ENGINEERING STUDY OF OPTIONS FOR UPGRADING PWT MD STARTING SYSTEM

AT

ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AFB, TENNESSEE
(CALSPAN'S SUBCONTRACT 94-06)

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BACKGROUND

This study was performed to provide an engineering evaluation of various upgrading alternatives "a" through "e" for the PWT MD at Arnold AFB as stated in the objectives of the attached work statement from Calspan's Subcontract 94-06. Also preliminary costs are to be provided along with the effect of new equipment on power factor. Using previous harmonic current effects studies from LCI (Load Commutated Inverter) on the Arnold AFB power system (see Appendix I) and harmonic torques effects on shafts in PES drive at Arnold AFB, calculate these effects for this PWT MD study. Estimate the harmonic distortion on line side (power system) and the effects of the harmonic torques on the PWT MD shafts for the various alternatives.

Refer to Appendix I for previous power system harmonic distortion analysis which was used extensively to evaluate the various alternatives in this report. Refer to Appendices II and III for the torsional analysis with the 16T transonic compressor and the 16S supersonic compressor respectively.

I. ALTERNATIVE "a"

Two adjustable frequency PWM drive systems of approximately 35,000 HP each powering the existing M2 and M3 wound rotor induction motors. Windings of the motor shorted at the slip rings and the brushes, brush assembly and the liquid rheostats scraped.

Two 35,000 HP (PWM) Pulse Width Modulated

Inverters

Cost = 35,000 HP x $50/HP = $1.7 M per WR Motor

(4 Breakers)

Total Cost Two Inverters = $3.4 M + $.08 M = $3.48 M

For 6 pulse operation using existing transformers

Estimated Line Harmonic Components (6 pulse)

5th	7th	11th	13th
.175	.110	.045	.029

(Actual harmonics must be investigated from supplier data)

Estimated Harmonic Distortion To Power System

(Normal Configuration Using Previous Study in Appendix II)

Bus	6 Pulse - Harmonic Distortion Factor %	12 Pulse = .65 of 6 Pulse
Franklin	.14 x (7.8 + 1) = 1.23%	.8%
Arnold	.43 x (7.8 + 1) = 3.8%	2.5%
PWT	.43 x (7.8 + 1) = 3.8% (PES)	2.5%

Bus harmonic distortions are below 5% maximum recommended allowable.

Estimated Shaft Stresses From Harmonic Torques

Based on torsional analysis in Appendix II on PWT MD with the 16T the significant shaft stresses are in the first two modes and the resonant conditions with the 6th and 12th harmonic torques occur between 1 and 283 RPM (as shown in Figure 1). From Table 1, we see that the largest stress occurs in the 22 7/8 diameter shaft between the induction motors M2 and M3. Assuming both WR motors M2 and M3 are operating, then at 54 RPM the 12th harmonic excites the first torsional mode which contributes the highest stress of

$$\overset{M2}{(682} + \overset{M3}{865)} = 1547 \text{ psi}$$

with 35,000 HP rated torque at each motor and an amplification of 1.0. The worst harmonic torque is the 12th based on review of existing PWM operated drives (extrapolated from 6000 HP to 10,000 HP range) with a magnitude of approximately .20 of the average torque.

Steady State Stresses with 16T Compressor (PWM)

With the transonic compressor, 16T connected to the drive, then based on results in Appendix II, steady state operation would be prohibited near 54 and 143 RPM with 35,000 HP torque on M2 and M3, the maximum stresses would be (Figure 1 and from Table 1) in Shaft 1 at 54 RPM and equal to (assuming 20% motor rated torque for 12th harmonic in PWM drives and amplification Q = 200):

824 x .2 x 200 = 32,960 from M2
1045 x .2 x 200 = 41,800 from M3
Maximum Stress is in Shaft 1 = 74,760 psi near 54 RPM

Therefore, steady state operation near 54 RPM would be prohibited. Also, operating near 142 RPM would be prohibited due to stress in Shaft 4 as computed below using Figure 1 and Table 1.

(442 - 111) x .2 x 200 = 13,240 psi near 142 RPM

No steady state operation near 54 and 142 RPM with rated PWM power on M2 and M3 with 16T compressor.*

Steady state stresses with 16S compressor (PWM)

For operation with the supersonic 16S compressor from Appendix III, Figure 2 and Table 6, there would also be steady state speed restrictions when operating with M2 and/or M3 at steady state. Since modal angular displacements are all in the same direction for M2 and M3 in the first five modes the stresses from M2 and M3 are additive and for full power are:

Mode	E	
1	12	(140+134) x .2 x 200 = 10960 psi in shaft 5 at 25.1 RPM
2	12	(323+267) x .2 x 200 = 23600 psi in shaft 5 at 48.5 RPM.
3	12	(743+549) x .2 x 200 = 51680 psi in shaft 5 at 58.5 RPM
4	12	Negligible stress
5	12	(26+159) x .2 x 200 = 7400 psi in shaft 5 at 147.1 RPM

Unless power levels are below 15% of rated then steady state operation near 25.1, 48.5, 58.5 and 147.1 RPM with PWM supplies on M2 and M3 with 16S compressor would be prohibited.

* NOTE: 6th harmonic stresses are usually small with PWM drives, but must be verified.

Accelerating through Resonances with 16T and PWMI

During accelerating through torsional resonances (Figure 1) the amplification, Q, is calculated by:

Total Torque = T = $26.04(10)^6$ lb-in
Total Inertia = I = 22964 lb-in-sec^2
Poles = P = 10
Harmonic = H = 12
Percent of Torque = a = .282

$$h_{12} = \frac{aTH\frac{P}{2}}{I2\pi} = \frac{.282 \times 26.04(10)^6 \times 12 \times 10/2}{22,964 \times 2 \times \pi} = 3054$$

h_{12} = 3054

with f_n = modal frequency

For 1st mode, f_n = 64 hz, $Q = 3.67\ f_n/\sqrt{h_{12}}$
$= 3.67 \times 64/\sqrt{3054} = 4.3$

For 2nd mode, f_n = 170 hz, $Q = 4.3 \times \frac{170}{64} = 11.4$

Therefore, accelerating through resonance shaft stresses with 16T compressor are:

Maximum Stress in Shaft 1 = 4.3/200 x 74,760 = 1608 psi
(1st mode near 54 RPM)

Maximum Stress in Shaft 4 = 11.4/200 x 13,240 = 755 psi
(2nd mode near 142 RPM)

These stresses are low and present no restrictions on torque during start up.

Accelerating Through Resonances with 16S and (PWMI)

During accelerating through torsional resonances (Figure 2) the amplifications, Q, is calculated by changing data from 16T to 16S data by:

Total Inertia = 74049 lb-in-sec^2

h_{12} = 3064 x 22964/74049 = 947

$Q = 3.67\ f_n / \sqrt{h_{12}} = 11.93\ f_n$

Q = .1193 x 30.2 = 3.6	1st mode
Q = .1193 x 58.3 = 7.0	2nd mode
Q = .1193 x 70.2 = 8.4	3rd mode

Maximum Stress in Shaft 5 = 3.6/200 x 10960 = 198 psi
1st mode near 25 RPM

Maximum Stress in Shaft 5 = 7.0/200 x 23600 = 826 psi
2nd mode near 49 RPM

Maximum Stress in Shaft 5 = 8.4/200 x 51680 = 2171 psi
3rd mode near 59 RPM

These stresses are low, thus there are no restrictions on torque during start up with M2 and M3 supplied by PWMI power supplies with the 16S supersonic compressor.

Advantages - Higher efficiency with low cost and eliminates brush assembly and liquid rheostats

Disadvantage - Power factor lower and risks higher than present mode of operation.

The present power factor is .91 on WR motors, but the power factor will be reduced to cos 35° = .82 due to phase back of 35° required at rectifier to get the proper voltage level to WR motors M2 and M3.

There would be restrictions near resonant speeds during variable speed steady state operation for either compressor.

Line side power factor can be improved substantially by overexciting M1 and M4 when operating at 600 RPM on line.

Another disadvantage is the loss of capability of line operation with M2 and M3 or must keep slip rings and brush assembly and put fixed resistor (stainless tube water cooled) with value to give rated torque at 600 RPM. Cost of resistors estimated at $100,000.00 to $200,000.00 per motor.

II. ALTERNATIVE "aa"

Two adjustable frequency PWMI drives of approximately 35,000 HP each with additional switchgear to allow simultaneously powering any two of the four PWT MD drive motors. Same as 'a', except need step up transformers if the inverters are 6.9 KV at the output.

Additional Cost to "a" would be:

$.04M (2 Breakers) + $1M Transformer for Each Inverter

2 x ($.04M + $1M) = $2.08M

Total Cost "aa" $2.08 + $3.48M = $5.56M + Resistors

Factory tests on M1 & M4 indicate sufficient margin for the temperature rise from harmonic currents, with PWM supply.

Line harmonics would be the same as "a".

Shaft stresses and restrictions from harmonic torques would be the same as "a" when PWMI supplies are driving M2 and M3 with either compressor on drive. However, when PWMI supplies are used on M1 and M4, the harmonic torques and restrictions would be more severe, as indicated by Table 1 with 16T compressor and Table 5 with 16S compressor.

In addition, the WR motors M2 and M3 must have the fixed resistors in rotor circuit to keep the full power operation on line capability. Also PWMI at these power levels must be considered high risk.

III. ALTERNATIVE "b"

Supply two adjustable frequency LCI drive systems of 50,000 HP each for powering new 12 pole synchronous motors replacing the WR induction motors M2 and M3 on same foundations.

For 6 pulse LCI's, no new transformers but must phase back rectifiers to match existing motor voltage, therefore, power factor would be lower during start-up and variable speed operation; however, line side power factor can be corrected to unity by overexciting large M1 and M4 synchronous motors when running on line.

Note: New 50,000 HP synchronous motors could be designed to handle higher voltage so there would be no need to phase back rectifiers, an improvement, not a reduction in power factor near rated speed.

Line harmonics from both M2 and M3 operating near rated load would be using 100K HP/9K HP = 11.1 times PES power, therefore:

BUS	Total Harmonic Distortion (6 pulse)	(12 Pulse)
Franklin	(1 + 11.1) x .14 = 1.7%	.9%
Arnold	(1 + 11.1) x .43 = 5.2%	3.4%
PWT	(1 + 11.1) x .43 = 5.2%	3.4%
	PES	

Calculation of Harmonic Torque Effects

The following calculations are based on .2 per unit torque for the 6th harmonic and .1 per unit torque for the 12th harmonic.

Steady State Stresses with 16T Compressor with LCI

Table 2 gives the steady state shaft stresses at torsional resonances as shown in Figure 1 for the 16T compressor driven with LCI's on M2 and M3 at 50,000 HP.

Mode	H		Shaft Stress (psi)		Speed
1	12	(23543 + 29856) =	53399 psi in Shaft 1	at	54 RPM
1	6	(47066 + 59711) =	106797 psi in Shaft 1	at	107 RPM
2	12	(12643 - 3172) =	9471 psi in Shaft 4	at	142 RPM
2	6	(25247 - 6343) =	18904 psi in Shaft 4	at	283 RPM

No steady state operation near 54, 107, 142 and 283 RPM.

For 12 pulse operation the H=6 stresses would essentially be eliminated and speed restrictions would be only at 54 and 142 RPM.

Acceleration Through Resonances, 16T with LCI

From Table 3 with M2 and M3 driving on LCI power the stresses at the above defined resonances are all below 3000 psi, thus there is no restrictions on torque during start up.

Steady State Stresses with 16S Compressor with LCI

Table 6 gives the steady shaft stresses for steady state operations at 50,000 HP on LCI power. Driving with M2 and M3, the steady state shaft stresses at the torsional resonances would be:

Mode	H	(M2 and M)	Shaft Stress (psi)		Speed
1	12	(4000 + 3840) =	7840 psi in Shaft 5	at	25.1 RPM
1	6	(8000 + 7670) =	15670 psi in Shaft 5	at	50.3 RPM
2	12	(9240 + 7640) =	16880 psi in Shaft 5	at	48.5 RPM
2	6	(18480 + 15280) =	33760 psi in Shaft 5	at	97 RPM
3	12	(21250 + 15700) =	36950 psi in Shaft 5	at	71 RPM
3	6	(42500 + 31410) =	73910 psi in Shaft 5	at	117 RPM

Based on the above stresses, steady state operation would be prohibited near the following speeds: 25.1, 50.3, 48.5, 97, 71 and 117 RPM with LCI's on M2 and M3 with 16S compressor. For 12 pulse operation restrictions would be only at 25.1, 48.5 and 71 RPM.

Accelerating Through Resonances, 16S with LCI

From Table 7, with M2 and M3 driving, the stresses are at or below 3000 psi, so there are no restrictions on torque during startup.

Costs

100K HP x $48/HP	= $4.8M	LCI with Transformers
100K HP x $36/HP	= $3.6M	New Synchronous Motors
4 Circuit Breakers 4 x .02M	= $ .08M	(Based on Latest 12 pulse Price - GE)
Total Cost	= $8.48M	

Advantages are reliable variable speed operation up to 100K HP and reliable starting capability including high efficiency (good power factor) with efficient full power line operation capability.

Disadvantages are higher line harmonics near full power operation with LCI's on M2 and M3, but marginally acceptable and medium relative cost. Also, more disruption to facility during installation and restricted steady state operation as defined previously at several speed, all below 300 RPM. For 12 pulse operation, speed restriction would be below 150 RPM and line harmonics would be acceptable.

IV. **ALTERNATIVE** "bb" (similar to "b") but:

This option would convert the 10 pole WR induction motors to 10 pole synchronous motors by making changes to the existing WR motor rotor, motor cost would be reduced and disruption to the system would be much less, but a major disadvantage is line operation of M2 and M3 is no longer possible.

Line and load torque harmonics would be similar to alternative "b" and would always be present.

V. ALTERNATIVE "c"

Two new 12 pole 50,000 HP synchronous motors replacing the two W2 motor induction motors on the same foundations. Two new LCI (Load Commutated Inverter) for powering the new 50,000 HP motors and two new LCI inverters for full powering of the two existing 83,000 HP motors. Using existing transformers with 6 pulse operation the rectifiers would have to be phased back to get the proper output voltage to the motors. This would lower the power factor on the motors to around 80% and synchronous motors could not supply any reactive power in this mode of operation. Also the line harmonics would be too high at higher loads. For example, at full load:

$$\frac{278K\ HP}{9K\ HP} = 30.9 \text{ using previous power system in Appendix I}$$

BUS	Harmonic Distortion Factor	(6 Pulse)	(12 Pulse)
Franklin	.14 x 30.9 = 3.9%	4.35	2.17
Arnold	.43 x 30.9 = 12%	13.29	8.7
PWT	.43 x 30.9 = 12%	13.29	8.7

Torque harmonics would be much higher than "b" at the same speeds.

Approximate Cost: (Based on 12 pulse being most practical)

	100K HP x $36/HP	= $ 3.6M	New Motors
	278K HP x $48/HP	= $13.25M	LCI's +
8 (1000MVA) Circuit Breakers	8 x $.02M	= $ .16M	Breakers
	Total Cost	= $17.11M	+ M1 & M4 Motor changes if possible, may require new M1 & M4 at additional $6.41M.

Advantage - gives variable speed capability over total speed range with total horsepower, except for restrictions at resonant torsional speeds.

Disadvantages - line harmonics too high, power factor too low (6 pulse) and cost very high. Going to 12 pulse would improve power factor but, line harmonics would still be high - .28/.43 x 13.29 = 8.7% on Arnold and PWT buses. The cost for a 12 pulse drive is higher than the 6 pulse because of additional costs for LCI's and additional transformers but, 12 pulse is most practical at this power rating because of required paralleling to meet current levels.

Note: Must check 89,000 HP motor heating in stator from LCI harmonic currents if using either option

Torque harmonic shaft stresses would be much higher at the torsional resonances for either the 16T or 16S compressor on drive since harmonic torque energy would be input from all four motors to excite the torsional resonances. This would be true at all the resonant speeds defined in alternate "b" at both steady state and start up.

VI. ALTERNATIVE "d"

Consider a slip energy recovery system for M2 and M3 for full adjustable speed operation. A cyclo-converter would replace the liquid rheostats and the slip energy would be fed back to the power system.

The power system would see harmonic distortion levels similar to alternative "a" of about 5% when operating near full power levels. Harmonic torque pulsation frequencies are much above resonances and should not be a problem, except at full speed must be checked.

Cost of 32,000 KVA cyclo-converter at 100 per KVA is $3.2M or total cost = $64M for two motors.

VII. ALTERNATIVE "B"

For slip energy recovery at 600 RPM only the drive would see 6, 12, 18, etc. harmonics torques of the slip frequency with the 6th amplitude being about .20 of rated torque at 600 RPM. At rated torque and speed the 6th harmonic is at or near resonance with the 61.4 hz, 1st mode with 16T compressor or 2nd mode 58.3 hz with 16S compressor. (See Figures 1 and 2) From Table 1 the worst dynamic shaft stress is in Shaft 2, which means when driving the transonic compressor, this stress would be (assuming an amplification of Q = 200) equal to:

.2 (824 + 1045) 200 = 74760 psi in shaft 2

and .2 (682 + 865) 200 = 61880 psi in shaft 4

when driving the transonic compressor near 600 RPM.

When driving the supersonic compressor 16S, the maximum stress in shaft 5 would be the worst stress and equal to:

2 (323 + 267) 200 = 23,600 psi near 600 RPM

All of the above assumes that the damping in the third torsional mode is enough to limit the amplification to 200 - this is a reasonable and conservative assumption, but must be verified by test.

Conclusion - a six pulse slip energy recovery, LCI type, on both WR motors is questionable at 600 RPM and rated load. The line harmonics are marginal, around 5% the shaft stresses from harmonic torques at 600 RPM could be very high.

Shut down of Drive Procedure for "b"

The drive can be shut down by delaying firing angle in the rectifier beyond 90° and advancing the firing angle in inverter so it becomes a rectifier and the LCI works in reverse, feeding energy back to the system.

The initial portion of the shut down would be the same; that is reduce the compressor loads and shift load from M1 and M4 onto M2 and M3, then perform the above procedure to get dynamic breaking to 50 RPM where mechanical break takes over.

VIII. OTHER ALTERNATIVES

(1) Buy one 50,000 HP PWM inverter, put fixed stainless steel tubing, water cooled resistors on one WR motor, use PWM inverter for start-up and sub-synchronous operation on this motor, get experience and evaluation of PWM inverters.

Couplings - There should be no need to change any couplings for any of the alternatives and the existing capability to readily connect and disconnect PWT MD to the 16T and 16S compressors could remain.

Angular Alignment - for in-line operation should remain the same, providing shaft sizes of any new motors are consistent with the present drive, giving the same torsional stiffnesses. During start-up or steady running with LCI's on replacement synchronous motors for M2 and M3 angular alignment has no effect on operation; however, during in-line synchronous operation of M1, M2, M3 and M4 with M2 and M3 being new synchronous motors, the angular adjustment should be very small on M2 and M3 and could be accomplished by shimming the stators.

Since the angular displacements are different and in opposite directions, depending on whether 16S or 16T are being driven, a jack screw arrangement or a hydraulically driven stator on a rim support could be used to more readily make the angular adjustments to the frames. Toothed couplings could also be added to allow these angular adjustments, but they require more time to adjust.

Installation Considerations

For alternate "b" replacing the WR motors M2 and M3 with 50,000 HP synchronous motors on the same foundations, the following methods to minimize down time could be considered:

1. Remove and replace one WR motor with 50,000 HP synchronous motor, use remaining WR motor for start-up and line running with (89 + 89 + 35)K-HP or 213 HP available while installing and checking out LCI for the new synchronous motor. May be possible to use new synchronous motor for line running to get full power capability while installing 1st LCI. When installations of 1st new motor and LCI is completed and operational then proceed with 2.

2. Remove and replace second WR motor and associated LCI using newly installed LCI and motor for start-up, giving line running capability (89 + 89 + 50)K-HP or 228 HP and on a part time basis should have total line power capability when second 50,000 HP synchronous motor is installed and while installing its associated LCI.

Line Harmonic Distortion

The major harmonics contributing to the line distortions on the power system at normal and maximum configurations are the 17th and 19th harmonics, as illustrated by the bar charts in Appendix I. These can be greatly reduced by harmonic filters if the harmonic distortion projected at the Arnold Bus are too large. Estimated cost for 17th and 19th harmonic filters would be approximately $130,000.00 each.

Relaying Considerations

The PLC's controllers for the new PWT MD adjustable speed drives could have the capacity of handling existing hard-wired relay logic similar to the approach used in the existing 4T IDS installation. The 4T IDS uses a relatively large GE Series 6 PLC. This approach could provide a migration path from the existing hard wired relay logic.

CONCLUSION

The most technically feasible and cost effective alternative appears to be alternate "b". A schematic diagram of "b" is shown in Figure 3 sketch. Twelve pulse requires additional transformers, but twelve or twenty-four pulse will probably be required due to required paralleling of bridges to meet the power level requirements. Twenty-four pulse may pose no restrictions on speed due to harmonic torques. It may also be within acceptable levels of harmonic distortion at the various buses and the power system in general. For alternate "b" the cost includes 12 or 24 pulse operation.

TABLE 1 - Dynamic Shaft Stresses With Transonic Compressor and Q = 1.

