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RE-RATING OF BATTERY CHARGERS FOR

NEW YORK POWER AUTHORITY

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

PURCHASE ORDER 02268.5004

POWER CONVERSION PRODUCTS INC.
CRYSTAL LAKE, ILLINOIS, U.S.A.

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INDEX

Attachment 1. Computer analysis of transformer design per PCP drawing 04082

Attachment 2. Graphic presentation of amplitude of principal harmonic, q=6.

Attachment 3. Rectifier circuit constants from General Electric Co. *Rectifier components guide*

Attachment 4. Westinghouse Application data 29-160 (May,1976)

Attachment A-1. File E71836, Vol. 1, Sec. 3, Pages 1-4.

Attachment A-2. Essex GP-200 Product and Application Data, Pages 1-4.

Attachment B-1. Equation and graph from *Design Shortcuts & Procedures for Electronics Power Transformers and Inductors.*

Attachment D-1. Test circuit for voltage regulator (amplifier) board

1. General description of the methodology used in the re-rating

The equipment to be re-rated consists of two battery-charging rectifiers, model number 3MD130-300. This equipment is rated at 130 volts DC, 300 amperes continuous, at an ambient temperature of 40 degrees Celsius (104 degrees Fahrenheit). It is desired to re-rate this equipment to an ambient of 45 degrees Celsius continuous and 66 degrees Celsius (150 degrees Fahrenheit) for two hours. The re-rating will demonstrate for each component either that the component is suitable for continuous operation at the higher temperature, or that a two hour period will not have an undue effect on the component life.

The components to be re-rated are limited to power magnetic components, circuit breakers, capacitors, and semiconductors. Ancillary items such as alarm relays are not considered, since they do not have a safety-related function (see Appendix F).

Under ordinary circumstances, this re-rating would be performed by testing the device to be re-rated under the specified environmental conditions. In this case, the equipment was manufactured in 1971 and the plant has been in commercial operation since 1975. However, there are accepted methods to predict the temperature of the various components, and the temperature and stress level data are all that is needed. In the case of the voltage regulator circuit, it was fairly easy to build and test an identical unit, and this was the approach taken.

Since the manufacture of this unit preceded IEEE-650 by several years, this standard is not utilized in this re-rating of the unit. The re-rating of the unit at an ambient temperature of 113 degrees F continuously and 150 degrees F for two hours will be based on industry standards.

2. Magnetic components

At the time this equipment was manufactured, the company's standard insulation system used polyester/polyamide-imide magnet wire and polyamide (DuPont Nomex) paper ground and phase insulation. The standard PCP design practice at the time was to design for 115 degrees C rise over 40 degrees C ambient, but this insulation system is now accepted for continuous use at 200 degrees Celsius (see Appendix A). **It will be demonstrated that the magnetic components have a temperature rise of 134 degrees Celsius or less and they can function according to their design requirements. Therefore, it has a negligible effect on the expected life of the equipment.**

The main transformer is shown by computer analysis to have a temperature rise of 115 degrees Celsius at rated load. From this analysis, we may conclude that the transformer will operate safely for an indefinite period at the stated temperature (See Attachment A-1). This analysis was performed at the time of the original design using a commercial

transformer design program, using methods similar to those employed in Appendices B and C. Appendix E justifies the results by comparison with a similar transformer used in a 400 ampere charger of similar design.

The filter choke is analyzed in Appendix B and shown to have a temperature rise of less than 95 degrees Celsius at rated load. We conclude that the filter choke will also perform its design function at an ambient temperature of 66 degrees Celsius, since it uses the same Class 200 insulation as the main transformer.

The magnetic amplifier is analyzed in Appendix C and shown to have an expected temperature rise of no more than 70 degrees Celsius at rated load. We conclude that the magnetic amplifier will also be satisfactory for operation at 66 degrees C ambient:,since it also uses the Class 200 insulation system used in the main transformer.

3. Circuit breakers

The equipment uses Westinghouse molded-case circuit breakers for input and output control. The input breaker is type FB3150 and the output breaker is type DA2400. At rated output of 300 amperes, the input current is calculated at 74 amperes.

Westinghouse application data 29-160 (May,1976) assigns de-ratings as follows:

FB3150	138 amp at 50 degrees C	125 amp at 60 degrees C
DA2400	372 amp at 50 degrees C	340 amp at 60 degrees C

Extrapolation leads to calculated ratings at 66 degrees of 118 amperes for the FB3150 and 321 amperes for the DA2400. There is certainly plenty of margin in the AC input breaker, and the DC output breaker is satisfactory for operation at full load.

4. Filter capacitors

The filter capacitors originally furnished were rated 150 working volts DC (wvdc), 7800 uF. Our internal records indicate that they have been replaced with PCP p/n 0221215412, rated 150 wvdc, 12000 uF. This part has an ESR (equivalent series resistance) of .033 ohm max.

