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PROCEDURE FOR DETERMINING SYNCHRO SYSTEM LOADING CAPACITY

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References

(a) Military Specification MIL-S-20708, General Specification for Synchros.

(b) General Specifications for Ships of the United States Navy, Sections 9650-0 and 9650-5.

(c) Naval Applied Science Laboratory Synchro System Loading Manual - Parameters and Techniques for determining system loading capacity - 31 August 1965 - LAB. PROJECT 9500-15, FINAL REPORT.

(d) OP1303, United States Navy Synchros, Description and Operation.

(e) Drawing, NAVSHIPS 815-1853311, Synchro System Loading Tabulation Form.

9650-2-a. Scope

This design data sheet provides a guide in the analysis of synchro system loading. Procedures are provided for use in tabulating the data necessary to accomplish the analysis and to indicate the system status with respect to limitation on format similar to drawing, NAVSHIPS No. 815-1853311.

9650-2-b. Symbols

Abbreviation	Functional Classification
CX	Synchro control transmitter
CT	Synchro control transformer
CDX	Synchro control differential transmitter
TX	Synchro torque transmitter
TR	Synchro torque receiver
TRX	Synchro torque receiver-transmitter
TDX	Synchro torque differential transmitter

Symbols not indicated are identified in the particular paragraphs of formula development and application.

9650-2-c. Introduction

A minimum synchro system is comprised of one synchro transmitter and one synchro receiver. The system increases in complexity with the installation of additional receivers. Since these synchros have a range of size, and limitations exist as to the quantity of receivers any transmitter can drive without signal degradation, it is necessary to analyze each system, regardless of complexity, to determine whether or not the transmitter can accommodate the connected receivers and maintain the established system tolerance.

Synchro parameters that affect synchro system loading are:

Voltage regulation as a function of secondary load dependent upon load current and impedance.

Power factor corrected energizing current for CDX's, CT's and TDX's.

Value of power factor correcting capacitors for CDX's, CT's and TDX's.

Torque gradient for TX's, TDX's and TR's.

Relevant synchro performance characteristics measured in accordance with Mil. Spec. MIL-S-20708 are:

Z_{SS} and θ_{SS} - the magnitude and angle of the impedance of the stator with the rotor terminals short circuited, for calculating voltage regulation of CX's and TX's for specified values of load current.

Z_{rs} and Θ_{rs} - the magnitude and angle of the impedance of the rotor with the stator terminals short-circuited, for calculating voltage regulation of CDX's and TDX's for specified values of load current and of CT's for specified load impedances.

Z_{so} and Θ_{so} - the magnitude and angle of the impedance of the stator with the rotor terminals open, for calculating the value of power factor correcting capacitor for CDX's, TDX's and CT's.

$P_{nominal}$ - nominal primary power, needed to calculate power factor corrected energizing current of CDX's, TDX's and CT's.

Torque gradient of TX's, TR's and TDX's needed to calculate system torque gradient.

Short circuit impedance values for both magnitude and angle cover a range between maximum and minimum values, as indicated in Mil. Spec. MIL-S-20708. Depending on which combination of impedance magnitude and angle is selected, the calculated value of voltage regulation can have a variation up to 100 percent. The conservative approach is to select impedance magnitude and angle so that maximum voltage regulation is obtained for a specified load current. Therefore, for maximum voltage regulation it is necessary to select maximum short circuit impedance magnitude and minimum short circuit impedance angle in Mil. Spec. MIL-S-20708.

9650-2-d. Formulas Derivation

Synchro performance characteristics determine the limiting criteria of synchro loading and these characteristics have been evolved into formulas which may be used to determine acceptable synchro loading. The following paragraphs provide a dissertation as to the derivation of formulas and the application thereof for evaluating the practicability of any synchro system.

1. To solve for voltage regulation of transmitters, the selected values are used in the following equation:

$$k = \left(1 + \frac{R_{ss} I_L}{E}\right) - \sqrt{1 + \frac{I_L^2}{E^2}\left(R_{ss}^2 - Z_{ss}^2\right)} \qquad (1)$$

where:

k = voltage regulation for specified secondary synchro load.

E = 78 volts for CX's and TX's rated at 115 volts primary, 90 volts maximum secondary $\left(\frac{\sqrt{3}}{2} \times 90 = 78\right)$.

E = 10.2 volts for CX's and TX's rated at 26 volts primary, 11.8 volts maximum secondary

Z_{ss} and Θ_{ss} = magnitude and angle of impedance of stator with rotor terminals short circuited, for CX's and TX's.

$R_{ss} = Z_{ss} \times \cos \Theta_{ss}$, for CX's and TX's.

I_L = specified secondary synchro load current at unity power factor.

Where it is desired to solve for secondary load current for a given voltage regulation the equation is expressed as follows:

$$I_L = \frac{E}{Z_{ss}^2}\left[-R_{ss}(1-k) + \sqrt{\left[(1-k)R_{ss}\right]^2 + k\,(2-k)\,Z_{ss}^2}\right] \qquad (2)$$

2. To solve for voltage regulation of differentials, the selected values are used in the following equation:

$$k = \left(1 + \frac{R_{rs} I_L}{E}\right) \sqrt{1 + \frac{I_L^2}{E^2}\left(R_{rs}^2 - Z_{rs}^2\right)} \qquad (3)$$

where:

k = voltage regulation for specified secondary synchro load.

E = 78 volts for CDX's and TDX's rated at 90 volts primary, 90 volts maximum secondary.

E = 10.2 volts for CDX's and TDX's rated at 11.8 volts primary, 11.8 volts maximum secondary.

Z_{rs} and Θ_{rs} = magnitude and angle of impedance of rotor with stator terminals short circuited, for CDX's and TDX's.

$R_{rs} = Z_{rs} \times \cos \Theta_{rs}$, for CDX's and TDX's.

I_L = specified secondary synchro load current at unity power factor.

3. To solve for voltage regulation of control transformers, the selected values are used in the following equation:

$$k = 1 - \sqrt{1 - \frac{Z_{rs}^2 + 2R_L R_{rs}}{Z_{rs}^2 + 2R_L R_{rs} + R_L^2}} \qquad (4)$$

where:

k = voltage regulation.

Z_{rs} and Θ_{rs} = magnitude and angle of impedance of rotor with the stator terminals short circuited, for CT's.

$R_{rs} = Z_{rs} \times \cos \Theta_{rs}$, for CT's.

R_L = actual load impedance across secondary of CT.

4. To calculate power factor corrected energizing current of a synchro, select the value of power specified in Mil. Spec. MIL-S-20708 inasmuch as this is a nominal value and can be readily applied to the equation below:

$$I_{(corrected)} = \frac{P_{nominal}}{V} \qquad (5)$$

where:

$I_{(corrected)}$ = corrected energizing current.

$P_{nominal}$ = primary power, as listed in synchro specification Mil. Spec. MIL-S-20708.

V = 78 volts for CDX's and TDX's rated at 90 volts primary, 90 volts maximum secondary and for CT's rated at 90 volts primary, 57.3 volts maximum secondary.

V = 10.2 volts for CDX's and TDX's rated at 11.8 volts primary, 11.8 volts maximum secondary and for CT's rated at 11.8 volts primary, 22.5 volts maximum secondary.

In determining synchro loading, allowance is made in the values of corrected energizing current of CDX's, TDX's and CT's to account for normal variation in supply frequency and variation in optimum capacity among units of the same type. Therefore, the value of $I_{(corrected)}$, obtained from equation (5), is increased by 30 percent for 400- hertz synchros and 10 percent for 60-hertz synchros to obtain $I'_{(corrected)}$ as shown by the following two equations:

$$I'_{(corrected)} = I_{(corrected)} + 0.30\ I_{(corrected)} \quad \text{(400 hertz synchros)} \tag{6}$$

$$I'_{(corrected)} = I_{(corrected)} + 0.10\ I_{(corrected)} \quad \text{(60 hertz synchros)} \tag{7}$$

In all synchro loading calculations that follow, the corrected values of energizing current for CDX's, TDX's and CT's obtained from equation (6) or (7), as applicable, is used.

5. To calculate the value of power factor correcting capacitors for CDX's, TDX's and CT's, obtain the average of the minimum and maximum values for Z_{so} and Θ_{so}, namely magnitude and angle respectively of the stator impedance with the rotor terminals open. Use these average values in the equation below.

$$C = \frac{1}{2}\ \frac{(10^6)\ [\sin\ \Theta_{so(avg)}]}{(2\pi f)\ [Z_{so(avg)}]} \quad \text{mfds per leg} \tag{8}$$

where:

$Z_{so(avg)}$ and $\Theta_{so\ (avg)}$ = the average values of magnitude and angle of the impedance of the stator with the rotor terminals open, for CDX's, TDX's and CT's.

f = frequency in hertz.

C = optimum capacity in microfarads across each pair of stator terminals.

The value of power factor correcting capacitors used should be within plus or minus five percent of the calculated value. However, the delta connected capacitors should be matched to within one percent total variation before connections are made and to within 0.5 percent total variation measured as a closed delta.

6. The torque gradient value listed in Mil. Spec. MIL-S-20708 for TX's, TDX's and TR's as a performance characteristic is one of the required synchro parameters for calculating synchro loading. It is used in latter sections in connection with system torque gradient equations.

9650-2-e. Control systems

The quantity of synchros that may be carried in a control system depends upon the specific arrangement of the system. The three arrangements shown in Figure 1 may be considered. The third arrangement is a combination of the first two.

In Figure 1 each CDX and each CT is provided with a power factor correcting capacitor. In this manner, systems can carry a greater load of CDX and CT units.

1. Limiting criteria-The primary factors that limit synchro loading for the systems shown in Figure 1 are:

a. The allowed temperature rise of the CX and CDX units, produced by their respective load currents. Experiments on temperature rise of synchros under load indicate that for the stated values of regulation synchros operate satisfactorily within their allowable temperature rise.

b. The allowed system regulation as a percent drop in voltage gradient of the control transformers, contributed by the CX, CDX, and load impedance of the CT units. The limiting system regulation for a 400 hertz system is approximately 10 percent, and the limiting voltage regulation for CX's and CDX's is approximately four percent. The limiting system regulation for a 60 hertz system is approximately 15 to 20 percent, and the limiting voltage regulation for CX's and CDX's is approximately 10 percent. These limiting values are higher for 60-hertz synchros as compared to 400-hertz units because of poor voltage regulation per unit current for 60-hertz synchros. Experience has shown that for the above mentioned limiting regulations the variation in CT error gradient will not be excessive as synchros are switched into or out of the system. This will assure that the associated servo systems will remain stable.

2. <u>System Equations for Control System A</u> - The following system equations are applicable:

$$VR_s = VR_{cx} + VR_{ct} \qquad (9)$$

$$I_{cx} = \sum I_{ct\,(corrected)} \qquad (10)$$

where:

VR_s = system regulation expressed in percent.

VR_{cx} = percent voltage regulation of CX, or CDX used as a CX, due to unity power factor load current it delivers to its load of CT's.