Total Torque = 2.604(10)^6 lb-in

Shaft No.	1	2	3	4	5	6
	TC -	CPLG -	M1 -	M2 -	M3 -	M4 - CPLG

Rated Motor Torques in Per Unit

		SHAFT NO. Stresses (psi)					
Freq (Hz)	Mode	1	2	3	4	5	6
				.359 Torque on M1			
64	1	1	1652	60.4	1366	421	235
169.6	2	1	424	544	1854	669	415
408	3	1	89	119	27	116	203
				.359 Torque on M4			
64	1	1	2988	1087	2456	756	421
169.6	2	1	270	347	1181	426	265
408	3	1	24	32	8	31	54
				.141 Torque on M2			
64	1	1	824	302	682	210	117
169.6	2	1	101	130	442	159	99
408	3	1	132	178	41	173	302
				.141 Torque on M3			
64	1	1	1045	383	865	267	149
169.6	2	1	26	33	111	40	25
408	3	1	153	206	47	201	351

TABLE 2 - Steady State Solution for Shaft Stresses
With Transonic Compressor

6th = .2 12th = .1

Mode	RPM	Shaft No.		6th Stress (psi)	RPM	12th Stress (psi)
			M1 with 50,000 HP			
1	107	4	1366 x 50/89 x .2 x 200	= 30,599	54	15,299
2	283	4	1854 x 22.5	= 41,530	142	20,765
			M4 with 50,000 HP			
1	107	4	2456 x 22.5	= 55,015(+)	54	27,508(+)
2	283	4	1181 x 22.5	= 26,455(-)	142	13,228(-)
			M2 with 50,000 HP			
1	107	1	824 x .2 x 200 x 50/35	= 47,086	54	23,543
2	283	4	442 x 57.14	= 25,247(+)	142	12,623(+)
			M3 with 50,000 HP			
1	107	1	1045 x 57.14	= 59,711	54	29,856
2	283	4	111 x 57.14	= 6,343(-)	142	3,172(-)

TABLE 3 - Shaft Stresses During Acceleration Through Resonances with Transonic Compressor

6th = .2 12th = .1

P=12 poles

$T_T = 26.04(10)^6$ lb-in

$I_T = 92368$ lb-in-sec^2

6th = .20 motor torque

12th = .10 motor torque

$$h_H = \frac{50/89 \times .359 \times T_T \times h \times p/2}{I_T \times 2 \times \pi} = 325 \text{ for } H=6 \text{ or } 650 \text{ for } H=12$$

$Q_6 = 3.67\ f_N/\sqrt{325}$ for H=6

$Q_{12} = 3.67\ f_N/\sqrt{650}$ for H=12 ($\frac{1}{2} \times 1/\sqrt{2} = .354$)

Mode	f_n (hz)	Shaft No.	H=6 Stress (psi)	H=12 Stress (psi)
			M1 with 50,000 HP	
1	64	4	30,599 x 13/200 = 1,989	.354 x 1989 = 703
2	169.6	4	41,530 x 35/200 = 7,268	.354 x 7268 = 2570
			M4 with 50,000 HP	
1	64	4	55,015 x 13/200 = 3,576	.354 x 3576 = 1266
2	169.6	4	28,455 x 35/200 = 3,307	.354 x 3307 = 1171
			M2 with 50,000 HP	
1	64	1	32,960 x 13/200 = 2,143	.354 x 2143 = 759
2	169.6	4	17,680 x 35/200 = 3,094	.354 x 3094 = 1095
			M3 with 50,000 HP	
1	64	1	41,800 x 13/200 = 2,717	.354 x 2717 = 962
2	169.6	4	4,440 x 35/200 = 777	.354 x 777 = 275

TABLE 4 - Summary of Steady State (SS) and Accelerating Through (AT) Resonance Shaft Stresses with Transonic

Compressor 16T

Mode	Freq. (Hz)	Shaft No.	H=6 Speed (RPM)	Stress (psi) SS	Stress (psi) AT	H=12 Speed (RPM)	Stress (psi) SS	Stress (psi) AT
			Rated Torque at M2 (50,000 HP)					
1	64	4	107	47,086	2143	54	23,543	759
2	169.6	4	283	25,247	3094	142	12,623	1095
			Rated Torque at M3 (50,000 HP)					
1	64	4	107	59,711	2717	54	29,856	962
2	169.6	4	283	6,343(-)	777	142	2,172(-)	275

Cannot Run Steady State in Neighborhood of
54, 107, 142 or 282 RPM
Driving With M2 and M3

6th = .2 12th = .1

TABLE 5 - Dynamic Shaft Stresses with Super Sonic Compressor and Q=1.

Total Torque = 2.604(10)^6 lb-in

Shaft No.	1	2	3	4	5	6
	TC -	CPLG -	M1 -	M2 -	M3 -	M4 - CPLG

Rated Motor Torques in Per Unit

		SHAFT NO. Stresses (psi)					
Freq (Hz)	Mode	1	2	3	4	5	6
				.359 Torque on M1			
30.2	1	43	78	258	119	363	1
58.3	2	122	220	718	321	899	1
70.2	3	322	577	1865	816	2159	1
85.4	4	8	14	43	19	44	1
176.6	5	235	382	1043	291	371	1
525.9	7	392	9	190	51	257	1
563.	8	320	78	23	67	370	1
				.359 Torque on M4			
30.2	1	39	71	232	107	327	1
58.3	2	77	139	453	202	567	1
70.2	3	151	271	876	383	1014	1
85.4	4	2	3	10	5	10	1
176.6	5	403	654	1787	498	635	1
414.	6	181	128	22	130	89	1
525.9	7	156	4	76	20	102	1
563.	8	338	82	25	71	390	1

TABLE 6 - Steady State Solution for Shaft Stresses
With Super Sonic Compressor

Mode	Freq (Hz)	Shaft No.				6th-S.S. Stress (psi)	12th-S.S. Stress (psi)
			M1 with 50,000 HP				
1	30.2	5	363 x 50/89 x .2 x 200		=	8,157	4,079
2	58.3	5	899 x	22.5	=	20,202	10,101
3	70.2	5	2159 x	22.5	=	48,517	24,259
5	176.6	3	1043 x	22.5	=	23,439	11,720
			12th Harmonic Responses are ½ of the above				
			M4 with 50,000 HP				
1	30.2	5	327 x	22.5	=	7,359	3,679
2	58.3	5	567 x	22.5	=	12,758	6,379
3	70.2	5	1014 x	22.5	=	22,815	11,408
5	176.6	3	1787 x	22.5	=	40,308	20,154
			12th Harmonic Responses are ½ of the above				
			M2 with 50,000 HP Torque				
1	30.2	5	140 x 50/35 x .2 x 200		=	8,000	4,000
2	58.3	5	323 x	57.2	=	18,480	9,240
3	70.2	5	743 x	57.2	=	42,500	21,250
			M3 with 50,000 HP Torque				
1	30.2	5	134 x	57.2	=	7,670	3,840
2	58.3	5	323 x	57.2	=	15,280	7,640
3	70.2	5	743 x	57.2	=	31,410	15,700
			(6th = .2 and 12th = .1 for the above)				

$h_6 = 325$ $h_{12} = 650$ $Q = 3.67 f_N / V h_8$

Mode	f_N (Hz)		
1	30.2	$Q_6 = \frac{3.67 \times 30.2}{325} \approx 6.15$	$Q_{12} = 4.35$
2	58.3	$Q_6 = 11.9$	$Q_{12} = 8.42$
3	70.2	$Q_6 = 14.3$	$Q_{12} = 10.1$
5	176.6	$Q_6 = 36$	$Q_{12} = 25.5$

TABLE 7 - Shaft Stresses During Acceleration Through Resonances with Super-Sonic Compressor 16S

Mode	Freq. (Hz)	Shaft No.		5th H Stress (psi)	12th H Stress (psi)
			M1 with 50,000 HP		
1	30.2	5	8,157 x 6.15/200 = 251	251 x .354 =	89
2	58.3	5	20,202 x 11.9/200 = 1202	1202 x .354 =	426
3	70.2	5	48,517 x 14.3/200 = 3469	3469 x .354 =	1228
5	176.6	3	23,439 x 36/200 = 4219	4219 x .354 =	1494
			M4 with 50,000 HP		
1	30.2	5	7,358 x 6.15/200 = 227	227 x .354 =	81
2	58.3	5	12,758 x 11.9/200 = 759	759 x .354 =	269
3	70.2	5	22,815 x 14.3/200 = 1632	1632 x .354 =	578
5	176.6	3	40,208 x 36/200 = 7238	7238 x .354 =	2562
			M2 with 50,000 HP		
1	30.2	5	8,000 x 6.15/200 = 250	250 x .354 =	90
2	58.3	5	18,480 x 11.9/200 = 1100	1100 x .354 =	390
3	70.2	5	42,500 x 14.3/200 = 3040	3040 x .354 =	1080
			M3 with 50,000 HP		
1	30.2	5	7,670 x 6.15/200 = 240	240 x .354 =	90
2	58.3	5	15,280 x 11.9/200 = 910	910 x .354 =	330
3	70.2	5	31,410 x 14.3/200 = 2250	2250 x .354 =	800

TABLE 8 - Summary of Steady State (SS) and Accelerating Through (AT) Resonance shaft Stresses With Super-Sonic Compressor 16S

Mode	Freq. (Hz)	Shaft No.	H=6 Speed (RPM)	Stress (psi) SS	Stress (psi) AT	H=12 Speed (RPM)	Stress (psi) SS	Stress (psi) AT
			Rated Torque at M2 (50,000 HP)					
1	30.2	5	50.3	8,000	250	25.1	400	9
2	58.3	5	97	18,480	1100	48.5	924	39
3	70.2	5	117	42,500	3040	58.5	2125	108
			Rated Torque at M2 (50,000 HP)					
1	30.2	5	50.3	7,670	240	25.1	384	9
2	58.3	5	97	15,280	910	48.5	764	33
3	70.2	5	117	31,410	2250	58.5	1570	80

Alternate "b"

PWT MD with 16T Transonic Compressor

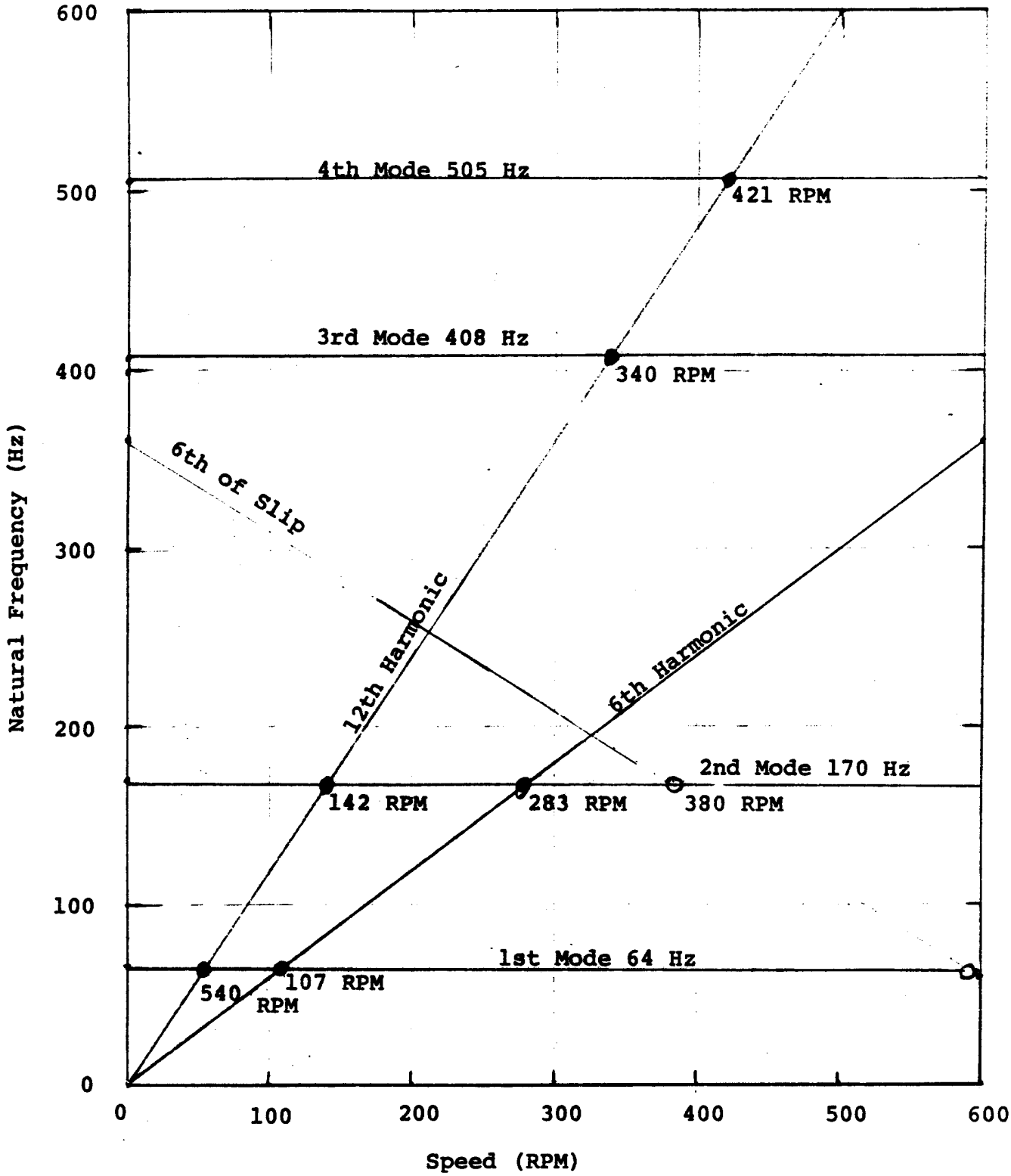

Fig.1 - Harmonic Torque Resonances with 16T Compressor

PWT MD with 16S Supersonic Compressor

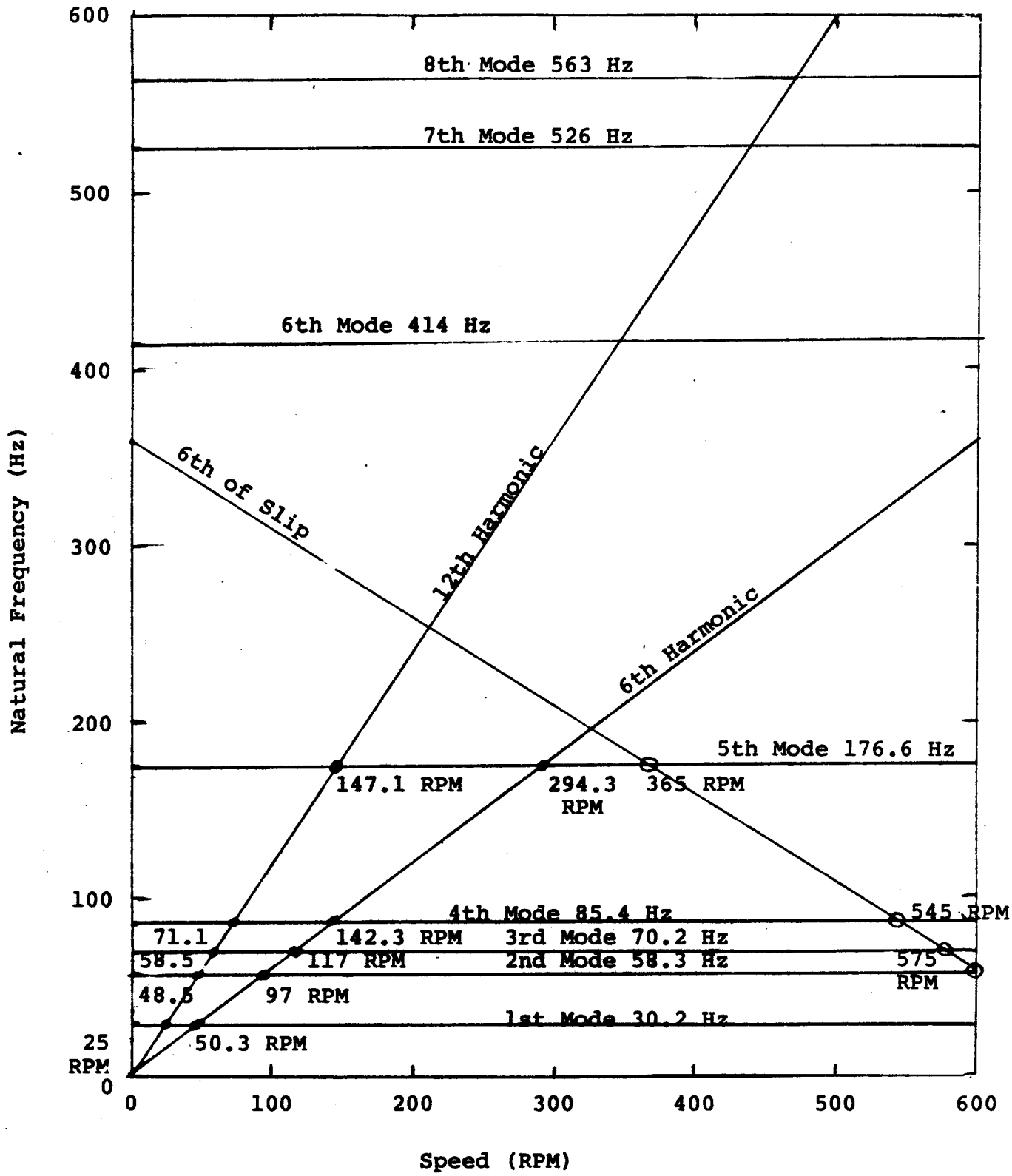

Fig.2 - Harmonic Torque Resonances with 16S Compressor

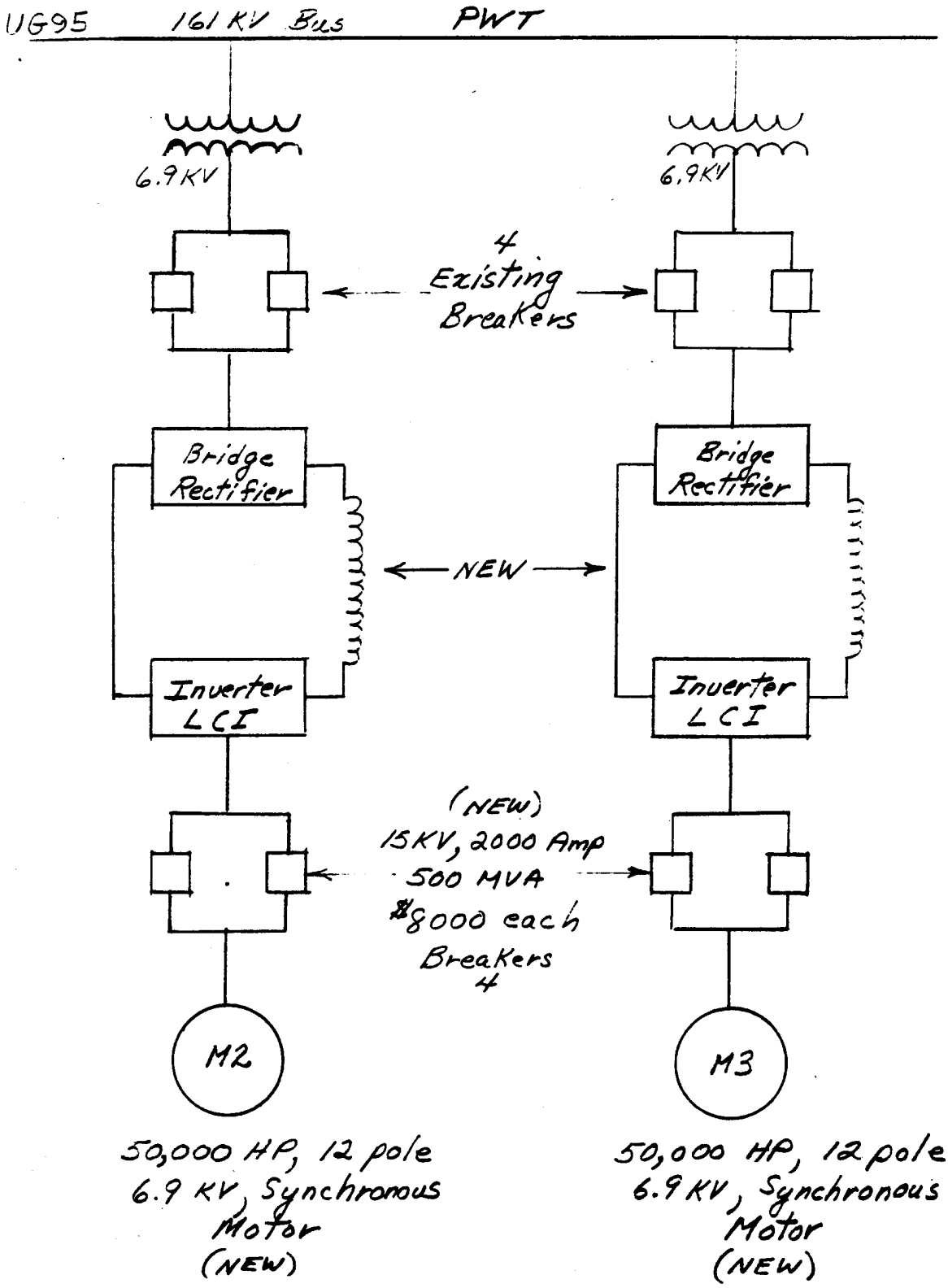

Fig. 3 — Alternate "b" schematic diagram

SECTION IV - VFPS ELECTRICAL HARMONIC ANALYSIS

The Variable Frequency Power Supply (VFPS) harmonic analysis is based on the circuit configuration of Figure 55. The constants for the circuit configuration were calculated from furnished circuit constants and from standard text and handbooks with the bases properly adjusted to the 100 MVA base used in the study. The constants were then reduced to capacitance, inductance and resistance values. These values were prepared for a balanced three phase steady state analysis using a Small System Simulator digital program. The Small System Simulator (SSS) produced the voltage effects on each bus at each harmonic frequency. These effects were combined to form the total harmonic distortion factor THDF.

CIRCUIT SELECTION

The circuits involving the 500 kV Franklin Bus were furnished and included 500 kV lines to Sequoyah and Maury with sources at each point, three 500 to 161 kV transformers, 161 kV lines to Wartrace, Belfast, and Winchester and sources at each point. Two 161 kV lines to Arnold (or Main) completed the Franklin Bus detail.

The 161 kV Arnold bus included the two lines from Franklin and a 161 kV cable to the PES bus. The detail at Arnold was completed by a load representing the remaining connections and a capacitance equivalent to two additional cable circuits.