The transformer secondary voltage is 174 volts, which will produce a DC output of 235 volts from a three-phase bridge rectifier (see Attachment 1). From figure 15.12 in the textbook ***Rectifier Circuits: Theory and Design*** by Johannes Schaefer (see attachment 2), we see that the amplitude of the ripple voltage is about 70 volts peak, or 42 volts rms, at 360 Hz. The inductance of the filter choke is 1.5 mH, leading to a capacitor ripple current of 12 amp total or 4 amp/capacitor.

Ripple current of 4 amperes leads to a loss of .5 watts per capacitor. Such a small loss results in a negligible temperature rise in the capacitor core. Since the capacitor is rated for operation with high ripple at 85 degrees Celsius, we conclude that operation at 66 degrees Celsius has little effect.

5. Power diodes

The rectifier assembly used in these battery chargers consists of six 275 ampere rated diodes (1N4052), each mounted on a standard Wakefield model 486 6.25" x 6.25" x 6" extruded heat sink. The rating may be calculated as follows. Each diode carries 300 amperes peak at 1/3 duty cycle, for an average DC current of 100 amperes. The loss is readily calculated as the forward drop multiplied by the average current.

The forward drop of the subject diode at 300 amperes is .95 volts and the total loss is .95*300/3, or 95 watts.

Thermal resistance from junction to heatsink is 0.32 K/W (Kelvin/watt) and the thermal resistance of the heatsink is 0.43 K/W for a total of 0.75 K/W. The temperature rise from ambient to junction is 95*.75=72 degrees Celsius. At an ambient temperature of 66 degrees, the junction temperature will be no more than 138 degrees, which is within the manufacturer's rating of 190 degrees C.

At the maximum current limit setting of 375 amperes, the forward drop is 1.0 volt and the junction temperature is calculated to be 156 degrees Celsius at an ambient temperature of 66 degrees Celsius.

6. Voltage regulator assembly

This assembly was tested as described in Appendix D, and was shown to perform its design function at the maximum required ambient temperature.

7. Conclusion

The testing and analysis has demonstrated that, since each of the components is capable of the desired re-rating, the entire battery charging rectifier may be re-rated for continuous operation at an ambient temprature of 113 degrees F, followed by two hours at an ambient temprature of 150 degrees F.

8. Reference Material

PCP drawing 04082 dated 10/11/71

PCP drawing 04083 dated 10/11/71
PCP drawing 04084 dated 10/11/71
PCP bill of materials Model No. 3MD130-300 F/O No. 04062

APPENDIX A

Qualification of Polyester/Polyamide-Imide Wire at 200 Degrees Celsius

This wire construction consists of a polyester basecoat with a polyamide-imide overcoat. It was originally introduced as a Class 180 component, but further testing - and over twenty years of successful use - has shown it to be a Class 200 material. Attachment A-1 is extracted from PCP's UL report for Class 200 transformer insulation systems, showing the use of this material with DuPont Nomex 410 as ground and phase insulation. This is essentially the same system that was used in the subject transformers.

Attachment A-2 is representative test data for the magnet wire, as shown in the Essex magnet wire catalog. The catalog states "Extrapolated ASTM-D-2307 data yields a temperature of 210 degrees C for copper conductor and 230 degrees C on aluminum conductor at 20,000 hours."

These data demonstrate that operation continuously at 160 degrees C, with occasional operation to 181 degrees C, is within the continuous rating of the insulation system. Therefore, magnetic components made with this insulation system will be capable of performing its design function at a temperature of 160 degrees C continuously (115 degrees C rise over 45 degrees ambient) followed by 2 hours of operation at a temperature of 181 degrees C (115 degrees rise over 66 degrees ambient.)

APPENDIX B

Analysis of Filter Choke Per PCP Drawing 04082

1. The subject component is wound with four parallelled conductors of .129 x .500 copper magnet wire; 48 turns are wound on a 4.5" stack of EI-287 lamination to provide an inductance of 1.5 mHy.

2. The coil form is 2.938" x 4.625" and the build (thickness) of the coil is 1.69". The mean length of turn is the length of a turn halfway through the coil. It is calculated as the circumference of the coil form plus the diameter of a circle having radius of 1/2 the build. In this case, the calculation is MLT=2*(2.938+4.625)+3.14*1.69. Allowing a 10% safety margin to account for loose winding, these dimensions lead to mean length of turn of 22.5".

3. Total coil length=48 x 22.5 or 1080 inches=90 ft.

4. At 180 degrees C, the winding resistance is calculated to be 4.61 milliohm, and the total copper loss is 415 watts at 300 amperes.