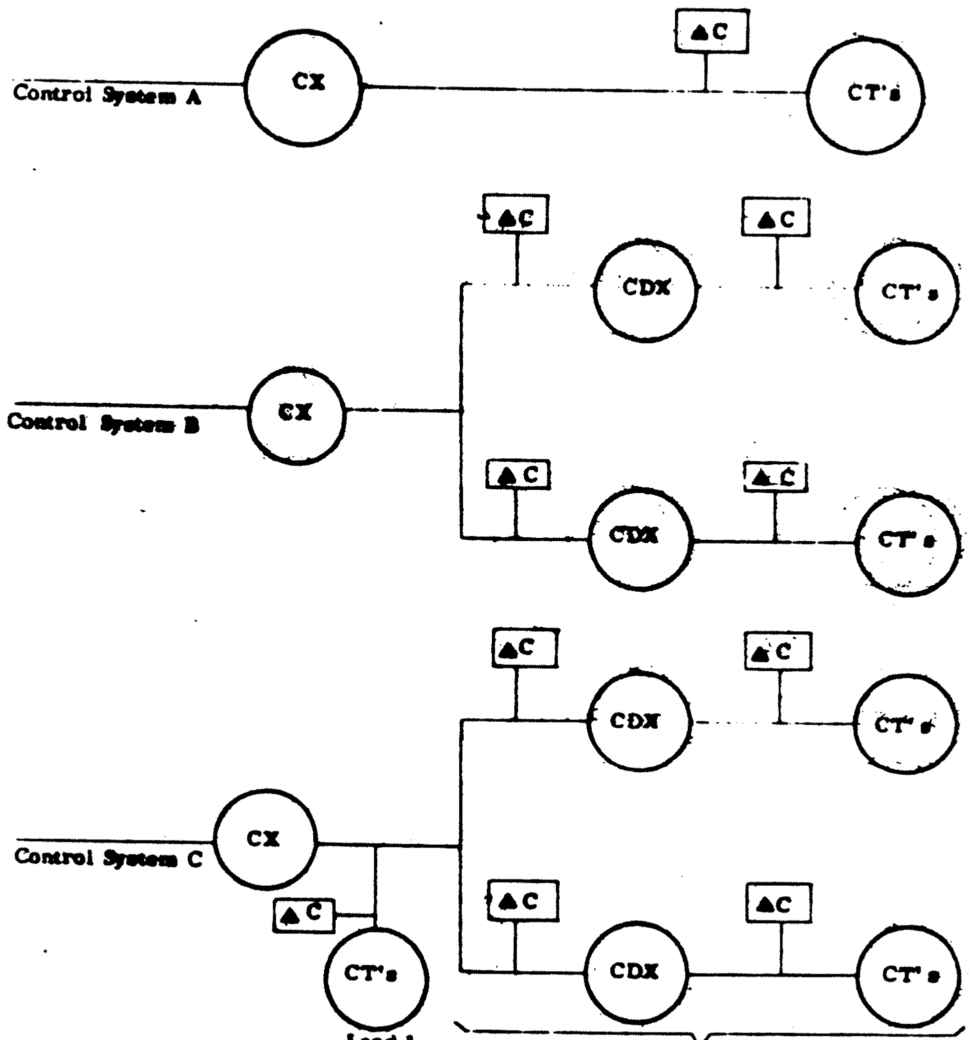

FIGURE 1 - System Designation Key for Control Systems

VR_{ct} = percent voltage regulation of a CT due to its actual load impedance.

I_{cx} = total corrected energizing current drawn from the CX, or CDX used as a CX, by its load of CT's.

$I'_{ct(corrected)}$ = corrected energizing current required by a CT.

3. System equations for Control System B - The following system equations are applicable:

$$VR_s = VR_{cx} + VR_{cdx} + VR_{ct} \quad (11)$$

$$I_a = \Sigma I'_{ct(corrected)} \text{ per differential} \quad (12)$$

$$I_{cx} = \Sigma [I_a + I'_{cdx(corrected)}] \quad (13)$$

Where:

VR_s = system regulation expressed in percent.

VR_{cx} = percent voltage regulation of CX, or CDX used as a CX, due to unity power factor load current it delivers to all units.

VR_{cdx} = percent voltage regulation of a CDX due to unity power factor load current it delivers to its load of CT's.

VR_{ct} = percent voltage regulation of a CT due to its actual load impedance.

I_a = total corrected energizing current drawn from a CDX by its load of CT's.

$I'_{ct(corrected)}$ = corrected energizing current required by a CT.

$I'_{cdx(corrected)}$ = corrected energizing current required by a CDX.

I_{cx} = total load current delivered by the CX, or CDX used as a CX, to power factor corrected CDX's and CT's.

4. System equations for Control System C - There are two CT loads in this system, CT load 1 connected directly to the CX, and CT load 2 connected directly to the CDX. System regulation, or drop in voltage gradient of the CT, is always poorer for load 2 because voltage regulation of the CX affects both CT loads equally, but voltage regulation of the CDX is included in the system regulation for the CT's in load 2 only. The same system equations are applicable for this system as for Control System B except that VR_{cx} and I_{cx} include also the loading due to the CT's of load 1 which are energized directly by the CX.

5. Procedure for Calculating System Voltage Regulation - The procedure for obtaining system voltage regulation of a control system load is shown below for Control System C:

a. Calculated voltage regulation of each CT in Load 2 for the actual load impedance across the secondary. A load impedance of 15,000 ohms is used for illustrative purposes only in the calculations for control system "C". Use equation (4).

b. Calculate corrected energizing current and value of power factor correcting capacitor for each CT in load 2 using equations (5), (6) or (7), and (8).

c. For each CDX or TDX used, sum the corrected energizing currents for all of its CT's in Load 2.

d. Calculate voltage regulation of each CDX or TDX, using the summation obtained in subparagraph c above as the secondary load current, I_L, in equation (3).

e. Calculate the corrected energizing current and value of power factor correcting capacitor for each CDX or TDX using equations (5), (6), or (7), and (8).

f. Same as subparagraph a above for each CT in Load 1.

g. Same as subparagraph b above for each CT in Load 1.

h. Add the corrected energizing currents for all CT's and CDX's or TDX's in the system.

i. Calculate the voltage regulation of the CX, using the value obtained in subparagraph h for the secondary load current, I_L, in equation (1).

j. Calculate system voltage regulation for all paths using the results obtained in subparagraphs i, d, and a for the CT's in Load 2 and subparagraphs i and f for CT's in Load 1.

A similar procedure is followed for computing system voltage regulation for Control Systems A and B. The applicable portions of the above procedure are selected for the particular system being evaluated.

6. Illustrative example - Figure 2 shows a synchro system loading configuration for a 400-hertz Control System C. System voltage regulation is calculated and analysed, as shown below, for all paths of this system following the procedure of paragraph 5.

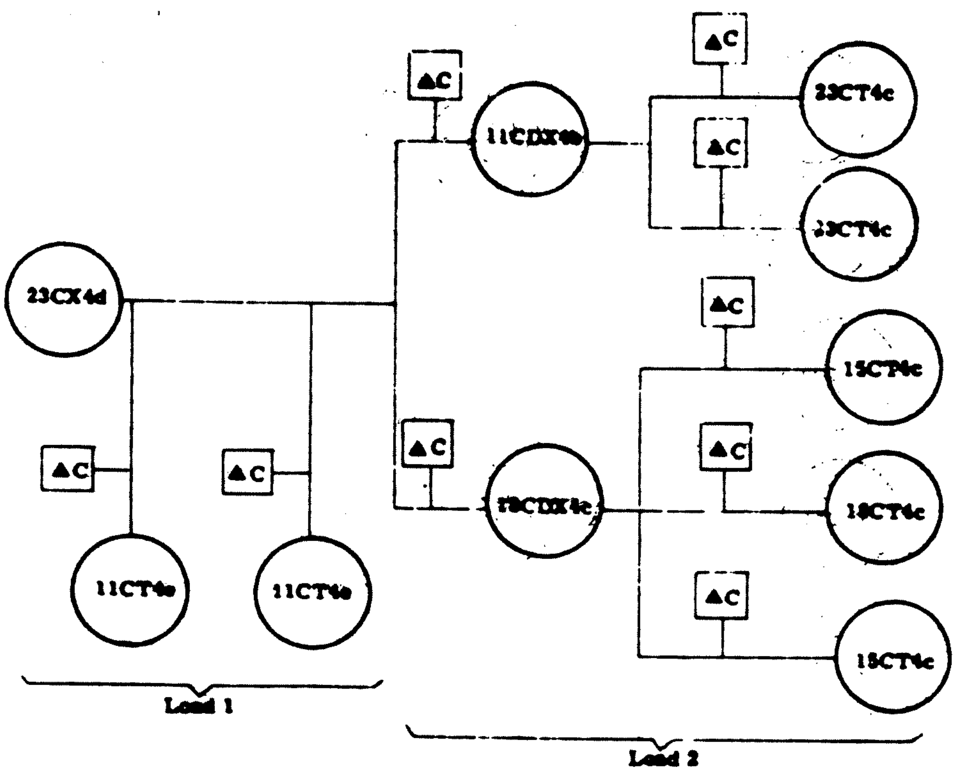

FIGURE 2 - Illustrative Example, System C (400 hertz system)

a. Voltage Regulation of CT's in Load 2, Section 9650-2-f and equation (4), shown below, apply.

$$k = 1 - \sqrt{1 - \frac{Z_{rs}^2 + 2R_L R_{rs}}{Z_{rs}^2 + 2R_L R_{rs} + R_L^2}}$$

For the 23CT4c,

Z_{rs} = 1260 ohms, Θ_{rs} = 46°

R_{rs} = 1260 x Cos 46° = 875.3 ohms

R_L = 15,000 ohms

$$k = 1 - \sqrt{1 - \frac{(1260)^2 + (2)\ (15000)\ (875.3)}{(1260)^2 + (2)\ (15000)\ (875.3) + (15000)^2}}$$

$$= 1 - \sqrt{1 - 0.11013} = 0.057$$

Therefore, VR_{ct} = 5.7%

In like manner, $VR_{ct\ (15CT4c)}$ = 7.3%

$VR_{ct\ (18CT4c)}$ = 5.7%

b. Calculations for corrected energizing current and value of corresponding power factor correcting capacitor for CT's in Load 2. Equations (5), (6), and (8) apply:

$$I_{(corrected)} = \frac{P_{nominal}}{V}$$

$$I'_{(corrected)} = I_{(corrected)} + 0.30\ I_{(corrected)}$$

$$C = \frac{1}{2}\ \frac{(10^6)}{(2\pi f)}\ \frac{[\sin \Theta_{so(avg)}]}{[Z_{so\ (avg)}]} \text{ mfds per leg}$$

For the 23CT4c,

$P_{nominal}$ = 0.05 watt

V = 78 volts

$$I_{(corrected)} = \frac{0.05}{78} \times 1000 = 0.64 \text{ ma}$$

Increase $I_{(corrected)}$ by 30 percent as indicated in section 9650-2-d so that $I'_{(corrected)}$ = 0.64 + 0.19 = 0.83 ma.

In like manner,

$I'_{(corrected)\ (15CT4c)}$ = 1.8 + 0.5 = 2.3 ma

$I'_{(corrected)\ (18CT4c)}$ = 0.64 + 0.19 = 0.83ma

For the 23CT4c,

$Z_{so(avg)}$ = 15,050 ohms

$\Theta_{so(avg)}$ = 82.75°

$$C = \frac{1}{2}\ \frac{(10^6)\ (0.99201)}{(2)\ (3.14)\ (400)\ (15,050)} = 0.013 \text{ mfd per leg}$$

In like manner,

C (15CT4c) = 0.023 mfd per leg
C (18CT4c) = 0.018 mfd per leg

c. Summation of the corrected energizing currents of CT's in Load 2 for each CDX. Equation (12) applies:

$$I_a = \Sigma I' \text{ ct (corrected)}$$

For the 11CDX4b,

$$I_a = 0.83 + 0.83 = 1.7 \text{ ma}$$

For the 18CDX4c,

$$I_a = 2.3 + 0.83 + 2.3 = 5.4 \text{ ma}$$

d. Regulation of each CDX for its corresponding load of CT's. Equation (3) applies:

$$k = \left(1 + \frac{R_{rs} I_L}{E}\right) - \sqrt{1 + \frac{I_L^2}{E^2}\left(R_{rs}^2 \quad Z_{rs}^2\right)}$$

For the 11CDX4b,

I_L = 1.7 ma

E = 78 volts

Z_{rs} = 570 ohms, Θ_{rs} = 23°

R_{rs} = 570 x cos 23° = 524.7 ohms

$$k = \left[1 + \frac{(524.7)\ (.0017)}{78}\right] - \sqrt{1 + \left(\frac{.0017}{78}\right)^2 \quad \left[(524.7)^2 - (570)^2\right]}$$

k = 0.012 $\quad VR_{cdx}$ = 1.2%

In like manner,

VR_{cdx} (18CDX4c) = 0.6%

e. Calculations of corrected energizing current of CDX's and corresponding values of power factor correcting capacitors. The equations listed in subparagraph b above are applicable.

For the 11CDX4b,

$P_{nominal}$ = 0.53 watt

V = 78 volts

$$I_{(corrected)} = \frac{0.53}{78} \times 1000 = 6.8 \text{ ma}$$

Increase $I_{(corrected)}$ by 30 percent as indicated in paragraph 6b so that $I'_{(corrected)}$ = 6.8 + 2.0 = 8.8 ma.

In like manner,

$I'_{(corrected)}$ (18CDX4c) - 12.2 + 3.7 = 15.9 ma.

For the 11CDX4b,

$Z_{so(avg)}$ = 1820 ohms

$\Theta_{so(avg)}$ = 82°

$$C = \frac{1}{2} \frac{(10^6)\ (0.99026)}{(2)\ (3.14)\ (400)\ (1820)} = 0.11 \text{ mfd per leg}$$

In like manner,

$$C(18CDX4c) = 0.28 \text{ mfd per leg}$$

The load 2 portion of Figure 2 is redrawn below as Figure 3. Voltage regulation and corrected energizing current for each CDX and each CT, and load current delivered by each CDX are shown in Figure 3.

