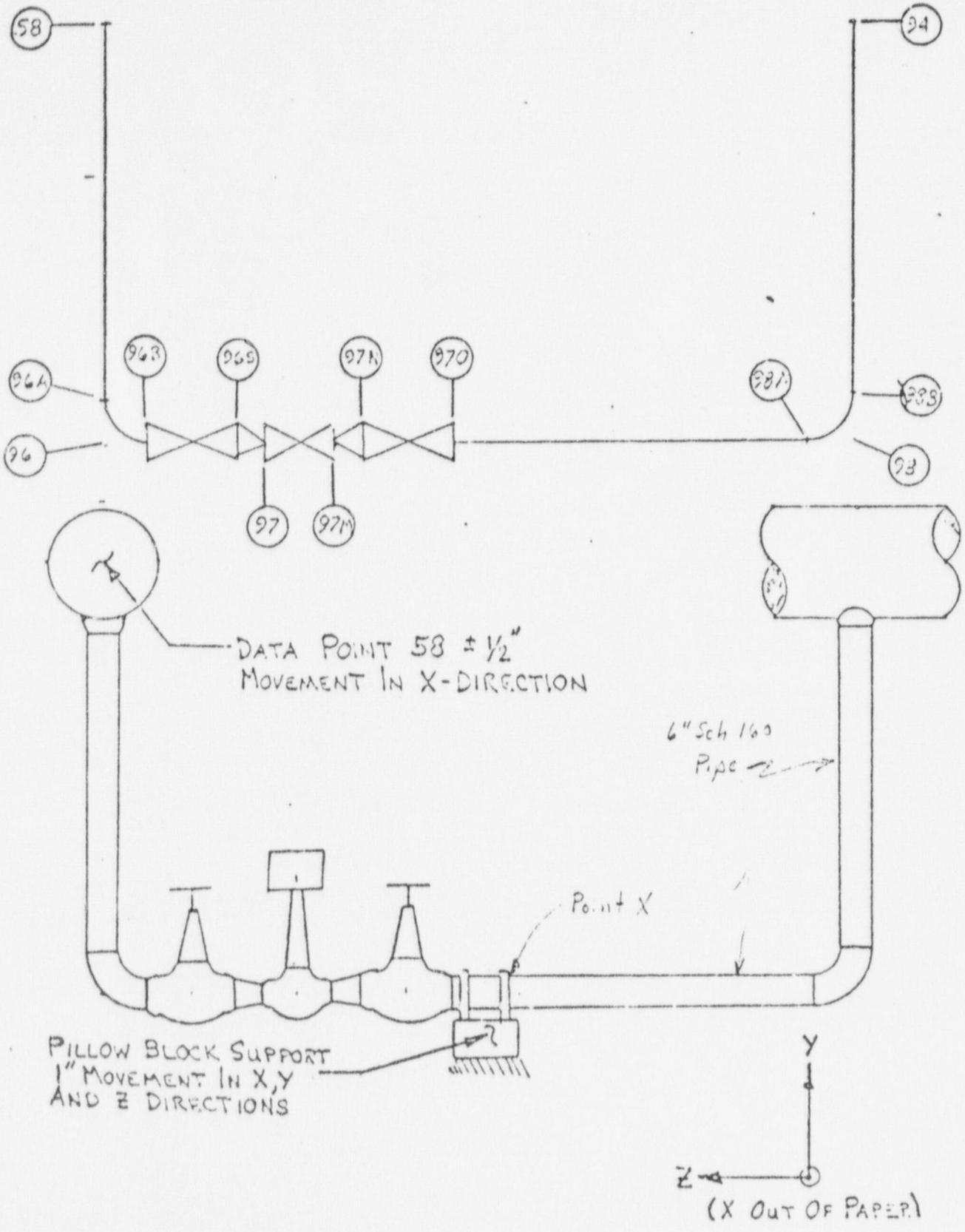

Figure 8. Portion of Piping System with Highest Calculated Stresses, From Reference (4)

Accordingly, the criteria gives:

$$B_1 \frac{PD_o}{2t} + B_2 \frac{M}{Z} < 1.5 \times 30500$$

$$\frac{1}{2} \times \frac{1250 \times 6.625}{2 \times 0.718} + 1.0 \times (53,328 + 651) < 45,750$$

$$2883 + 53,979 \leq 45,750$$

$$56,862 \leq 45,750$$

The ratio of 56,862 to 45,750 is 1.24, hence the stress in this incident exceeded the criteria limit by 24 percent. However, there was no evidence of loss of functional capability or any damage to the pipe.

This bit of quantified service experience adds confidence to the adequacy of the criteria. Additional evidence of this type may be developed and should aid in removing excess conservatism in the criteria.

4. REFERENCES

1. E. C. Rodabaugh, and S. E. Moore, **Evaluation of the Plastic Characteristics of Piping Products in Relation to Code Criteria**, NUREG/CR-0261, July 1978, ORNL/Sub-2913/8.

2. E. C. Rodabaugh, S. K. Iskander, and S. E. Moore, **End Effects on Elbows Subjected to Moment Loadings**, March 1978, ORNL/Sub-2913/7.

3. ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, **Pressure Vessels**, 1977 Edition with Addenda up to and including Summer 1978.

4. **Analysis of Reactor Feedwater (Piping System) Under Pressure Transients**, Sargent & Lundy Report, Dresden-3, Project No. 4989, October 1974.

5. E. C. Rodabaugh and S. E. Moore, **Stress Indices for Girth Welded Joints, Including Radial Weld Shrinkage, Mismatch and Tapered-Wall Transitions**, September 1978, NUREG/CR-0371, ORNL/Sub-2913/9.

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TITLE PAGE

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SUMMARY

This document gives "Functional Capability Criteria" for evaluation of piping in Mark II nuclear power plants. The criteria were selected so as to be conservative and, equally important, excess conservatism has been avoided where possible to assist in assuring maximum reliability of the piping considering all aspects of design, fabrication, in-service inspection, and operation.

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ATTACHMENT A

FINANCIAL REPORT

1976-77

UNIVERSITY OF VIRGINIA

ATTACHMENT B

UNIVERSITY OF VIRGINIA BUDGET SUMMARY

280

Engineering - Nuclear Reactor
(School, Department or Major Activity)

1977-78 REVISED BUDGET	TOTAL		State General		Source State Res (Spon. F
Academic Personnel	FTE's	Amount	FTE's	Amount	FTE's
Professors					
Associate Professors					
Assistant Professors					
Instructors					
Other					
Vacant					
Subtotal					
Graduate Instructors					
Non-academic Personnel	7.00	100,804	7.00	100,804	
Wages		250		250	
Subtotal		101,054		101,054	
Other Than Personal Services		23,800		23,800	
TOTAL		124,854		124,854	
1978-79 BUDGET ALLOWANCE					
Academic Personnel					
Professors					
Associate Professors					
Assistant Professors					
Instructors					
Other					
Vacant					
Subtotal					
Graduate Instructors					
Non-academic Personnel	7.00	100,804	7.00	100,804	
Wages		270		270	
Subtotal		101,074		101,074	
Other Than Personal Services		25,230		25,230	
TOTAL		126,304		126,304	

ATTACHMENT C

OFFICE OF THE
UNIVERSITY COMPTROLLER

December 8, 1978

TELEPHONE
(804) 924-3946

Mr. Thomas G. Williamson, Chairman
Department of Nuclear Engineering
University of Virginia

Dear Mr. Williamson:

I have reviewed the materials which you transmitted to me on November 9, 1978 concerning renewal of reactor operating license for twenty years. As requested by the Nuclear Regulatory Commission I will comment on the financial data requirements outlined in the Lincense Renewal Review Items under section A1(f).