5. The surface area is approximately that of a rectangular parallellipiped of the same dimensions as the core. A=2*(13.75*9.75)+2*(9.75*4.5)+2*(13.75*4.5)=479.6 sq in.

6. Typical temperature rise for transformers is shown in a graph from the book *Design Shortcuts & Procedures for Electronics Power Transformers and Inductors*, by Ordean Kiltie (Attachment B-1). In this case, the losses of .87 watts/sq inch lead to a predicted internal temperature rise of 75-95 degrees C when operating at design load. The equipment is capable of performing its design function at an total temperature of 161 degrees C (95 degrees rise above 66 degrees ambient).

APPENDIX C

Qualification of Magnetic Amplifier Per PCP Drawing 04083

1. The subject component is wound with two parallel conductors of .129 x .500 magnet wire wound on a c-core with cross-section 4" x 1.8125 and window area 2.25" x 8.125" (Westinghouse p/n A-540). Each gate winding carries the current of one diode - 174 amperes rms (see Attachment 1 for this calculation). The build of the winding is 1.41".

2. The mean length of turn (see Appendix B for discussion) is calculated as MLT=2*(4+1.8125)+3.14*1.41. Allowing 10 % for loose winding, the mean length of turn is 12.75", and the total winding length is 55.25 feet.

3. At 180 degrees C, the winding resistance is calculated as 3.47 milliohms, and the total copper loss is 105 watts/winding or 210 watts total. The core weighs 101 pounds and the iron loss is estimated at 0.7 watts/lb. We thus arrive at 281 watts loss for this component.

4. Using the same methods as used in the analysis of the filter choke, the surface area of the component is calculated as 468 sq inches. The resulting loss of 0.6 watts/sq in indicates a temperature rise of 55-70 degrees Celsius.

APPENDIX D

Qualification by test of the voltage regulator assembly

1. General character of the test

The purpose of the test is to demonstrate that the circuit will function at the specified ambient temperature. In the original design, germanium power transistors were used as the control elements. When the re-rating was proposed, PCP felt that there was a danger of increased leakage in the power transistors causing a functional failure (thermal runaway) of the circuit.

Replacing the transistors with silicon devices - which have leakage current orders of magnitude less than germanium would assure stable operation at high temperature. This test will demonstrate that the circuit is stable at elevated temperatues. Since it is only a static test of device characteristics, and not an endurance test, the duration need only be long enough to stabilize device temperatures.

2. Equipment required:

0-200 vdc power supply Hewlett-Packard 6010A or equal
DMM Hewlett-Packard 3468A or equal (2 required)
Resistor 150 0hm 2 watt (2 required)
Environmental test chamber

3. Test method:

a.) Install test board in environmental chamber at room temperature
b.) Connect equipment as shown in Attachment D-1
c.) Set power supply to 130.0 volts on meter M1
d.) Adjust power supply to obtain +5.0 to +5.5 volts on M2.
e.) Record reading of meters M1 and M2
f.) Adjust power supply voltage to obtain -5.0 to -5.5 volts on M2
g.) Record readings of meters M1 and M2
h.) Close environmental chamber and set temperature to 70 degrees Celsius
i.) Allow chamber 30 minutes to stabilize
j.) Adjust power supply to obtain +5.0 to +5.5 volts on M2
k.) Record readings of M1 and M2
l.) Adjust power supply to obtain -5.0 to -5.5 volts on M2
m.) Record readings of M1 and M2
n.) Test is now complete.

4. Conclusions:

The difference in voltage between the readings on M1 at the two extremes are an indication of the gain of the circuit. If the voltage difference is no less at high temperature than at room temperature, then we can assume that the rectifier will regulate at least as well at high temperature as at room temperature. The average of the two readings can be considered the balance point of the circuit. The ability to obtain a balance or null indicates that the circuit is functional at the specified elevated temperature.

TEST RESULTS

Temperature	M1	M2
25 C	130.8	-5.12
	129.64	+5.17
70 C	130.52	-5.28
	129.31	+5.20

4. Equipment used:

Instrument model no	PCP Inst no	Calibration due
Hewlett-Packard 3468A DMM	L-387	03/17/93
Fluke 87 DMM	L-579	02/04/93
Omega 650 digital thermometer	IN362	01/31/93

APPENDIX E

Confirmation of computer analysis of transformer per PCP drawing 04084

This appendix will demonstrate that the as-built main transformer will not exceed the 115 degree C rise shown in the computer analysis; the as-built transformer differs in some details from the computer generated design.

1. The subject component has a primary winding consisting of 61 turns of .129x.500 copper conductor. The secondary winding consists of 32 turns of two paralleled conductors of .129x.500 copper. The core consists of a 6.5" stack of 3.6" 3-phase EI lamination. Winding configuration is wye-delta.