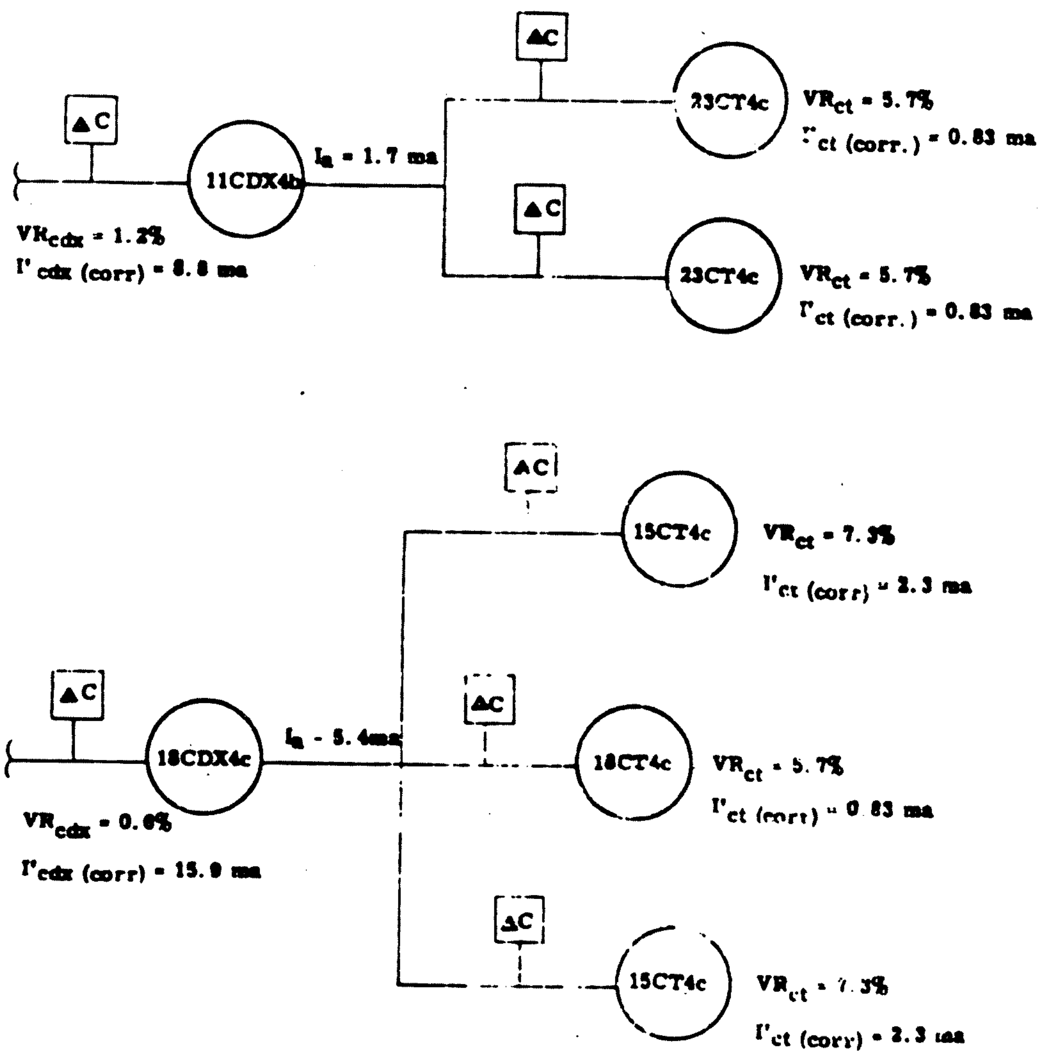

FIGURE 3 - Voltage Regulation, Corrected Energizing Current and Load Current for Load 2 Synchros of Figure 2.

f. **Voltage Regulation for CT's in Load 1.** The equation listed in a above is applicable.

For the 11CT4e,

$$Z_{rs} = 700 \text{ ohms}, \ \Theta_{rs} = 22°$$

$$R_{rs} = 700 \times \text{Cos } 22 = 649 \text{ ohms}$$

$$R_L = 15,000 \text{ ohms}$$

$$k = 1 - \sqrt{1 - \frac{(700)^2 + (2)\ (15,000)\ (649)}{(700)^2 + (2)\ (15,000)\ (649) + (15,000)^2}}$$

$$k = 1 - \sqrt{1 - 0.0815} = 0.042$$

$$VR_{ct} = 4.2\%$$

g. Calculations for corrected energizing current and corresponding power factor correcting capacitance of CT's in Load 1. The equations listed in subparagraph b above are applicable.

$$I'_{(corrected)}\ (11CT4e) = 2.6 + 0.8 = 3.4 \text{ ma}$$

$$C\ (11CT4e) = 0.039 \text{ mfd per leg}$$

The load 1 portion of Figure 2 is redrawn below as Figure 4. Voltage regulation and corrected energizing current of each CT are shown in Figure 4.

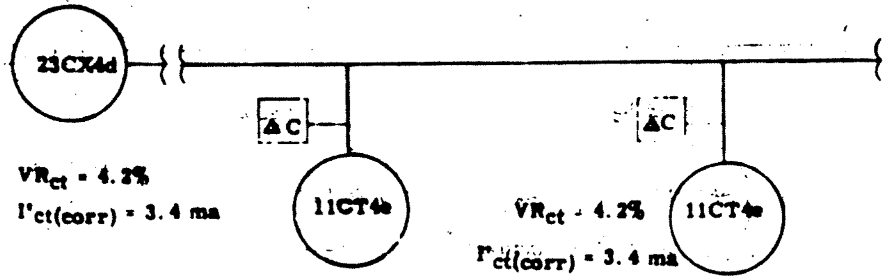

FIGURE 4 - Voltage Regulation and Corrected Energizing Current for Load 1 Synchros of Figure 2.

h. Summation of all corrected energizing currents of all CT's and CDX's shown in Figures 3 and 4. Equation (13) applies:

$$I_{cx} = \sum [I_a + I'_{cdx\ (corrected)}]$$

Units	Corrected Energizing Current (Ma)
2-11CT4e	6.8
2-15CT4c	4.6
1-18CT4c	0.83
2-23CT4c	1.66
1-11CDX4b	8.8
1-18CDX4c	15.9
Total Current	38.59 ma = 39 ma

i. Voltage Regulation of 23CX4d. Equation (1) applies.

$$k = \left(1 + \frac{R_{ss}I_L}{E}\right)\sqrt{1 + \frac{I_L^2}{E^2}\left(R_{ss}^2 - Z_{ss}^2\right)}$$

For the 23CX4d,

I_L = 39 ma

E = 78 volts

Z_{ss} = 26 ohms, Θ_{ss} = 42°

R_{ss} = 26 x Cos 42° = 19.3 ohms

$$k = \left[1 + \frac{(19.3)\ (0.039)}{78}\right] - \sqrt{1 + \left(\frac{0.039}{78}\right)^2 \left[(19.3)^2 - (26)^2\right]}$$

$k = 0.01 \quad VR_{cx} = 1\%$

j. System regulation using equations (9) and (11)

$VR_s = VR_{cx} + VR_{ct}$

$VR_s = VR_{cx} + VR_{cdx} + VR_{ct}$

The system regulation for each path is shown below:

Path	Voltage Regulation						
	CX		CDX		CT		System
23CX4d-11CT4e	1.0%			+	4.2%	=	5.2%
23CX4d-11CDX4b-23CT4c	1.0%	+	1.2%	+	5.7%	=	7.9%
23CX4d-18CDX4c-15CT4c	1.0%	+	0.6%	+	7.3%	=	8.9%
23CX4d-18CDX4c-18CT4c	1.0%	+	0.6%	+	5.7%	=	7.3%

7. The tabulation in subparagraph 6j for the illustrative example of Figure 2 indicates the following:

a. The voltage regulation is well within the limiting values of 10 percent for a 400-hertz system, four percent for the CX and four percent for the CDX.

b. More synchros could be carried in loads 1 and 2 without exceeding the limiting condition specified in subparagraph a above.

8. The load on transmitters may be increased when the control transmitters are replaced by torque transmitters of the same size. This larger load with the TX will not deteriorate the voltage gradient. However, the null voltage output of the CT units may be several times higher than the CT null voltages for systems made up of control units only, because 60- and 400-hertz torque synchros generally have higher null voltages than control synchros. In 60-hertz control systems, where a satisfactory control system cannot be set up, available torque transmitters and torque differential transmitters may be used in the determination of control systems, keeping in mind the higher null voltages of the torque units. Control loads may be supplied from a torque differential, dictated by existing equipment design, within the system parameters. This practice is not desirable for new equipment circuit design. Use of a torque transmitter is mandatory when both control and torque loads are supplied from a single transmitter.

9650-2-f. Torque systems

The load on receivers that may be carried in a torque system depends upon the arrangement of the system. The three arrangements shown in Figure 5 may be considered. The third arrangement is a combination of the first two. The TDX units in Torque Systems B and C are provided with power factor correcting capacitors to reduce the load current drawn from the other synchro units.

1. Limiting criteria for Torque System A - The primary factors controlling the limiting load of receivers are:

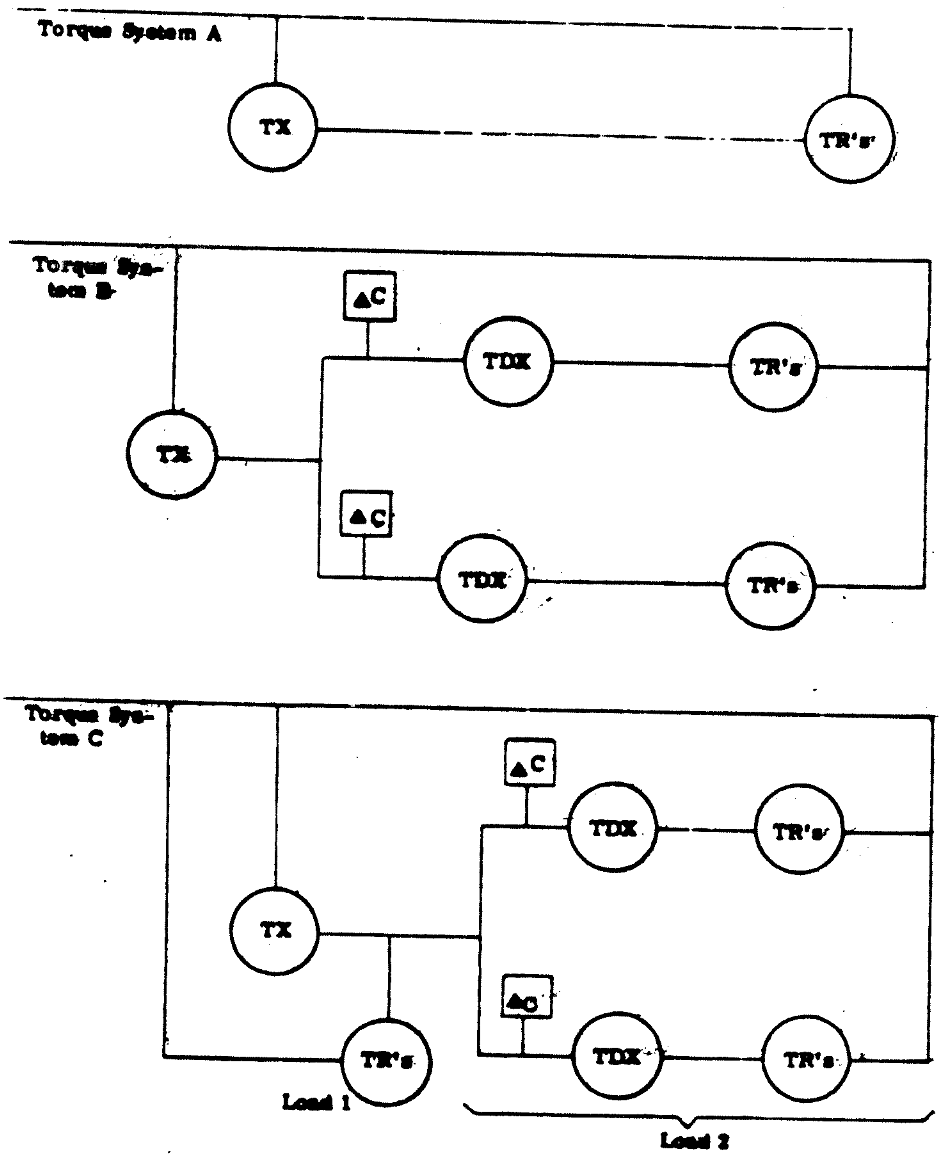

FIGURE 5 - System Designation Key for Torque Systems

a. The allowed maximum receiver error under static operation. As the number of receivers in a system is increased, the system torque gradient gets weaker and the receivers require larger position errors to overcome their restraining torque and follow the transmitter. Therefore an excessive system loading would produce excessive receiver errors. A practical solution is to limit the number of receivers to a value that gives a system torque gradient no less than 2/3 the value of the unit torque gradient of the receivers. With this limitation, at full system load, the receivers will give 50 percent increase in the restraining torque component of position error as compared to that obtained by one receiver controlled by a duplicate size transmitter. The increase in the total position error is actually less than 50 percent because the electrical error component of position error is not dependent on the number of receivers in the system.

b. The allowed temperature rise in the TX and TR produced by circulating currents and by error currents. In normal practice, with the receivers used only for position indication, past experience indicates that circulating and error currents are small and the temperature rise of the transmitter and receiver will not be excessive.