The PES 161 kV bus included the cable UG98 from Arnold, three transformers with 13.8 kV secondaries, and two transformers with 6.9 kV secondaries. Transformers 1 and 4 (13.8 kV) supplied the busses A, B, D, and E, each with a 28,500 HP synchronous motor. Transformers 2 and 3 (6.9 kV) supplied busses C and F, each with a 14,000 HP synchronous motor. Transformer 5 (the New

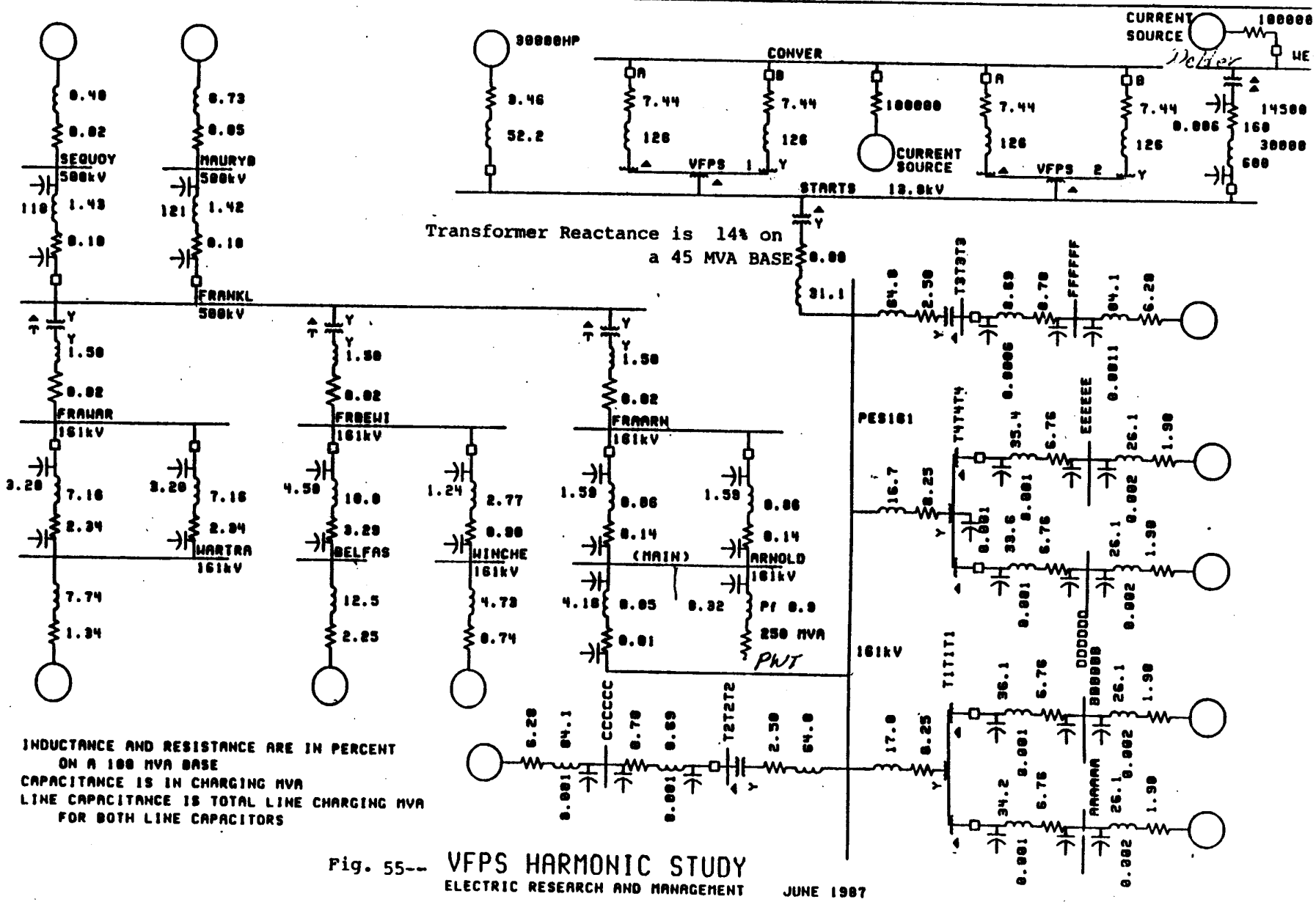

Fig. 55-- VFPS HARMONIC STUDY

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transformer with a 13.8 kV secondary) supplied the 13.8 kV Start Bus. The Start Bus supplied a 30,000 HP motor, a station service transformer with a welder on its secondary, and the VFPS transformers.

Each section of circuit was connected with a breaker which could be used to signal the digital program to omit the branch with the breaker. The breakers were used to conveniently select desired circuit configurations.

CIRCUIT CONFIGURATIONS CHOSEN

The circuits chosen included a maximum configuration, a "normal" configuration, a minimum configuration and a "cold start" configuration. The maximum configuration included all lines and sources connected on the Franklin Bus, a 125 MVA load on the Arnold Bus, motors A, B, C, D, E, and F connected to the PES Bus, and the VFPS and welder connected to the Start Bus. Only the 30,000 HP motor was not connected to the PES Bus as it was assumed to be operating at 9000 HP using the VFPS in the 6 pulse mode.

The "normal" configuration was selected half way between the maximum and minimum configuration. The "normal" term is included in quotations since the actual normal operating configuration was not available. This assumed configuration included all the lines and sources connected to the Franklin Bus, 50 MVA load connected at the Arnold Bus, motors A, C, and D connected to the PES bus, and the VFPS, the 30,000 HP motor and the welder connected to the Start Bus. The VFPS was assumed to be operating at 9000 HP carrying motor E using a 6 pulse mode of operation.

The minimum system was chosen to maximize harmonics and remain within reasonable operating constraints. The Maury source and line only supplied Franklin. Only one line between Franklin and Arnold was utilized. The load at Arnold was 0 MVA. There were

no motors connected to the PES Bus. The Start Bus had only the VFPS connected for 6 pulse operation at 9000 HP. The welder and the 30,000 HP motor were disconnected.

The "Cold Start" configuration was selected as the worst case for harmonics possible on the system and was identical to the minimum system except the Belfast source and line supplied the Franklin Bus rather than the Maury source and line.

CALCULATION OF THE DISTORTION FACTOR

As suggested in the IEEE standard 519-1981, "IEEE Recommended Practices and Requirements For Harmonic Control In Electric Power Systems", the current injection into the rectifier side of the VFPS transformers was sized according to the expected harmonic levels.

HARMONIC LEVELS FOR CURRENT INJECTION IN PER UNIT

Harmonic	6 Pulse	12 Pulse	Arc Source
5	0.175	0.026	0.077
7	0.110	0.016	0.031
11	0.045	0.045	
13	0.029	0.029	
17	0.015	0.002	
19	0.010	0.001	
23	0.009	0.009	
25	0.008	0.008	

The resultant voltages from the current injections were used in an RMS calculation where all eight harmonic voltages were squared and summed at each bus. The Total Distortion Factor (TDF) was calculated at each bus by taking the square root of the summation. A bus is considered acceptable if the TDF is less than five percent.

RESULTS

The results of the study may be summarized in the following table.

TOTAL DISTORTION FACTORS IN PERCENT

	System Configuration					
Bus	Maximum	Normal	Minimum	Cold Start		Normal
Pulses	6	6	6	6	+Wartrace	12
Franklin	0.18	0.14	1.28	29.17	5.80	0.09
Arnold	0.53	0.43	2.69	31.57	6.90	0.28
PES	0.53	0.43	2.70	31.58	6.91	0.28
A	0.14	0.15	*	*		0.09
C	0.30	0.24	*	*		0.16
Start	3.40	2.10	4.98	32.59	8.96	~~1.38~~ 2.12

* Not Connected

This tabulation indicates the boundary of acceptable operation. The Franklin Bus must be supplied at least one of the 500 kV lines with a reasonably normal utility source. If the 500 kV lines are not in service, then it is possible that the 161 kV lines may be too weak of a source and harmonic resonance may occur as in the "Cold Start" configuration. In the "Cold Start" circuit, the fifth harmonic was approaching resonance at the Belfast Source. With the 500 kV lines in service, the harmonic levels should be below 5 percent distortion for all operating conditions.

A look at the harmonic activity on the various circuit configurations was made by comparing the distortion factor for each harmonic at a specific bus. The maximum configuration had a slight resonance at the nineteenth harmonic. The normal configuration had a small resonance at the seventeenth harmonic. The minimum configuration had a resonance at the eleventh harmonic and the "Cold Start" configuration had a serious fifth harmonic resonance. These comparisons are shown in Figures 56 through 59 for the Arnold Bus.

Figure 56 - Maximum Configuration

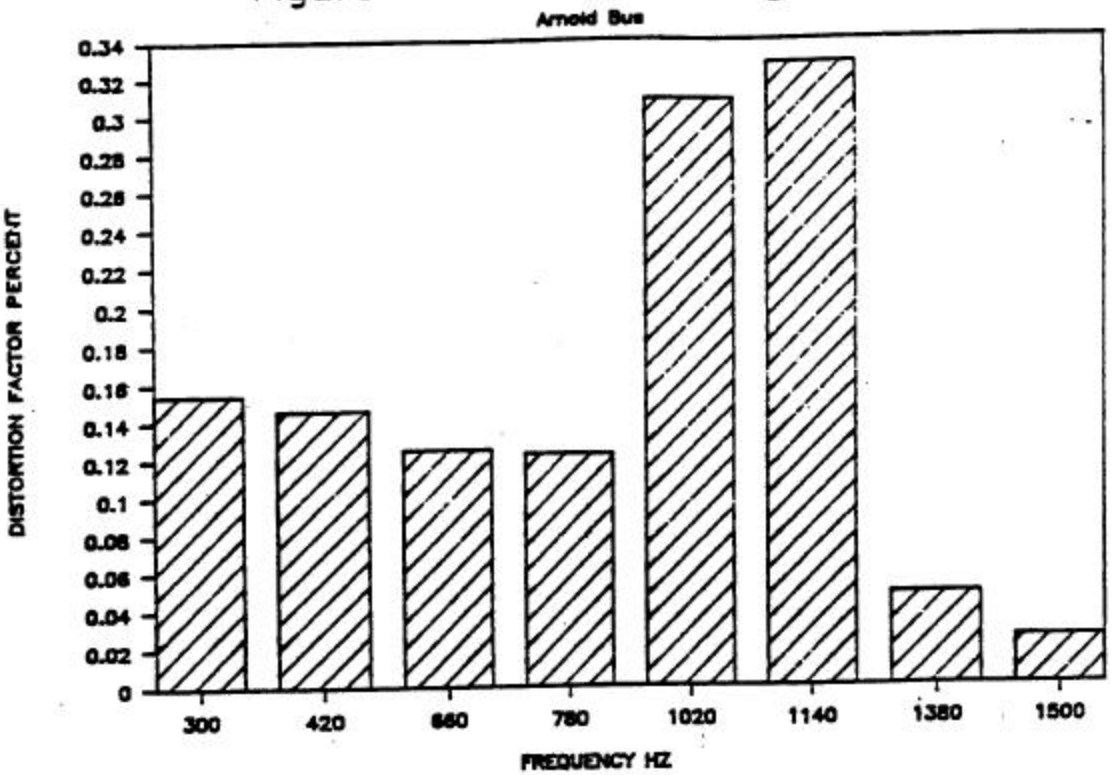


Figure 57 - Normal Configuration

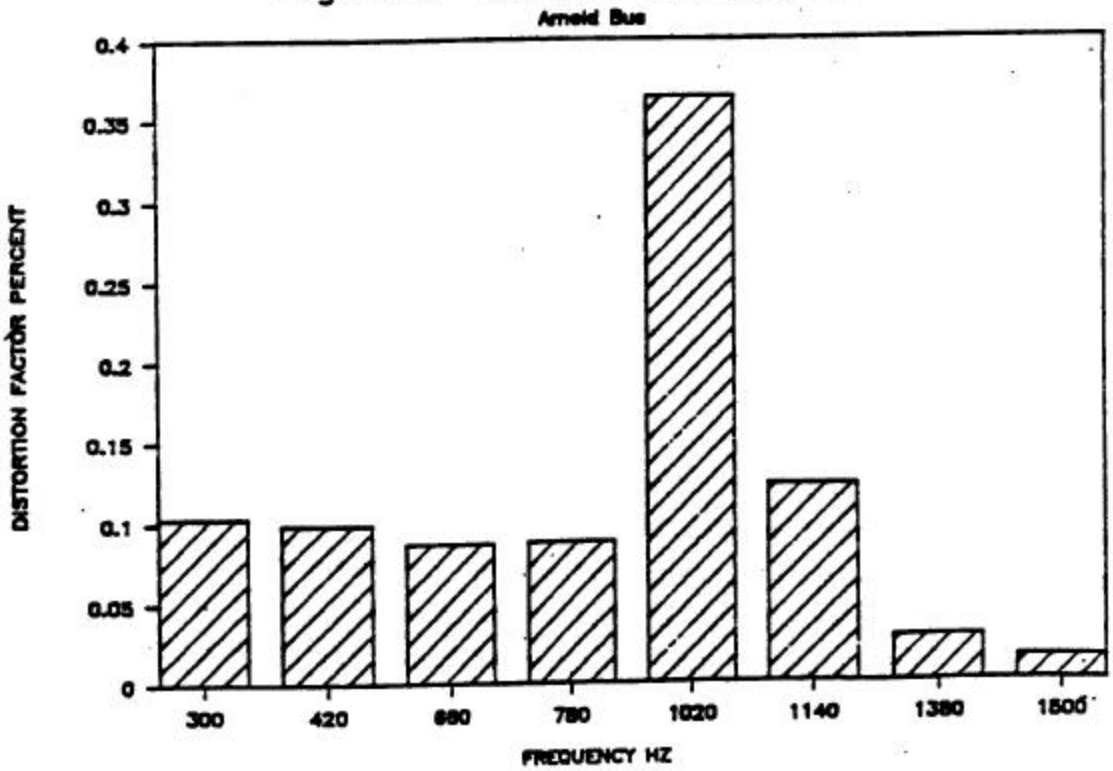


Figure 58 -Minimum Configuration

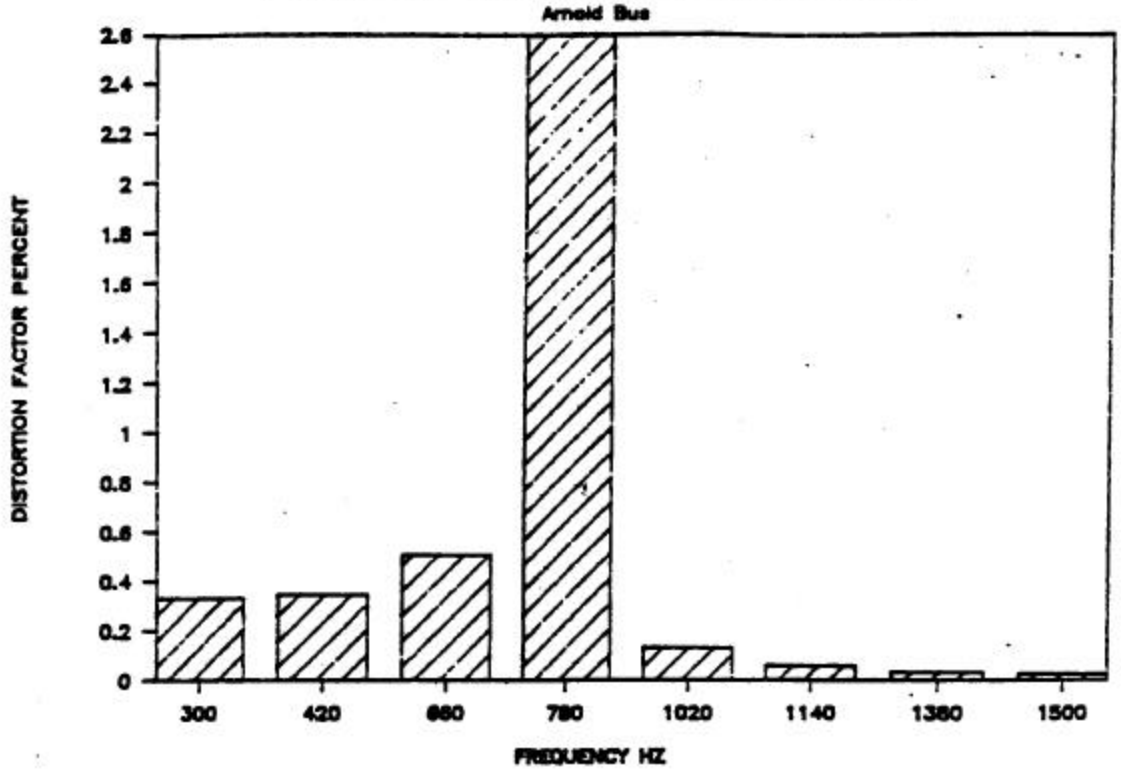
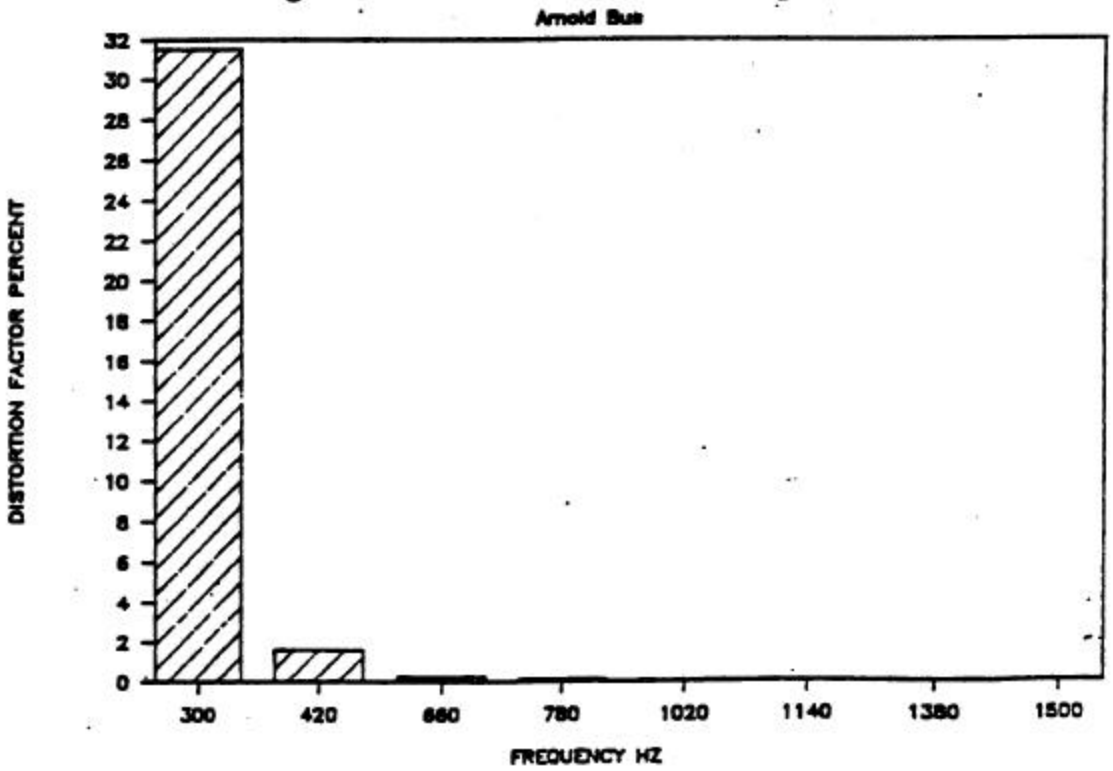


Figure 59--Cold Start Configuration



The welder bus was injected with a harmonic current source using the fifth and seventh harmonics. The system used was the "Cold Start" configuration since the harmonics would be maximized. The configuration was changed by adding the welder to the Start Bus and removing the VFPS transformers. A final case for the welder was done with the normal system configuration but without the VFPS connected.

TOTAL DISTORTION FACTOR IN PERCENT FOR THE WELDER

Bus	Normal	Cold Start
Franklin	0.001	0.502
Arnold	0.002	0.544
PES	0.002	0.544
Start	0.026	0.561
Welder	0.793	1.136

The welder does not affect the harmonic levels significantly on any bus other than its own supply bus.

CONCLUSIONS

The VFPS may operate in any configuration with the restriction that at least one 500 kV line supplies the Franklin Bus. The Welder may operate without restrictions due to harmonics.

(See Discussion of Result on Next Page)

Discussion of Result

The previous results were based on 9000 hp single channel 6 pulse converter power. If two channels are supplying 6 pulse power at 18000 hp then all the distortions must be multiplied by two. Under these conditions the minimum configuration distortion factor would be 2.7 x 2 = 5.4% at the PES bus which is above the 5.0% guideline. If the minimum configuration is a realistic/common condition then a 13th harmonic filter may be required to reduce the distortion.

For the cold start configuration at the PES bus the distortion factor would also be doubled making it 2 x 31.58 = 63.16% which makes an already bad condition much worse. If twelve pulse power is used on each channel then the 63.16% reduces to (.026/.175) x 63.16 = 9.36%. This is still above the maximum 5.0% value recommended but a large improvement. A 5th harmonic filter would also be required to reduce this distortion to acceptable levels.

At low speed the .175 5th harmonic current factor used would be .198 (overlap angle = 4°) which means the distortion factors would be .198/.175 = 1.13, and at low speed the 5th harmonic distortion calculated above must be multiplied by a 1.13 factor.

Conclusions

(Section IV)

The results of the electrical harmonic study on PES and TVA systems indicate no problems from the VFPS converter harmonic currents under normal operating conditions (6 pulse, 9000 hp VFPS power). Under certain minimum configuration or cold start conditions the harmonic distortion can be quite high (above 30%, 5th harmonic) on all buses.

The 12 pulse converter for each channel is recommended for this application for the following reasons:

(1) less harmonic distortion effects on the power system, motors, relays and other equipment

(2) allows for larger accelerating torques on motor drives with shorter start up times which meet all start up time objectives--this is especially helpful if torque is reduced in the lower speed range (below 40% speed) because of 30000 hp motor design consideration

A small induction motor/clutch/gear drive for each unit is the most reliable/practical approach for slow roll at this time.

Regenerative breaking of 4T drive from 180 rpm to 10 rpm can be accomplished with VFPS, but the same restrictions on torque level as during start up must be maintained.

Reducing 4T motor torque (because of design considerations) by making it proportional to speed from 40% to 10% speed increases start up time by approximately 30%, but start up time objectives are still met.

These results are based on six pulse 9000 hp operation. If a 12 pulse converter were used the cold start distortion would be reduced to 4.7^{o} on all buses. If the cold start condition is realistic/common then the VFPS should be a 12 pulse design.

For two identical VFPS channels operating in parallel (18000 hp) all the distortions would be doubled.

The 13th harmonic distortion in a particular minimum configuration is 2.7% at the PES bus with 9000 hp, 6 pulse power. This distortion would be 5.4% for 18000 hp operation in either the 6th or 12th pulse modes. Lowering this distortion would require a 13th harmonic tuned filter.

To reduce the 5th harmonic distortion during a cold start with 18000 hp 12 pulse power to below 9.4% distortion would require a 5th harmonic tuned filter.