2. The coil form is 3.625 x 7.0 and the build (thickness) of the coil is 1.26". The mean length of turn (see Appendix B) is calculated as 2*(3.625+7)+3.14*1.26. Allowing a 10% safety margin, this leads to MLT=27.75"

3. Total primary length=61*27.75 or 1692 inches=141 feet. Total secondary length=32*27.75 or 888 inches=74 feet.

4. The secondary current at 300 ampere output is 0.816*300/1.732=141 amperes and the primary current is calculated as 74 amperes.

5. At 180 degrees C, the primary resistance is calculated to be 28.9 milliohm and the secondary resistance is 7.59 milliohms. The total copper loss is then 927 watts and the iron loss at 444 watts (at 1.1 watt/lb.).

6. The transformer designer used 155 amperes as a conservative value for secondary current, leading to primary current of 82 amperes. The design program used .180x.330 copper for primary conductor and 2 paralleled .170x.330 for secondary. These values led to total copper losses of 1416 watts, whereas the actual transformer has calculated copper loss of 927 watts. The core loss calculated by the design program is approximately the same as calculated above, and the total loss for the calculated design is 1875 watts for the computer design compared to 1371 watts for the transformer as built. The surface area is calculated as 2*(16.2*18)+2*(16.2*6.5)+2*(18*6.5)=1028 sq. in. and the losses are 1.33 watts per square inch.

7. A similar design for a 400 ampere charger calculates losses of 1460 watts. This unit had a 9" stack of the same lamination used in the transformer to be analyzed, leading to a calculated surface area of 2*(16.2*18)+2*(16.2*9)+2*(18*9)=1200 sq. in. The losses of 1.22 watts per square inch resulted in a measured temperature rise of 100 degrees C.

8. Considering the relationship between losses per unit area and temperature rise to be linear over a small range, a temperature rise of 109 degrees C is predicted for the unit to

be qualified. We conclude that there is justification for the 115 degree rise predicted by the computer analysis..

APPENDIX F

Justification for the analysis of certain components

The object of the re-rating was to demonstrate that the rectifier could deliver rated output at an ambient temperature of 113 degrees F continuously, followed by two hours at an ambient of 150 degrees F. In this report, certain components were analyzed to prove that they could perform the required function at these temperatures. Other components were not analyzed - either because the function of the component is unrelated to the required function of regulating and delivering rated load, or because the component is rated for continuous operation at an ambient temperature higher than 150 degree F. PCP's policy in qualification to IEEE-650 has been that components such as timers, indicators, and alarm relays are not safety-related, since fuses in the alarm circuit will prevent a failure in an alarm circuit from affecting the charger output. That philosophy is followed here. Following is a list of components from the Bill of material.

Component	Comment
AC/DC failure alarm	May not function properly, but will not be damaged - not essential to required function
Low voltage alarm	May not function properly, but will not be damaged - not essential to required function
Amplifier board	Qualified by test (Appendix D)
AC Fail disconnect	Within its rated ambient temperature range
Surge suppressor D4	Within its rated ambient temperature range
Surge suppressor D6	Within its rated ambient temperature range
Timer	Within its rated ambient temperature range
Transformer	Analyzed (Appendix E and Attachment 1)
Magnetic amplifier	Analyzed (Appendix C)
Filter choke	Analyzed (Appendix B)
AC pilot light	Within its rated ambient temperature range
Current transformer	Negligible temperature rise
Ground detector	May not function properly, but will not be damaged - not essential to required function
Meters	Within its rated ambient temperature range
Nameplates	Within its rated ambient temperature range
Filter capacitors	Analyzed
Lugs	Within its rated ambient temperature range
Instrument shunt	Within its rated ambient temperature range
Terminal blocks	Within its rated ambient temperature range
Fuse blocks	Within its rated ambient temperature range

ATTACHMENT 1

1

OPTIMIZED [illegible] SERVICE, INC.
35 PARK ST. [illegible]
PHONE (215) 243-5300

34-130-310

3-PHASE TYPE DESIGN FROM LAMINS VA RATING 79501.12 @ 100.00% DUTY CYCLE
FREQUENCY 57. GRADE M 5 THICKNESS .014
CORE EI 3.600 STACK 6.606 EFF. AREA 21.402 WEIGHT 372.141
WINDOW: 3.501 X 9.000 THICKNESS 0.125 LENGTH 9.875
WINDING FORM: INS. DIA. 3.725 X 7.196

WIRE SPECIFICATIONS

WNDG	WIRE		LENGTH	MEAN TURNS	MARGIN	FT
P1#2 RECT	.1800X 0.3300	CU.0595	135.16	25.94	0.500	31.179
S1#2RECT2X	1(.1700X 0.3300)	CU.1120	89.90	32.69	0.500	37.555