2. System equations for Torque System A - With receivers segregated by size in groups n_1, n_2, n_3. . . receivers, the system torque gradient of a receiver in any one group is given with sufficient accuracy by:

$$TS = \frac{2T_u T_{ur}}{T_u + n_1 T_{ur1} + n_2 T_{ur2} + n_3 T_{ur3} + \ldots} \tag{14}$$

where

T_s = system torque gradient of particular receiver in group n_1, n_2, or n_3.

T_{ur} = unit torque gradient of same receiver.

T_u = unit torque gradient of TX, or TDX used as a TX.

n_1 = number of receivers at equal unit torque gradient T_{ur1}.

n_2 = number of receivers at equal unit torque gradient T_{ur2}.

n_3 = number of receivers at equal unit torque gradient T_{ur3}.

The system torque gradient of equal size receivers reduces to:

$$T_s = \frac{2r}{n_a + r} T_{ur} \tag{15}$$

where,

T_s = system torque gradient.

$r = \frac{T_u}{T_{ur}}$ = $\frac{\text{unit torque gradient of the TX, or TDX used as a TX}}{\text{unit torque gradient of each TR}}$

n_a = number of equal size TR's.

3. Procedure for calculating system torque gradient in System A - System torque gradient is obtained by solving equation (14).

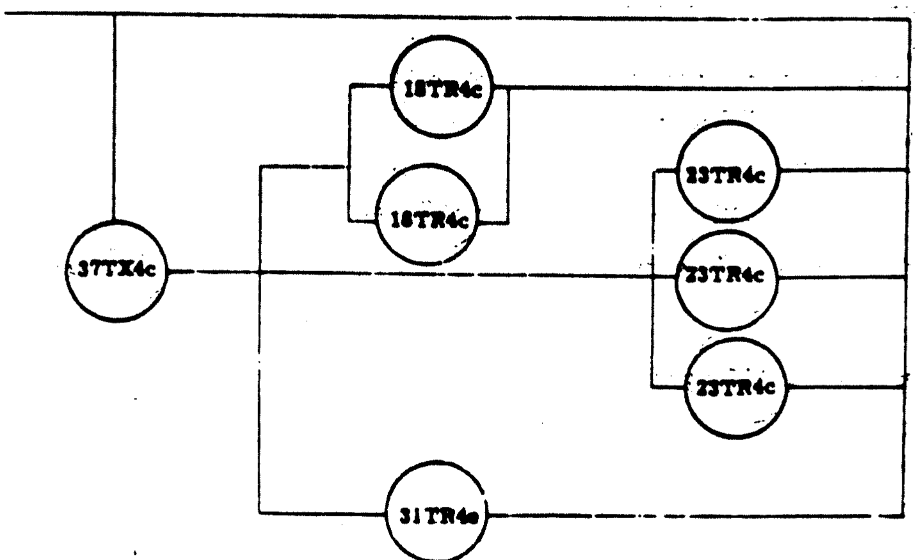

FIGURE 6 - Illustrative Example, Torque System A (400 hertz System)

For the synchros shown in Figure 6, performance characteristics in Mil. Spec. MIL-S-[illegible] were used for the illustrative example shown below.

T_u = 0.90 oz-in/deg $\quad n_{18} = 2$

T_{ur18} = 0.10 oz in/deg $\quad n_{23} = 3$

T_{ur23} = 0.25 oz-in/deg $\quad n_{31} = 1$

T_{ur31} = 0.67 oz-in/deg

Substituting these values into equation (14) yields the following:

$$T_s = \frac{(2)\ (0.90)\ T_{ur}}{0.90 + (2)\ (0.10) + (3)\ (.025) + (1)\ (0.67)} = 0.71\ T_{ur}$$

The solution T_s = 0.71 T_{ur} shows that the number of receivers is limited to a value that gives a system torque gradient no less than 2/3 the value of the unit torque gradient of the receivers in the system.

4. Limiting criteria for Torque System B - The limiting number of differential units and receivers is based on the following considerations:

a. The minimum system torque gradient of the receivers is set at 2/3 the value of their unit torque gradient, as discussed in subparagraph 1a for Torque System A.

b. The load current required to energize the differential units is limited to the value that the TX can carry at a safe temperature rise and at a voltage regulation not exceeding three percent for 400-hertz units and not exceeding seven percent for 60-hertz units. The limiting regulation value is higher for 60-hertz than for 400-hertz TX's because 60-hertz TX's have poorer voltage regulation per unit current than 400-hertz units. It is assumed that the differential units in the system are energized solely by the TX unit, without contribution by the receivers. The allowable load determined in this manner will assure safe operation of the TX and TR units regardless of how many receivers may be switched off the system. It is further noted that all TX units up to and including size 37 can supply unity power factor load current up to three percent regulation for 400-hertz units and up to seven percent regulation for 60-hertz units without excessive temperature rise.

5. System equations for Torque System B

a. The secondary load current drawn from the transmitter is given by the following equation:

$$I_{tx} = n_d \times I'_{tdx\,(corrected)} \qquad (16)$$

where

I_{tx} = unity power factor load current of the TX, or the TDX used as a TX.

$I'_{tdx\,(corrected)}$ = corrected energizing current of a given size TDX.

n_d = number of equal size TDX units.

b. For equal size differential units and equal number and size of receivers on each differential, the system torque gradient of the receivers in this system may be specified by the following approximate formula:

$$T_s = \frac{2r_b}{n_b + r_b} T_{ur} \qquad (17)$$

where

$$r_b = \frac{n_d\, r_r}{n_d + r_d} \qquad (18)$$

and

T_s = system torque gradient of each TR.

T_{ur} = unit torque gradient of the TR's.

n_b = number of equal size TR's.

n_d = number of equal size TDX's.

$r_r = \frac{T_u}{T_{ur}} = \frac{\text{unit torque gradient of TX, or TDX used as a TX}}{\text{unit torque gradient of TR}}$

$r_d = \frac{T_u}{T_{ud}} = \frac{\text{unit torque gradient of TX, or TDX used as a TX}}{\text{unit torque gradient of TDX}}$

6. Procedure for calculating voltage regulation and system torque gradient in Torque System B

a. Calculate corrected energizing current and value of power factor correcting capacitor for the TDX. Equations (5), (6) or (7), and (8) apply.

b. Solve equation (16) for the secondary load current of the TX.

c. Calculate the voltage regulation of the TX, using the value obtained in subparagraph b for the secondary load current I_L in equation (1).

d. Calculate system torque gradient using equations (17) and (18).

7. Illustrative Example for System B- Figure 7 shows a synchro system loading configuration for Torque System B. Transmitter voltage regulation and system torque gradient are calculated and analyzed below.

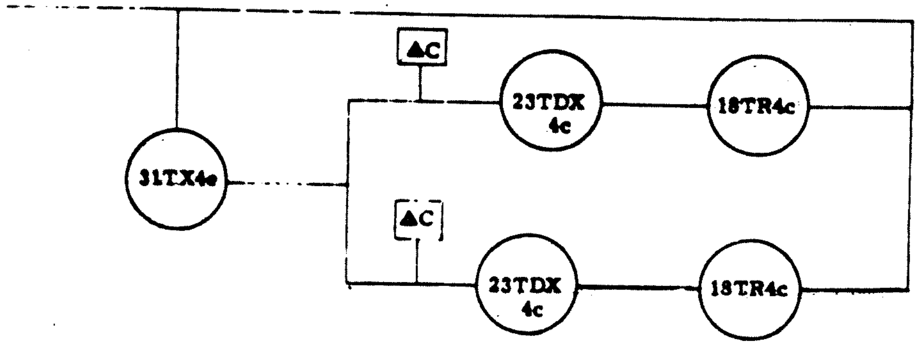

FIGURE 7 - Illustrative Example, Torque System B (400-hertz System)

a. Calculations for corrected energizing current of TDX and corresponding power factor correcting capacitance. Equations (5), (6), and (8) apply.

For the 23TDX4c,

$$P_{nominal} = 7.0 \text{ watts}$$

$$V = 78 \text{ volts}$$

$$I_{(corrected)} = \frac{P_{nominal}}{V} = \frac{7.0}{78} \times 1000 = 90 \text{ ma}$$

Increase $I_{(corrected)}$ by 30 percent as indicated in Section 9650-2-f so that $I'_{(corrected)} = 90 + 27 = 117$ ma

For the 23TDX4c,

$$Z_{so(avg)} = 101 \text{ ohms}$$

$$\theta_{so(avg)} = 85°$$

$$C = \frac{1}{2}\frac{(10^6)}{(2\pi f)}\left[\frac{\sin\theta_{so(avg)}}{Z_{so(avg)}}\right] = \frac{1}{2}\frac{(10^6)}{(2)(3.14)}\frac{(0.996)}{(400)(101)} = 2.0 \text{ mfd per leg}$$

b. Calculation of secondary load current delivered by 31TX4e. Equation (16) applies:

$$I_{tx} = n_d \times I'_{tdx\ (corrected)} = (2)\ (117\text{ma}) = 234 \text{ ma}$$

c. Calculation of voltage regulation of 31TX4e using the value of secondary load current obtained in subparagraph b as I_L in equation (1)

For the 31TX4e,

$$I_L = 234 \text{ ma}$$

$$E = 78 \text{ volts}$$

$$Z_{ss} = 3.5 \text{ ohms}, \quad \theta_{ss} = 51^{\circ}$$

$$R_{ss} = 3.5 \times \cos 51^{\circ} = 2.2 \text{ ohms}$$

$$k = \left(1 + \frac{R_{ss} I_L}{E}\right) - \sqrt{1 + \frac{I_L^2}{E^2}\left(R_{ss}^2 - Z_{ss}^2\right)}$$

$$\left[1 + \frac{(2.2)\ (0.234)}{78}\right] - \sqrt{1 + \left(\frac{0.234}{78}\right)^2 \left[(2.2)^2\ (3.5)^2\right]}$$

$$k = 0.007 \qquad VR_{tx} = 0.7\%$$

d. Calculation of system torque gradient in System B using equations (17) and (18).

n_d = number of equal size TDX units = 2

$$r_r = \frac{T_u}{T_{ur}} = \frac{0.67}{.010} = 6.7$$

$$r_d = \frac{T_u}{T_{ud}} = \frac{0.67}{0.16} = 4.2$$

n_b = number of equal size TR's = 2

Equation (18) yields

$$r_b \simeq \frac{n_d\ r_r}{n_d + r_d} \simeq \frac{2\ (6.7)}{2 + 4.2} \simeq 2.2$$

Equation (17) yields

$$T_s \simeq \frac{2 r_b}{n_b + r_b}\ T_{ur} \simeq \frac{2\ (2.2)}{2 + 2.2}\ T_{ur} \simeq 1.0\ T_{ur} \simeq 1.0\ T_{ur}$$

8. The system in this illustrative example for Torque System B complies with the requirements of paragraph 4 in that the voltage regulation of the 31TX4e is less than three percent and the system torque gradient of the receivers exceeds the minimum required value of 2/3 the unit torque gradient. In fact, the results show that the system of Figure 7 could carry more differentials and more receivers without exceeding its limiting load.