Recommendations

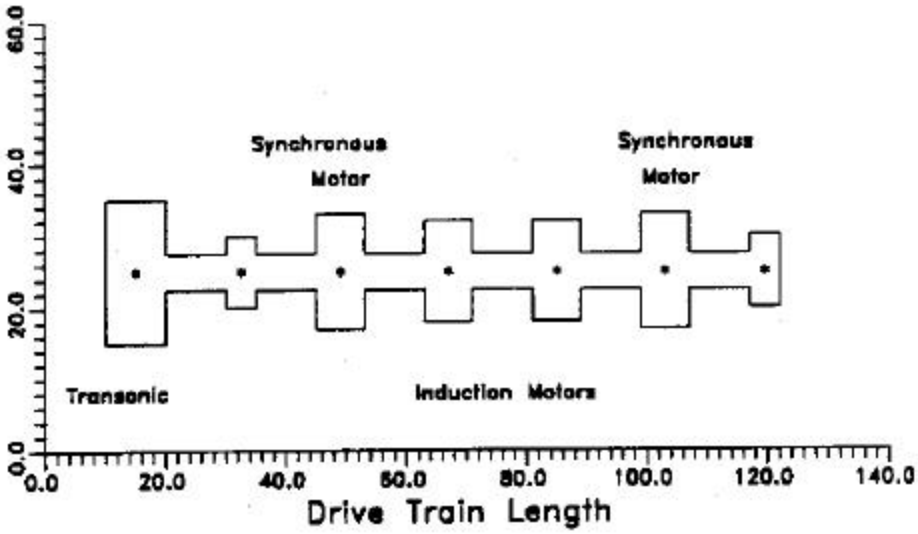
Results of PES drive lateral study should be compared to actual field data including vibration levels at bearing housings (pedestals).

A detailed lateral analysis should be made on the 4T-IDS compressor drive to determine the lateral vibration levels and resonances throughout the operating speed range when operating with a VFPS.

A detailed torsional analysis of the 4T-IDS compressor drive should be made to determine shaft stresses and compressor blade stresses of all important modes for both start up and steady state running in the operating speed range with a VFPS. The effect of fault, electrical unbalance and short circuits throughout the operating speed range on shaft and compressor blades should be calculated.

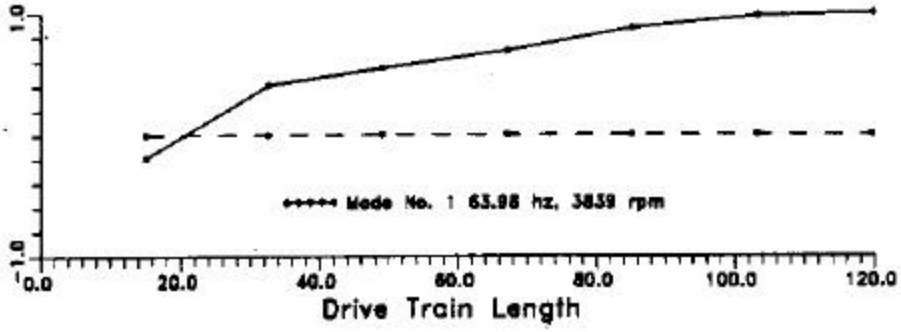
If the minimum configuration is a practical/common condition then consideration should be given to adding 13th harmonic filters to the system. If the cold start condition is a practical/common condition then consideration should be given to adding 5th harmonic filters to the system.

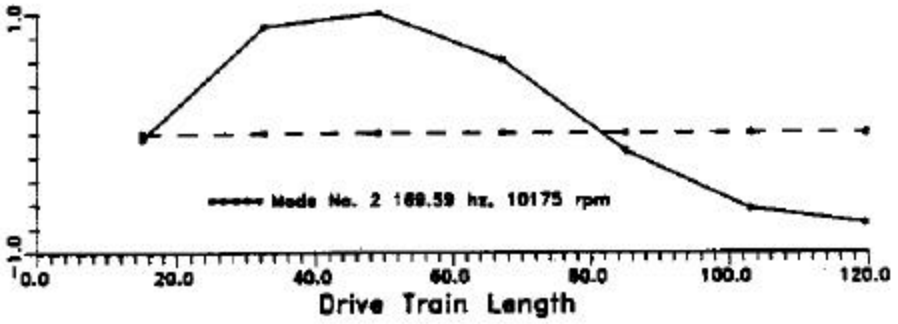
APPENDIX II



Arnold Air-Force Base Tullahoma PWT
[Transonic Operation]

Torsional Study





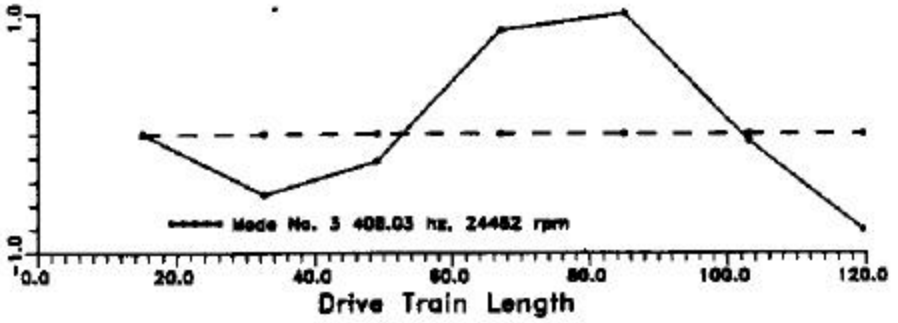


Figure Arnold Air-force Base Tullahoma PWT
[Transonic Operation First 3 Modes]

Arnold Air-Force Tullahoma PWT

NO OF INERTIAS 7
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 6
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF 2SF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 9348360.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	18318.8	.000000E+00	.00000E+00	.000
2	469.1	.000000E+00	.00000E+00	.000
3	1352.6	.000000E+00	.00000E+00	.359
4	505.2	.000000E+00	.00000E+00	.000
5	509.2	.000000E+00	.00000E+00	.000
6	1352.6	.000000E+00	.00000E+00	.000
7	469.1	.000000E+00	.00000E+00	.000
TOTAL	22962.6			.359

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.949000E+09	.00000E+00	.0000	1.0000
2 - 3	.384700E+10	.00000E+00	24.5000	1.0000
3 - 4	.284000E+10	.00000E+00	31.5000	1.0000
4 - 5	.193000E+10	.00000E+00	22.8750	1.0000
5 - 6	.284000E+10	.00000E+00	31.5000	1.0000
6 - 7	.333200E+10	.00000E+00	24.5000	1.0000

1

MODAL DATA

MODE NO 1
FREQUENCY (HZ) .00000 (RPM) .00
DAMPING (%) 100.00000
GENERALIZED MASS 3.17788E+03
GENERALIZED STIFFNESS 0.00000E+00
EFFECTIVE MASS 2.29426E+04
PARTICIPATION FACTOR -1.68808E+00

MODE SHAPE

(1, 1)=-3.7201E-01 (2, 1)=-3.7201E-01 (3, 1)=-3.7201E-01 (4, 1)=-3.7201E-01
(5, 1)=-3.7201E-01 (6, 1)=-3.7201E-01 (7, 1)=-3.7201E-01 (

MODE NO 2
FREQUENCY (HZ) 63.97500 (RPM) 3838.50
DAMPING (%) .00000
GENERALIZED MASS 1.52771E+03
GENERALIZED STIFFNESS 5.89998E+06
EFFECTIVE MASS 1.98787E-06
PARTICIPATION FACTOR -2.32556E-06

MODE SHAPE

(1, 2)=-1.9103E-01 (2, 2)= 4.0478E-01 (3, 2)= 5.4378E-01 (4, 2)= 6.8981E-01
(5, 2)= 8.7565E-01 (6, 2)= 9.7725E-01 (7, 2)= 1.0000E+00 (

MODE NO 3
FREQUENCY (HZ) 169.58737 (RPM) 10175.24
DAMPING (%) .00000
GENERALIZED MASS 2.77234E+03
GENERALIZED STIFFNESS 3.14769E+09
EFFECTIVE MASS 4.14131E-24
PARTICIPATION FACTOR 3.86497E-14

MODE SHAPE

(1, 3)=-4.2685E-02 (2, 3)= 8.9283E-01 (3, 3)= 1.0000E+00 (4, 3)= 6.0553E-01
(5, 3)=-1.5162E-01 (6, 3)=-6.3841E-01 (7, 3)=-7.5773E-01 (

MODE NO 4
FREQUENCY (HZ) 408.03046 (RPM) 24481.83
DAMPING (%) .00000
GENERALIZED MASS 1.37222E+03
GENERALIZED STIFFNESS 9.01925E+09
EFFECTIVE MASS 5.88674E-29
PARTICIPATION FACTOR 2.07121E-16

MODE SHAPE

(1, 4)= 4.0369E-03 (2, 4)=-5.0814E-01 (3, 4)=-2.2723E-01 (4, 4)= 8.6153E-01
(5, 4)= 1.0000E+00 (6, 4)=-4.0155E-02 (7, 4)=-4.0581E-01 (

MODE NO 5
FREQUENCY (HZ) 505.38305 (RPM) 30322.98
DAMPING (%) .00000
GENERALIZED MASS 1.40039E+03
GENERALIZED STIFFNESS 1.00872E+10
EFFECTIVE MASS 3.22992E-30
PARTICIPATION FACTOR 5.68214E-17

MODE SHAPE

(1, 5)= 2.3165E-03 (2, 5)=-4.4857E-01 (3, 5)=-8.2604E-03 (4, 5)= 6.2606E-01
(5, 5)=-7.1092E-02 (6, 5)=-4.1959E-01 (7, 5)= 1.0000E+00 (

MODE NO 6
FREQUENCY (HZ) 579.51076 (RPM) 34230.65
DAMPING (%) .00000
GENERALIZED MASS 9.19369E-02
GENERALIZED STIFFNESS 1.18004E+10
EFFECTIVE MASS 8.19262E-28
PARTICIPATION FACTOR 9.43934E-15

MODE SHAPE

(1, 6)=-4.0480E-03 (2, 6)= 1.0000E+00 (3, 6)=-3.1918E-01 (4, 6)=-1.5327E-01
(5, 6)= 5.9895E-01 (6, 6)=-1.4083E-01 (7, 6)= 2.9768E-01 (

MODE NO	7		
FREQUENCY (HZ)	621.13594	(RPM)	37268.16
DAMPING (%)	.00000		
GENERALIZED MASS	1.36942E+03		
GENERALIZED STIFFNESS	2.085796+10		
EFFECTIVE MASS	1.07505E-28		
PARTICIPATION FACTOR	2.80188E-16		

MODE SHAPE

(1, 7)=-2.0981E-03 (2, 7)= 6.1479E-01 (3, 7)=-3.7486E-01 (4, 7)= 1.0000E+00
(5, 7)=-9.1075E-01 (6, 7)= 2.2535E-01 (7, 7)=-1.9693E-01 (

STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1	TO 2	TORQUE	0.0000E+00	STRESS	3.7201E-01	PER UNIT	9.0000E+00
SHAFT	2	2	TO 3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	9.0000E+00
SHAFT	3	3	TO 4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	9.0000E+00
SHAFT	4	4	TO 5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	9.0000E+00
SHAFT	5	5	TO 6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	9.0000E+00
SHAFT	6	6	TO 7	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	9.0000E+00

FOR MODE 2 FREQUENCY 63.9750

SHAFT	1	1	TO 2	TORQUE	5.0626E+06	STRESS	1.9103E-01	PER UNIT	1.9365E-01
SHAFT	2	2	TO 3	TORQUE	4.7690E+06	STRESS	1.6516E+03	PER UNIT	1.8314E-01
SHAFT	3	3	TO 4	TORQUE	3.7091E+06	STRESS	6.0438E+02	PER UNIT	1.4264E-01
SHAFT	4	4	TO 5	TORQUE	3.2119E+06	STRESS	1.3666E+03	PER UNIT	1.2335E-01
SHAFT	5	5	TO 6	TORQUE	2.5808E+06	STRESS	4.2052E+02	PER UNIT	9.9197E-02
SHAFT	6	6	TO 7	TORQUE	4.7598E+05	STRESS	2.3410E+02	PER UNIT	2.5959E-02

FOR MODE 3 FREQUENCY 169.5874

SHAFT	1	1	TO 2	TORQUE	2.6367E+06	STRESS	4.2685E-02	PER UNIT	1.0126E-01
SHAFT	2	2	TO 3	TORQUE	1.2344E+06	STRESS	4.2403E+02	PER UNIT	4.7020E-02
SHAFT	3	3	TO 4	TORQUE	3.3366E+06	STRESS	5.4368E+02	PER UNIT	1.2813E-01
SHAFT	4	4	TO 5	TORQUE	4.3579E+06	STRESS	1.8542E+03	PER UNIT	1.6735E-01
SHAFT	5	5	TO 6	TORQUE	4.1022E+06	STRESS	6.6862E+02	PER UNIT	1.5753E-01
SHAFT	6	6	TO 7	TORQUE	1.1986E+06	STRESS	4.1509E+02	PER UNIT	4.6029E-02

FOR MODE 4 FREQUENCY 488.0305

SHAFT	1	1	TO 2	TORQUE	1.1448E+05	STRESS	4.0363E-03	PER UNIT	4.3961E-03
SHAFT	2	2	TO 3	TORQUE	2.5452E+05	STRESS	8.8144E+01	PER UNIT	9.7742E-03
SHAFT	3	3	TO 4	TORQUE	7.3029E+05	STRESS	1.1900E+02	PER UNIT	2.8045E-02
SHAFT	4	4	TO 5	TORQUE	6.3202E+04	STRESS	2.6892E+01	PER UNIT	2.4271E-03
SHAFT	5	5	TO 6	TORQUE	7.1111E+05	STRESS	1.1587E+02	PER UNIT	2.7308E-02
SHAFT	6	6	TO 7	TORQUE	5.8515E+05	STRESS	2.0265E+02	PER UNIT	2.2471E-02

FOR MODE 5 FREQUENCY 505.3831

SHAFT	1	1	TO 2	TORQUE	1.2757E+03	STRESS	2.3165E-03	PER UNIT	1.2579E-04
SHAFT	2	2	TO 3	TORQUE	1.3967E+04	STRESS	4.4907E+00	PER UNIT	4.9797E-04
SHAFT	3	3	TO 4	TORQUE	1.3830E+04	STRESS	2.2535E+00	PER UNIT	5.3108E-04
SHAFT	4	4	TO 5	TORQUE	1.0343E+04	STRESS	4.4008E+00	PER UNIT	3.9719E-04
SHAFT	5	5	TO 6	TORQUE	7.3980E+03	STRESS	1.2380E+00	PER UNIT	2.9178E-04
SHAFT	6	6	TO 7	TORQUE	3.6210E+04	STRESS	1.2540E+01	PER UNIT	1.3906E-03

FOR MODE 6 FREQUENCY 570.5108

SHAFT	1	1	TO 2	TORQUE	2.4693E+05	STRESS	4.8489E-03	PER UNIT	9.2524E-03
SHAFT	2	2	TO 3	TORQUE	1.2832E+06	STRESS	8.4440E+02	PER UNIT	4.9275E-02
SHAFT	3	3	TO 4	TORQUE	1.1948E+05	STRESS	1.9469E+01	PER UNIT	4.5883E-03
SHAFT	4	4	TO 5	TORQUE	3.6856E+05	STRESS	1.5682E+02	PER UNIT	1.4154E-02
SHAFT	5	5	TO 6	TORQUE	6.0469E+05	STRESS	9.8530E+01	PER UNIT	2.3221E-02
SHAFT	6	6	TO 7	TORQUE	4.5370E+05	STRESS	1.5712E+02	PER UNIT	1.7423E-02

FOR MODE 7 FREQUENCY 621.1359

SHAFT	1	1	TO 2	TORQUE	9.8355E+04	STRESS	2.0981E-03	PER UNIT	3.7771E-03
SHAFT	2	2	TO 3	TORQUE	6.3363E+05	STRESS	2.2153E+02	PER UNIT	2.4566E-02
SHAFT	3	3	TO 4	TORQUE	6.5788E+05	STRESS	1.0719E+02	PER UNIT	2.5263E-02
SHAFT	4	4	TO 5	TORQUE	6.2214E+05	STRESS	2.6471E+02	PER UNIT	2.3892E-02
SHAFT	5	5	TO 6	TORQUE	5.4361E+05	STRESS	8.8579E+01	PER UNIT	2.0876E-02
SHAFT	6	6	TO 7	TORQUE	2.3640E+05	STRESS	8.1848E+01	PER UNIT	9.0782E-03

Arnold Air-Force Tullahoma PWT ss2

NO OF INERTIAS 7
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 6
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF 2SF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26540000.00
RATED SPEED 690.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 9368360.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	18319.8	.000000E+00	.00000E+00	.000
2	469.1	.000000E+00	.00000E+00	.000
3	1352.6	.000000E+00	.00000E+00	.000
4	500.2	.000000E+00	.00000E+00	.000
5	500.2	.000000E+00	.00000E+00	.000
6	1352.6	.000000E+00	.00000E+00	.359
7	469.1	.000000E+00	.00000E+00	.000
TOTAL	22963.6			.359

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.949000E+09	.00000E+00	.0000	1.0000
2 - 3	.384700E+10	.00000E+00	24.5000	1.0000
3 - 4	.284800E+10	.00000E+00	31.5000	1.0000
4 - 5	.193800E+10	.00000E+00	22.8750	1.0000
5 - 6	.284800E+10	.00000E+00	31.5000	1.0000
6 - 7	.333200E+10	.00000E+00	24.5000	1.0000

STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1	TO	2	TORQUE	0.0000E+00	STRESS	3.7281E-01	PER UNIT	0.0000E+00
SHAFT	2	2	TO	3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3	TO	4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4	TO	5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5	TO	6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	4	TO	7	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 63.3750

SHAFT	1	1	TO	2	TORQUE	9.0623E+06	STRESS	1.9103E+01	PER UNIT	3.4802E-01
SHAFT	2	2	TO	3	TORQUE	8.5706E+06	STRESS	2.9681E+03	PER UNIT	3.2913E-01
SHAFT	3	3	TO	4	TORQUE	6.6658E+06	STRESS	1.0862E+03	PER UNIT	2.5599E-01
SHAFT	4	4	TO	5	TORQUE	5.7713E+06	STRESS	2.4560E+03	PER UNIT	2.2147E-01
SHAFT	5	5	TO	6	TORQUE	4.6180E+06	STRESS	7.5573E+02	PER UNIT	1.7811E-01
SHAFT	6	6	TO	7	TORQUE	1.2148E+06	STRESS	4.2071E+02	PER UNIT	4.6852E-02

FOR MODE 3 FREQUENCY 169.5674

SHAFT	1	1	TO	2	TORQUE	1.6786E+06	STRESS	4.2685E-02	PER UNIT	6.4661E-02
SHAFT	2	2	TO	3	TORQUE	7.7947E+05	STRESS	2.6984E+02	PER UNIT	2.9934E-02
SHAFT	3	3	TO	4	TORQUE	2.1241E+06	STRESS	3.4611E+02	PER UNIT	8.1571E-02
SHAFT	4	4	TO	5	TORQUE	2.7743E+06	STRESS	1.1804E+03	PER UNIT	1.0654E-01
SHAFT	5	5	TO	6	TORQUE	2.6115E+06	STRESS	4.2553E+02	PER UNIT	1.0029E-01
SHAFT	6	4	TO	7	TORQUE	7.6304E+05	STRESS	2.6425E+02	PER UNIT	1.9903E-02

FOR MODE 4 FREQUENCY 408.0305

SHAFT	1	1	TO	2	TORQUE	3.0306E+04	STRESS	4.0389E-03	PER UNIT	1.1618E-03
SHAFT	2	2	TO	3	TORQUE	6.7380E+04	STRESS	2.3335E+01	PER UNIT	2.5876E-03
SHAFT	3	3	TO	4	TORQUE	1.8333E+05	STRESS	2.1503E+01	PER UNIT	7.4245E-03
SHAFT	4	4	TO	5	TORQUE	1.6732E+04	STRESS	7.1191E+00	PER UNIT	6.6254E-04
SHAFT	5	5	TO	6	TORQUE	1.8825E+05	STRESS	2.0675E+01	PER UNIT	7.2294E-03
SHAFT	6	6	TO	7	TORQUE	1.5451E+05	STRESS	5.3648E+01	PER UNIT	5.9489E-03

FOR MODE 5 FREQUENCY 505.3931

SHAFT	1	1	TO	2	TORQUE	1.6639E+05	STRESS	2.3165E-03	PER UNIT	6.3897E-03
SHAFT	2	2	TO	3	TORQUE	6.5867E+05	STRESS	2.2811E+02	PER UNIT	2.5294E-02
SHAFT	3	3	TO	4	TORQUE	7.0248E+05	STRESS	1.1446E+02	PER UNIT	2.8977E-02
SHAFT	4	4	TO	5	TORQUE	5.2537E+05	STRESS	2.2356E+02	PER UNIT	2.0175E-02
SHAFT	5	5	TO	6	TORQUE	3.8594E+05	STRESS	6.2887E+01	PER UNIT	1.4821E-02
SHAFT	6	6	TO	7	TORQUE	1.8393E+06	STRESS	4.3698E+02	PER UNIT	7.0634E-02

FOR MODE 6 FREQUENCY 570.5108

SHAFT	1	1	TO	2	TORQUE	1.8179E+05	STRESS	4.0400E-03	PER UNIT	6.8613E-03
SHAFT	2	2	TO	3	TORQUE	9.6824E+05	STRESS	3.3532E+02	PER UNIT	3.7183E-02
SHAFT	3	3	TO	4	TORQUE	9.0152E+04	STRESS	1.4690E+01	PER UNIT	3.4631E-03
SHAFT	4	4	TO	5	TORQUE	2.7810E+05	STRESS	1.1833E+02	PER UNIT	1.0680E-02
SHAFT	5	5	TO	6	TORQUE	4.5626E+05	STRESS	7.4345E+01	PER UNIT	1.7522E-02
SHAFT	6	6	TO	7	TORQUE	3.4234E+05	STRESS	1.1854E+02	PER UNIT	1.3147E-02