TOTAL CONDUCTOR WEIGHT 213.206

NUMBER OF COILS 3

WNDG	TURNS	LO TAP	HI TAP	LAYRS	T/L	LAYR INS	SEC. INS	BUILD
P1	63.0			4 3	16 23	1(.010000)	1(.010000)	3.375
S1	33.0			2 2	16 22	1(.010000)	1(.010000)	3.719

TOTAL BUILD(%) 82.94

WNDG	INTERNAL DUCTS			EXTERNAL DUCTS
P1	2	0.375 IN.	END	
S1	1	0.375 IN.	END	

ELECTRICAL ANALYSIS

WNDG	FULL-LOAD VOLTS	TAP VOLTS LOW	HIGH	TEST KV	LOAD CURRENT	RESIST. 85C	CURRENT DENSITY	ZSEC
P1	331.93			3.5	83.330	0.01935	1431.	1.7
S1	170.87			1.5	155.885	0.00576	1434.	

FLUX DENSITY KG 15.068
CORE LOSS WATTS 458.120
TOTAL COPPER LOSS 1416.562
EXCITATION VA 4332.613
EXCIT. CURRENT AMP 2.942

LEAKAGE INDUCTANCE MHYS 0.210
POWER FACTOR 0.9970
IMPEDANCE % 2.51
EFFICIENCY % 98.56

AMBIENT TEMP. 40.00
TEMP.RISE 115.65
OPERATING TEMP. 155.65

NOMINAL LENGTH 21.50
NOMINAL DEPTH 13.21
NOMINAL HEIGHT 15.20

34 DO YOU WANT MANUFACTURING COSTS?NO

35 MODIFY(NO. OF LINES)?0

PROGRAM STOP AT 3380
USED 37.19 UNITS
0037.19 CRU 0000.35 TCH 0004.51 KC

OFF AT 10:10EDT 10/09/71

$P_B = 4(.125) + .03$ (.5)