9. Limiting criteria for Torque System C- The limiting number of receivers in loads 1 and 2 and differentials are based on the following:

a. For load current furnished by the TX, paragraph 4b is likewise applicable for Torque System C. The number of differential units that may be used with the TX is the same as for Torque System B.

b. The system torque gradient for load 2 receivers, exclusive of load 1 receivers, should be greater than 2/3 the value of their unit torque gradient.

c. The system torque gradient for load 2 receivers should not be reduced to less than 2/3 their unit torque gradient by the addition of load 1 receivers. For the limiting condition that system torque gradient equals 2/3 the unit torque gradient of the receiver, the maximum number of equal size receivers in load 1 should be calculated from equation (19).

10. System equations for Torque System C-

a. The secondary load current drawn from the transmitter is given by equation (16).

b. For equal size differential units, equal number and size of load 2 receivers on each differential, and the number of load 1 receivers equal to zero, equations (17) and (18) are applicable to obtain system torque gradient of load 2 receivers.

c. The following approximate equation is used to obtain the maximum number of receivers in load 1, assuming equal size receivers for both loads.

$$n_1 = \frac{r_1 (2r_2 n_d - r_d n_2 - n_2 n_d)}{r_2 n_d + r_d n_2} \qquad (19)$$

where:

n_1 = limiting number of equal size TR's in load 1.

n_2 = number of equal size TR's in load 2.

n_d = number of equal size TDX's.

$r_1 = \dfrac{T_u}{T_{ur1}} = \dfrac{\text{unit torque gradient of TX, or TDX used as a TX}}{\text{unit torque gradient of TR in load 1}}$

$r_2 = \dfrac{T_u}{T_{ur2}} = \dfrac{\text{unit torque gradient of TX, or TDX used as a TX}}{\text{unit torque gradient of TR in load 2}}$

$r_d = \dfrac{T_u}{T_{ud}}$ = ratio of unit torque gradients of TX and TDX

11. <u>Procedure for calculating voltage regulation, system torque gradient and the allowable receiver for Torque System C.</u>

a. Calculate corrected energizing current and power factor correcting capacitance for the TDX, Equations (5), (6) or (7) and (8) apply.

b. Solve equation (16) for the secondary load current of the TX.

c. Calculate the voltage regulation of the TX, using the value obtained in subparagraph b for the secondary load current I_L in equation (1).

d. With the number of load 1 receivers set equal to zero, calculate system torque gradient using equations (17) and (18).

e. If the calculated system torque gradient in subparagraph d is greater than 2/3 T_{ur}, solve for the maximum allowable receivers in load 1 using equation (19).

12. <u>Illustrative example</u> - Figure 8 shows a synchro system loading configuration for a Torque System C. The dotted portion of this figure is Torque System B, Transmitter voltage regulation, system torque gradient for the dotted portion of the figure, and the maximum allowable receivers in load 1 are calculated and analyzed below.

a. Calculations for transmitter voltage regulation and system torque gradient for the dotted portion of Figure 8 are the same as for Torque System B and are shown in paragraph 7. The calculations show that $T_s \cong 1.0\ T_{ur}$.

b. Calculation for maximum allowable receivers in load 1 using equation (19).

$n_2 = 2$

$n_d = 2$

$r_1 = 6.7$

$r_2 = 6.7$

$r_d = 4.2$

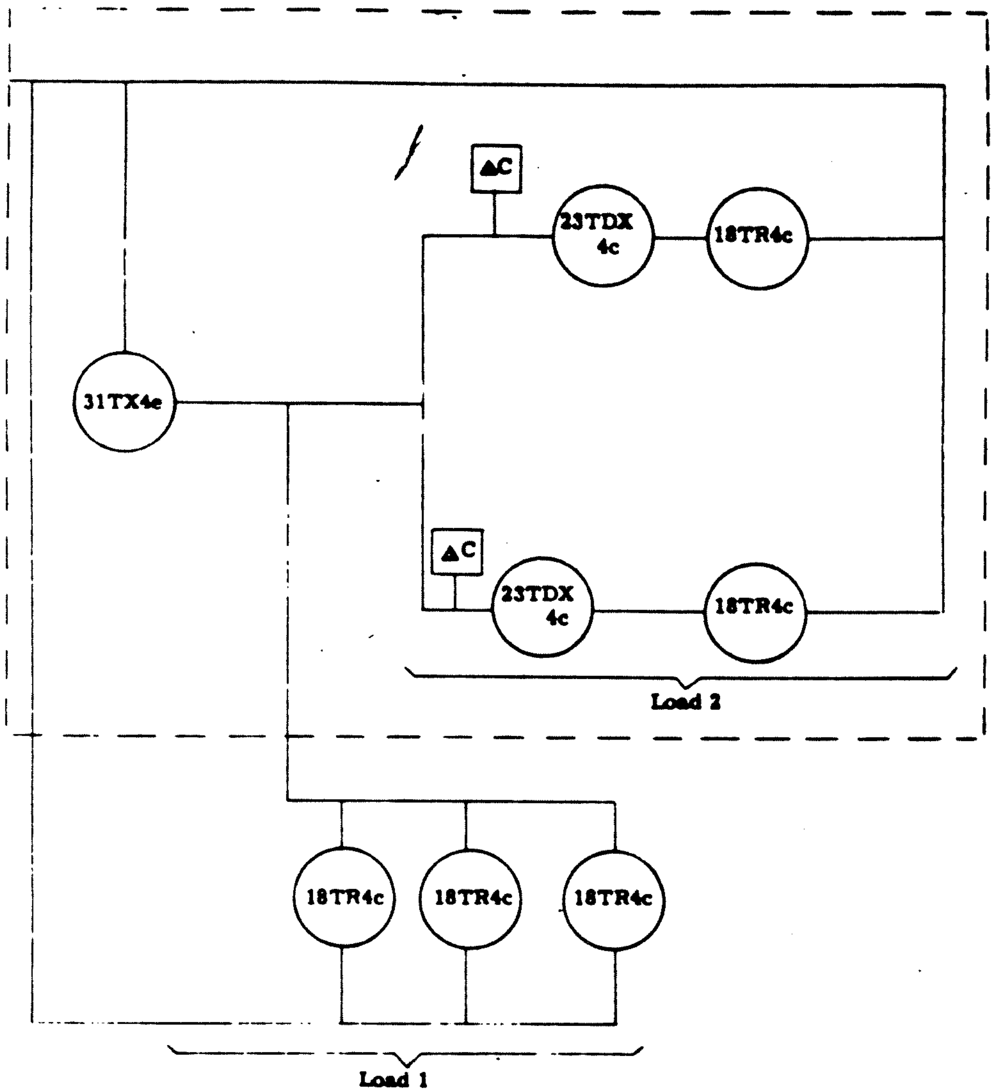

FIGURE 8 - Illustrative Example, Torque System C (400-hertz System)

$$n_1 \cong \frac{r_1 (2r_2 n_d - r_d n_2 - n_2 n_d)}{r_2 n_d + r_d n_2}$$

$$n_1 \cong \frac{6.7 [(2)(6.7)(2) - (4.2)(2) - (2)(2)]}{(6.7)(2) + (4.2)(2)} = 4$$

13. The system in this illustrative example for Torque System C complies with the requirements of paragraph 9 in that the voltage regulation of the 31TX4c is less than three percent, the system torque gradient of load 2 receivers, exclusive of the receivers in load 1, is greater than 2/3 the value of their unit torque gradient, and the actual number of receivers in load 1 is less than the maximum allowable number computed from equation (19).

14. Mixed sizes of TDX and of TR Units - To simplify calculations of loads in Torque Systems B and C, the same size receivers and equal size differentials should be used. Systems using mixed size differentials and mixed size receivers may be analyzed by procedures shown in the paragraphs that follow.

15. Mixing of differentials in Torque System B - These systems can be modified to include differentials of mixed sizes by noting that the differentials can be mixed by relation to their proportional weight on a given transmitter and that the quota of receivers is fixed by the size of the differential. Consider the following mixed system:

31TX4c { One 23TDX4c - Two 18TR4c's per TDX; Two 18TDX4c's - One 18TR4c per TDX }

To determine the feasibility of the above mixed system solve for the limiting load for each size TDX with its associated receivers as a Torque System B and then mix the differentials, without changing the associated receiver load, by the proportional weight of each TDX on the TX.

a. Applicable equations - The applicable equations for mixing TDX's in Torque System B are shown below:

$$n_{dmax} = \frac{I_{tx} \begin{cases} \text{for 3\% VR for 400 hertz} \\ \text{for 7\% VR for 60 hertz} \end{cases}}{I'_{tdx\ (corrected)}} \qquad (20)$$

where:

I_{tx} = unity power factor load current of the TX.

$I'_{tdx\ (corrected)}$ = corrected energizing current of TDX.

n_{dmax} = limiting number of equal size TDX units.

$$n_{bmax} \cong 2r_b. \qquad (21)$$

where:

r_b is defined by equation (18)

n_{bmax} = limiting number of equal size TR units.

There must be at least one TR on every TDX in any physical system.

Thus,

$$\frac{n_{bmax}}{n_{dmax}} \geq 1 \text{ approximately} \qquad (22)$$

where:

n_{bmax} and n_{dmax} are defined above.

b. Calculations for System Containing 23TDX4c with Two 18TR4c Units per TDX - The load current for three percent voltage regulation for the 31TX4c is approximately one ampere using performance characteristics shown in paragraph 7c and equation (2). The power factor corrected energizing current for the 23TDX4c, as found in paragraph 7a is 117 milliamperes.

Therefore

$$n_{dmax} = \frac{1 \text{ ampere}}{0.117 \text{ ampere}} = 8$$

Use this value of n_{dmax} for n_d in equation (18) and solve for r_b as shown:

$$r_b = \frac{n_d r_r}{n_d + r_d} = \frac{8\left(\frac{0.67}{0.10}\right)}{8+\left(\frac{0.67}{0.16}\right)} = 4.4$$

From equations (21) and (22)

$$n_{bmax} = 2r_b = 2\ (4.4) = 8.8$$

$$\frac{n_{bmax}}{n_{dmax}} = \frac{8.8}{8} = 1.1 = \text{One 18TR4c per 23TDX4c}$$

Since the mixed system requires two 18TR4c's per 23TDX4c it is necessary to reduce n_{dmax} from its value of 8 and for each reduction to repeat the above calculations for r_b, n_{bmax} and n_{bmax}/n_d until $n_{bmax}/n_d = 2$ or more. Using this approach $n_d = 3$, $n_{bmax} = 6$ and $n_{bmax}/n_d = 2$. The resultant limiting Torque System B, where the 23TDX4c can carry two 18TR4c's per TDX is shown below:

31TX4e - Three 23TDX4c's - Two 18TR4c's per TDX

c. Calculations for System Containing 18TDX4c with One 18TR4c per TDX- A similar approach is used for the 18TDX4c with its associated receiver load, using 0.05 ampere as the power factor corrected energizing current for the 18TDX4c.

$$n_{dmax} = \frac{1 \text{ ampere}}{0.05 \text{ ampere}} = 20$$

$$r_b = \frac{20\left(\frac{0.67}{0.10}\right)}{20+\left(\frac{0.67}{0.06}\right)} = 4.3$$

$$n_{bmax} = 2r_b = (2)\ (4.3) = 8.6$$

$$n_{bmax}/n_{dmax} = \frac{8.6}{20} = 0.43$$

The above result is unsatisfactory as it does not comply with equation (22). namely

$$\frac{n_{bmax}}{n_{dmax}} \geqslant 1 \text{ approximately}$$

The mixed system requires one 18TR4c per 18TDX4c. Therefore n_{dmax} should be reduced from its value of 20 and for each such reduction the above calculations should be repeated until $n_{bmax}/n_d \geqslant 1$ approximately. Using this approach $n_d = 4$, $n_{bmax} = 4$ and $n_{bmax}/n_d = 1$. the resultant limiting Torque System B where the 18TDX4c can carry one 18TR4c per TDX is shown below:

31TX4e - Four 18TDX4c's - one 18TR4c per TDX

d. Mixing of differentials - The two comparable limiting Torque Systems B are:

31TX4a - Three 23TDX4c's - Two 18TR4c's per TDX

31TX4a - Four 18TDX4c's - One 18TR4c per TDX

As an approximation, one 23TDX4c with its quota of two 18TR4c's per TDX can be replaced by one 18TDX4c with its quota of one 18TR4c per TDX. Therefore, the mixed system being considered in this paragraph can be formed from the two separate limiting Torque Systems B:

31TX4a { One 23TDX4c - Two 18TR4c's per TDX
Two 18TDX4c's - One 18TR4c per TDX }

From the above it may be concluded that this system is satisfactory.