(1) I have enclosed a copy of the University's 1976-77 audited Financial Report which is the most recent published report. Since the reactor operation at the University is funded as part of the State unrestricted budget for educational and general activities, the primary source of funds used to cover cost would be as follows:

Student Tuition and Fees	$19,056,466
State Appropriation - Current Operations	40,437,423
	$59,493,889

(2) The 1978-79 State General Fund operating budget for the reactor totaled $126,304 which equals 0.2% of the primary funding source as described in item (1). I am not authorized to guarantee the continuation of State support. However, given the Dean Gibson's commitment (enclosed) to support the reactor facility from funds which are allocated to the School of Engineering, I can reasonably assure that the amounts designated in the application for renewal will be included in future budgets.

Please feel free to contact me if you need any additional information in support of the license renewal.

Sincerely,

Peter L. Munger
University Comptroller

PLM/dhb
Enclosure
cc: Dean John E. Gibson

ATTACHMENT C

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF VIRGINIA

OFFICE OF THE DEAN
THORNTON HALL

November 29, 1978

CORRESPONDENT'S PHONE
(804) 924-3072

To: Mr. Peter L. Munger
University Comptroller

From: J. E. Gibson
Commonwealth Professor
and Dean

Re: Reactor License Renewal

It is my pleasure to support the application for renewal of the nuclear reactor license now pending before the NRC. The University of Virginia under the leadership of Dean Emeritus Lawrence R. Quarles and past chairman of the Nuclear Engineering Department, J. Lawrence Meem, Jr., gained an early position of national leadership in nuclear engineering education approximately 20 years ago with the establishment of the department and the construction of the reactor facility. We have the reputation of standing among the top half dozen departments of nuclear engineering in the country at present, and we are proud of the research accomplishments of our faculty and the contributions of our graduates.

The reactor facility is an important research tool for the entire University, and we certainly continue to have a strong commitment to maintaining and improving this facility using resources allocated to the School by the University and from contributions from industry as gifts and research grants.

JLG/me

CHARLOTTESVILLE, VIRGINIA 22901

ATTACHMENT D

UNIVERSITY OF VIRGINIA
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
CHARLOTTESVILLE, 22901

DEPARTMENT OF NUCLEAR ENGINEERING
REACTOR FACILITY

TELEPHONE: 804-924-7136

March 9, 1977

Mr. Victor Stello, Director
Division of Operating Reactors
Nuclear Regulatory Commission
Washington, D. C. 20555

Re: Docket No. 50-62
License No. R-66

Gentlemen:

An amendment is hereby requested to facility license No. R-66, Docket No. 50-62 to extend the expiration date of the license, September 13, 1977, for a period of twenty years.

The license pertains to the University of Virginia Research Reactor (UVAR) which has been operating successfully and safely since 1960, first at a maximum power level of one megawatt, and since 1971 at a maximum power level of two megawatts.

The reactor has been well utilized for research and the training of students, and we expect this utilization to continue for the indefinite future.

Yours very truly,

Original signed by J. L. Meem

J. L. Meem, Director
Reactor Facility

JLM/lt

Subscribed and sworn before me this 9th. day of March, 1977

Witness my hand and official seal.

Lena R. Thorne, Notary Public

cc: Reactor Safety Committee
Senior Operators

1. Additional information concerning the business of the applicant as identified in 10 CFR 50.33(c) and 10 CFR 50.33(d):

The University of Virginia is an institution of higher learning operated by the Commonwealth of Virginia and located in Charlottesville, Virginia. The central purpose of the University of Virginia is the enrichment of the human mind by stimulating and sustaining a spirit of free inquiry directed to an understanding of the nature of the universe and man's role in it.

As a part of this goal the University serves to educate men and women in the School of Engineering and Applied Science. The University of Virginia Reactor (UVAR) is an integral part of the School of Engineering and Applied Science of the University of Virginia.

The present officers of the University of Virginia, as related to the University of Virginia Reactor are as follows:

Rector of the University	William L. Zimmer, III, Richmond, Virginia
Visitors of the University	Clifton W. Barrett, Charlottesville, Virginia William C. Battle, Charlottesville, Virginia Robert P. Buford, Richmond, Virginia William M. Dudley, Lynchburg, Virginia Warren B. French, Jr., Edinburg, Virginia DuPont Guerry, III, M.D., Richmond, Virginia Virginia R. Holton, Roanoke, Virginia William E. Leggett, Charlottesville, Virginia Howard W. McCall, Jr., New York, N.Y. Stephen C. Mahan, Fairfax, Virginia George C. Palmer, II, Charlottesville, Virginia William S. Potter, Wilmington, Delaware Frank S. Royal, Richmond, Virginia Hugh Scott, Philadelphia, Pennsylvania Daniel F. Slaughter, Jr., Culpeper, Virginia William L. Zimmer, III, Richmond, Virginia Raymond C. Bice, Jr., the Secretary of the Visitors Charlottesville, Virginia
President of the University	Frank L. Hereford, Charlottesville, Virginia
Dean of the School of Engineering and Applied Sciences	John E. Gibson, Charlottesville, Virginia

All of the officers are citizens of the United States. The University of Virginia is not owned, controlled, or dominated by an alien, foreign corporation, or foreign government.

2. Additional information concerning other licenses issued in connection with the University of Virginia Reactor Facility as identified in 10 CFR 50.33(e).

The licenses issued to the University of Virginia in connection with or used by the University of Virginia Reactor Facility are as follows:

License Number	Docket Number	Subject
R-66	50-62	Operation of two megawatt University of Virginia Reactor
R-123	50-396	Operation of 100 watt CAVALIER Reactor
SNM-184	70-432	Possession of Special Nuclear Material
45-00034-26	-	Possession of by-product, source and/or special nuclear material

UNIVERSITY OF VIRGINIA
FINANCIAL REPORT 1976-77

To the President and Board of Visitors of the University of Virginia:

I am pleased to submit the annual financial report of the University of Virginia for the year ended June 30, 1977. The accompanying financial statements set forth the financial position of the University as of June 30, 1977 and a summary of the financial activity for the year then ended. Price Waterhouse & Co. has examined these statements and their report on the financial statements is included herein.