$V_S = V_P \frac{T_S}{T_P}$

$N_S = \frac{V_S N_P}{V_P} = \frac{174}{332}$

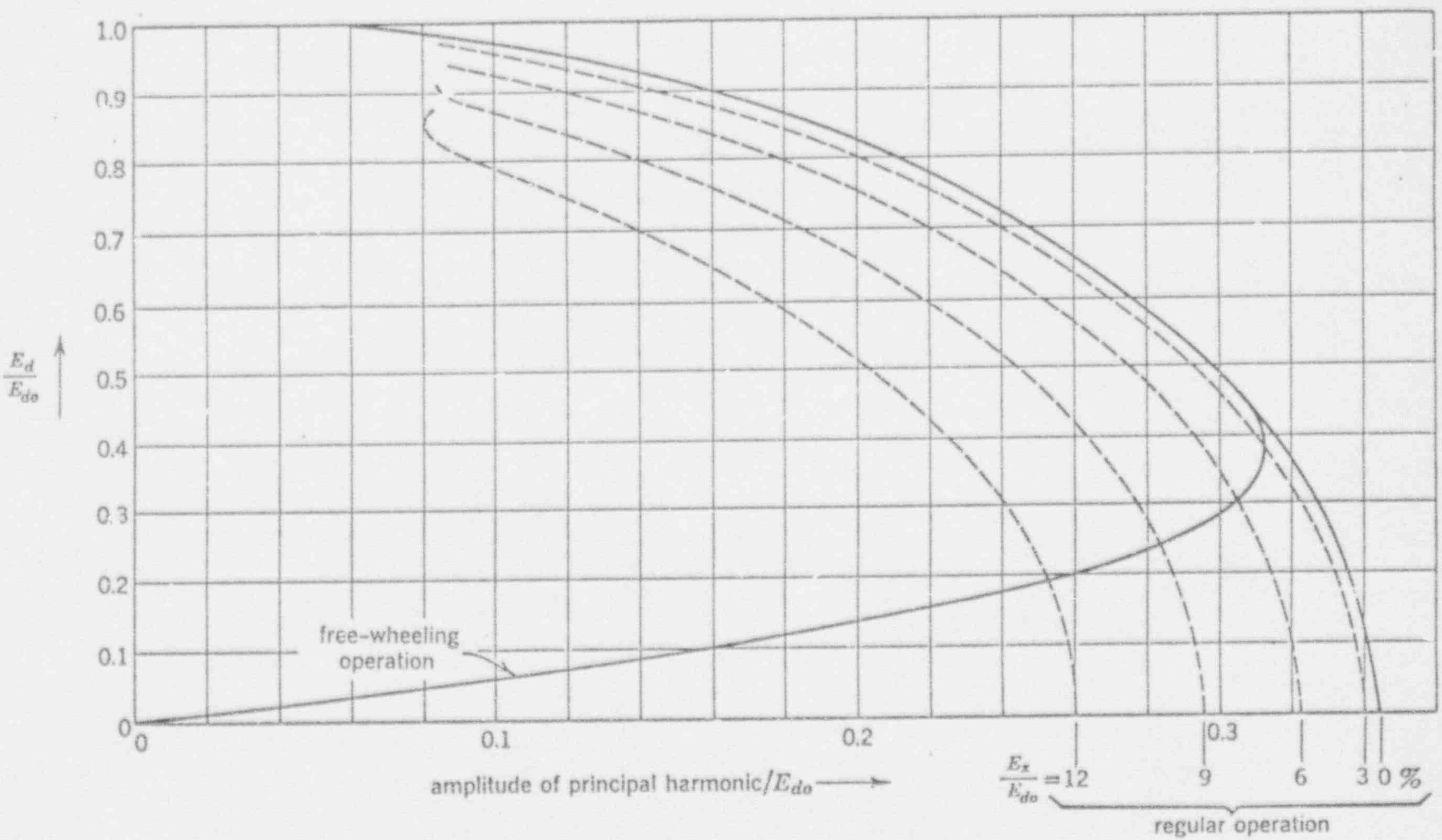


Fig. 15.12. Graphic presentation of amplitude of principal harmonic, $q = 6$.