16. Mixing of differentials in Torque System C - In this system there are two receiver loads, one on the primary side of the TDX units (load 1), the other on the secondary side (load 2). First use the approach of paragraph 11 for equal size units. Then use the approach of paragraphs 14 and 15 for mixing of differential units without the need of considering load 1.

17. Mixing of receiver loads in Torque Systems B and C - Receivers can be mixed by proportional weight on the TX and the TDX. A simple expression for changing the number of receivers of one size to an equivalent number of receivers of another size is shown below:

$$n_{15}\, T_{ur15} = n_{18}\, T_{ur18} = n_{23}\, T_{ur23} = n_{31}\, T_{ur31} = n_{37}\, T_{ur37} \qquad (23)$$

where

n = the number of receivers of size given by the subscript.

T_{ur} = unit torque gradient of receiver of size given by the subscript.

Example:

$T_{ur18TR4c}$ = 0.10 oz-in/deg.

$T_{ur15TRX4a}$ = 0.03 oz-in/deg.

$n_{18} = 1$

Using equation (23)

$n_{15}\, T_{ur15} = n_{18}\, T_{ur18}$

$n_{15}\,(0.03) = (1)\,(0.10)$

$n_{15} = 3$

Therefore, three 15TRX4a's can replace or be replaced by one 18TR4c.

9650-2-g. Application

Tables 1 through 6 have been compiled utilizing equations (1), (3) and (4) as applicable. These tables provide precalculated solutions for normal component control system configurations when used in conjunction with Synchro System Loading Tabulation Form drawing, NAVSHIPS No. 815-1853311. For a configuration which is not within the scope of the tables, calculations shall be accomplished as indicated in the preceding sections. Voltage regulation shall be tabulated to the nearest tenth of percent.

A signal flow diagram of the synchro system is required to provide the data for tabulation in columns 1 to 4, 9 to 12, 15, 17 and 19 to 22 of the synchro system load summary. Column 8 does not apply to control systems. Columns 6, 14, 15 and 16 do not apply to torque systems.

The corrected energizing current plus allowance (I' CORR column 13) of each component shall be determined by equations 5 and 6 for 400 hertz and 5 and 7 for 60 hertz system.

For control systems the value of the total corrected energizing current drawn from a differential by its load of receivers (indicated in column 12) shall be calculated by use of equation 12 and tabulated in column 14.

For control systems percent voltage regulation (VR column 16) for each component is determined by use of Tables 1 to 3. Table 1 was developed from equation 4 for the synchro loads most commonly encountered (15CT6d, 18CT6d, 23CT6c, 11CT4e, 15CT4c, 18CT4c and 23CT4c). The percent voltage regulation for a particular synchro having an established load impedance across the secondary is tabulated in relation to the impedance. Interpolation shall be used in determining the percent voltage regulation for values of impedance not tabulated. The percent voltage regulation for differentials shall be determined by the use of tables 2 and 3. Tables 2 and 3 were developed from equation 3 for synchro differential loads most commonly encountered (15CDX6c, 18CDX6d, 23CDX6c, 15CDX4d, 18CDX4d, 23CDX4c, 23TDX6c, 15TDX4c, 18TDX4c and 23TDX4c). The percent voltage regulation for a particular differential having an established total corrected energizing current (Ia column 14) drawn by its load is tabulated in relation to current drawn by the load. Interpolation shall be used in determining the percent voltage regulation for values of current not tabulated. For synchro loads not tabulated in tables 1 to 3 equations 3 or 4, as applicable, shall be used to calculate the voltage regulation value VR to be tabulated in column 16.

The value of the power factor correcting capacitors (column 18) shall be calculated by the use of equation 8.

The secondary synchro load current at unity power factor (I_L column 7) for the transmitter is arithmetical total of the corrected energizing load current (I' CORR column 13 - quantity columns 9 and 11 included).

For control systems percent voltage regulation (VR_{xmtr} column 5) for the transmitter is determined by use of tables 4 to 6. Table 4 was developed from equation 1 for the control synchro transmitters most commonly encountered (15CX6c, 18CX6c, 23CX6d, 11CX4e, 15CX4d, 18CX4d and 23CX4d). The percent voltage regulation for a particular synchro transmitter having an established secondary load current (I_L) is tabulated in relation to the current. Interpolation shall be used in determining the percent voltage regulation for values of current not tabulated. Tables 5 and 6 were developed for the torque synchro transmitters most commonly encountered (18TRX6b, 23TRX6b, 31TRX6a and 37TRX6a in Table 5 and 11TX4c, 15TRX4a, 18TRX4a, 23TRX4a, 31TRX4a and 37TRX4a in Table 6).

For torque systems the value for tabulation in column 5 shall be determined by equation 1.

Synchro signal distribution may be comprised of more than one circuit path. The system voltage regulation (control systems - VRs column 6) for such distribution shall be via the circuit path which provides the maximum value upon arithmetic addition of the voltage regulation of the transmitter and all loads comprising that circuit path.

The percent system voltage regulation (control systems - VRs column 6) value shall comply with the requirements established in 9650-2-e.

For torque systems the system torque gradient (T_s column 8) shall be determined by equations 14, 15, 17, 18 and 19 as applicable to the circuit configuration and shall comply with the requirement established by 9650-2-f.

TABLE 1

VOLTAGE REGULATION PERCENT FOR CONTROL TRANSFORMERS

Impedance Thousands Ohms	VOLTAGE REGULATION - PERCENT - (VR)						
(R_L)	15CT6d	18CT6d	23CT6c	11CT4e	15CT4c	18CT4c	23CT4c
2	44.85	50.22	44.80	24.87	37.87	33.16	33.66
4	28.82	33.41	28.76	14.10	23.07	19.17	19.34
6	21.23	25.01	21.17	9.83	16.56	13.42	13.48

TABLE I (Continued)

Impedance Thousands Ohms (R_L)	VOLTAGE REGULATION - PERCENT - (VR)						
	15CT6d	18CT6d	23CT6c	11CT4e	15CT4c	18CT4c	23CT4c
8	16.79	19.98	16.75	7.55	12.91	10.31	10.33
10	13.89	16.64	13.85	6.12	10.58	8.37	8.37
12	11.85	14.25	11.81	5.15	8.96	7.04	7.03
14	10.33	12.46	10.29	4.45	7.77	6.08	6.06
16	9.15	11.07	9.12	3.91	6.86	5.34	5.32
18	8.21	9.96	8.19	3.49	6.14	4.77	4.75
20	7.45	9.05	7.43	3.15	5.55	4.30	4.28
22	6.82	8.29	6.80	2.87	5.07	3.92	3.90
24	6.29	7.66	6.26	2.64	4.67	3.60	3.58
26	5.83	7.11	5.81	2.44	4.32	3.33	3.31
28	5.44	6.63	5.42	2.27	4.02	3.10	3.08
30	5.09	6.22	5.07	2.12	3.76	2.89	2.88
32	4.79	5.85	4.77	1.99	3.54	2.72	2.70
34	4.52	5.52	4.50	1.87	3.33	2.56	2.54
36	4.28	5.23	4.26	1.77	3.15	2.42	2.40
38	4.06	4.97	4.05	1.68	2.99	2.29	2.28
40	3.87	4.73	3.85	1.60	2.85	2.18	2.16
42	3.69	4.52	3.67	1.52	2.71	2.08	2.06
44	3.53	4.32	3.51	1.45	2.59	1.98	1.97
46	3.38	4.14	3.37	1.39	2.48	1.90	1.88
48	3.24	3.97	3.23	1.33	2.38	1.82	1.81
50	3.12	3.82	3.10	1.28	2.29	1.75	1.74
55	2.84	3.49	2.83	1.17	2.08	1.60	1.58
60	2.61	3.21	2.60	1.07	1.91	1.46	1.49
65	2.41	2.97	2.41	.99	1.77	1.35	1.33
70	2.25	2.76	2.24	.91	1.64	1.25	1.24
75	2.10	2.58	2.09	.86	1.53	1.17	1.16
80	1.97	2.42	1.96	.81	1.44	1.10	1.09
85	1.86	2.28	1.85	.76	1.36	1.03	1.02
90	1.75	2.16	1.75	.72	1.28	.99	.97
95	1.66	2.05	1.66	.68	1.22	.93	.92
100	1.58	1.95	1.58	.64	1.16	.88	.87
105	1.51	1.86	1.50	.61	1.10	.84	.83
110	1.44	1.77	1.44	.59	1.05	.80	.79
115	1.38	1.70	1.37	.56	1.01	.77	.76
120	1.32	1.63	1.32	.54	.97	.73	.73
125	1.27	1.56	1.26	.52	.93	.70	.70
130	1.22	1.50	1.22	.49	.89	.68	.67
135	1.18	1.45	1.17	.48	.86	.65	.65
140	1.13	1.40	1.13	.46	.83	.63	.62
145	1.10	1.35	1.09	.44	.80	.61	.60
150	1.06	1.31	1.06	.43	.77	.59	.58
155	1.03	1.26	1.22	.42	.75	.57	.56
160	.99	1.22	.99	.40	.73	.55	.56
165	.96	1.19	.96	.39	.70	.53	.53
170	.94	1.15	.93	.38	.68	.52	.51
175	.91	1.12	.91	.37	.66	.50	.50
180	.88	1.09	.88	.36	.65	.49	.49
185	.86	1.06	.86	.35	.63	.48	.47
190	.84	1.03	.83	.34	.61	.46	.46
195	.82	1.01	.81	.33	.60	.45	.45
200	.80	.98	.79	.32	.58	.44	.44
205	.78	.96	.77	.31	.57	.43	.43
210	.76	.94	.76	.30	.55	.42	.42

TABLE 1 (Continued)

Impedance Thousands Ohms (R_L)	VOLTAGE REGULATION - PERCENT - (VR)						
	15CT6d	18CT6d	23CT6c	11CT4c	15CT4c	18CT4c	23CT4c
215	.74	.91	.74	.30	.54	.41	.41
220	.72	.89	.72	.29	.53	.40	.40
225	.71	.87	.71	.29	.52	.39	.39
230	.69	.86	.69	.28	.51	.38	.38
235	.68	.84	.68	.27	.50	.36	.37
240	.66	.82	.66	.27	.48	.37	.36
245	.65	.80	.65	.26	.47	.36	.36
250	.64	.79	.64	.26	.47	.35	.35
255	.63	.77	.62	.25	.46	.35	.34
260	.61	.76	.61	.25	.45	.34	.34
265	.60	.74	.60	.24	.44	.33	.33
270	.59	.73	.59	.24	.43	.33	.32
275	.58	.72	.58	.23	.42	.32	.32
280	.57	.70	.57	.23	.42	.32	.31
285	.56	.69	.56	.23	.41	.31	.31
290	.55	.68	.55	.22	.40	.30	.30
295	.54	.67	.54	.22	.39	.30	.30
300	.53	.66	.53	.22	.39	.29	.30
305	.52	.65	.52	.21	.38	.29	.29
310	.52	.64	.51	.21	.38	.29	.28
315	.51	.63	.51	.20	.37	.28	.28
320	.50	.62	.50	.20	.36	.28	.27
325	.49	.61	.49	.20	.36	.27	.27
330	.48	.60	.48	.20	.35	.27	.26
335	.48	.59	.48	.19	.35	.26	.26
340	.47	.58	.47	.19	.34	.26	.26
345	.46	.57	.46	.19	.34	.26	.25
350	.46	.56	.46	.19	.33	.25	.25
355	.45	.56	.45	.18	.33	.25	.25
360	.44	.55	.44	.18	.32	.25	.24
365	.44	.54	.44	.18	.33	.24	.24
370	.43	.53	.43	.18	.31	.24	.24
375	.43	.53	.43	.17	.31	.24	.23
380	.42	.52	.42	.17	.31	.23	.23
385	.41	.51	.41	.17	.30	.23	.23
390	.41	.51	.41	.17	.30	.23	.22
395	.41	.50	.40	.16	.30	.22	.22
400	.40	.49	.40	.16	.29	.22	.22
405	.39	.49	.39	.15	.29	.22	.22
410	.39	.48	.39	.16	.28	.22	.21
415	.39	.48	.38	.16	.28	.21	.21
420	.38	.47	.38	.15	.28	.21	.21
425	.38	.46	.38	.15	.27	.21	.21
430	.37	.46	.37	.15	.27	.21	.20
435	.37	.45	.37	.15	.26	.20	.20
440	.36	.45	.36	.15	.26	.20	.20
445	.36	.44	.36	.15	.26	.20	.20
450	.36	.44	.35	.14	.26	.20	.19
455	.35	.43	.35	.14	.26	.19	.19
460	.35	.43	.35	.14	.25	.19	.19
465	.34	.42	.34	.14	.25	.19	.19
470	.34	.42	.34	.14	.25	.19	.19
475	.34	.42	.34	.14	.25	.19	.18
480	.33	.41	.33	.14	.24	.18	.18