FOR MODE 7 FREQUENCY 621.1359

SHAFT	1	1	TO	2	TORQUE	5.9128E+04	STRESS	2.0901E-03	PER UNIT	2.2707E-03
SHAFT	2	2	TO	3	TORQUE	3.8453E+05	STRESS	1.3317E+02	PER UNIT	1.4767E-02
SHAFT	3	3	TO	4	TORQUE	3.9548E+03	STRESS	4.4641E+01	PER UNIT	1.5187E-03
SHAFT	4	4	TO	5	TORQUE	3.7401E+05	STRESS	1.5914E+02	PER UNIT	1.4361E-02
SHAFT	5	5	TO	6	TORQUE	3.2680E+05	STRESS	5.3251E+01	PER UNIT	1.2550E-02
SHAFT	6	6	TO	7	TORQUE	1.4211E+05	STRESS	4.9216E+01	PER UNIT	5.4575E-03

1

Arnold Air-Force Tullahoma PWT ss3

NO OF INERTIAS 7
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 6
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF ISF CASES 0
STATUS OF TAPE 2
RATED TORQUE 36040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 3674244.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	16318.9	.000000E+00	.00000E+00	.000
2	469.1	.000000E+00	.00000E+00	.000
3	1352.6	.000000E+00	.00000E+00	.000
4	500.2	.000000E+00	.00000E+00	.141
5	500.2	.000000E+00	.00000E+00	.000
6	1352.6	.000000E+00	.00000E+00	.000
7	469.1	.000000E+00	.00000E+00	.000
TOTAL	22962.4			.141

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.949000E+09	.00000E+00	.0000	1.0000
2 - 3	.184700E+10	.00000E+00	24.5000	1.0000
3 - 4	.284800E+10	.00000E+00	31.5000	1.0000
4 - 5	.193800E+10	.00000E+00	22.8750	1.0000
5 - 6	.284800E+10	.00000E+00	31.5000	1.0000
6 - 7	.333200E+10	.00000E+00	24.5000	1.0000

1

STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1	TO	2	TORQUE	0.0000E+00	STRESS	1.7201E-01	PER UNIT	0.0000E+00
SHAFT	2	2	TO	3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3	TO	4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4	TO	5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5	TO	6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	6	TO	7	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 63.9750

SHAFT	1	1	TO	2	TORQUE	2.5142E+06	STRESS	1.9103E-01	PER UNIT	9.6551E-02
SHAFT	2	2	TO	3	TORQUE	2.3778E+06	STRESS	8.2546E+02	PER UNIT	9.1312E-02
SHAFT	3	3	TO	4	TORQUE	1.8693E+06	STRESS	3.0134E+02	PER UNIT	7.1018E-02
SHAFT	4	4	TO	5	TORQUE	1.6016E+06	STRESS	6.8138E+02	PER UNIT	6.1498E-02
SHAFT	5	5	TO	6	TORQUE	1.2867E+06	STRESS	2.0966E+02	PER UNIT	4.9413E-02
SHAFT	6	6	TO	7	TORQUE	3.3703E+05	STRESS	1.1672E+02	PER UNIT	1.2943E-02

FOR MODE 3 FREQUENCY 169.5874

SHAFT	1	1	TO	2	TORQUE	6.2752E+05	STRESS	4.2685E-02	PER UNIT	2.4098E-02
SHAFT	2	2	TO	3	TORQUE	2.5140E+05	STRESS	1.0892E+02	PER UNIT	1.1191E-02
SHAFT	3	3	TO	4	TORQUE	7.9400E+05	STRESS	1.2939E+02	PER UNIT	3.0495E-02
SHAFT	4	4	TO	5	TORQUE	1.0372E+06	STRESS	4.4138E+02	PER UNIT	3.9829E-02
SHAFT	5	5	TO	6	TORQUE	9.7629E+05	STRESS	1.5908E+02	PER UNIT	3.7482E-02
SHAFT	6	6	TO	7	TORQUE	2.8526E+05	STRESS	9.8769E+01	PER UNIT	1.0955E-02

FOR MODE 4 FREQUENCY 408.0305

SHAFT	1	1	TO	2	TORQUE	1.7059E+05	STRESS	4.0369E-02	PER UNIT	6.5811E-03
SHAFT	2	2	TO	3	TORQUE	3.7928E+05	STRESS	1.3135E+02	PER UNIT	1.4565E-02
SHAFT	3	3	TO	4	TORQUE	1.0883E+06	STRESS	1.7733E+02	PER UNIT	4.1793E-02
SHAFT	4	4	TO	5	TORQUE	9.4183E+04	STRESS	4.0874E+01	PER UNIT	3.6169E-03
SHAFT	5	5	TO	6	TORQUE	1.0597E+06	STRESS	1.7267E+02	PER UNIT	4.0895E-02
SHAFT	6	6	TO	7	TORQUE	9.7199E+05	STRESS	3.0198E+02	PER UNIT	3.3487E-02

FOR MODE 5 FREQUENCY 595.3831

SHAFT	1	1	TO	2	TORQUE	9.7577E+04	STRESS	2.3165E-03	PER UNIT	3.7472E-03
SHAFT	2	2	TO	3	TORQUE	3.8627E+05	STRESS	1.3377E+02	PER UNIT	1.4834E-02
SHAFT	3	3	TO	4	TORQUE	6.1196E+05	STRESS	6.7127E+01	PER UNIT	1.5820E-02
SHAFT	4	4	TO	5	TORQUE	3.0810E+05	STRESS	1.3109E+02	PER UNIT	1.1852E-02
SHAFT	5	5	TO	6	TORQUE	2.2637E+05	STRESS	3.6879E+01	PER UNIT	8.6917E-03
SHAFT	6	6	TO	7	TORQUE	1.0786E+06	STRESS	3.7355E+02	PER UNIT	4.1623E-02

FOR MODE 6 FREQUENCY 570.5108

SHAFT	1	1	TO	2	TORQUE	4.5471E+04	STRESS	4.0490E-03	PER UNIT	1.7462E-03
SHAFT	2	2	TO	3	TORQUE	2.4218E+05	STRESS	8.3871E+01	PER UNIT	9.3004E-03
SHAFT	3	3	TO	4	TORQUE	2.2549E+04	STRESS	1.6743E+00	PER UNIT	8.6895E-04
SHAFT	4	4	TO	5	TORQUE	6.9560E+04	STRESS	2.9597E+01	PER UNIT	2.6711E-03
SHAFT	5	5	TO	6	TORQUE	1.1412E+05	STRESS	1.8596E+01	PER UNIT	4.3826E-03
SHAFT	6	6	TO	7	TORQUE	8.5638E+04	STRESS	2.9454E+01	PER UNIT	3.3083E-03

FOR MODE 7 FREQUENCY 421.1359

SHAFT	1	1	TO	2	TORQUE	1.0312E+05	STRESS	2.0981E-03	PER UNIT	3.9602E-03
SHAFT	2	2	TO	3	TORQUE	6.7865E+05	STRESS	2.3228E+02	PER UNIT	2.5755E-02
SHAFT	3	3	TO	4	TORQUE	6.8974E+05	STRESS	1.1439E+02	PER UNIT	2.6487E-02
SHAFT	4	4	TO	5	TORQUE	6.5231E+05	STRESS	3.7758E+02	PER UNIT	2.5050E-02
SHAFT	5	5	TO	6	TORQUE	5.6997E+05	STRESS	9.2874E+01	PER UNIT	2.1889E-02
SHAFT	6	6	TO	7	TORQUE	2.4786E+05	STRESS	8.5837E+01	PER UNIT	9.5184E-03

Table 2.1

GEOMETRIC AND MATERIAL PROPERTIES
Arnold Air-Force Tullahoma PWT

Br#	Sect#	Geometry for Inertia Length (in)	OD (in)	ID (in)	Shaft (Lb in^2)	External (Lb in^2)	Geometry for Stiffness Length (in)	OD (in)	ID (in)	Stiffness (Lb in/rad)		DOF	N1	N2
1	1	16.000	20.000	.000	.0	7871000.0	10.000	20.000	.000	1.806E+16	Transonic	1	1	0
1	2	16.000	5.000	.000	173.6	.0	.000	.000	.000	9.490E+09	Transonic	0	1	2
1	3	5.000	10.000	.000	.0	181000.0	5.000	10.000	.000	2.258E+15	Brake	2	2	0
1	4	16.000	5.000	.000	173.6	.0	.000	.000	.000	3.847E+09	Brake	0	2	3
1	5	8.000	16.000	.000	.0	522000.0	9.000	16.000	.000	9.249E+15	Sym Mtr	3	3	0
1	6	16.000	5.000	.000	173.6	.0	.000	.000	.000	2.848E+09	Sym Mtr	0	3	4
1	7	8.000	14.000	.000	.0	193000.0	8.000	14.000	.000	5.422E+15	Ind Mtr	4	4	0
1	8	16.000	5.000	.000	173.6	.0	.000	.000	.000	1.938E+09	Ind Mtr	0	4	5
1	9	8.000	14.000	.000	.0	193000.0	8.000	14.000	.000	5.422E+15	Ind Mtr	5	5	0
1	10	16.000	5.000	.000	173.6	.0	.000	.000	.000	2.848E+09	Ind Mtr	0	5	6
1	11	8.000	16.000	.000	.0	522000.0	8.000	16.000	.000	9.249E+15	Sym Mtr	6	6	0
1	12	16.000	5.000	.000	173.6	.0	.000	.000	.000	3.332E+09	Sym Mtr	0	6	7
1	13	5.000	10.000	.000	.0	181000.0	5.000	10.000	.000	2.258E+15	Brake	7	7	0

BRANCH INERTIA 8864041.9 22963.839 LB IN SEC^2 BRANCH WEIGHT 333.4 LB

TOTAL INERTIA 8864041.9 22963.839 LB IN SEC^2 TOTAL WEIGHT 333.4 LB

MATERIAL PROPERTY TABLE NO 1
DENSITY 2.8300E-01
SHEAR MODULUS 1.1500E+07

MATERIAL PROPERTY TABLE NO 2
DENSITY 1.0000E-09
SHEAR MODULUS 1.1500E+13

DEGREES OF FREEDOM

DOF #	INERTIA		
1	7.071087E+06	1.831888E+04	LB IN SEC^2
2	1.811736E+05	4.693618E+02	LB IN SEC^2
3	5.221736E+05	1.352781E+03	LB IN SEC^2
4	1.931736E+05	5.004499E+02	LB IN SEC^2
5	1.931736E+05	5.004499E+02	LB IN SEC^2
6	5.221736E+05	1.352781E+03	LB IN SEC^2
7	1.810868E+05	4.691368E+02	LB IN SEC^2

FROM	TO	STIFFNESS
1	2	9.489998E+08
2	3	3.846996E+09
3	4	3.847999E+09
4	5	1.937999E+09
5	6	3.847999E+09
6	7	3.331997E+09

MAX Y COORDINATES FOR EACH BRANCH

BRANCH NO 1 MAX VALUE 20.00000 Y CENTER COORD 25.00000

SHAFT	5	5	TO	6	TORQUE	2.5481E+05	STRESS	8.8246E-01	PER UNIT	9.7855E-03
SHAFT	6	6	TO	7	TORQUE	1.7533E+05	STRESS	5.5078E-01	PER UNIT	6.7330E-03
SHAFT	7	7	TO	8	TORQUE	1.3738E+03	STRESS	4.5370E-03	PER UNIT	5.2758E-05
SHAFT	8	8	TO	9	TORQUE	1.7754E+01	STRESS	5.4044E-05	PER UNIT	6.8181E-07
SHAFT	9	9	TO	10	TORQUE	2.3590E-01	STRESS	7.3825E-07	PER UNIT	9.0590E-09

FOR MODE 8 FREQUENCY 525.8449

SHAFT	1	1	TO	2	TORQUE	4.4833E+05	STRESS	1.5526E+02	PER UNIT	1.7217E-02
SHAFT	2	2	TO	3	TORQUE	2.0283E+04	STRESS	3.3050E+00	PER UNIT	7.7891E-04
SHAFT	3	3	TO	4	TORQUE	1.7690E+05	STRESS	7.5268E+01	PER UNIT	6.7934E-03
SHAFT	4	4	TO	5	TORQUE	1.2433E+05	STRESS	3.0359E+01	PER UNIT	4.7747E-03
SHAFT	5	5	TO	6	TORQUE	2.9430E+05	STRESS	1.0192E+03	PER UNIT	1.1302E-02
SHAFT	6	6	TO	7	TORQUE	9.9052E+04	STRESS	8.7737E-01	PER UNIT	3.8039E-03
SHAFT	7	7	TO	8	TORQUE	4.7739E+02	STRESS	4.4516E-03	PER UNIT	1.8333E-05
SHAFT	8	8	TO	9	TORQUE	3.7848E+00	STRESS	3.2552E-05	PER UNIT	1.4534E-07
SHAFT	9	9	TO	10	TORQUE	3.0865E-02	STRESS	2.7275E-07	PER UNIT	1.1853E-09

FOR MODE 9 FREQUENCY 563.0233

SHAFT	1	1	TO	2	TORQUE	9.7395E+05	STRESS	3.3730E+02	PER UNIT	3.7402E-02
SHAFT	2	2	TO	3	TORQUE	5.0322E+05	STRESS	8.1997E+01	PER UNIT	1.9325E-02
SHAFT	3	3	TO	4	TORQUE	5.6560E+04	STRESS	2.4066E+01	PER UNIT	2.1720E-03
SHAFT	4	4	TO	5	TORQUE	4.3365E+05	STRESS	7.0661E+01	PER UNIT	1.6653E-02
SHAFT	5	5	TO	6	TORQUE	1.1241E+06	STRESS	3.8928E+02	PER UNIT	4.3166E-02
SHAFT	6	6	TO	7	TORQUE	3.1615E+05	STRESS	1.0000E+00	PER UNIT	1.2141E-02
SHAFT	7	7	TO	8	TORQUE	1.3270E+03	STRESS	4.4202E-03	PER UNIT	5.0961E-05
SHAFT	8	8	TO	9	TORQUE	9.1580E+00	STRESS	2.8139E-05	PER UNIT	3.5169E-07
SHAFT	9	9	TO	10	TORQUE	6.5017E-02	STRESS	2.0523E-07	PER UNIT	2.4968E-09

FOR MODE 10 FREQUENCY 619.3617

SHAFT	1	1	TO	2	TORQUE	3.3593E+05	STRESS	1.1634E+02	PER UNIT	1.2901E+02
SHAFT	2	2	TO	3	TORQUE	4.8418E+05	STRESS	7.8894E+01	PER UNIT	1.8594E-02
SHAFT	3	3	TO	4	TORQUE	5.0037E+05	STRESS	2.1290E+02	PER UNIT	1.9215E-02
SHAFT	4	4	TO	5	TORQUE	4.7090E+05	STRESS	7.6731E+01	PER UNIT	1.8094E-02
SHAFT	5	5	TO	6	TORQUE	2.8961E+05	STRESS	1.0030E+02	PER UNIT	1.1122E-02
SHAFT	6	6	TO	7	TORQUE	6.4116E+04	STRESS	3.8310E-01	PER UNIT	2.4622E-03
SHAFT	7	7	TO	8	TORQUE	2.2198E+02	STRESS	1.3972E-03	PER UNIT	8.5247E-06
SHAFT	8	8	TO	9	TORQUE	1.2628E+00	STRESS	7.3332E-06	PER UNIT	4.8494E-08
SHAFT	9	9	TO	10	TORQUE	7.3908E-03	STRESS	4.4086E-08	PER UNIT	2.8383E-10

Arnold Air-Force Tullahoma PWT 484

NO OF INERTIAS 7
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 6
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF INF CASES 0
STATUS OF TAPE 3
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 3674244.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	18311.8	.000000E+00	.00000E+00	.000
2	469.1	.000000E+00	.00000E+00	.000
3	1352.6	.000000E+00	.00000E+00	.000
4	506.2	.000000E+00	.00000E+00	.000
5	506.2	.000000E+00	.00000E+00	.141
6	1351.6	.000000E+00	.00000E+00	.000
7	469.1	.000000E+00	.00000E+00	.000
TOTAL	22962.6			.141

SHAFT ELEMENTS

LT NT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.549000E+09	.00000E+00	.0000	1.0000
2 - 3	.384700E+10	.00000E+00	24.5000	1.0000
3 - 4	.284800E+10	.00000E+00	31.5000	1.0000
4 - 5	.193800E+10	.00000E+00	22.8750	1.0000
5 - 6	.284800E+10	.00000E+00	31.5000	1.0000
6 - 7	.333200E+10	.00000E+00	24.5000	1.0000

STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1 TO 2	TORQUE	0.0000E+00	STRESS	3.7201E-01	PER UNIT	0.0000E+00
SHAFT	2	2 TO 3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3 TO 4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4 TO 5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5 TO 6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	6 TO 7	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 63.9750

SHAFT	1	1 TO 2	TORQUE	3.1915E+06	STRESS	1.9103E-01	PER UNIT	1.2256E-01
SHAFT	2	2 TO 3	TORQUE	3.0183E+06	STRESS	1.0453E+03	PER UNIT	1.1591E-01
SHAFT	3	3 TO 4	TORQUE	2.3475E+06	STRESS	3.8252E+02	PER UNIT	9.0150E-02
SHAFT	4	4 TO 5	TORQUE	2.0328E+06	STRESS	8.6494E+02	PER UNIT	7.8064E-02
SHAFT	5	5 TO 6	TORQUE	1.6334E+06	STRESS	2.6618E+02	PER UNIT	6.2725E-02
SHAFT	6	6 TO 7	TORQUE	4.2783E+05	STRESS	1.4816E+02	PER UNIT	1.6430E-02

FOR MODE 3 FREQUENCY 169.5874

SHAFT	1	1 TO 2	TORQUE	1.5713E+05	STRESS	4.2685E-02	PER UNIT	6.0342E-03
SHAFT	2	2 TO 3	TORQUE	7.2967E+04	STRESS	2.5270E+01	PER UNIT	2.8021E-03
SHAFT	3	3 TO 4	TORQUE	1.9884E+05	STRESS	3.2400E+01	PER UNIT	7.6359E-03
SHAFT	4	4 TO 5	TORQUE	2.5970E+05	STRESS	1.1050E+02	PER UNIT	9.9733E-03
SHAFT	5	5 TO 6	TORQUE	2.4466E+05	STRESS	3.9834E+01	PER UNIT	9.3880E-03
SHAFT	6	6 TO 7	TORQUE	7.1628E+04	STRESS	2.4737E+01	PER UNIT	2.7430E-03

FOR MODE 4 FREQUENCY 408.0305

SHAFT	1	1 TO 2	TORQUE	1.9801E+05	STRESS	4.0369E-03	PER UNIT	7.6040E-03
SHAFT	2	2 TO 3	TORQUE	4.4024E+05	STRESS	1.5266E+02	PER UNIT	1.6906E-02
SHAFT	3	3 TO 4	TORQUE	1.2832E+06	STRESS	2.0583E+02	PER UNIT	4.8510E-02
SHAFT	4	4 TO 5	TORQUE	1.9932E+05	STRESS	4.6515E+01	PER UNIT	4.1982E-03
SHAFT	5	5 TO 6	TORQUE	1.2300E+06	STRESS	2.0842E+02	PER UNIT	4.7235E-02
SHAFT	6	6 TO 7	TORQUE	1.0121E+06	STRESS	3.5052E+02	PER UNIT	3.8849E-02

FOR MODE 5 FREQUENCY 505.1831

SHAFT	1	1 TO 2	TORQUE	1.1080E+04	STRESS	2.3165E-03	PER UNIT	4.2551E-04
SHAFT	2	2 TO 3	TORQUE	4.3863E+04	STRESS	1.5191E+01	PER UNIT	1.6845E-03
SHAFT	3	3 TO 4	TORQUE	4.6781E+04	STRESS	7.6226E+00	PER UNIT	1.7955E-03
SHAFT	4	4 TO 5	TORQUE	3.4986E+04	STRESS	1.4886E+01	PER UNIT	1.3436E-03
SHAFT	5	5 TO 6	TORQUE	2.5701E+04	STRESS	4.1879E+00	PER UNIT	9.8699E-04
SHAFT	6	6 TO 7	TORQUE	1.2249E+05	STRESS	4.2419E+01	PER UNIT	4.7038E-03

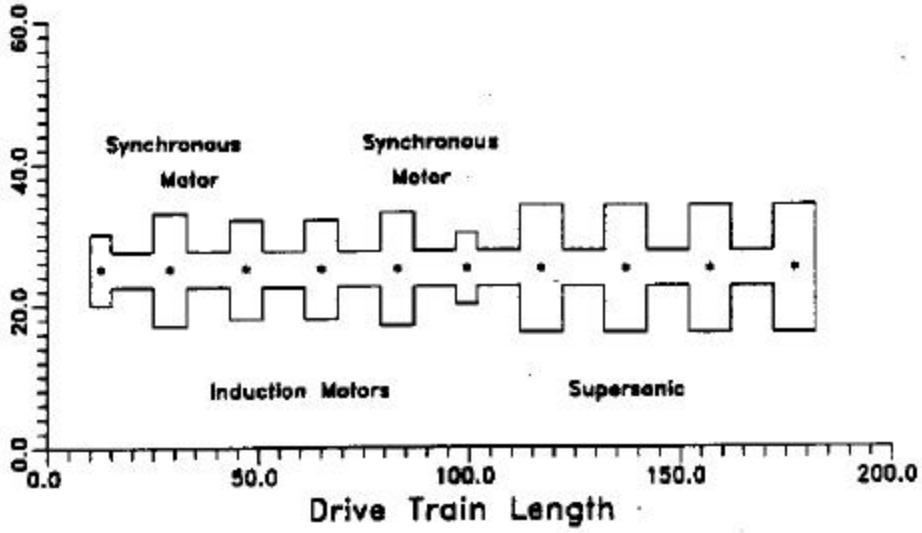
FOR MODE 6 FREQUENCY 570.5108

SHAFT	1	1 TO 2	TORQUE	1.7767E+05	STRESS	4.0480E-03	PER UNIT	6.8230E-03
SHAFT	2	2 TO 3	TORQUE	9.4628E+05	STRESS	3.2771E+02	PER UNIT	3.6339E-02
SHAFT	3	3 TO 4	TORQUE	8.8107E+04	STRESS	1.4357E+01	PER UNIT	3.3835E-03
SHAFT	4	4 TO 5	TORQUE	2.7179E+05	STRESS	1.1564E+02	PER UNIT	1.0437E-02
SHAFT	5	5 TO 6	TORQUE	4.4591E+05	STRESS	7.2659E+01	PER UNIT	1.7124E-02
SHAFT	6	6 TO 7	TORQUE	3.3457E+05	STRESS	1.1587E+02	PER UNIT	1.2848E-02