This is the first time that the University has issued an audited financial report. The engagement of Price Waterhouse & Co. by the State Auditor of Public Accounts to conduct annual audits for each fiscal year through June 30, 1979 represents a significant and welcomed change in policy. Not only will audits be conducted annually but also under the terms of the engagement the University will adopt the accrual method of accounting and conform its financial statements to generally accepted accounting principles for colleges and universities as provided by the AICPA audit guide for colleges and universities. As a result of the conversion to the accrual method of accounting and other changes in accounting procedures necessary to present financial information in accordance with generally accepted accounting principles as well as the problems associated with the development of historical information necessary to phase in the change, the Price Waterhouse & Co. report on the financial statements is qualified in several respects.

First, the report is qualified as to the reported balances for equipment. Historical records of equipment additions are not maintained nor is replacement or additional equipment generally capitalized and included in the balance sheet except to the extent it is part of the original equipment in a newly constructed facility. The statement of significant accounting policies describes the University's accounting policy regarding the reporting of both plant and equipment.

The qualification related to third party settlements again relates to a problem in documentation necessary to support reimbursement rates at the University Hospital as well as potential recoveries resulting from the University's requested relief from limitations on hospital routine care costs as described in Note 3.

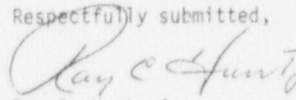
It is the judgment of management that the medical private clinic allowance for doubtful accounts is adequate to provide for possible losses in connection with collectibility. The Price Waterhouse & Co. qualification is based on the lack of sufficient documented historical data on which to express an opinion on the adequacy of this allowance. We are taking the appropriate actions to provide sufficient documentation of actual bad debt experience in the private clinics so that an auditable record on which to judge the adequacy of the allowance for doubtful accounts will exist.

Finally, for the purposes of financial reporting the University has adopted the accrual basis of accounting at June 30, 1977. However, it was not deemed feasible or necessary by terms of the engagement to attempt to determine and document all July 1, 1976 (beginning of the year) accruals such as accounts receivable and accounts payable balances. As a result, the statement of current funds revenues, expenditures and other changes is reported on a modified cash basis with accruals at June 30, 1977 reflected as an adjustment to the statement of changes in fund balances. For the year ended June 30, 1978, the balance sheet, the statement of current funds revenues, expenditures and other changes, and the statement of changes in fund balances will all be presented on an accrual basis since beginning accrual balances will be established. The adoption of the accounting principles prescribed in the AICPA audit guide resulted in numerous adjustments, additions, eliminations, and reclassifications in the accounting records. This matter is discussed in detail in Note 2 to the financial statements and I will not seek to paraphrase or repeat that note here.

As for the financial affairs of the University, unrestricted current fund revenues exceed expenditures and mandatory transfers on a modified cash basis by approximately $6.6 million. $3.1 million was transferred to quasi-endowment as designated by the Board, while $4.2 million was transferred to plant funds. The combined result of these actions reduced current fund balances on a cash basis by approximately $.7 million.

This report is, of necessity, a transitional financial report and as noted above the balance sheet is presented on an accrual basis while the statement of current fund revenues, expenditures and other changes is on a modified cash basis. Over the succeeding two years every attempt will be made to take the steps necessary to present the balance sheet, the statement of current funds revenues, expenditures and other changes, and the statement of changes in fund balances on an accrual basis. The progress toward this end made in preparing the fiscal report for 1977 along with the planning and documentation for the fiscal year ended June 30, 1978 is encouraging.