TABLE 1 (Continued)

Impedance Thousands Ohms (R_L)	VOLTAGE REGULATION - PERCENT - (VR)						
	15CT6d	18CT6d	23CT6c	11CT4e	15CT4c	18CT4c	23CT4c
485	.33	.41	.33	.13	.24	.18	.18
490	.33	.40	.33	.13	.24	.18	.18
495	.32	.40	.32	.13	.24	.18	.18
500	.32	.39	.32	.13	.23	.18	.17

TABLE 2

VOLTAGE REGULATION PERCENT FOR CONTROL DIFFERENTIAL TRANSMITTERS

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_s)					
	15CDX6c	18CDX6d	23CDX6c	15CDX4d	18CDX4d	23CDX4c
.1	.066	.065	.15	.30	.93	2.20
.2	.13	.13	.29	.60	1.85	4.41
.3	.20	.20	.44	.91	2.77	6.61
.4	.26	.26	.59	1.21	3.70	8.81
.5	.33	.33	.73	1.51	4.62	11.00
.6	.40	.39	.88	1.81	5.54	13.20
.7	.46	.46	1.03	2.11	6.46	15.39
.8	.53	.52	1.17	2.41	7.38	17.58
.9	.59	.59	1.32	2.71	8.30	19.77
1.0	.66	.65	1.46	3.01	9.22	21.96
1.1	.73	.72	1.61	3.32	10.14	24.13
1.2	.79	.78	1.76	3.62	11.06	26.32
1.3	.86	.85	1.90	3.92	11.98	28.49
1.4	.93	.91	2.05	4.22	12.90	30.67
1.5	.99	.98	2.19	4.52	13.81	32.85
1.6	1.06	1.04	2.34	4.82	14.73	35.02
1.7	1.13	1.11	2.49	5.12	15.64	37.19
1.8	1.19	1.17	2.64	5.42	16.56	39.36
1.9	1.26	1.24	2.78	5.72	17.47	41.52
2.0	1.32	1.30	2.93	6.02	18.38	43.69
2.1	1.39	1.37	3.07	6.32	19.30	45.85
2.2	1.46	1.43	3.22	6.62	20.21	48.01
2.3	1.52	1.50	3.37	6.92	21.12	50.17
2.4	1.59	1.56	3.51	7.22	22.03	52.32
2.5	1.65	1.63	3.66	7.52	22.94	54.48
2.6	1.72	1.69	3.81	7.82	23.85	56.63
2.7	1.79	1.76	3.95	8.12	24.76	58.78
2.8	1.85	1.82	4.10	8.42	25.67	60.93
2.9	1.92	1.89	4.24	8.72	26.57	63.07
3.0	1.98	1.95	4.39	9.02	27.48	65.22
3.1	2.05	2.02	4.54	9.32	28.39	67.36
3.2	2.12	2.08	4.68	9.62	29.29	69.50
3.3	2.18	2.15	4.83	9.92	30.20	71.64
3.4	2.25	2.21	4.97	10.22	31.10	73.77
3.5	2.31	2.28	5.12	10.52	32.01	75.91
3.6	2.38	2.34	5.27	10.82	32.91	78.04
3.7	2.45	2.41	5.41	11.12	33.81	80.17
3.8	2.51	2.47	5.56	11.41	34.71	82.29
3.9	2.58	2.54	5.71	11.71	35.62	84.42

TABLE 2 (Continued)

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_a)					
	15CDX6c	18CDX6d	23CDX6c	15CDX4d	19CDX4d	23CDX4c
4.0	2.65	2.60	5.85	12.01	36.52	86.54
4.1	2.71	2.67	6.00			
4.2	2.78	2.73	6.14			
4.3	2.85	2.80	6.29			
4.4	2.91	2.86	6.44			
4.5	2.98	2.93	6.58			
4.6	3.04	2.99	6.73			
4.7	3.11	3.06	6.87			
4.8	3.18	3.12	7.02			
4.9	3.24	3.19	7.17			
5.0	3.31	3.25	7.31			
5.1	3.37	3.32	7.46			
5.2	3.44	3.38	7.60			
5.3	3.51	3.45	7.75			
5.4	3.57	3.51	7.90			
5.5	3.64	3.58	8.04			
5.6	3.70	3.64	8.19			
5.7	3.77	3.71	8.33			
5.8	3.84	3.77	8.48			
5.9	3.90	3.84	8.63			
6.0	3.97	3.90	8.77			
6.1	4.03	3.97	8.92			
6.2	4.10	4.03	9.06			
6.3	4.17	4.10	9.21			
6.4	4.23	4.16	9.35			
6.5	4.30	4.23	9.50			
6.6	4.36	4.29	9.65			
6.7	4.43	4.35	9.79			
6.8	4.50	4.42	9.94			
6.9	4.56	4.48	10.08			
7.0	4.63	4.55	10.23			
7.1	4.69	4.61	10.37			
7.2	4.76	4.68	10.52			
7.3	4.83	4.74	10.67			
7.4	4.89	4.81	10.81			
7.5	4.96	4.87	10.96			
7.6	5.03	4.94	11.10			
7.7	5.09	5.00	11.25			
7.8	5.16	5.07	11.40			
7.9	5.22	5.13	11.54			
8.0	5.29	5.20	11.69			
8.1	5.34	5.26	11.83			
8.2	5.42	5.33	11.98			
8.3	5.49	5.40	12.12			
8.4	5.55	5.46	12.27			
8.5	5.62	5.52	12.42			
8.6	5.68	5.59	12.56			
8.7	5.75	5.65	12.71			
8.8	5.82	5.72	12.85			
8.9	5.88	5.78	13.00			
9.0	5.95	5.85	13.14			
9.1	6.02	5.91	13.29			
9.2	6.08	5.98	13.44			
9.3	6.15	6.04	13.58			

TABLE 2 (Continued)

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_s)		
	15CDX6c	18CDX6d	23CDX6e
9.4	6.21	6.11	13.73
9.5	6.28	6.17	13.87
9.6	6.35	6.24	14.02
9.7	6.41	6.30	14.16
9.8	6.48	6.37	14.31
9.9	6.54	6.43	14.45
10.0	6.61	6.49	14.60

TABLE 3

VOLTAGE REGULATION PERCENT FOR TORQUE DIFFERENTIAL TRANSMITTERS

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_s)			
	23TDX6c	15TDX4c	18TDX4c	23TDX4c
.1	.37	.63	3.01	7.62
.2	.73	1.27	6.01	15.23
.3	1.10	1.90	9.01	22.83
.4	1.47	2.54	12.01	30.43
.5	1.83	3.17	15.00	38.01
.6	2.20	3.80	18.00	45.59
.7	2.57	4.44	20.98	53.16
.8	2.94	5.07	23.97	60.72
.9	3.30	5.70	26.95	68.27
1.0	3.67	6.34	29.92	75.81
1.1	4.04	6.97	32.90	83.34
1.2	4.40	7.60	35.87	90.87
1.3	4.77	8.23	38.84	98.38
1.4	5.14	8.86	41.80	105.89
1.5	5.50	9.50	44.76	113.39
1.6	5.87	10.13	47.72	120.89
1.7	6.24	10.76	50.67	128.37
1.8	6.60	11.39	53.62	135.84
1.9	6.97	12.02	56.57	143.31
2.0	7.34	12.65	59.51	150.77
2.1	7.70	13.29	62.46	158.22
2.2	8.07	13.92	65.39	165.66
2.3	8.44	14.55	68.33	173.10
2.4	8.80	15.18	71.26	180.52
2.5	9.17	15.81	74.19	187.94
2.6	9.53	16.44	77.11	195.35
2.7	9.90	17.07	80.03	202.75
2.8	10.27	17.70	82.95	210.15
2.9	10.63	18.33	85.87	217.53
3.0	11.00	18.96	88.78	224.91
3.1	11.37	19.59	91.69	232.26
3.2	11.73	20.22	94.60	239.64
3.3	12.10	20.84	97.50	247.00
3.4	12.46	21.47	100.40	254.34
3.5	12.83	22.10	103.30	261.68
3.6	13.20	22.73	106.19	269.01

TABLE 3 (Continued)

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_a)			
	23TDX6c	15TDX4c	18TDX4c	23TDX4c
3.7	13.56	23.36	109.08	276.33
3.8	13.93	23.90	111.97	283.65
3.9	14.29	24.62	114.85	290.96
4.0	14.66	25.24	117.73	298.28
4.1	15.03			
4.2	15.39			
4.3	15.76			
4.4	16.13			
4.5	16.49			
4.6	16.86			
4.7	17.22			
4.8	17.59			
4.9	17.95			
5.0	18.32			
5.1	18.69			
5.2	19.05			
5.3	19.42			
5.4	19.78			
5.5	20.15			
5.6	20.51			
5.7	20.88			
5.8	21.24			
5.9	21.61			
6.0	21.98			
6.1	22.34			
6.2	22.71			
6.3	23.07			
6.4	23.44			
6.5	23.80			
6.6	24.17			
6.7	24.53			
6.8	24.90			
6.9	25.26			
7.0	25.63			
7.1	25.99			
7.2	26.36			
7.3	26.72			
7.4	27.09			
7.5	27.46			
7.6	27.82			
7.7	28.19			
7.8	28.55			
7.9	28.92			
8.0	29.28			
8.1	29.65			
8.2	30.01			
8.3	30.37			
8.4	30.74			
8.5	31.10			
8.6	31.47			
8.7	31.83			
8.8	32.20			
8.9	32.56			
9.0	32.93			

TABLE 3 (Continued)

Voltage Regulation Percent (VR)	LOAD CURRENT - MILLI-AMPS (I_a) 23TDX6c
9.1	33.29
9.2	33.66
9.3	34.02
9.4	34.39
9.5	34.75
9.6	35.12
9.7	35.48
9.8	35.85
9.9	36.21
10.0	36.57

TABLE 4

VOLTAGE REGULATION PERCENT FOR CONTROL TRANSMITTERS

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)						
	15CX6c	18CX6c	23CX6d	11CX4e	15CX4d	18CX4d	23CX4d
.1	.096	.097	.26	.16	.63	1.65	4.04
.2	.19	.19	.51	.33	1.26	3.30	8.07
.3	.29	.29	.77	.49	1.89	4.95	12.10
.4	.38	.39	1.02	.65	2.52	6.60	16.12
.5	.48	.49	1.28	.81	3.16	8.24	20.14
.6	.58	.58	1.53	.98	3.79	9.89	24.16
.7	.67	.68	1.79	1.14	4.42	11.53	28.18
.8	.77	.78	2.04	1.30	5.05	13.18	32.19
.9	.87	.88	2.30	1.47	5.68	14.82	36.20
1.0	.96	.97	2.55	1.63	6.31	16.47	40.20
1.1	1.06	1.07	2.81	1.79	6.94	18.11	44.20
1.2	1.15	1.17	3.07	1.96	7.57	19.75	48.20
1.3	1.25	1.27	3.32	2.12	8.20	21.39	52.20
1.4	1.35	1.36	3.58	2.28	8.83	23.03	56.20
1.5	1.44	1.46	3.83	2.46	9.46	24.67	60.18
1.6	1.54	1.56	4.09	2.61	10.08	26.31	64.17
1.7	1.64	1.66	4.34	2.77	10.71	27.95	68.16
1.8	1.73	1.75	4.60	2.93	11.34	29.59	72.14
1.9	1.83	1.85	4.85	3.10	11.97	31.23	76.12
2.0	1.93	1.95	5.11	3.26	12.60	32.86	80.09
2.1	2.02	2.05	5.36	3.42	13.23	34.50	84.06
2.2	2.12	2.14	5.62	3.58	13.86	36.13	88.03
2.3	2.21	2.24	5.87	3.75	14.48	37.77	91.99
2.4	2.31	2.34	6.13	3.91	15.11	39.40	95.96
2.5	2.41	2.44	6.38	4.07	15.74	41.03	99.91
2.6	2.50	2.53	6.64	4.24	16.37	42.66	103.87
2.7	2.60	2.63	6.90	4.40	16.99	44.29	107.82
2.8	2.69	2.73	7.15	4.56	17.62	45.92	111.77
2.9	2.79	2.83	7.41	4.72	18.25	47.55	115.72
3.0	2.89	2.92	7.66	4.89	18.88	49.18	119.66
3.1	2.98	3.02	7.92	5.05	19.50	50.81	123.60
3.2	3.08	3.12	8.17	5.21	20.13	52.44	127.54
3.3	3.18	3.22	8.43	5.37	20.76	54.07	131.47
3.4	3.27	3.31	8.68	5.54	21.39	55.69	135.41