FOR MODE 7 FREQUENCY 621.1359

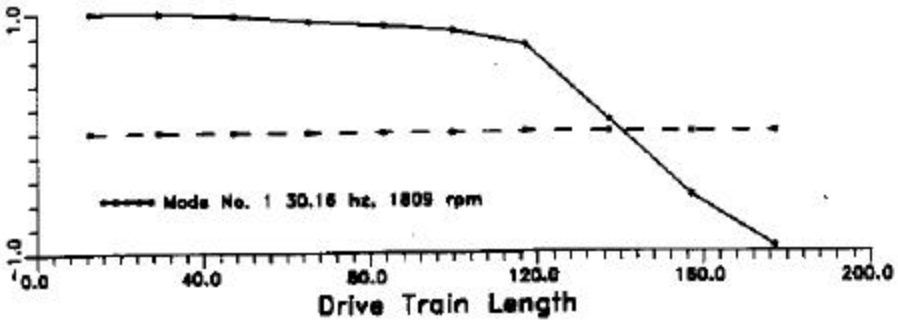
SHAFT	1	1 TO 2	TORQUE	9.3920E+04	STRESS	2.0981E-03	PER UNIT	3.6068E-03
SHAFT	2	2 TO 3	TORQUE	4.1079E+05	STRESS	2.1153E+02	PER UNIT	2.3456E-02
SHAFT	3	3 TO 4	TORQUE	4.2819E+05	STRESS	1.9336E+02	PER UNIT	2.4124E-02
SHAFT	4	4 TO 5	TORQUE	5.9469E+05	STRESS	2.5273E+02	PER UNIT	3.2818E-02
SHAFT	5	5 TO 6	TORQUE	5.1910E+05	STRESS	8.4584E+01	PER UNIT	1.9935E-02
SHAFT	6	6 TO 7	TORQUE	2.2574E+05	STRESS	7.8174E+01	PER UNIT	8.6689E-03

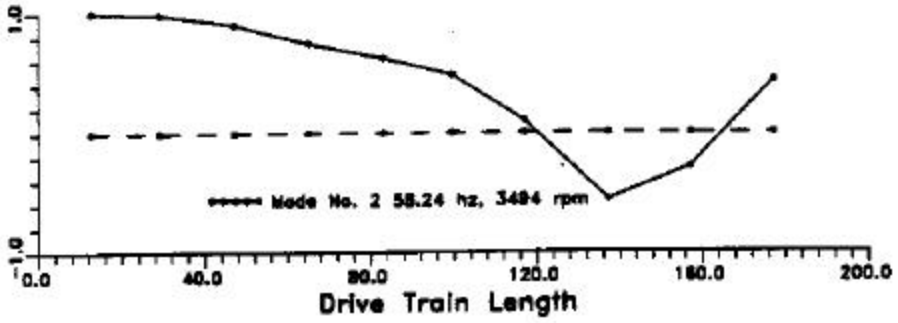
APPENDIX III



Arnold Air-Force Base Tullahoma PWT
[Supersonic Operation]

Torsional Study





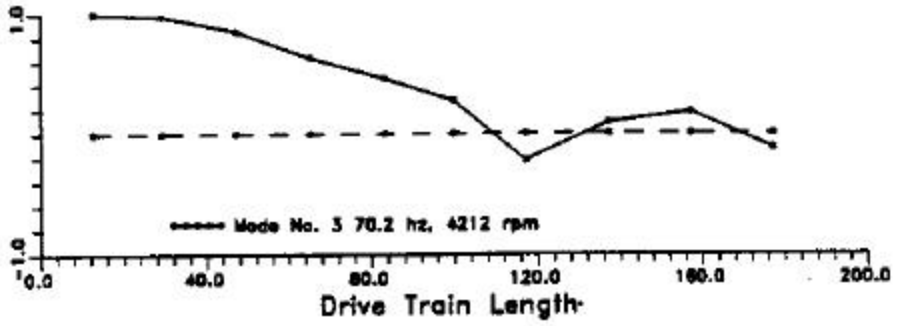


Figure Arnold Air-force Base Tullahoma PWT
[Supersonic Operation First 3 Modes]

Table I.1

GEOMETRIC AND MATERIAL PROPERTIES
Arnold Air-Force Tullahoma PWT

Brn	Sect#	Geometry for Inertia Length (in)	OD (in)	ID (in)	Shaft (Lb in^2)	External (Lb in^2)	Geometry for Stiffness Length (in)	OD (in)	ID (in)	Stiffness (Lb in/rad)		DOF	N1	N2
1	1	5.000	10.000	.000	.0	181000.0	5.000	10.000	.000	2.25E+15	Brake	2	1	0
1	2	10.000	5.000	.000	173.6	.0	.000	.000	.000	3.947E+09	Brake	0	1	2
1	3	8.000	16.000	.000	.0	522000.0	8.000	16.000	.000	9.249E+15	Syn Mtr	3	2	0
1	4	10.000	5.000	.000	173.6	.0	.000	.000	.000	2.84E+09	Syn Mtr	0	2	3
1	5	8.000	14.000	.000	.0	193000.0	8.000	14.000	.000	5.422E+15	Ind Mtr	4	3	0
1	6	10.000	5.000	.000	173.6	.0	.000	.000	.000	1.938E+09	Ind Mtr	0	3	4
1	7	8.000	14.000	.000	.0	193000.0	8.000	14.000	.000	5.422E+15	Ind Mtr	5	4	0
1	8	10.000	5.000	.000	173.6	.0	.000	.000	.000	2.84E+09	Ind Mtr	0	4	5
1	9	8.000	16.000	.000	.0	522000.0	8.000	16.000	.000	9.249E+15	Syn Mtr	6	5	0
1	10	10.000	5.000	.000	173.6	.0	.000	.000	.000	3.352E+09	Syn Mtr	0	5	6
1	11	5.000	10.000	.000	.0	181000.0	5.000	10.000	.000	2.25E+15	Brake	7	6	0
1	12	10.000	5.000	.000	173.6	.0	.000	.000	.000	1.293E+09	Brake	0	6	7
1	13	10.000	18.000	.000	.0	9030000.0	10.000	18.000	.000	1.185E+16	Super 1	8	7	0
1	14	10.000	5.000	.000	173.6	.0	.000	.000	.000	1.216E+09	Super 1	0	7	8
1	15	10.000	18.000	.000	.0	5970000.0	10.000	18.000	.000	1.185E+16	Super 2	9	8	0
1	16	10.000	5.000	.000	173.6	.0	.000	.000	.000	1.317E+09	Super 2	0	8	9
1	17	10.000	18.000	.000	.0	5650000.0	10.000	18.000	.000	1.185E+16	Super 3	10	9	0
1	18	10.000	5.000	.000	173.6	.0	.000	.000	.000	1.253E+09	Super 3	0	9	10
1	19	10.000	18.000	.000	.0	6140000.0	10.000	18.000	.000	1.185E+16	Super 4	11	10	0

BRANCH INERTIA 28583562.8 74050.691 LB IN SEC^2 BRANCH WEIGHT 500.1 LB

TOTAL INERTIA 28583562.8 74050.691 LB IN SEC^2 TOTAL WEIGHT 500.1 LB

MATERIAL PROPERTY TABLE NO 1
DENSITY 2.8300E-01
SHEAR MODULUS 1.1500E+07

MATERIAL PROPERTY TABLE NO 2
DENSITY 1.0000E-09
SHEAR MODULUS 1.1500E+13

DEGREES OF FREEDOM

DOF #	INERTIA		
1	1.810868E+05	4.691368E+02	LB IN SEC^2
2	5.221736E+05	1.352781E+03	LB IN SEC^2
3	1.931736E+05	5.004459E+02	LB IN SEC^2
4	1.931736E+05	5.004459E+02	LB IN SEC^2
5	5.221736E+05	1.352781E+03	LB IN SEC^2
6	1.811736E+05	4.693618E+02	LB IN SEC^2
7	9.030174E+06	2.339423E+04	LB IN SEC^2
8	5.970174E+06	1.546677E+04	LB IN SEC^2
9	5.650174E+06	1.463774E+04	LB IN SEC^2
10	6.140087E+06	1.590694E+04	LB IN SEC^2

FROM	TO	STIFFNESS
1	2	3.846996E+09
2	3	2.847999E+09
3	4	1.937999E+09
4	5	2.847999E+09
5	6	3.331997E+09
6	7	1.283000E+09
7	8	1.216000E+09
8	9	1.317000E+09
9	10	1.283000E+09

MAX Y COORDINATES FOR EACH BRANCH

BRANCH NO 1 MAX VALUE 18.00000 Y CENTER COORD 25.00000

Arnold Air-Force Tullahoma PWT Super ssl

NO OF INERTIAS 10
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 9
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF 2SF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 9348360.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	469.1	.000000E+00	.00000E+00	.000
2	1352.6	.000000E+00	.00000E+00	.359
3	500.2	.000000E+00	.00000E+00	.000
4	500.2	.000000E+00	.00000E+00	.000
5	1352.6	.000000E+00	.00000E+00	.000
6	469.1	.000000E+00	.00000E+00	.000
7	23394.0	.000000E+00	.00000E+00	.000
8	15466.6	.000000E+00	.00000E+00	.000
9	14637.5	.000000E+00	.00000E+00	.000
10	15906.8	.000000E+00	.00000E+00	.000
TOTAL	74048.7			.359

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.384700E+10	.00000E+00	24.5000	1.0000
2 - 3	.284800E+10	.00000E+00	31.5000	1.0000
3 - 4	.193800E+10	.00000E+00	22.8750	1.0000
4 - 5	.284800E+10	.00000E+00	31.5000	1.0000
5 - 6	.333200E+10	.00000E+00	24.5000	1.0000
6 - 7	.128300E+10	.00000E+00	.0000	1.0000
7 - 8	.121600E+10	.00000E+00	.0000	1.0000
8 - 9	.131700E+10	.00000E+00	.0000	1.0000
9 -10	.128300E+10	.00000E+00	.0000	1.0000

1

MODAL DATA

MODE NO 1
FREQUENCY (HZ) .00000 (RPM) .00
DAMPING (%) 100.00000
GENERALIZED MASS 6.54733E+03
GENERALIZED STIFFNESS 0.00000E+00
EFFECTIVE MASS 7.40487E+04
PARTICIPATION FACTOR -3.36300E+00

MODE SHAPE

(1, 1)=-2.9735E-01 (2, 1)=-2.9735E-01 (3, 1)=-2.9736E-01 (4, 1)=-2.9736E-01
(5, 1)=-2.9736E-01 (6, 1)=-2.9736E-01 (7, 1)=-2.9736E-01 (8, 1)=-2.9735E-01
(9, 1)=-2.9735E-01 (10, 1)=-2.9735E-01 (

MODE NO 2
FREQUENCY (HZ) 30.16455 (RPM) 1809.87
DAMPING (%) .00000
GENERALIZED MASS 3.53362E+04
GENERALIZED STIFFNESS 1.26933E+09
EFFECTIVE MASS 3.82431E-14
PARTICIPATION FACTOR 1.04032E-09

MODE SHAPE

(1, 2)= 1.0000E+00 (2, 2)= 9.9562E-01 (3, 2)= 9.7272E-01 (4, 2)= 9.3004E-01
(5, 2)= 8.9514E-01 (6, 2)= 8.5225E-01 (7, 2)= 7.2967E-01 (8, 2)= 9.6083E-02
(9, 2)=-5.2945E-01 (10, 2)=-9.5458E-01 (

MODE NO 3
FREQUENCY (HZ) 58.24512 (RPM) 3494.71
DAMPING (%) .00000
GENERALIZED MASS 1.22625E+04
GENERALIZED STIFFNESS 1.64232E+09
EFFECTIVE MASS 4.24981E-24
PARTICIPATION FACTOR 1.96164E-14

MODE SHAPE

(1, 3)= 1.0000E+00 (2, 3)= 9.8367E-01 (3, 3)= 8.8904E-01 (4, 3)= 7.4360E-01
(5, 3)= 6.2033E-01 (6, 3)= 4.8124E-01 (7, 3)= 9.6459E-02 (8, 3)=-5.5806E-01
(9, 3)=-2.8464E-01 (10, 3)= 4.3095E-01 (

MODE NO 4
FREQUENCY (HZ) 70.20331 (RPM) 4212.20
DAMPING (%) .00000
GENERALIZED MASS 4.61582E+03
GENERALIZED STIFFNESS 8.98098E+08
EFFECTIVE MASS 1.80722E-11
PARTICIPATION FACTOR 6.25721E-08

MODE SHAPE

(1, 4)= 1.0000E+00 (2, 4)= 9.7627E-01 (3, 4)= 8.5401E-01 (4, 4)= 6.3145E-01
(5, 4)= 4.5843E-01 (6, 4)= 2.7433E-01 (7, 4)=-2.2330E-01 (8, 4)= 8.7518E-02
(9, 4)= 1.7452E-01 (10, 4)=-1.2357E-01 (

MODE NO 5
FREQUENCY (HZ) 85.33649 (RPM) 5120.19
DAMPING (%) .00000
GENERALIZED MASS 2.96961E+04
GENERALIZED STIFFNESS 8.53746E+09
EFFECTIVE MASS 4.56374E-25
PARTICIPATION FACTOR 3.92022E-15

MODE SHAPE

(1, 5)=-3.9158E-01 (2, 5)=-3.7785E-01 (3, 5)=-3.0772E-01 (4, 5)=-1.8182E-01
(5, 5)=-8.6965E-02 (6, 5)= 4.2593E-03 (7, 5)= 2.4072E-01 (8, 5)=-8.4122E-01
(9, 5)= 1.0000E+00 (10, 5)=-3.8996E-01 (