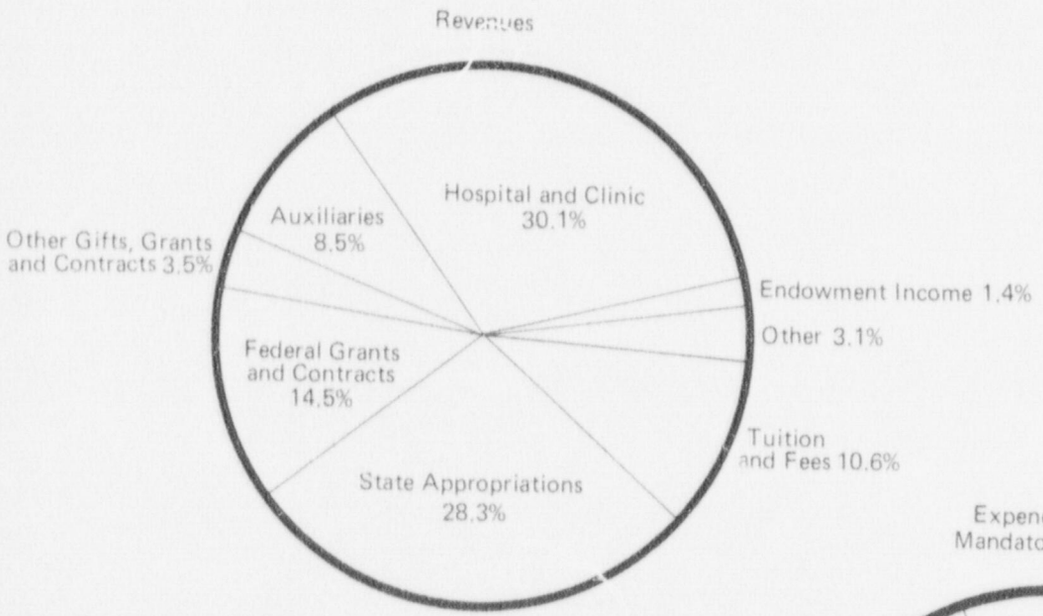
Respectfully submitted,

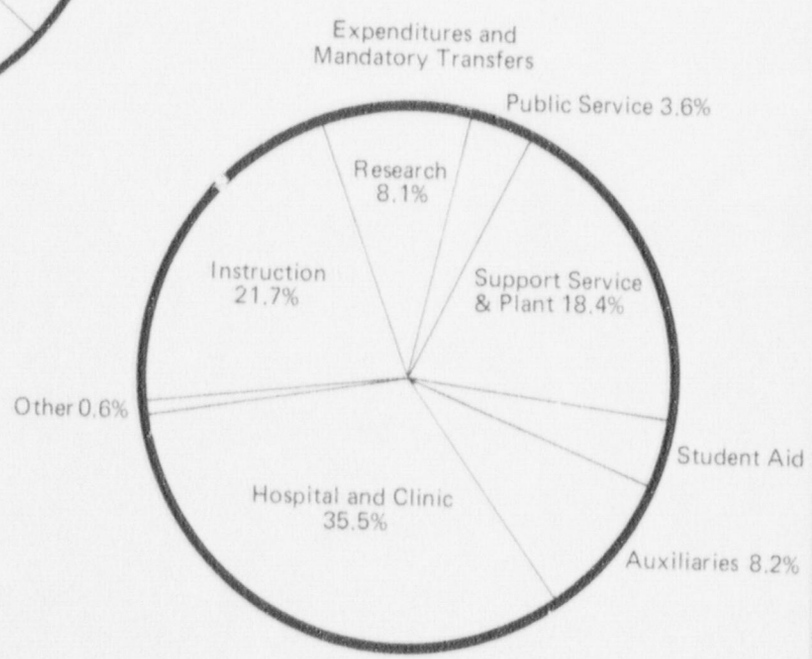


Ray C. Hunt, Jr.
Vice President for Business and Finance

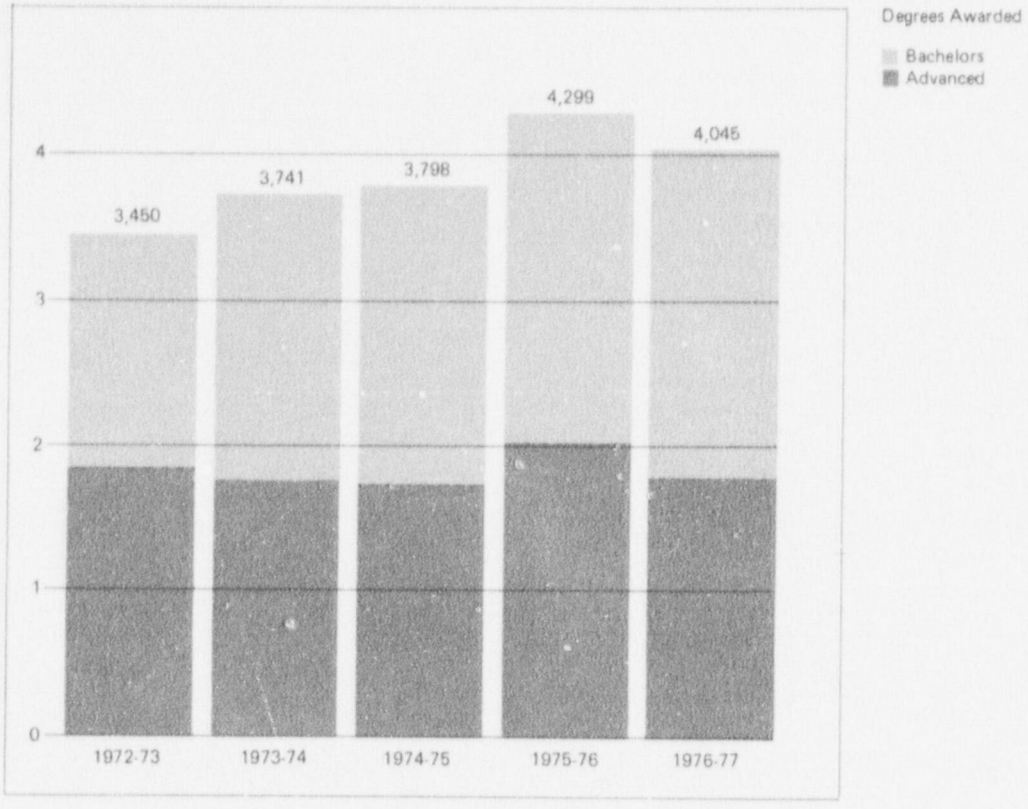
FINANCIAL HIGHLIGHTS

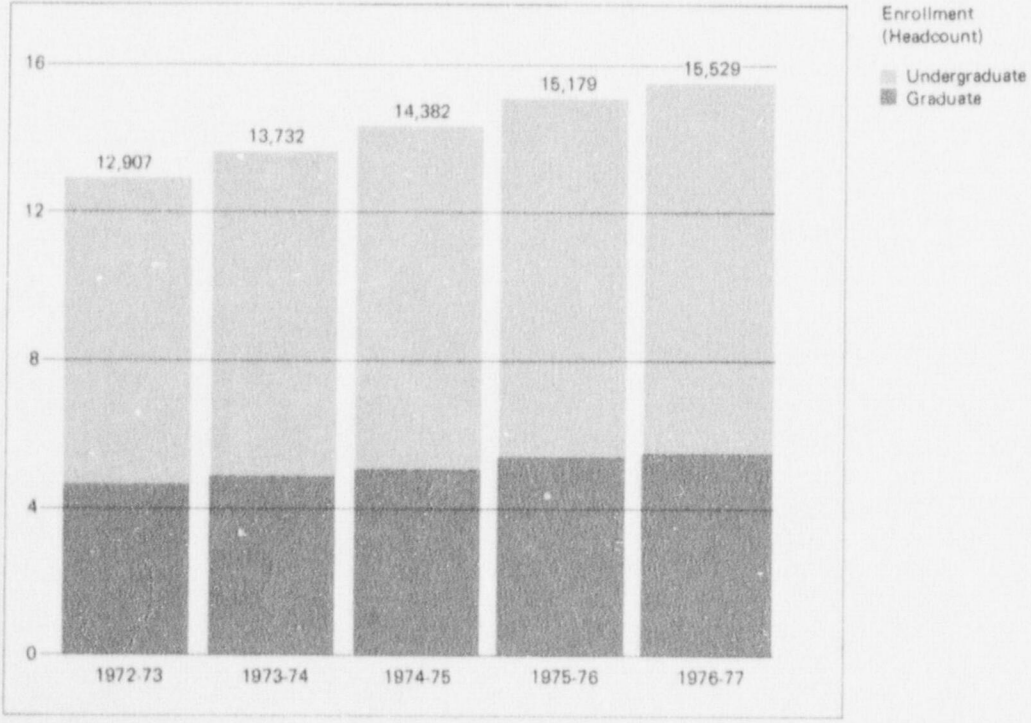
	1976-77
Total Current Fund Revenues	$ 177,135,538
Total Current Fund Expenditures and Mandatory Transfers	$ 170,490,822
Restricted Current Fund Revenues/Expenditures	$ 28,733,002
Endowment and Similar Fund Balances (Market Value)	
University Funds	$ 96,455,624
Funds Held by Trustees	$ 29,812,367
Faculty - University Division (Head-Count)	
Full-Time	1,531
Part-Time	129
Tuition and Fees - University Division (Arts and Sciences)	
Virginia Resident	$ 734
Out-of-State	$ 1,819





DEGREES AWARDED AND STUDENTS ENROLLED - UNIVERSITY DIVISION





Price Waterhouse & Co.

510 ROSS BUILDING
RICHMOND, VIRGINIA 23219
804-648-9281

April 21, 1978

Auditor of Public Accounts
Commonwealth of Virginia

Board of Visitors
University of Virginia

We have examined the balance sheet of the University of Virginia as of June 30, 1977 and the related statement of current funds revenues, expenditures and other changes and the statement of changes in fund balances (both on the basis of accounting described in Note 1) for the year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances, except as indicated in the following paragraph.

The University does not maintain detail accounting records relating to equipment included in plant funds - investment in plant. As a result we were not able to perform such tests as would be necessary to satisfy us as to these amounts. In addition, as described in Note 1, current funds expenditures for equipment and library acquisitions are generally not capitalized.

As explained in Note 3, revenues received by the University Hospital under cost reimbursement agreements with third party payors are subject to audit and retroactive adjustments. The University is in the process of reviewing the bases on which reimbursable costs have been determined, which may result in revised bases of cost allocation and additional documentation for costs considered reimbursable under these programs. In addition, the University is requesting relief from limitations which have been imposed upon reimbursable routine care costs. The final reimbursement under these programs cannot be determined at this time.