Attachment 2. Reproduced from Rectifier Circuits: Theory and Design

Attachment 3. Reproduced from *Rectifier Components Guide*

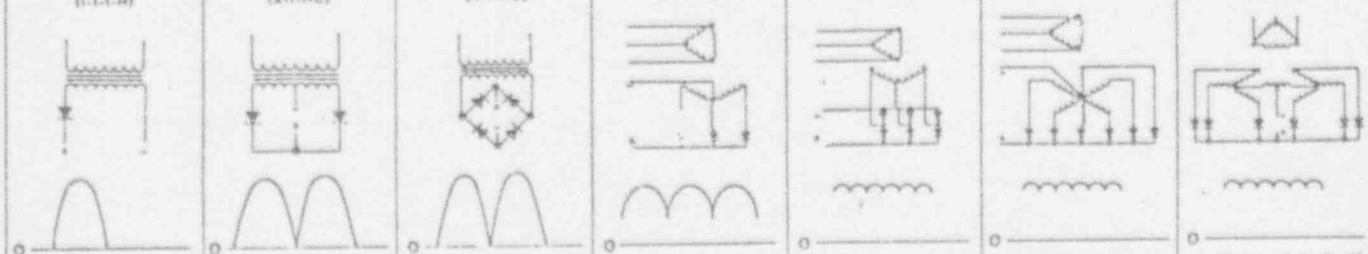
TYPE OF CIRCUIT		SINGLE PHASE HALF WAVE (1-1-1-H)	SINGLE PHASE CENTER-TAP (2-1-1-C)	SINGLE PHASE BRIDGE (4-1-1-B)	THREE PHASE STAR (WYE) (3-1-1-Y)	THREE PHASE BRIDGE (6-1-1-B)	SIX PHASE STAR (THREE PHASE DIAMETRIC) (6-1-1-S)	THREE PHASE DOUBLE WYE WITH INTERPHASE TRANSFORMER (6-1-1-Y)	* Assumes zero forward drop and zero reverse current in rectifiers and no AC line or source resistance. TO DETERMINE ACTUAL VALUE OF PARAMETER IN FIRST COLUMN, MULTIPLY FACTOR SHOWN BY VALUE OF:
PRIMARY / SECONDARY / ONE CYCLE WAVE OF RECTIFIER OUTPUT VOLTAGE (NO OVERLAP)									
NUMBER OF RECTIFIER ELEMENTS IN CIRCUIT		1	2	4	3	6	6	6	
AVERAGE D.C. VOLTS OUTPUT	=	1.00	1.00	1.00	1.00	1.00	1.00	1.00	× AVERAGE D.C. VOLTAGE OUTPUT
RMS D.C. VOLTS OUTPUT	=	1.57	1.11	1.11	1.02	1.00	1.00	1.00	× AVERAGE D.C. VOLTAGE OUTPUT
PEAK D.C. VOLTS OUTPUT	=	3.14	1.57	1.57	1.21	1.05	1.05	1.05	× AVERAGE D.C. VOLTAGE OUTPUT
PEAK REVERSE VOLTS PER RECTIFIER ELEMENT	=	3.14	3.14	1.57	2.09	1.05	2.09	2.42	× AVERAGE D.C. VOLTAGE OUTPUT
	=	1.41	2.82 -	1.41	2.45	2.45	2.83	2.83	× RMS SECONDARY VOLTS PER TRANSFORMER LEG
	=	1.41	1.41	1.41	1.41	1.41	1.41	1.41 (DIAMETRIC)	× RMS SECONDARY VOLTS LINE-TO-LINE
AVERAGE D.C. OUTPUT CURRENT	=	1.00	1.00	1.00	1.00	1.00	1.00	1.00	× AVERAGE D.C. OUTPUT CURRENT
AVERAGE D.C. OUTPUT CURRENT PER RECTIFIER ELEMENT	=	1.00	0.500	0.500	0.333	0.333	4.67 .167	0.167	× AVERAGE D.C. OUTPUT CURRENT
RMS CURRENT PER RECTIFIER ELEMENT — RESISTIVE LOAD	=	1.57	0.785	0.785	0.587	0.579	0.409	0.293	× AVERAGE D.C. OUTPUT CURRENT
RMS CURRENT PER RECTIFIER ELEMENT — INDUCTIVE LOAD	=	----	0.707	0.707	0.578	0.578	0.408	0.289	× AVERAGE D.C. OUTPUT CURRENT
PEAK CURRENT PER RECTIFIER ELEMENT — RESISTIVE LOAD	=	3.14	1.57	1.57	1.21	1.05	1.05	0.525	× AVERAGE D.C. OUTPUT CURRENT
PEAK CURRENT PER RECTIFIER ELEMENT — INDUCTIVE LOAD	=	----	1.00	1.00	1.00	1.00	1.00	0.500	× AVERAGE D.C. OUTPUT CURRENT
RATIO: PEAK TO AVERAGE CURRENT PER ELEMENT — RESISTIVE LOAD		3.14	3.14	3.14	3.63	3.15	6.30	3.15	
RATIO: PEAK TO AVERAGE CURRENT PER ELEMENT — INDUCTIVE LOAD		----	2.00	2.00	3.00	3.00	6.00	3.00	
% RIPPLE (RMS OF RIPPLE / AVERAGE OUTPUT VOLTAGE)		121%	48%	48%	18.3%	4.2%	4.2%	4.2%	
		Resistive Load	Inductive Load or Large Choke Input Filter						
TRANSFORMER SECONDARY RMS VOLTS PER LEG	=	2.22	1.11 (TO CENTER-TAP)	1.11 (TOTAL)	0.855 (TO NEUTRAL)	0.4[illegible]3 (TO NEUTRAL)	0.740 (TO NEUTRAL)	0.855 (TO NEUTRAL)	× AVERAGE D.C. VOLTAGE OUTPUT
TRANSFORMER SECONDARY RMS VOLTS LINE-TO-LINE	=	2.22	2.22	1.11	1.48	0.740	1.48 (MAX.)	1.71 (MAX.—NO LOAD)	× AVERAGE D.C. VOLTAGE OUTPUT
SECONDARY LINE CURRENT	=	1.57	0.707	1.00	0.578	0.816	0.408	0.289	× AVERAGE D.C. OUTPUT CURRENT
TRANSFORMER SECONDARY VOLT-AMPERES PER LEG	=	3.49	1.57	1.11	1.48	1.05	1.81	1.48	× D.C. WATTS OUTPUT
TRANSFORMER PRIMARY RMS AMPERES PER LEG	=	1.57	1.00	1.00	0.471	0.816	0.577	0.408	× AVERAGE D.C. OUTPUT CURRENT
TRANSFORMER PRIMARY VOLT-AMPERES PER LEG	=	3.49	1.11	1.11	1.21 :3=0.4034	1.05	1.28	1.05	× D.C. WATTS OUTPUT
AVERAGE OF PRIMARY AND SECONDARY VOLT-AMPERES	=	3.49	1.34	1.11	1.35	1.05	1.55	1.26	× D.C. WATTS OUTPUT
PRIMARY LINE CURRENT	=	1.57	1.00	1.00	0.817	1.41	0.817	0.707	× AVE. LOAD CURRENT × SEC. LEG VOLT / PRI. LINE VOLT.
LINE POWER FACTOR		----	0.900	0.900	0.826	0.955	0.955	0.955	

Table D: Derating Chart for Non-Compensated Thermal Magnetic Breakers Calibrated for 40°C