MODE NO 6
FREQUENCY (HZ) 176.54856 (RPM) 10592.91

```
DAMPING (%)                          .00000
GENERALIZED MASS                  2.58766E+03
GENERALIZED STIFFNESS             3.18416E+09
EFFECTIVE MASS                    4.58119E-25
PARTICIPATION FACTOR              1.33056E-14

MODE SHAPE

( 1, 6)=-6.8630E-01  ( 2, 6)=-5.8332E-01  ( 3, 6)=-1.0332E-01  ( 4, 6)= 6.3488E-01
( 5, 6)= 1.0000E+00  ( 6, 6)= 8.1256E-01  ( 7, 6)=-3.9795E-02  ( 8, 6)= 2.9532E-03
( 9, 6)=-2.5305E-04  (10, 6)= 1.7806E-05  (

MODE NO          7
FREQUENCY (HZ)                     413.96371        (RPM)       24837.82
DAMPING (%)                          .00000
GENERALIZED MASS                  1.34774E+03
GENERALIZED STIFFNESS             9.11790E+09
EFFECTIVE MASS                    8.85602E-29
PARTICIPATION FACTOR              2.56340E-16

MODE SHAPE

( 1, 7)=-6.6591E-01  ( 2, 7)=-1.1657E-01  ( 3, 7)= 1.0000E+00  ( 4, 7)= 8.9474E-01
( 5, 7)=-2.4001E-01  ( 6, 7)=-5.5078E-01  ( 7, 7)= 4.5370E-03  ( 8, 7)=-5.4044E-05
( 9, 7)= 7.3825E-07  (10, 7)=-8.9078E-09  (

MODE NO          8
FREQUENCY (HZ)                     525.84490        (RPM)       31550.69
DAMPING (%)                          .00000
GENERALIZED MASS                  1.28606E+03
GENERALIZED STIFFNESS             1.60398E+10
EFFECTIVE MASS                    3.18205E-31
PARTICIPATION FACTOR              1.57298E-17

MODE SHAPE

( 1, 8)= 1.0000E+00  ( 2, 8)=-3.3112E-01  ( 3, 8)=-4.1247E-01  ( 4, 8)= 6.3012E-01
( 5, 8)= 1.3148E-01  ( 6, 8)=-8.7737E-01  ( 7, 8)= 4.4516E-03  ( 8, 8)=-3.2552E-05
( 9, 8)= 2.7275E-07  (10, 8)=-2.0303E-09  (

MODE NO          9
FREQUENCY (HZ)                     563.02329        (RPM)       33781.40
DAMPING (%)                          .00000
GENERALIZED MASS                  1.14219E+03
GENERALIZED STIFFNESS             1.42939E+10
EFFECTIVE MASS                    1.66829E-28
PARTICIPATION FACTOR              3.82179E-16

MODE SHAPE

( 1, 9)= 6.7626E-01  ( 2, 9)=-3.5572E-01  ( 3, 9)= 3.6452E-01  ( 4, 9)= 3.4555E-01
( 5, 9)=-3.7511E-01  ( 6, 9)= 1.0000E+00  ( 7, 9)=-4.4202E-03  ( 8, 9)= 2.8139E-05
( 9, 9)=-2.0523E-07  (10, 9)= 1.3313E-09  (

MODE NO         10
FREQUENCY (HZ)                     619.36169        (RPM)       37161.70
DAMPING (%)                          .00000
GENERALIZED MASS                  1.35671E+03
GENERALIZED STIFFNESS             2.05463E+10
EFFECTIVE MASS                    9.29566E-28
PARTICIPATION FACTOR             -8.27746E-16

MODE SHAPE

( 1,10)= 3.6382E-01  ( 2,10)=-3.0804E-01  ( 3,10)= 1.0000E+00  ( 4,10)=-9.8651E-01
( 5,10)= 2.9566E-01  ( 6,10)=-3.8310E-01  ( 7,10)= 1.3972E-03  ( 8,10)=-7.3332E-06
( 9,10)= 4.4086E-08  (10,10)=-2.3606E-10  (
1

STATIC TORQUE AND STRESS

FOR MODE        1        FREQUENCY          .0000

SHAFT  1   1  TO  2   TORQUE  0.0000E+00   STRESS  0.0000E+00   PER UNIT  0.0000E+00
SHAFT  2   2  TO  3   TORQUE  0.0000E+00   STRESS  0.0000E+00   PER UNIT  0.0000E+00
SHAFT  3   3  TO  4   TORQUE  0.0000E+00   STRESS  0.0000E+00   PER UNIT  0.0000E+00
SHAFT  4   4  TO  5   TORQUE  0.0000E+00   STRESS  0.0000E+00   PER UNIT  0.0000E+00
SHAFT  5   5  TO  6   TORQUE  0.0000E+00   STRESS  0.0000E+00   PER UNIT  0.0000E+00
SHAFT  6   6  TO  7   TORQUE  0.0000E+00   STRESS  2.9735E-01   PER UNIT  0.0000E+00
SHAFT  7   7  TO  8   TORQUE  0.0000E+00   STRESS  2.9735E-01   PER UNIT  0.0000E+00
SHAFT  8   8  TO  9   TORQUE  0.0000E+00   STRESS  2.9735E-01   PER UNIT  0.0000E+00
SHAFT  9   9  TO 10   TORQUE  0.0000E+00   STRESS  2.9735E-01   PER UNIT  0.0000E+00

FOR MODE        2        FREQUENCY        30.1646

SHAFT  1   1  TO  2   TORQUE  1.2356E+05   STRESS  4.2790E+01   PER UNIT  4.7450E-03
SHAFT  2   2  TO  3   TORQUE  4.7827E+05   STRESS  7.7931E+01   PER UNIT  8.8367E-02
SHAFT  3   3  TO  4   TORQUE  6.0642E+05   STRESS  2.5803E+02   PER UNIT  2.3288E-02
SHAFT  4   4  TO  5   TORQUE  7.2896E+05   STRESS  1.1078E+02   PER UNIT  2.7994E-02
SHAFT  5   5  TO  6   TORQUE  1.0479E+06   STRESS  3.6289E+02   PER UNIT  4.0241E-02
SHAFT  6   6  TO  7   TORQUE  1.1532E+06   STRESS  8.5225E-01   PER UNIT  4.4285E-02
SHAFT  7   7  TO  8   TORQUE  5.6493E+06   STRESS  7.2967E-01   PER UNIT  2.1695E-01
SHAFT  8   8  TO  9   TORQUE  6.0407E+06   STRESS  9.6083E-02   PER UNIT  2.3198E-01
SHAFT  9   9  TO 10   TORQUE  3.9995E+06   STRESS  5.2945E-01   PER UNIT  1.5359E-01

FOR MODE        3        FREQUENCY        58.2451

SHAFT  1   1  TO  2   TORQUE  3.5178E+05   STRESS  1.2183E+02   PER UNIT  1.3509E-02
SHAFT  2   2  TO  3   TORQUE  1.3495E+06   STRESS  2.1990E+02   PER UNIT  5.1825E-02
SHAFT  3   3  TO  4   TORQUE  1.6868E+06   STRESS  7.1770E+02   PER UNIT  6.4776E-02
SHAFT  4   4  TO  5   TORQUE  1.9657E+06   STRESS  3.2038E+02   PER UNIT  7.5487E-02
SHAFT  5   5  TO  6   TORQUE  2.5949E+06   STRESS  8.9865E+02   PER UNIT  9.9651E-02
SHAFT  6   6  TO  7   TORQUE  2.7642E+06   STRESS  4.8124E-01   PER UNIT  1.0615E-01
SHAFT  7   7  TO  8   TORQUE  4.4564E+06   STRESS  9.6458E-02   PER UNIT  1.7114E-01
SHAFT  8   8  TO  9   TORQUE  2.0163E+06   STRESS  5.5806E-01   PER UNIT  7.7429E-02
SHAFT  9   9  TO 10   TORQUE  5.1407E+06   STRESS  2.8464E-01   PER UNIT  1.9741E-01

FOR MODE        4        FREQUENCY        70.2033

SHAFT  1   1  TO  2   TORQUE  9.2752E+05   STRESS  3.2121E+02   PER UNIT  3.5619E-02
SHAFT  2   2  TO  3   TORQUE  3.5385E+06   STRESS  5.7657E+02   PER UNIT  1.3589E-01
SHAFT  3   3  TO  4   TORQUE  4.3831E+06   STRESS  1.8650E+03   PER UNIT  1.6832E-01
SHAFT  4   4  TO  5   TORQUE  5.0076E+06   STRESS  8.1596E+02   PER UNIT  1.9210E-01
SHAFT  5   5  TO  6   TORQUE  6.2336E+06   STRESS  2.1588E+03   PER UNIT  2.3939E-01
SHAFT  6   6  TO  7   TORQUE  6.4881E+06   STRESS  2.7431E-01   PER UNIT  2.4916E-01
SHAFT  7   7  TO  8   TORQUE  3.8408E+06   STRESS  2.2330E-01   PER UNIT  1.4750E-01
SHAFT  8   8  TO  9   TORQUE  1.1644E+06   STRESS  8.7518E-02   PER UNIT  4.4717E-02
SHAFT  9   9  TO 10   TORQUE  3.8866E+06   STRESS  1.7452E-01   PER UNIT  1.4925E-01

FOR MODE        5        FREQUENCY        85.3365

SHAFT  1   1  TO  2   TORQUE  2.1850E+04   STRESS  7.5669E+00   PER UNIT  8.3908E-04
SHAFT  2   2  TO  3   TORQUE  8.2643E+04   STRESS  1.3464E+01   PER UNIT  3.1737E-03
SHAFT  3   3  TO  4   TORQUE  1.0095E+05   STRESS  4.2954E+01   PER UNIT  3.8768E-03
SHAFT  4   4  TO  5   TORQUE  1.1177E+05   STRESS  1.8212E+01   PER UNIT  4.2922E-03
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SHAFT	5	5	TO	6	TORQUE	1.2576E+05	STRESS	4.3553E+01	PER	UNIT	4.8295E-03
SHAFT	6	6	TO	7	TORQUE	1.2552E+05	STRESS	4.2593E-03	PER	UNIT	4.8204E-03
SHAFT	7	7	TO	8	TORQUE	5.4434E+05	STRESS	2.4072E-01	PER	UNIT	2.0904E-02
SHAFT	8	8	TO	9	TORQUE	1.0033E+06	STRESS	8.4122E-01	PER	UNIT	3.8528E-02
SHAFT	9	9	TO	10	TORQUE	7.3783E+05	STRESS	1.0000E+00	PER	UNIT	2.8335E-02

FOR MODE 6 FREQUENCY 176.5486

SHAFT	1	1	TO	2	TORQUE	6.7845E+05	STRESS	2.3496E+02	PER	UNIT	2.6054E-02
SHAFT	2	2	TO	3	TORQUE	2.3412E+06	STRESS	3.8148E+02	PER	UNIT	8.9906E-02
SHAFT	3	3	TO	4	TORQUE	2.4501E+06	STRESS	1.0425E+03	PER	UNIT	9.4089E-02
SHAFT	4	4	TO	5	TORQUE	1.7808E+06	STRESS	2.9018E+02	PER	UNIT	6.8389E-02
SHAFT	5	5	TO	6	TORQUE	1.0696E+06	STRESS	3.7041E+02	PER	UNIT	4.1074E-02
SHAFT	6	6	TO	7	TORQUE	1.8728E+06	STRESS	8.1256E-01	PER	UNIT	7.1921E-02
SHAFT	7	7	TO	8	TORQUE	8.9022E+04	STRESS	3.9795E-02	PER	UNIT	3.4187E-03
SHAFT	8	8	TO	9	TORQUE	7.2333E+03	STRESS	2.9532E-03	PER	UNIT	2.7778E-04
SHAFT	9	9	TO	10	TORQUE	5.9688E+02	STRESS	2.5385E-04	PER	UNIT	2.2922E-05

FOR MODE 7 FREQUENCY 413.9637

SHAFT	1	1	TO	2	TORQUE	2.5257E+05	STRESS	8.7470E+01	PER	UNIT	9.6994E-03
SHAFT	2	2	TO	3	TORQUE	3.8006E+05	STRESS	6.1928E+01	PER	UNIT	1.4595E-02
SHAFT	3	3	TO	4	TORQUE	2.4381E+04	STRESS	1.0374E+01	PER	UNIT	9.3628E-04
SHAFT	4	4	TO	5	TORQUE	3.8625E+05	STRESS	6.2936E+01	PER	UNIT	1.4833E-02
SHAFT	5	5	TO	6	TORQUE	1.2375E+05	STRESS	4.2858E+01	PER	UNIT	4.7525E-03
SHAFT	6	6	TO	7	TORQUE	8.5151E+04	STRESS	5.5078E-01	PER	UNIT	3.2700E-03
SHAFT	7	7	TO	8	TORQUE	6.6722E+02	STRESS	4.5370E-03	PER	UNIT	2.5623E-05
SHAFT	8	8	TO	9	TORQUE	8.6227E+00	STRESS	5.4044E-05	PER	UNIT	3.3113E-07
SHAFT	9	9	TO	10	TORQUE	1.1457E-01	STRESS	7.3825E-07	PER	UNIT	4.3997E-09

FOR MODE 8 FREQUENCY 525.8449

SHAFT	1	1	TO	2	TORQUE	1.1291E+06	STRESS	3.9102E+02	PER	UNIT	4.3360E-02
SHAFT	2	2	TO	3	TORQUE	5.1081E+04	STRESS	8.3234E+00	PER	UNIT	1.9616E-03
SHAFT	3	3	TO	4	TORQUE	4.4551E+05	STRESS	1.8956E+02	PER	UNIT	1.7169E-02
SHAFT	4	4	TO	5	TORQUE	3.1313E+05	STRESS	5.1022E+01	PER	UNIT	1.2025E-02
SHAFT	5	5	TO	6	TORQUE	7.4118E+05	STRESS	2.5668E+02	PER	UNIT	2.8463E-02
SHAFT	6	6	TO	7	TORQUE	2.4946E+05	STRESS	8.7737E-01	PER	UNIT	9.5798E-03
SHAFT	7	7	TO	8	TORQUE	1.2023E+03	STRESS	4.4516E-03	PER	UNIT	4.6170E-05
SHAFT	8	8	TO	9	TORQUE	9.5317E+00	STRESS	3.2552E-05	PER	UNIT	3.6604E-07
SHAFT	9	9	TO	10	TORQUE	7.7733E-02	STRESS	2.7275E-07	PER	UNIT	2.9851E-09

FOR MODE 9 FREQUENCY 563.0233

SHAFT	1	1	TO	2	TORQUE	9.2360E+05	STRESS	3.1986E+02	PER	UNIT	3.5469E-02
SHAFT	2	2	TO	3	TORQUE	4.7720E+05	STRESS	7.7758E+01	PER	UNIT	1.8326E-02
SHAFT	3	3	TO	4	TORQUE	5.3636E+04	STRESS	2.2821E+01	PER	UNIT	2.0597E-03
SHAFT	4	4	TO	5	TORQUE	4.1123E+05	STRESS	6.7008E+01	PER	UNIT	1.5792E-02
SHAFT	5	5	TO	6	TORQUE	1.0659E+06	STRESS	3.6915E+02	PER	UNIT	4.0935E-02
SHAFT	6	6	TO	7	TORQUE	2.9980E+05	STRESS	1.0000E+00	PER	UNIT	1.1513E-02
SHAFT	7	7	TO	8	TORQUE	1.2586E+03	STRESS	4.4202E-03	PER	UNIT	4.8326E-05
SHAFT	8	8	TO	9	TORQUE	8.6845E+00	STRESS	2.8139E-05	PER	UNIT	3.1351E-07
SHAFT	9	9	TO	10	TORQUE	6.1656E-02	STRESS	2.0523E-07	PER	UNIT	2.3677E-09

FOR MODE 10 FREQUENCY 619.3617

SHAFT	1	1	TO	2	TORQUE	3.6225E+05	STRESS	1.2545E+02	PER	UNIT	1.3911E-02
SHAFT	2	2	TO	3	TORQUE	5.2412E+05	STRESS	8.5077E+01	PER	UNIT	2.0051E-02
SHAFT	3	3	TO	4	TORQUE	5.3958E+05	STRESS	2.2958E+02	PER	UNIT	2.0721E-02
SHAFT	4	4	TO	5	TORQUE	5.0780E+05	STRESS	8.2744E+01	PER	UNIT	1.9501E-02
SHAFT	5	5	TO	6	TORQUE	3.1231E+05	STRESS	1.0816E+02	PER	UNIT	1.1993E-02
SHAFT	6	6	TO	7	TORQUE	6.9140E+04	STRESS	3.8310E-01	PER	UNIT	2.6551E-03
SHAFT	7	7	TO	8	TORQUE	2.3938E+02	STRESS	1.3972E-03	PER	UNIT	9.1927E-06
SHAFT	8	8	TO	9	TORQUE	1.3617E+00	STRESS	7.3332E-06	PER	UNIT	5.2294E-08
SHAFT	9	9	TO	10	TORQUE	7.9700E-03	STRESS	4.4086E-08	PER	UNIT	3.0607E-10

Arnold Air-Force Tullahoma PWT Super ss2

NO OF INERTIAS 10
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 9
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF SSF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 9348360.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	469.1	.000000E+00	.00000E+00	.000
2	1352.6	.000000E+00	.00000E+00	.000
3	500.2	.000000E+00	.00000E+00	.000
4	500.2	.000000E+00	.00000E+00	.000
5	1352.6	.000000E+00	.00000E+00	.359
6	469.1	.000000E+00	.00000E+00	.000
7	23394.0	.000000E+00	.00000E+00	.000
8	15466.6	.000000E+00	.00000E+00	.000
9	14637.5	.000000E+00	.00000E+00	.000
10	15906.8	.000000E+00	.00000E+00	.000
TOTAL	74048.7			.359

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.384700E+10	.00000E+00	24.5000	1.0000
2 - 3	.284800E+10	.00000E+00	31.5000	1.0000
3 - 4	.193800E+10	.00000E+00	22.8750	1.0000
4 - 5	.284800E+10	.00000E+00	31.5000	1.0000
5 - 6	.333200E+10	.00000E+00	24.5000	1.0000
6 - 7	.128300E+10	.00000E+00	.0000	1.0000
7 - 8	.121600E+10	.00000E+00	.0000	1.0000
8 - 9	.131700E+10	.00000E+00	.0000	1.0000
9 -10	.128300E+10	.00000E+00	.0000	1.0000

STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1 TO 2	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	2	2 TO 3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3 TO 4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4 TO 5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5 TO 6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	6 TO 7	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	7	7 TO 8	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	8	8 TO 9	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00
SHAFT	9	9 TO 10	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 30.1646

SHAFT	1	1 TO 2	TORQUE	1.1109E+05	STRESS	3.8472E+01	PER UNIT	4.2661E-03
SHAFT	2	2 TO 3	TORQUE	4.3000E+05	STRESS	7.0066E+01	PER UNIT	1.6513E-02
SHAFT	3	3 TO 4	TORQUE	5.4522E+05	STRESS	2.3198E+02	PER UNIT	2.0938E-02
SHAFT	4	4 TO 5	TORQUE	6.5539E+05	STRESS	1.0679E+02	PER UNIT	2.5169E-02
SHAFT	5	5 TO 6	TORQUE	9.4211E+05	STRESS	3.2627E+02	PER UNIT	3.6179E-02
SHAFT	6	6 TO 7	TORQUE	1.0368E+06	STRESS	8.5225E-01	PER UNIT	3.9815E-02
SHAFT	7	7 TO 8	TORQUE	5.0792E+06	STRESS	7.2967E-01	PER UNIT	1.9505E-01
SHAFT	8	8 TO 9	TORQUE	5.4311E+06	STRESS	9.6083E-02	PER UNIT	2.0857E-01
SHAFT	9	9 TO 10	TORQUE	3.5958E+06	STRESS	5.2945E-01	PER UNIT	1.3809E-01

FOR MODE 3 FREQUENCY 58.2451

SHAFT	1	1 TO 2	TORQUE	2.2184E+05	STRESS	7.6827E+01	PER UNIT	8.5193E-03
SHAFT	2	2 TO 3	TORQUE	8.5105E+05	STRESS	1.1867E+02	PER UNIT	3.2683E-02
SHAFT	3	3 TO 4	TORQUE	1.0637E+06	STRESS	4.5260E+02	PER UNIT	4.0858E-02
SHAFT	4	4 TO 5	TORQUE	1.2396E+06	STRESS	2.0199E+02	PER UNIT	4.7604E-02
SHAFT	5	5 TO 6	TORQUE	1.6364E+06	STRESS	5.6672E+02	PER UNIT	6.2842E-02
SHAFT	6	6 TO 7	TORQUE	1.7432E+06	STRESS	4.8124E-01	PER UNIT	6.6942E-02
SHAFT	7	7 TO 8	TORQUE	2.8103E+06	STRESS	9.6458E-02	PER UNIT	1.0792E-01
SHAFT	8	8 TO 9	TORQUE	1.2715E+06	STRESS	5.5806E-01	PER UNIT	4.8829E-02
SHAFT	9	9 TO 10	TORQUE	3.2418E+06	STRESS	2.8464E-01	PER UNIT	1.2449E-01

FOR MODE 4 FREQUENCY 70.2033

SHAFT	1	1 TO 2	TORQUE	4.3554E+05	STRESS	1.5083E+02	PER UNIT	1.6726E-02
SHAFT	2	2 TO 3	TORQUE	1.6616E+06	STRESS	2.7074E+02	PER UNIT	6.3808E-02
SHAFT	3	3 TO 4	TORQUE	2.0582E+06	STRESS	8.7573E+02	PER UNIT	7.9039E-02
SHAFT	4	4 TO 5	TORQUE	2.3514E+06	STRESS	3.8315E+02	PER UNIT	9.0300E-02
SHAFT	5	5 TO 6	TORQUE	2.9271E+06	STRESS	1.0137E+03	PER UNIT	1.1241E-01
SHAFT	6	6 TO 7	TORQUE	3.0466E+06	STRESS	2.7433E-01	PER UNIT	1.1700E-01
SHAFT	7	7 TO 8	TORQUE	1.8015E+06	STRESS	2.2330E-01	PER UNIT	6.9260E-02
SHAFT	8	8 TO 9	TORQUE	5.4678E+05	STRESS	8.7518E-02	PER UNIT	2.0998E-02
SHAFT	9	9 TO 10	TORQUE	1.8250E+06	STRESS	1.7452E-01	PER UNIT	7.0085E-02

FOR MODE 5 FREQUENCY 85.3365

SHAFT	1	1 TO 2	TORQUE	5.0288E+03	STRESS	1.7416E+00	PER UNIT	1.9312E-04
SHAFT	2	2 TO 3	TORQUE	1.9021E+04	STRESS	3.0993E+00	PER UNIT	7.3044E-04
SHAFT	3	3 TO 4	TORQUE	2.3246E+04	STRESS	9.8860E+00	PER UNIT	8.9226E-04
SHAFT	4	4 TO 5	TORQUE	2.5724E+04	STRESS	4.1916E+00	PER UNIT	9.8788E-04
SHAFT	5	5 TO 6	TORQUE	2.8945E+04	STRESS	1.0024E+01	PER UNIT	1.1115E-03
SHAFT	6	6 TO 7	TORQUE	2.8890E+04	STRESS	4.2593E-03	PER UNIT	1.1094E-03
SHAFT	7	7 TO 8	TORQUE	1.2528E+05	STRESS	2.4072E-01	PER UNIT	4.8111E-03
SHAFT	8	8 TO 9	TORQUE	2.3091E+05	STRESS	8.4123E-01	PER UNIT	8.8675E-03
SHAFT	9	9 TO 10	TORQUE	1.6982E+05	STRESS	1.0000E+00	PER UNIT	6.5214E-03

FOR MODE 6 FREQUENCY 176.5466

SHAFT	1	1 TO 2	TORQUE	1.1631E+06	STRESS	4.0279E+02	PER UNIT	4.4665E-02
SHAFT	2	2 TO 3	TORQUE	4.0135E+06	STRESS	6.5397E+02	PER UNIT	1.5413E-01
SHAFT	3	3 TO 4	TORQUE	4.2002E+06	STRESS	1.7871E+03	PER UNIT	1.6130E-01
SHAFT	4	4 TO 5	TORQUE	3.0529E+06	STRESS	4.9746E+02	PER UNIT	1.1724E-01
SHAFT	5	5 TO 6	TORQUE	1.8336E+06	STRESS	6.3499E+02	PER UNIT	7.0413E-02
SHAFT	6	6 TO 7	TORQUE	3.2106E+06	STRESS	8.1256E-01	PER UNIT	1.2330E-01
SHAFT	7	7 TO 8	TORQUE	1.5261E+05	STRESS	3.9795E-02	PER UNIT	5.8607E-03
SHAFT	8	8 TO 9	TORQUE	1.2400E+04	STRESS	2.9532E-03	PER UNIT	4.7620E-04
SHAFT	9	9 TO 10	TORQUE	1.0232E+03	STRESS	2.5385E-04	PER UNIT	3.9295E-05

FOR MODE 7 FREQUENCY 413.9637

SHAFT	1	1 TO 2	TORQUE	5.2005E+05	STRESS	1.8010E+02	PER UNIT	1.9971E-02
SHAFT	2	2 TO 3	TORQUE	7.8256E+05	STRESS	1.2751E+02	PER UNIT	3.0052E-02
SHAFT	3	3 TO 4	TORQUE	5.0201E+04	STRESS	2.1360E+01	PER UNIT	1.9278E-03
SHAFT	4	4 TO 5	TORQUE	7.9529E+05	STRESS	1.2959E+02	PER UNIT	3.0541E-02

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Arnold Air-Force Tullahoma PWT Super s43

NO OF INERTIAS 10
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 9