In conjunction with the adoption of accrual basis accounting effective June 30, 1977 (as described in Notes 1 and 2) accounts receivable of the private clinics were recorded together with an allowance for doubtful accounts of $6,354,927. This allowance was established by University management based on an analysis of outstanding accounts and represents their best judgment of potential uncollectibility under the circumstances. However, the private clinic accounts receivable records have been primarily oriented to cash collections and do not contain sufficient historical information to relate collections or account write-off and contractual adjustment experience to charges for services performed. As a result, we are unable to satisfy ourselves as to the reasonableness of management's estimate of ultimate collectibility of private clinic accounts receivable.

As described in Note 2, the University has made significant changes in accounting and financial reporting for the year ended June 30, 1977. To the extent that such changes relate to the nature or fund classification of accounts included in the accompanying financial statements, adjustments have been made to beginning fund balances in the statement of changes in fund balances. Adjustments relating to the adoption of the accrual basis of accounting as of June 30, 1977 are shown separately as adjustments of fund balances in the statement of changes in fund balances.

In our opinion, subject to (1) the effects, if any, on estimated amounts due on settlement with third party payors arising from the matters referred to in the third paragraph above, and (2) the effects of such adjustments, if any, as might have been required had the ultimate collectibility of private clinic accounts receivable been susceptible of reasonable estimation as described in the fourth paragraph above, and except for the amounts reflected as capitalized for equipment in plant funds - investment in plant as explained in the second paragraph above, the aforementioned financial statements examined by us present fairly the financial position of the University of Virginia at June 30, 1977 in conformity with generally accepted accounting principles and the current funds revenues, expenditures and other changes and changes in fund balances for the year then ended on the basis of accounting described in Note 1, which, except for the changes (with which we concur) referred to in the preceding paragraph, have been applied on a basis consistent with that of the preceding year.

Price Waterhouse & Co.

STATEMENT OF CURRENT FUNDS REVENUES, EXPENDITURES AND OTHER CHANGES
(ON THE BASIS OF ACCOUNTING DESCRIBED IN NOTE 1)
FOR THE YEAR ENDED JUNE 30, 1977

	Total	Unrestricted	Restricted
REVENUES			
Student Tuition and Fees	$ 19,056,466	$ 19,056,466	$ . . . . .
State Appropriations - Hospital	8,748,503	8,748,503	. . . . .
State Appropriations - Current Operations	41,348,307	40,437,423	910,884
Federal Grants and Contracts	25,741,004	5,031,242	20,709,762
State Grants and Contracts	265,160	13,893	251,267
Local Grants and Contracts	7,951	450	7,501
Private Gifts, Grants and Contracts	6,002,562	1,032,603	4,969,959
Endowment Income	2,448,324	567,527	1,880,797
Sales and Services of Educational Departments	1,300,128	1,300,128	. . . . .
Sales and Services of Auxiliary Enterprises	15,131,060	15,131,060	. . . . .
Sales and Services of Hospital	40,286,369	40,286,369	. . . . .
Sales and Services of Private Clinics	12,823,471	12,823,471	. . . . .
Sales and Services of Independent Operations	928,255	928,255	. . . . .
Other Sources	3,047,978	3,045,146	2,832
Total - Revenues	$ 177,135,538	$ 148,402,536	$ 28,733,002
EXPENDITURES AND MANDATORY TRANSFERS			
Educational and General			
Instruction	$ 36,939,979	$ 33,128,803	$ 3,811,176
Research	13,848,909	415,769	13,433,140
Public Service	6,097,672	1,491,824	4,605,848
Academic Support	12,340,236	11,581,036	759,200
Student Services	3,558,886	3,551,075	7,811
Institutional Support	8,056,958	7,794,028	262,930
Operation and Maintenance of Plant	7,344,570	7,321,616	22,954
Scholarships and Fellowships	6,632,135	908,246	5,723,889
Total - Educational and General	$ 94,819,345	$ 66,192,397	$ 28,626,948
Mandatory Transfers for Debt Service	42,544	42,544	. . . . .
Total - Educational and General Expenditures and Mandatory Transfers	$ 94,861,889	$ 66,234,941	$ 28,626,948
Auxiliary Enterprises			
Operating Expenditures	$ 12,525,456	$ 12,525,456	$ . . . . .
Mandatory Transfers for Debt Service	1,532,869	1,532,869	. . . . .
Total - Auxiliary Enterprises Expenditures and Mandatory Transfers	$ 14,058,325	$ 14,058,325	$ . . . . .
Hospitals	$ 48,963,399	$ 48,857,345	$ 106,054
Private Clinics	$ 11,679,969	$ 11,679,969	$ . . . . .
Independent Operations			
Operating Expenditures	$ 466,824	$ 466,824	$ . . . . .
Mandatory Transfers for Debt Service	460,416	460,416	. . . . .
Total - Independent Operations Expenditures and Mandatory Transfers	$ 927,240	$ 927,240	$ . . . . .
Total - Expenditures and Mandatory Transfers	$ 170,490,822	$ 141,757,820	$ 28,733,002
OTHER TRANSFERS AND ADDITIONS/(DEDUCTIONS)			
Excess of Restricted Receipts over Transfers to Revenues	$ 3,066,322	$	$ 3,066,322
Refunded to Grantors	(173,791)	. . . . .	(173,791)
Non-Mandatory Transfers:			
To Endowment Funds	(3,688,239)	(3,168,778)	(519,461)
To Loan Funds	(19,221)	. . . . .	(19,221)
To Plant Funds	(4,305,702)	(4,171,524)	(134,178)
Net Increase/(Decrease) In Fund Balances	$ 1,524,085	$ (695,586)	$ 2,219,671

BALANCE SHEET
As of June 30, 1977

ASSETS

CURRENT FUNDS	
Unrestricted:	
Cash and Temporary Investments	$ 14,213,598
Notes Receivable	26,587
Accounts Receivable - Hospital, less allowance for doubtful accounts and contractual adjustments of $8,682,975	15,212,731
Estimated Amounts due from Third Party Payors (Note 3)	8,725,468
Accounts Receivable - Private Clinics, less allowance for doubtful accounts of $6,354,927	4,636,170
Accounts Receivable - Other, less allowance for doubtful accounts of $131,440	652,055
Inventories	2,880,425
Prepaid Expenses	806,943
Due from Current Restricted Funds	253,612
Due from Loan Funds	58,472
Due from Unexpended Plant Funds	32,203
Due from Endowment and Similar Funds	223,550
Loan Receivable from Investment in Plant Funds (Note 6)	1,001,032
Total Unrestricted	$ 48,722,846
Restricted:	
Cash and Temporary Investments	$ 8,398,391
Grants and Contracts Receivable	1,789,697
Accounts Receivable	643,820
Prepaid Expenses	1,392
Due from Current Unrestricted Funds	514,978
Due from Endowment and Similar Funds	936,972
Total Restricted	$ 12,285,250
TOTAL CURRENT FUNDS	$ 61,008,096
LOAN FUNDS	
Cash and Temporary Investments	$ 575,647
Notes Receivable, less allowance for doubtful notes receivable of $913,268	7,527,808
TOTAL LOAN FUNDS	$ 8,103,455