TABLE 4 (Continued)

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)						
	15CX6c	18CX6c	23CX6d	11CX4e	15CX4d	18CX4d	23CX4d
3.5	3.37	3.41	8.94	5.70	22.01	57.32	139.34
3.6	3.46	3.51	9.19	5.86	22.63	58.94	143.26
3.7	3.56	3.61	9.45	6.03	23.26	60.57	147.18
3.8	3.66	3.70	9.70	6.19	23.89	62.19	151.10
3.9	3.75	3.80	9.96	6.35	24.51	63.81	155.02
4.0	3.85	3.90	10.21	6.51	25.14	65.43	158.93
4.1	3.95	3.99	10.47				
4.2	4.04	4.09	10.72				
4.3	4.14	4.19	10.98				
4.4	4.23	4.29	11.23				
4.5	4.33	4.38	11.48				
4.6	4.43	4.48	11.74				
4.7	4.52	4.58	12.00				
4.8	4.62	4.68	12.25				
4.9	4.71	4.77	12.51				
5.0	4.81	4.87	12.76				
5.1	4.91	4.97	13.02				
5.2	5.00	5.07	13.27				
5.3	5.10	5.16	13.53				
5.4	5.20	5.26	13.78				
5.5	5.29	5.36	14.04				
5.6	5.39	5.46	14.29				
5.7	5.48	5.55	14.55				
5.8	5.58	5.65	14.80				
5.9	5.68	5.75	15.06				
6.0	5.77	5.85	15.31				
6.1	5.87	5.94	15.57				
6.2	5.96	6.04	15.82				
6.3	6.06	6.14	16.08				
6.4	6.16	6.23	16.34				
6.5	6.25	6.33	16.59				
6.6	6.35	6.43	16.85				
6.7	6.44	6.53	17.10				
6.8	6.54	6.62	17.36				
6.9	6.64	6.72	17.61				
7.0	6.73	6.82	17.87				
7.1	6.83	6.92	18.12				
7.2	6.92	7.01	18.37				
7.3	7.02	7.11	18.63				
7.4	7.12	7.21	18.88				
7.5	7.21	7.31	19.14				
7.6	7.31	7.40	19.39				
7.7	7.40	7.50	19.65				
7.8	7.50	7.60	19.90				
7.9	7.60	7.69	20.16				
8.0	7.70	7.79	20.41				
8.1	7.79	7.89	20.67				
8.2	7.88	7.99	20.92				
8.3	7.98	8.08	21.18				
8.4	8.08	8.18	21.43				
8.5	8.17	8.28	21.69				
8.6	8.27	8.38	21.94				
8.7	8.36	8.47	22.20				
8.8	8.46	8.57	22.45				

TABLE 4 (Continued)

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)		
	15CX6c	18CX6c	23CX6d
8.9	8.56	8.67	22.71
9.0	8.65	8.76	22.96
9.1	8.75	8.86	23.22
9.2	8.85	8.96	23.47
9.3	8.94	9.06	23.73
9.4	9.04	9.15	23.98
9.5	9.13	9.25	24.24
9.6	9.23	9.35	24.49
9.7	9.33	9.45	24.75
9.8	9.42	9.54	25.00
9.9	9.52	9.64	25.26
10.0	9.61	9.74	25.51

TABLE 5

VOLTAGE REGULATION PERCENT FOR TORQUE RECEIVER-TRANSMITTERS

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)			
	18TRX6b	23TRX6b	31TRX6a	37TRX6a
.1	.19	.55	2.46	9.10
.2	.38	1.09	4.92	18.19
.3	.57	1.64	7.38	27.28
.4	.76	2.18	9.83	36.37
.5	.96	2.73	12.29	45.46
.6	1.14	3.28	14.75	54.54
.7	1.33	3.82	17.21	63.62
.8	1.53	4.37	19.66	72.69
.9	1.72	4.92	22.12	81.76
1.0	1.91	5.46	24.58	90.88
1.1	2.10	6.01	27.04	99.90
1.2	2.29	6.55	29.49	108.96
1.3	2.48	7.10	31.95	118.02
1.4	2.67	7.65	34.40	127.07
1.5	2.86	8.19	36.86	136.13
1.6	3.05	8.74	39.32	145.17
1.7	3.24	9.28	41.77	154.22
1.8	3.43	9.83	44.23	163.26
1.9	3.62	10.38	46.68	172.30
2.0	3.81	10.92	49.14	181.34
2.1	4.00	11.47	51.59	190.37
2.2	4.19	12.01	54.05	199.40
2.3	4.38	12.56	56.50	208.43
2.4	4.57	13.10	58.95	217.45
2.5	4.76	13.65	61.41	226.47
2.6	4.95	14.20	63.86	235.49
2.7	5.14	14.74	66.32	244.50
2.8	5.33	15.29	68.77	253.51
2.9	5.52	15.83	71.22	262.52
3.0	5.71	16.38	73.68	271.52
3.1	5.90	16.92	76.13	280.52

TABLE 5 (Continued)

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)			
	18TRX6b	23TRX6b	31TRX6a	37TRX6a
3.2	6.09	17.47	78.58	289.52
3.3	6.28	18.02	81.03	298.52
3.4	6.47	18.56	83.49	307.51
3.5	6.66	19.11	85.94	316.50
3.6	6.85	19.65	88.39	325.48
3.7	7.04	20.20	90.84	334.46
3.8	7.23	20.74	93.29	343.44
3.9	7.42	21.29	95.74	352.42
4.0	7.61	21.84	98.19	361.49
4.1	7.80	22.38	100.65	370.36
4.2	7.99	22.93	103.10	379.33
4.3	8.18	23.47	105.55	388.29
4.4	8.37	24.02	108.00	397.25
4.5	8.56	24.56	110.45	406.21
4.6	8.75	25.11	112.90	415.16
4.7	8.94	25.65	115.35	424.11
4.8	9.13	26.20	117.79	433.06
4.9	9.32	26.74	120.24	442.00
5.0	9.51	27.29	122.69	450.94
5.1	9.70	27.84	125.14	459.88
5.2	9.89	28.38	127.59	468.82
5.3	10.08	28.93	130.03	477.75
5.4	10.27	29.47	132.49	486.68
5.5	10.46	30.02	134.93	496.60
5.6	10.65	30.56	137.38	504.52
5.7	10.84	31.11	139.83	513.44
5.8	11.03	31.66	142.28	522.36
5.9	11.22	32.20	144.72	531.27
6.0	11.41	32.74	147.17	540.18
6.1	11.60	33.29	149.62	549.09
6.2	11.79	33.83	152.06	557.99
6.3	11.98	34.38	154.51	566.89
6.4	12.17	34.92	156.96	575.79
6.5	12.35	35.47	159.40	584.69
6.6	12.54	36.01	161.85	593.58
6.7	12.73	36.56	164.29	602.47
6.8	12.92	37.10	166.74	611.35
6.9	13.11	37.65	169.18	620.23
7.0	13.30	38.19	171.63	629.11
7.1	13.49	38.74	174.07	637.99
7.2	13.68	39.28	176.52	646.86
7.3	13.87	38.83	179.96	655.73
7.4	14.06	40.37	181.41	664.60
7.5	14.25	40.92	183.85	673.46
7.6	14.44	41.46	186.29	682.33
7.7	14.63	42.01	188.74	691.18
7.8	14.81	42.55	191.18	700.04
7.9	15.00	43.10	193.62	708.89
8.0	15.19	43.64	196.07	717.74
8.1	15.38	44.19	198.51	726.58
8.2	15.57	44.73	200.95	735.43
8.3	15.76	45.28	203.39	744.27
8.4	15.95	45.82	205.84	753.10
8.5	16.14	46.37	208.28	761.94

TABLE 5 (Continued)

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)			
	18TRX6b	23TRX6b	31TRX6a	37TRX6a
8.6	16.33	46.91	210.72	770.77
8.7	16.52	47.46	213.16	779.60
8.8	16.71	48.00	215.60	788.42
8.9	16.90	48.55	218.05	797.24
9.0	17.08	49.09	220.49	806.06
9.1	17.27	49.64	222.93	814.88
9.2	17.46	50.18	225.37	823.69
9.3	17.65	50.73	227.81	832.50
9.4	17.84	51.27	230.25	841.31
9.5	18.03	51.82	232.69	850.11
9.6	18.22	52.36	235.13	858.91
9.7	18.41	52.90	237.57	867.71
9.8	18.60	53.45	240.00	876.50
9.9	18.78	53.99	242.45	885.29
10.0	18.97	54.54	244.89	894.08

TABLE 6

VOLTAGE REGULATION PERCENT FOR TORQUE TRANSMITTERS

AND TORQUE DIFFERENTIAL TRANSMITTERS

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)					
	11TX4c	15TRX4a	18TRX4a	23TRX4a	31TRX4a	37TRX4a
.1	.34	1.13	4.71	12.95	22.19	47.81
.2	.67	2.27	9.42	25.89	44.29	95.39
.3	1.01	3.40	14.13	38.82	66.30	142.73
.4	1.35	4.53	18.83	51.75	88.21	189.84
.5	1.68	5.66	23.53	64.66	110.04	236.72
.6	2.02	6.80	28.23	77.56	131.78	283.38
.7	2.35	7.93	32.92	90.45	153.44	329.81
.8	2.69	9.06	37.61	103.33	175.09	376.03
.9	3.03	10.19	42.30	116.19	196.49	422.03
1.0	3.36	11.32	46.99	129.06	217.89	467.82
1.1	3.70	12.45	51.67	141.90	239.21	513.40
1.2	4.03	13.58	56.35	154.74	260.44	558.78
1.3	4.37	14.70	61.03	167.57	281.60	603.95
1.4	4.71	15.83	65.71	180.38	302.67	648.92
1.5	5.04	16.96	70.38	193.19	323.67	693.69
1.6	5.38	18.09	75.06	205.99	344.58	738.26
1.7	5.71	19.21	79.71	218.78	365.42	782.64
1.8	6.05	20.34	84.38	231.56	386.18	826.83
1.9	6.38	21.46	89.04	244.32	406.87	870.83
2.0	6.72	22.59	93.70	257.08	427.48	914.65
2.1	7.05	23.71	98.35	269.83	448.02	958.28
2.2	7.39	24.84	103.01	282.56	468.48	1001.73
2.3	7.73	25.96	107.66	295.29	488.88	1045.00
2.4	8.06	27.08	112.30	308.00	509.19	1088.09
2.5	8.40	28.21	116.96	320.71	529.44	1131.01
2.6	8.73	29.33	121.59	333.41	549.62	1173.75

TABLE 6 (Continued)

Voltage Regulation Percent (VR_{xmtr})	SECONDARY LOAD CURRENT - MILLI-AMPS (I_L)					
	11TX4c	15TRX4a	18TRX4a	23TRX4a	31TRX4a	37TRX4a
2.7	9.07	30.45	126.23	346.10	569.73	1216.32
2.8	9.40	31.57	130.86	358.78	589.77	1258.73
2.9	9.74	32.69	135.50	371.45	609.74	1300.96
3.0	10.07	33.81	140.13	384.10	629.64	1343.04
3.1	10.41	34.93	144.76	396.75	649.48	1384.94
3.2	10.74	36.05	149.38	409.39	669.35	1426.69
3.3	11.07	37.17	154.00	422.02	688.95	1468.28
3.4	11.41	38.29	158.62	434.64	708.59	1509.71
3.5	11.74	39.41	163.24	447.28	728.17	1550.98
3.6	12.08	40.52	167.85	459.85	747.68	1592.09
3.7	12.41	41.64	172.47	472.44	767.12	1663.06
3.8	12.75	42.76	177.08	485.02	786.51	1673.87
3.9	13.08	43.87	181.68	497.59	805.83	1714.54
4.0	13.42	44.99	186.28	510.15	825.09	1755.05