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF 2SF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 2971164.00

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	469.1	.000000E+00	.00000E+00	.000
2	1352.6	.000000E+00	.00000E+00	.000
3	500.2	.000000E+00	.00000E+00	.114
4	500.2	.000000E+00	.00000E+00	.000
5	1352.6	.000000E+00	.00000E+00	.000
6	469.1	.000000E+00	.00000E+00	.000
7	23394.0	.000000E+00	.00000E+00	.000
8	15466.6	.000000E+00	.00000E+00	.000
9	14637.5	.000000E+00	.00000E+00	.000
10	15906.8	.000000E+00	.00000E+00	.000
TOTAL	74048.7			.114

80% rated Torque 1.12

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.384700E+10	.00000E+00	24.5000	1.0000
2 - 3	.284800E+10	.00000E+00	31.5000	1.0000
3 - 4	.193800E+10	.00000E+00	22.8750	1.0000
4 - 5	.284800E+10	.00000E+00	31.5000	1.0000
5 - 6	.333200E+10	.00000E+00	24.5000	1.0000
6 - 7	.128300E+10	.00000E+00	.0000	1.0000
7 - 8	.121600E+10	.00000E+00	.0000	1.0000
8 - 9	.131700E+10	.00000E+00	.0000	1.0000
9 -10	.128300E+10	.00000E+00	.0000	1.0000

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STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1 TO 2	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	2	2 TO 3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3 TO 4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4 TO 5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5 TO 6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	6 TO 7	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	7	7 TO 8	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	8	8 TO 9	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00
SHAFT	9	9 TO 10	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 30.1646

SHAFT	1	1 TO 2	TORQUE	3.8367E+04	STRESS	1.3287E+01	PER UNIT	1.4734E-03
SHAFT	2	2 TO 3	TORQUE	1.4051E+05	STRESS	2.4199E+01	PER UNIT	5.7032E-03
SHAFT	3	3 TO 4	TORQUE	1.8830E+05	STRESS	8.0121E+01	PER UNIT	7.2114E-03
SHAFT	4	4 TO 5	TORQUE	2.2635E+05	STRESS	3.6883E+01	PER UNIT	8.6925E-03
SHAFT	5	5 TO 6	TORQUE	9.2538E+05	STRESS	1.1260E+02	PER UNIT	1.2495E-02
SHAFT	6	6 TO 7	TORQUE	1.5808E+05	STRESS	8.5225E-01	PER UNIT	1.3751E-02
SHAFT	7	7 TO 8	TORQUE	1.7542E+06	STRESS	7.2967E-01	PER UNIT	6.7366E-02
SHAFT	8	8 TO 9	TORQUE	1.8757E+06	STRESS	9.6083E-02	PER UNIT	7.2033E-02
SHAFT	9	9 TO 10	TORQUE	1.2419E+06	STRESS	5.2945E-01	PER UNIT	4.7692E-02

FOR MODE 3 FREQUENCY 58.2451

SHAFT	1	1 TO 2	TORQUE	1.0219E+05	STRESS	3.5389E+01	PER UNIT	3.9242E-03
SHAFT	2	2 TO 3	TORQUE	3.9202E+05	STRESS	6.3877E+01	PER UNIT	1.5054E-02
SHAFT	3	3 TO 4	TORQUE	4.8998E+05	STRESS	2.0848E+02	PER UNIT	1.8816E-02
SHAFT	4	4 TO 5	TORQUE	5.7100E+05	STRESS	9.3041E+01	PER UNIT	2.1928E-02
SHAFT	5	5 TO 6	TORQUE	7.5378E+05	STRESS	2.6104E+02	PER UNIT	2.8947E-02
SHAFT	6	6 TO 7	TORQUE	8.0295E+05	STRESS	4.8124E-01	PER UNIT	3.0835E-02
SHAFT	7	7 TO 8	TORQUE	1.2945E+06	STRESS	9.6458E-02	PER UNIT	4.9712E-02
SHAFT	8	8 TO 9	TORQUE	5.8569E+05	STRESS	5.5806E-01	PER UNIT	2.2492E-02
SHAFT	9	9 TO 10	TORQUE	1.4933E+06	STRESS	2.8464E-01	PER UNIT	5.7345E-02

FOR MODE 4 FREQUENCY 70.2033

SHAFT	1	1 TO 2	TORQUE	2.5787E+05	STRESS	8.9306E+01	PER UNIT	9.9030E-03
SHAFT	2	2 TO 3	TORQUE	9.8378E+05	STRESS	1.6030E+02	PER UNIT	3.7780E-02
SHAFT	3	3 TO 4	TORQUE	1.2186E+06	STRESS	5.1850E+02	PER UNIT	4.6798E-02
SHAFT	4	4 TO 5	TORQUE	1.3922E+06	STRESS	2.2686E+02	PER UNIT	5.3466E-02
SHAFT	5	5 TO 6	TORQUE	1.7331E+06	STRESS	6.0020E+02	PER UNIT	6.6556E-02
SHAFT	6	6 TO 7	TORQUE	1.8038E+06	STRESS	2.7433E-01	PER UNIT	6.9272E-02
SHAFT	7	7 TO 8	TORQUE	1.0678E+06	STRESS	2.2330E-01	PER UNIT	4.1008E-02
SHAFT	8	8 TO 9	TORQUE	3.2374E+05	STRESS	8.7518E-02	PER UNIT	1.2432E-02
SHAFT	9	9 TO 10	TORQUE	1.0806E+06	STRESS	1.7452E-01	PER UNIT	4.1496E-02

FOR MODE 5 FREQUENCY 85.3365

SHAFT	1	1 TO 2	TORQUE	5.4555E+03	STRESS	1.9586E+00	PER UNIT	2.1718E-04
SHAFT	2	2 TO 3	TORQUE	2.1391E+04	STRESS	3.4055E+00	PER UNIT	8.2146E-04
SHAFT	3	3 TO 4	TORQUE	2.6138E+04	STRESS	1.1118E+01	PER UNIT	1.0038E-03
SHAFT	4	4 TO 5	TORQUE	2.8930E+04	STRESS	4.7139E+00	PER UNIT	1.1110E-03
SHAFT	5	5 TO 6	TORQUE	3.2551E+04	STRESS	1.1273E+01	PER UNIT	1.2500E-03
SHAFT	6	6 TO 7	TORQUE	3.2490E+04	STRESS	4.2593E-03	PER UNIT	1.2477E-03
SHAFT	7	7 TO 8	TORQUE	1.4089E+05	STRESS	2.4072E-01	PER UNIT	5.4106E-03
SHAFT	8	8 TO 9	TORQUE	2.5968E+05	STRESS	8.4122E-01	PER UNIT	9.9725E-03
SHAFT	9	9 TO 10	TORQUE	1.9098E+05	STRESS	1.0000E+00	PER UNIT	7.3340E-03

FOR MODE 6 FREQUENCY 176.5446

SHAFT	1	1 TO 2	TORQUE	3.8194E+04	STRESS	1.3227E+01	PER UNIT	1.4667E-03
SHAFT	2	2 TO 3	TORQUE	1.3180E+05	STRESS	2.1476E+01	PER UNIT	5.0614E-03
SHAFT	3	3 TO 4	TORQUE	1.3793E+05	STRESS	5.8687E+01	PER UNIT	5.2968E-03
SHAFT	4	4 TO 5	TORQUE	1.0025E+05	STRESS	1.6336E+01	PER UNIT	3.8500E-03
SHAFT	5	5 TO 6	TORQUE	6.0212E+04	STRESS	2.0952E+01	PER UNIT	2.3123E-03
SHAFT	6	6 TO 7	TORQUE	1.0543E+05	STRESS	8.1256E-01	PER UNIT	4.0489E-03
SHAFT	7	7 TO 8	TORQUE	5.0116E+03	STRESS	3.9795E-02	PER UNIT	1.9246E-04
SHAFT	8	8 TO 9	TORQUE	4.0721E+02	STRESS	2.9512E-03	PER UNIT	1.5638E-05
SHAFT	9	9 TO 10	TORQUE	3.3602E+01	STRESS	2.5385E-04	PER UNIT	1.2904E-06

FOR MODE 7 FREQUENCY 413.9637

SHAFT	1	1 TO 2	TORQUE	6.8865E+05	STRESS	2.3849E+02	PER UNIT	2.6446E-02
SHAFT	2	2 TO 3	TORQUE	1.0362E+06	STRESS	1.6885E+02	PER UNIT	3.9794E-02
SHAFT	3	3 TO 4	TORQUE	6.6476E+04	STRESS	2.8285E+01	PER UNIT	2.5528E-03

SHAFT	4	4	TO	5	TORQUE	1.0531E+06	STRESS	1.7160E+02	PER	UNIT	4.0442E-02
SHAFT	5	5	TO	6	TORQUE	3.3743E+05	STRESS	1.1686E+02	PER	UNIT	1.2959E-02
SHAFT	6	6	TO	7	TORQUE	2.3217E+05	STRESS	5.5079E-01	PER	UNIT	8.9159E-03
SHAFT	7	7	TO	8	TORQUE	1.9192E+03	STRESS	4.5370E-03	PER	UNIT	6.9862E-05
SHAFT	8	8	TO	9	TORQUE	2.3510E+01	STRESS	5.4044E-05	PER	UNIT	9.0285E-07
SHAFT	9	9	TO	10	TORQUE	3.1237E-01	STRESS	7.3825E-07	PER	UNIT	1.1996E-08

FOR MODE 8 FREQUENCY 525.8449

SHAFT	1	1	TO	2	TORQUE	4.4702E+05	STRESS	1.5481E+02	PER	UNIT	1.7166E-02
SHAFT	2	2	TO	3	TORQUE	2.0223E+04	STRESS	3.2953E+00	PER	UNIT	7.7662E-04
SHAFT	3	3	TO	4	TORQUE	1.7638E+05	STRESS	7.5048E+01	PER	UNIT	6.7734E-03
SHAFT	4	4	TO	5	TORQUE	1.2397E+05	STRESS	2.0200E+01	PER	UNIT	4.7607E-03
SHAFT	5	5	TO	6	TORQUE	2.9344E+05	STRESS	1.0162E+02	PER	UNIT	1.1269E-02
SHAFT	6	6	TO	7	TORQUE	9.8762E+04	STRESS	8.7737E-01	PER	UNIT	3.7927E-03
SHAFT	7	7	TO	8	TORQUE	4.7599E+02	STRESS	4.4516E-03	PER	UNIT	1.8279E-05
SHAFT	8	8	TO	9	TORQUE	3.7737E+00	STRESS	3.2552E-05	PER	UNIT	1.4492E-07
SHAFT	9	9	TO	10	TORQUE	3.0775E-02	STRESS	2.7275E-07	PER	UNIT	1.1818E-09

FOR MODE 9 FREQUENCY 563.0233

SHAFT	1	1	TO	2	TORQUE	3.0081E+05	STRESS	1.0417E+02	PER	UNIT	1.1552E-02
SHAFT	2	2	TO	3	TORQUE	1.5542E+05	STRESS	2.5325E+01	PER	UNIT	5.9685E-03
SHAFT	3	3	TO	4	TORQUE	1.7469E+04	STRESS	7.4327E+00	PER	UNIT	6.7084E-04
SHAFT	4	4	TO	5	TORQUE	1.3393E+05	STRESS	2.1824E+01	PER	UNIT	5.1434E-03
SHAFT	5	5	TO	6	TORQUE	3.4717E+05	STRESS	1.2023E+02	PER	UNIT	1.3332E-02
SHAFT	6	6	TO	7	TORQUE	9.7642E+04	STRESS	1.0000E+00	PER	UNIT	3.7497E-03
SHAFT	7	7	TO	8	TORQUE	4.0985E+02	STRESS	4.4202E-03	PER	UNIT	1.5739E-05
SHAFT	8	8	TO	9	TORQUE	2.8285E+00	STRESS	2.8139E-05	PER	UNIT	1.0862E-07
SHAFT	9	9	TO	10	TORQUE	2.0081E-02	STRESS	2.0523E-07	PER	UNIT	7.7114E-10

FOR MODE 10 FREQUENCY 619.3617

SHAFT	1	1	TO	2	TORQUE	3.7376E+05	STRESS	1.2944E+02	PER	UNIT	1.4353E-02
SHAFT	2	2	TO	3	TORQUE	5.3871E+05	STRESS	8.7779E+01	PER	UNIT	2.0688E-02
SHAFT	3	3	TO	4	TORQUE	5.5672E+05	STRESS	2.3688E+02	PER	UNIT	2.1379E-02
SHAFT	4	4	TO	5	TORQUE	5.2394E+05	STRESS	8.5372E+01	PER	UNIT	2.0120E-02
SHAFT	5	5	TO	6	TORQUE	3.2223E+05	STRESS	1.1159E+02	PER	UNIT	1.2374E-02
SHAFT	6	6	TO	7	TORQUE	7.1136E+04	STRESS	3.8310E-01	PER	UNIT	2.7395E-03
SHAFT	7	7	TO	8	TORQUE	2.4698E+02	STRESS	1.3972E-03	PER	UNIT	9.4847E-06
SHAFT	8	8	TO	9	TORQUE	1.4050E+00	STRESS	7.3332E-06	PER	UNIT	5.3955E-08
SHAFT	9	9	TO	10	TORQUE	8.2232E-03	STRESS	4.4086E-08	PER	UNIT	3.1579E-10

Arnold Air-Force Tullahoma PWT Super ss4

NO OF INERTIAS 10
INPUT TORQUE AT INERTIA 1
NO OF SHAFTS 9
NDAMP 0
NO OF POLES 10
NO OF DYNAMIC CASES 0
NO OF STEADY CASES 0
NO OF 2SF CASES 0
STATUS OF TAPE 2
RATED TORQUE 26040000.00
RATED SPEED 600.0000
PER UNIT LOAD 1.0000
EXPONENT OF LOAD CURVE 2.0000

INPUT TORQUE 2971164.00

80% rated torque M3

NO	INERTIA	GRD SPRING	GRD DAMPER	INPUT
1	469.1	.000000E+00	.00000E+00	.000
2	1352.6	.000000E+00	.00000E+00	.000
3	500.2	.000000E+00	.00000E+00	.000
4	500.2	.000000E+00	.00000E+00	.114
5	1352.6	.000000E+00	.00000E+00	.000
6	469.1	.000000E+00	.00000E+00	.000
7	23394.0	.000000E+00	.00000E+00	.000
8	15466.6	.000000E+00	.00000E+00	.000
9	14637.5	.000000E+00	.00000E+00	.000
10	15906.8	.000000E+00	.00000E+00	.000
TOTAL	74048.7			.114

SHAFT ELEMENTS

LT RT	SHAFT SPRING	SHAFT DAMPER	DIAMETER	GEAR RATIO
1 - 2	.384700E+10	.00000E+00	24.5000	1.0000
2 - 3	.284800E+10	.00000E+00	31.5000	1.0000
3 - 4	.193800E+10	.00000E+00	22.8750	1.0000
4 - 5	.284800E+10	.00000E+00	31.5000	1.0000
5 - 6	.333200E+10	.00000E+00	24.5000	1.0000
6 - 7	.128300E+10	.00000E+00	.0000	1.0000
7 - 8	.121600E+10	.00000E+00	.0000	1.0000
8 - 9	.131700E+10	.00000E+00	.0000	1.0000
9 -10	.128300E+10	.00000E+00	.0000	1.0000

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STATIC TORQUE AND STRESS

FOR MODE 1 FREQUENCY .0000

SHAFT	1	1	TO 2	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	2	2	TO 3	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	3	3	TO 4	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	4	4	TO 5	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	5	5	TO 6	TORQUE	0.0000E+00	STRESS	0.0000E+00	PER UNIT	0.0000E+00
SHAFT	6	6	TO 7	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	7	7	TO 8	TORQUE	0.0000E+00	STRESS	2.9736E-01	PER UNIT	0.0000E+00
SHAFT	8	8	TO 9	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00
SHAFT	9	9	TO 10	TORQUE	0.0000E+00	STRESS	2.9735E-01	PER UNIT	0.0000E+00

FOR MODE 2 FREQUENCY 30.1646

SHAFT	1	1	TO 2	TORQUE	3.6684E+04	STRESS	1.2704E+01	PER UNIT	1.4088E-03
SHAFT	2	2	TO 3	TORQUE	1.4199E+05	STRESS	2.3137E+01	PER UNIT	5.4529E-03
SHAFT	3	3	TO 4	TORQUE	1.8004E+05	STRESS	7.6606E+01	PER UNIT	6.9141E-03
SHAFT	4	4	TO 5	TORQUE	2.1642E+05	STRESS	3.5265E+01	PER UNIT	8.3112E-03
SHAFT	5	5	TO 6	TORQUE	3.1111E+05	STRESS	1.0774E+02	PER UNIT	1.1947E-02
SHAFT	6	6	TO 7	TORQUE	3.4237E+05	STRESS	8.5225E-01	PER UNIT	1.3148E-02
SHAFT	7	7	TO 8	TORQUE	1.6772E+06	STRESS	7.2967E-01	PER UNIT	6.4410E-02
SHAFT	8	8	TO 9	TORQUE	1.7935E+06	STRESS	9.6083E-02	PER UNIT	6.8873E-02
SHAFT	9	9	TO 10	TORQUE	1.1874E+06	STRESS	5.2945E-01	PER UNIT	4.5600E-02

FOR MODE 3 FREQUENCY 58.2451

SHAFT	1	1	TO 2	TORQUE	8.4518E+04	STRESS	2.9270E+01	PER UNIT	3.2457E-03
SHAFT	2	2	TO 3	TORQUE	3.2424E+05	STRESS	5.2833E+01	PER UNIT	1.2452E-02
SHAFT	3	3	TO 4	TORQUE	4.0526E+05	STRESS	1.7243E+02	PER UNIT	1.5563E-02
SHAFT	4	4	TO 5	TORQUE	4.7227E+05	STRESS	7.6954E+01	PER UNIT	1.8137E-02
SHAFT	5	5	TO 6	TORQUE	6.2345E+05	STRESS	2.1591E+02	PER UNIT	2.3942E-02
SHAFT	6	6	TO 7	TORQUE	6.6412E+05	STRESS	4.8124E-01	PER UNIT	2.5504E-02
SHAFT	7	7	TO 8	TORQUE	1.0707E+06	STRESS	9.6458E-02	PER UNIT	4.1117E-02
SHAFT	8	8	TO 9	TORQUE	4.8443E+05	STRESS	5.5806E-01	PER UNIT	1.8603E-02
SHAFT	9	9	TO 10	TORQUE	1.2351E+06	STRESS	2.8464E-01	PER UNIT	4.7430E-02

FOR MODE 4 FREQUENCY 70.2033

SHAFT	1	1	TO 2	TORQUE	1.9067E+05	STRESS	6.6032E+01	PER UNIT	7.3222E-03
SHAFT	2	2	TO 3	TORQUE	7.2741E+05	STRESS	1.1853E+02	PER UNIT	2.7934E-02
SHAFT	3	3	TO 4	TORQUE	9.0104E+05	STRESS	3.8338E+02	PER UNIT	3.4603E-02
SHAFT	4	4	TO 5	TORQUE	1.0294E+06	STRESS	1.6774E+02	PER UNIT	3.9532E-02
SHAFT	5	5	TO 6	TORQUE	1.2815E+06	STRESS	4.4379E+02	PER UNIT	4.9211E-02
SHAFT	6	6	TO 7	TORQUE	1.3338E+06	STRESS	2.7433E-01	PER UNIT	5.1220E-02
SHAFT	7	7	TO 8	TORQUE	7.8956E+05	STRESS	2.2330E-01	PER UNIT	3.0321E-02
SHAFT	8	8	TO 9	TORQUE	2.3937E+05	STRESS	8.7519E-02	PER UNIT	9.1925E-03
SHAFT	9	9	TO 10	TORQUE	7.9897E+05	STRESS	1.7452E-01	PER UNIT	3.0682E-02

FOR MODE 5 FREQUENCY 85.3365

SHAFT	1	1	TO 2	TORQUE	3.3416E+03	STRESS	1.1572E+00	PER UNIT	1.2832E-04
SHAFT	2	2	TO 3	TORQUE	1.2639E+04	STRESS	2.0594E+00	PER UNIT	4.8534E-04
SHAFT	3	3	TO 4	TORQUE	1.5439E+04	STRESS	6.5691E+00	PER UNIT	5.9289E-04
SHAFT	4	4	TO 5	TORQUE	1.7093E+04	STRESS	2.7853E+00	PER UNIT	6.5643E-04
SHAFT	5	5	TO 6	TORQUE	1.9233E+04	STRESS	4.6607E+00	PER UNIT	7.3860E-04
SHAFT	6	6	TO 7	TORQUE	1.9197E+04	STRESS	4.2593E-03	PER UNIT	7.3720E-04
SHAFT	7	7	TO 8	TORQUE	8.3248E+04	STRESS	2.4072E-01	PER UNIT	3.1969E-03
SHAFT	8	8	TO 9	TORQUE	1.5344E+05	STRESS	8.4122E-01	PER UNIT	5.8923E-03
SHAFT	9	9	TO 10	TORQUE	1.1284E+05	STRESS	1.0000E+00	PER UNIT	4.3333E-03

FOR MODE 6 FREQUENCY 176.5486

SHAFT	1	1	TO 2	TORQUE	2.3469E+05	STRESS	8.1276E+01	PER UNIT	9.0126E-03
SHAFT	2	2	TO 3	TORQUE	8.0985E+05	STRESS	1.3196E+02	PER UNIT	3.1100E-02
SHAFT	3	3	TO 4	TORQUE	8.4752E+05	STRESS	3.6061E+02	PER UNIT	3.2547E-02
SHAFT	4	4	TO 5	TORQUE	6.1603E+05	STRESS	1.0038E+02	PER UNIT	2.3657E-02
SHAFT	5	5	TO 6	TORQUE	3.6998E+05	STRESS	1.2813E+02	PER UNIT	1.4208E-02
SHAFT	6	6	TO 7	TORQUE	6.4785E+05	STRESS	8.1256E-01	PER UNIT	2.4879E-02
SHAFT	7	7	TO 8	TORQUE	3.0794E+04	STRESS	3.9795E-02	PER UNIT	1.1826E-03
SHAFT	8	8	TO 9	TORQUE	2.5021E+03	STRESS	2.9932E-03	PER UNIT	9.6089E-05
SHAFT	9	9	TO 10	TORQUE	2.0647E+02	STRESS	2.5185E-04	PER UNIT	7.9291E-06

FOR MODE 7 FREQUENCY 413.9637

SHAFT	1	1	TO 2	TORQUE	6.1616E+05	STRESS	2.1339E+02	PER UNIT	2.3662E-02
SHAFT	2	2	TO 3	TORQUE	9.2717E+05	STRESS	1.5108E+02	PER UNIT	3.5605E-02
SHAFT	3	3	TO 4	TORQUE	5.9478E+04	STRESS	2.5307E+01	PER UNIT	2.2841E-03

SHAFT	4	4	TO	5	TORQUE	9.4227E+05	STRESS	1.5354E+02	PER	UNIT	3.6185E-02
SHAFT	5	5	TO	6	TORQUE	3.0191E+05	STRESS	1.0456E+02	PER	UNIT	1.1594E-02
SHAFT	6	6	TO	7	TORQUE	2.0773E+05	STRESS	5.5078E-01	PER	UNIT	7.9774E-03
SHAFT	7	7	TO	8	TORQUE	1.6277E+03	STRESS	4.5370E-03	PER	UNIT	6.2508E-05
SHAFT	8	8	TO	9	TORQUE	2.1036E+01	STRESS	5.4044E-05	PER	UNIT	8.0782E-07
SHAFT	9	9	TO	10	TORQUE	2.7949E-01	STRESS	7.3825E-07	PER	UNIT	1.0733E-08

FOR MODE 8 FREQUENCY 525.8449

SHAFT	1	1	TO	2	TORQUE	6.8290E+05	STRESS	2.3650E+02	PER	UNIT	2.6225E-02
SHAFT	2	2	TO	3	TORQUE	3.0895E+04	STRESS	5.0341E+00	PER	UNIT	1.1864E-03
SHAFT	3	3	TO	4	TORQUE	2.6945E+05	STRESS	1.1465E+02	PER	UNIT	1.0348E-02
SHAFT	4	4	TO	5	TORQUE	1.8939E+05	STRESS	3.0859E+01	PER	UNIT	7.2729E-03
SHAFT	5	5	TO	6	TORQUE	4.4828E+05	STRESS	1.5525E+02	PER	UNIT	1.7215E-02
SHAFT	6	6	TO	7	TORQUE	1.5088E+05	STRESS	9.7737E-01	PER	UNIT	5.7941E-03
SHAFT	7	7	TO	8	TORQUE	7.2716E+02	STRESS	4.4516E-03	PER	UNIT	2.7925E-05
SHAFT	8	8	TO	9	TORQUE	5.7650E+00	STRESS	3.2552E-05	PER	UNIT	2.2139E-07
SHAFT	9	9	TO	10	TORQUE	4.7015E-02	STRESS	2.7275E-07	PER	UNIT	1.8055E-09

FOR MODE 9 FREQUENCY 563.0233

SHAFT	1	1	TO	2	TORQUE	2.0264E+05	STRESS	7.0176E+01	PER	UNIT	7.7817E-03
SHAFT	2	2	TO	3	TORQUE	1.0470E+05	STRESS	1.7060E+01	PER	UNIT	4.0206E-03
SHAFT	3	3	TO	4	TORQUE	1.1768E+04	STRESS	5.0070E+00	PER	UNIT	4.5190E-04
SHAFT	4	4	TO	5	TORQUE	9.0223E+04	STRESS	1.4701E+01	PER	UNIT	3.4648E-03
SHAFT	5	5	TO	6	TORQUE	2.3387E+05	STRESS	8.0991E+01	PER	UNIT	8.9810E-03
SHAFT	6	6	TO	7	TORQUE	6.5776E+04	STRESS	1.0000E+00	PER	UNIT	2.5259E-03
SHAFT	7	7	TO	8	TORQUE	2.7609E+02	STRESS	4.4202E-03	PER	UNIT	1.0603E-05
SHAFT	8	8	TO	9	TORQUE	1.9054E+00	STRESS	2.8139E-05	PER	UNIT	7.3171E-08
SHAFT	9	9	TO	10	TORQUE	1.3527E-02	STRESS	2.0523E-07	PER	UNIT	5.1948E-10

FOR MODE 10 FREQUENCY 619.3617

SHAFT	1	1	TO	2	TORQUE	3.6872E+05	STRESS	1.2769E+02	PER	UNIT	1.4160E-02
SHAFT	2	2	TO	3	TORQUE	5.3144E+05	STRESS	8.6596E+01	PER	UNIT	2.0409E-02
SHAFT	3	3	TO	4	TORQUE	5.4921E+05	STRESS	2.3368E+02	PER	UNIT	2.1091E-02
SHAFT	4	4	TO	5	TORQUE	5.1687E+05	STRESS	8.4221E+01	PER	UNIT	1.9849E-02
SHAFT	5	5	TO	6	TORQUE	3.1788E+05	STRESS	1.1009E+02	PER	UNIT	1.2208E-02
SHAFT	6	6	TO	7	TORQUE	7.0374E+04	STRESS	3.8310E-01	PER	UNIT	2.7025E-03
SHAFT	7	7	TO	8	TORQUE	2.4365E+02	STRESS	1.3972E-03	PER	UNIT	9.3568E-06
SHAFT	8	8	TO	9	TORQUE	1.3860E+00	STRESS	7.3332E-06	PER	UNIT	5.3228E-08
SHAFT	9	9	TO	10	TORQUE	8.1123E-03	STRESS	4.4086E-08	PER	UNIT	3.1153E-10