LIABILITIES AND FUND BALANCES

CURRENT FUNDS

Unrestricted:	
Accounts Payable and Accrued Expenses	$ 4,507,996
Deposits and Deferred Revenues	1,963,225
Advance from Alumni Board of Trustees	65,000
Advance from Treasurer of Virginia	875,600
Due to Current Restricted Funds	514,978
Due to Unexpended Plant Funds	1,732,912
Fund Balance	39,063,135
Total Unrestricted	$ 48,722,846
Restricted:	
Accounts Payable and Accrued Expenses	$ 493,463
Grants and Contracts Prepayments	1,004,244
Advance from Treasurer of Virginia	1,100,000
Due to Current Unrestricted Funds	253,612
Fund Balances	9,433,931
Total Restricted	$ 12,285,250
TOTAL CURRENT FUNDS	$ 61,008.096

LOAN FUNDS

Due to Current Unrestricted Funds	$ 58,472
Fund Balances:	
U.S. Government Grants Refundable	6,770,608
University Funds - Restricted	1,274,375
TOTAL LOAN FUNDS	$ 8,103,455

BALANCE SHEET (CONT'D)
As of June 30, 1977

ASSETS, CONTINUED

ENDOWMENT AND SIMILAR FUNDS	
Cash and Temporary Investments	$ 7,872,731
Investments at Market Value (Note 4)	94,600,334
Loan Receivable from Investment in Plant (Note 6)	3,317,618
TOTAL ENDOWMENT AND SIMILAR FUNDS	$ 105,790,683
PLANT FUNDS	
Unexpended:	
Cash and Temporary Investments	$ 3,189,743
Undrawn Appropriations	181,324
Accounts Receivable	2,418,554
Due from Current Unrestricted Funds	1,732,912
Total Unexpended	$ 7,522,533
Renewals and Replacements:	
Cash and Temporary Investments	$ 1,277,908
Retirement of Indebtedness:	
Cash and Temporary Investments	$ 465,733
Investments with Treasurer of Virginia	1,071,337
Total Retirement of Indebtedness	$ 1,537,070
Investment in Plant:	
Land	$ 7,633,136
Land Improvements	8,828,704
Buildings	141,201,472
Equipment	10,232,839
Total Investment in Plant	$ 167,896,151
TOTAL PLANT FUNDS	$ 178,233,662
AGENCY FUNDS	
Cash and Temporary Investments	$ 201,934
TOTAL AGENCY FUNDS	$ 201,934

LIABILITIES AND FUND BALANCES, CONTINUED

ENDOWMENT AND SIMILAR FUNDS

Due to Current Unrestricted Funds	$ 223,550
Due to Current Restricted Funds	936,972
Bonds Payable,	
Less Discount and Closing Costs (Note 6)	8,174,537
Fund Balances:	
Endowment	40,559,343
Term Endowment	1,207,604
Quasi-endowment - Unrestricted	23,131,648
Quasi-endowment - Restricted	31,557,029
TOTAL ENDOWMENT AND SIMILAR FUNDS	$ 105,790,683

PLANT FUNDS

Unexpended:	
Accounts Payable	$ 1,221,300
Due to Current Unrestricted Funds	32,203
Fund Balances:	
Restricted	2,548,662
Unrestricted	3,720,368
Total Unexpended	$ 7,522,533
Renewals and Replacements:	
Fund Balances:	
Unrestricted	$ 1,277,908
Retirement of Indebtedness:	
Fund Balances:	
Unrestricted	$ 1,537,070
Total Retirement of Indebtedness	$ 1,537,070
Investment in Plant:	
Advance from Treasurer of Virginia	$ 3,974,000
Bonds Payable (Note 6)	19,197,036
Loan Payable to Current Unrestricted (Note 6)	1,001,032
Loan Payable to Endowment (Note 6)	3,317,618
Net Investment in Plant	140,406,465
Total Investment in Plant	$ 167,896,151
TOTAL PLANT FUNDS	$ 178,233,662

AGENCY FUNDS

Deposits Held in Custody for Others	$ 201,934
TOTAL AGENCY FUNDS	$ 201,934

STATEMENT OF CHANGES IN FUND BALANCES
(On the Basis of Accounting Described in Note 1)
For the Year Ended June 30, 1977

	Current Funds		
	Unrestricted	Restricted	Loan Funds
Revenues and Other Additions:			
Unrestricted Current Fund Revenues	$ 148,402,536	$	$ . . . .
State Appropriations - Restricted	. . . . .	913,799	. . . .
Federal Grants and Contracts - Restricted	. . . . .	23,836,994	. . . .
State Grants and Contracts - Restricted	. . . . .	897,081	. . . .
Local Grants and Contracts - Restricted	. . . . .	11,800	. . . .
Private Gifts, Grants and Contracts - Restricted	. . . . .	6,352,205	28,153
Endowment Income	. . . . .	4,644,338	9,076
Interest on Loans Receivable	. . . . .	. . . .	68,737
U. S. Government Advances	. . . . .	. . . .	1,060,799
Expended for Plant Facilities	. . . . .	. . . .	. . . .
Realized Gains on Investments	. . . . .	. . . .	. . . .
Retirement of Indebtedness	. . . . .	. . . .	. . . .
Other Sources	. . . . .	30,883	745
Total Revenues and Other Additions	$ 148,402,536	$ 36,687,100	$ 1,167,510
Expenditures and Other Deductions:			
Educational and General Expenditures	$ 66,192,397	$ 28,626,948	$ . . . .
Auxiliary Enterprise Expenditures	12,525,456	. . . .	. . . .
Hospital Expenditures	48,857,345	106,054	. . . .
Private Clinic Expenditures	11,679,969	. . . .	. . . .
Independent Operations Expenditures	466,824	. . . .	. . . .
Indirect Costs Recovered	. . . . .	4,887,776	. . . .
Refunded to Grantors	. . . . .	173,791	12,025
Loan Cancellations and Write-offs	. . . . .	. . . .	111,765
Administrative and Collection Costs	. . . . .	. . . .	744
Expended for Plant Facilities (Including $12,990 Not Capitalized)	. . . . .	. . . .	. . . .
Retirement of Indebtedness	. . . . .	. . . .	. . . .
Interest on Indebtedness	. . . . .	. . . .	. . . .
Unrealized Loss of Endowments (Due to Decrease in Market Value)	. . . . .	. . . .	. . . .
Additional Plant Indebtedness	. . . . .	. . . .	. . . .
Total Expenditures and Other Deductions	$ 139,721,991	$ 34,794,569	$ 124,534
Transfers Among Funds:			
Mandatory:			
Principal and Interest	$ (2,035,829)	$	$ . . . .
Non-mandatory:			
Principal and Interest	(469,626)	(134,178)	. . . .
(To)/From Other Funds	(6,870,676)	(538,682)	19,221
Total Transfers	$ (9,376,131)	$ (672,860)	$ 19,221
Net Increase/(Decrease) for the Year	$ (695,586)	$ 2,219,671	$ 1,062,197
Fund Balance at Beginning of Year	8,072,042	12,519,663	7,717,690
Adjustments to Beginning Fund Balance	5,331,014	(5,899,532)	236,836
Accrual Adjustments	26,355,665	594,129	(971,740)
Fund Balance at End of Year	$ 39,063,135	$ 9,433,931	$ 8,044,983

Endowment and Similar Funds	Plant Funds: Unexpended	Plant Funds: Renewal and Replacements	Plant Funds: Retirement of Indebtedness	Plant Funds: Investment in Plant
$	$	$	$	$ . . . .
. . . .	337,118	. . . .	. . . .	. . . .
. . . .	1,265,812	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
2,589,558	1,287,381	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	6,610,148
2,402,596	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	1,759,747
. . . .	2,938,800	220,473	398,206	. . . .
$ 4,992,154	$ 5,829,111	$ 220,473	$ 398,206	$ 8,369,895
$	$	$	$	$ . . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
67,430	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	6,537,964	85,174	. . . .	. . . .
. . . .	. . . .	. . . .	1,759,747	. . . .
. . . .	. . . .	. . . .	1,137,899	. . . .
3,532,482	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	2,413,205
$ 3,599,912	$ 6,537,964	$ 85,174	$ 2,897,646	$ 2,413,205
$	$	$	$ 2,035,829	$ . . . .
. . . .	(56,300)	(57,900)	718,004	. . . .
3,686,964	3,234,170	469,003	. . . .	. . . .
$ 3,686,964	$ 3,177,870	$ 411,103	$ 2,753,833	$ . . . .
$ 5,079,206	$ 2,469,017	$ 546,402	$ 254,393	$ 5,956,690
131,636,192	1,615,541	. . . .	1,232,627	130,716,998
(40,259,774)	(713,491)	731,506	50,050	2,511,477
. . . .	2,897,963	. . . .	. . . .	1,221,300
$ 96,455,624	$ 6,269,030	$ 1,277,908	$ 1,537,070	$140,406,465

NOTES TO THE FINANCIAL STATEMENTS

NOTE 1 - SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

The accompanying financial statements include the accounts of all organizational units of the University of Virginia including the University Division, the University Hospital, the Division of Continuing Education and Clinch Valley College. The significant accounting policies followed by the University are as follows:

a. Basis of accounting

The University has historically reported on a modified cash basis of accounting whereby revenues and expenses were generally recognized as received or paid (See Note 2). Effective June 30, 1977, the University has adopted the accrual basis of accounting in accordance with generally accepted accounting principles for educational institutions. It was not practicable to determine appropriate accrual adjustments as of the beginning of the year ended June 30, 1977. Consequently, the accompanying Statement of Current Funds Revenues, Expenditures and Other Changes and the Statement of Changes in Fund Balances are presented on the modified cash basis, except that the net amount necessary to convert each fund to the accrual basis as of June 30, 1977 is reflected as an adjustment of fund balances at the end of the year. As a result of these changes, comparative financial statements for the prior year are not provided.

The accrual basis of accounting has been adopted by the University in accordance with the American Institute of Certified Public Accountants' audit guide for colleges and universities. Accruals for investment income, interest on student loans and interest payable on bonds have not been recorded and are not considered by management to be material in relation to the accompanying financial statements. In addition, the University follows the practice of recording gifts and pledges when collected. No value is assigned to art and other collections received as gifts.

Non-faculty salaried employees' attendance and leave regulations make provision for the granting of a specified number of days leave with pay each year. The amount of leave earned but not taken as of June 30, 1977 is not recorded on the balance sheet; however, records are maintained for each employee showing the number of days accrued.

b. Fund accounting

In order to ensure observance of limitations and restrictions placed on the use of resources available to the University, the accounts of the University are maintained in accordance with principles of fund accounting. The accounts relating to specified activities or objectives have been classified into separate funds. Similar funds have been combined for financial reporting purposes.

Within each fund group, fund balances restricted by outside sources are so indicated and are distinguished from unrestricted funds allocated to specific purposes by action of the Board of Visitors. Restricted resources may only be used for the purposes established by the source of such funds.

Restricted gifts, appropriations, endowment income and other restricted sources are accounted for in the appropriate restricted funds. Restricted funds are reported as revenues and expenditures when expended for current operating purposes.

Gains and losses arising from the sale, collection or other disposition of investments and other noncash assets are accounted for in the fund owning such assets, except for income derived from investments of endowment and current restricted funds, which income is accounted for in the fund to which it is restricted, or, if unrestricted, as revenues in unrestricted current funds.

c. Inventories

Inventories are valued at the lower of cost (generally determined on the first-in, first-out method) or market.

d. Investments

Temporary investments and endowment fund investments in corporate stocks and marketable bonds are recorded at market value. Mortgages held for investment by the endowment fund are recorded at book value representing amounts currently due.

e. Net investment in plant

Plant assets are stated at cost or, in the case of Hospital, at estimated historical cost determined by an independent appraisal with subsequent additions at cost. Current fund expenditures for renewals and replacements are capitalized only to the extent that such expenditures represent

long term improvements to properties. Current fund expenditures for equipment and library acquisitions are generally not capitalized.

The accompanying financial statements include no provision for depreciation of plant assets.

f. Interfund borrowings and advances

Interfund borrowings and advances represent the temporary use of current funds pending the receipt of monies from grants, loan agreements or the receipt of pledged gifts from various donors.

g. Funds held in trust by others

Assets of funds held by trustees for the benefit of the University are not reflected in the accompanying balance sheet. The University has irrevocable rights to all or a portion of the income of these funds. However, assets of the funds are not under the management discretion of the University according to the trust agreements. The following table reflects the market value of these funds at June 30, 1977 and the amount of income received from their trustees during the year then ended:

Market value of funds held by trustees for the benefit of the University	$ 29,812,367
Income received from funds held by trustees for the benefit of the University	$ 1,200,187

Assets of affiliated foundations which are separately incorporated and managed by their own boards are not included in these statements. These foundations are organized as fund raising activities which either support the University or benefit specific schools. Income received from such foundations is recorded as a gift when received.

NOTE 2 - CHANGES IN METHOD OF REPORTING

The adjustments of June 30, 1976 fund balances shown in the Statement of Changes in Fund Balances result primarily from the following changes in financial reporting from that used by the University in prior years:

a. Inclusion of Clinch Valley College Division.

b. Reclassification of unrestricted and restricted funds, principally relating to medical private clinic funds.

c. Exclusion from endowment funds of funds held in trust by others.

d. Creation of "plant funds - renewal and replacement" by reclassifying amounts from "unexpended plant funds."

In addition, as described in Note 1, the University has adopted the accrual basis of accounting effective June 30, 1977. Except for the recognition of certain accounts receivable and inventories and the recording of grants and contracts when awarded in prior years, the University has been on the cash basis of accounting. In conjunction with the adoption of accrual accounting, various changes in presentation and classification have also been made, including changes in amounts identified as restricted or unrestricted and in the classification of different types of endowment funds.

NOTE 3 - ESTIMATED AMOUNTS DUE ON SETTLEMENT WITH THIRD PARTY PAYORS

Revenues under reimbursement agreements with Medicare and Medicaid are determined on the basis of the cost of providing services to patients covered by these plans, subject to certain limitations. Revenues received under these cost reimbursement agreements are subject to audit and retroactive adjustments by the third party payors. Adjustments resulting from audits of cost reports filed for periods through June 30, 1976 have been reflected in the accompanying financial statements. The University is in the process of reviewing the bases on which reimbursable costs have been determined, which may result in revised bases of cost allocation and additonal documentation of costs considered reimbursable under these programs.

For each of the three years ended June 30, 1977 the Hospital's cost reimbursement has been subject to a limitation on inpatient general routine service costs arising from its classification as a "non-urban" hospital. During this period, actual costs based on cost reports filed or adjusted, as appropriate, exceeded this limitation by an aggregate of approximately $3,500,000. On January 9, 1978, the Hospital submitted to the Health Care Financing Administration a request for relief from such limitations under various exemptions or exceptions as provided by Medicare regulations.

The changes, if any, in final reimbursement under these programs which may result from the above described matters cannot be determined at this time.

NOTE 4 - VALUATION AND PERFORMANCE OF ENDOWMENT AND SIMILAR FUNDS

Investments of endowment and similar funds at June 30, 1977 are composed of the following:

	Market Value	Cost
Corporate Stocks	$ 55,581,885	$ 47,505,807
Bonds	12,847,104	12,360,023
Mortgages	17,672,761	17,672,761
Miscellaneous	1,297,439	1,307,376
Cash and Short-Term Investments	7,201,145	7,190,098
	$ 94,600,334	$ 86,036,065

Included in endowment investments are $10,840,825 of real estate mortgages which are held by Virginia National Bank as trustee under a bond indenture agreement related to outstanding bonds of $8,174,537 issued in 1972. These real estate mortgages are pledged as security for the bonds outstanding. Under the terms of the agreement, the principal and interest payments on the mortgages are collected by the trustee and, in turn, used to pay the principal and interest on the bonds outstanding.

The major portion of the investments of endowment and similar funds are pooled under two major funds. The Consolidated Endowment Fund is the general endowment pool for the University. Investments in this fund are based upon a total return policy which includes the utilization of endowment resources in conformity with the Uniform Endowment Law. Accordingly, the University has adopted a policy of utilizing total return (income and appreciation) from its endowment resources up to, but not exceeding, 4% of the average market value of its consolidated assets for the preceding three years. To the extent that the total return requirement for the current year is not fulfilled by interest and dividends, the University utilizes the realized gains of the Consolidated Endowment Fund. During the past two years income from dividends and interest has exceeded the amount authorized, making it unnecessary to utilize endowment resources.

The Eminent Scholars Fund is the second major pooled fund. Income from the fund is used to attract and retain distinguished scholars in conjunction with the Commonwealth of Virginia Eminent Scholars Fund. This fund is not operated under a total return formula.

Both the Consolidated Endowment Fund and the Eminent Scholars Fund are pooled on a market value basis, with each individual fund subscribing to or disposing of units on the basis of the market value per unit at the beginning of the calendar quarter within which the transaction takes place. A summary of book and market values as of June 30, 1977, together with unit value information and earnings per unit for the year then ended for the pooled funds is presented below:

Separately Invested Funds		
Book value		$ 11,824,621
Unrealized net loss		(373,751)
Market value		$ 11,450,870
Consolidated Endowment Fund		
Book value		$ 68,941,172
Unrealized net gain		8,118,982
Market value		$ 77,060,154
Unit Values		
Number of units		349,284
Book value	$	197.38
Unrealized net gains		23.24
Market value	$	220.62
Earnings per unit (Exclusive of net gain)	$	10.77

Eminent Scholars Fund

Book value	$ 7,125,561
Unrealized net gain	819,039
Market Value	$ 7,944,600

Unit Values

Number of units	77,768
Book value	$ 91.63
Unrealized net gain	10.53
Market value	$ 102.16
Earnings per unit (Exclusive of net gain)	$ 6.66

NOTE 5 - PENSION PLANS

Full time faculty and certain administrative staff participate in the University's retirement annuity program through TIAA/CREF Insurance Companies. Individual contracts issued under the plan provide for full and immediate vesting of both the University's and the participants' contributions. Total pension costs under this plan were approximately $2,752,682 in 1977.

All other full-time salaried employees are participants in the Virginia Supplemental Retirement System. The employer's cost related to the contributory retirement program is largely funded through central appropriations at the State level. Consequently, such costs are included in current fund expenditures only to the extent of direct charges to sponsored programs and auxiliary enterprise activites. VSRS retirement payments are based on a guaranteed retirement formula based on years of service and achieved salary levels.

NOTE 6 - LONG-TERM DEBT

Long-term debt at the University at June 30, 1977 consists of the following:

Investment in Plant Fund:	
Temporary advances with interest at 4% from the Treasurer of Virginia for construction of the Primary Care Center and Student Housing. Long-term financing for these projects has been authorized.	$ 3,974,000
Loans payable to endowment funds represent loans for long-term financing of auxiliary facilities approved by the Board of Visitors with interest from 4% to 7%. Loans are payable over periods of up to 20 years.	3,317,618
Loans payable to current unrestricted funds represent advances for periods of up to 5 years for construction of several facilities approved by the Board of Visitors.	1,001,032
Commonwealth of Virginia bonds issued by the Treasurer of Virginia pursuant to the provisions of Section 9(c) of Article X of the Constitution of Virginia. This subsection provides that the General Assembly may authorize the creation of debt secured by a pledge of net revenues derived from rates, fees or other charges and the full faith and credit of the Commonwealth, provided that such debt is created for specific revenue producing capital projects of, among others, institutions of higher learning of the Commonwealth. Interest rates on these bonds range from 3.5% to 6%.	11,555,000
University of Virginia Housing Revenue Bonds with interest from 3% to 4%.	6,145,000
Other bonds including $994,000 of Department of Housing and Urban Development supported issues with interest rates from 2.875% to 7.5%.	1,497,036
Endowment Funds:	
Faculty Mortgage Revenue Bonds with interest rates from 3.9% to 5.5%. These bonds are payable in installments to maturity in 1997.	8,174,537
	$35,664,223

NOTE 7 - COMMITMENTS

At June 30, 1977 the University was a party to construction contracts and commitments totaling $13,787,199 of which $5,048,020 has been incurred.

The University occupies certain buildings and uses various types of equipment under lease arrangements. Commitments for subsequent fiscal years are as follows:

1977-78	$ 1,950,000
1978-79	$ 1,937,000
1979-80	$ 1,566,000
1980-81	$ 900,000
1981-82	$ 42,000

The total rental expense for all property and equipment under such arrangements was approximately $3,100,000 for fiscal year 1976-77.

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