Breaker Ampere Rating at 40° C	Ampere Rating At 25° C (77° F)	50° C (122° F)	60° C (140° F)
Type EB			
15	17	13	11
20	22	18	16
25	28	23	21
30	33	28	26
35	39	30	25
40	44	37	34
50	55	46	42
60	66	56	52
70	77	65	60
90	99	84	78
100	110	94	87
Type EHB			
15	17	13	11
20	22	18	16
25	28	23	21
30	33	28	26
35	39	30	25
40	44	37	34
50	55	46	42
60	66	56	52
70	77	65	60
90	99	84	78
100	110	94	87
Type FB			
15	17	13	11
20	22	18	16
25	28	23	21
30	33	28	26
35	39	30	25
40	44	37	34
50	55	46	42
60	66	56	52
70	77	65	60
90	99	84	78
100	110	94	87
125	137	116 ✓	105
150	165	138	125
Type CA			
125	137	114	100
150	165	136	120
175	192	158	140
200	220	182	160
225	247	205	180
Type JB, KB			
70	79	63	55
90	102	81	71
100	115	89	76
125	140	114	102
150	171	134	116
175	200	156	134
200	230	178	153
225	252	205	183
250	281	227	201
Type DA			
250	275	235	220
300	330	276	252
350	385	325	301
400	440	372	340
Type LBB, LB			
70	85	63	55
90	107	82	73
100	121	90	79
125	145	116	106
150	188	132	111
175	210	159	141
200	243	180	157
225	255	212	198
250	294	250	208
300	364	270	236
350	412	322	291
400	471	368	333
Type LA 600 Amp Frame			
250	275	235	220
300	330	276	252
350	385	325	301
400	440	372	340
500	550	468	435
600	660	564	525
Type MA			
125	138	115	103
150	165	139	128
175	192	163	151
200	220	186	170
225	247	210	195
250	275	232	213
300	332	277	252
350	388	322	282
400	444	368	334
450	495	418	383
500	550	468	435
600	660	564	525
700	770	658	613
800	880	754	704
Type NB			
700	770	658	613
800	880	754	704
900	990	828	749
1000	1100	900	825
1200	1320	1090	1000
Type PB			
600	660	540	474
700	770	630	554
800	880	728	632
900	990	820	720
1000	1100	920	800
1100	1210	1010	891
1200	1320	1115	972
1400	1540	1304	1148
1600	1760	1500	1320
1800	1980	1690	1485
2000	2200	1880	1650
2500	2750	2350	2060
3000	3300	2820	2470

SELTRONIC Breakers

SELTRONIC breakers are insensitive to changes in ambient temperature. However they include circuitry to protect the components from abnormally high temperatures.

DESCRIPTION

PRODUCT COVERED:

Component - Systems, Electrical Insulation; Class 200(N) transformer designated PCP200R.

See Page 3 for limitations.

GENERAL CHARACTER:

The insulation system covered by this Report is for a transformer, see Page 3.

The limit of thermal endurance of the insulating system was determined by subjecting samples of the submitted system and a presently acceptable system (control) to a specific set of functional testing procedures and securing "limit of thermal endurance" points for all the samples at certain specified temperatures which are above the normal expected operating class rating.

The system performances were then analyzed by using the least squares method of regression analysis. A continuous relationship of thermal endurance and temperature was assumed and a regression line equation was calculated. This equation was used to predict the thermal endurance expected for a certain temperature class rating.

FACTORY LOCATION:

See Procedure Authorization Page (Sec. Gen.).

MARKING:

System designation on frame, coil, or core.

ENGINEERING CONSIDERATIONS (NOT FOR INSPECTOR USE):

Use - For use only in products where the acceptability of the combination is determined by Underwriters Laboratories Inc.

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lbry

Conditions of Acceptability - The following are among the considerations to be made in judging the use of this system in an end-use product.

1. The use of these insulation systems shall be employed in applications wherein the limitations as set forth in Table A are not exceeded.

2. The acceptable constructional features of the motor transformer, or coil assemblies, such as spacings, insulation thicknesses (greater than those specified under "Construction Details"), thickness and voltage rating of lead insulation (if applicable), etc., shall be determined in the end-use application.

3. The suitability for use when exposed to oil, chemicals, refrigerant, soaps, X-rays, ultra-violet light and the like, has not been determined by this investigation.

4. Acceptable combinations of materials are covered as separate tables under "Construction Details".

TABLE A

Insulation Class	Maximum Temperature	Indoor	Outdoor (Enclosed)	Maximum V
200(N)	200°C hot spot+	Yes	Yes	600

\+ - The maximum (hot spot) temperature is the highest temperature this insulation system can be operated at without decreasing the design life. This limiting temperature is made up of the ambient temperature, an observable temperature rise, and a hottest spot temperature allowance. Each of these may vary some for the application and type of equipment, but their sum should not exceed the maximum temperatures for the insulation system. The relationship among the ambient, hot spot allowance, and observable temperature rise is to be established in the end-product category.

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CONSTRUCTION DETAILS:

TABLE I

* CLASS 200(N) TRANSFORMER INSULATION SYSTEM

Insulation thicknesses indicated below are minimum.

The use of this insulation system is limited to the combination of materials specified below.

Insulation Function	Insulating Material
1. Magnet Wire	Copper or aluminum, round or rectangular or sheet.
2. Magnet Wire Insulation	Recognized Component - Magnet wire (OBMW2), single build or greater. A. Polyester basecoat with a polyamideimide topcoat (ANSI MW35 type). 1. "Anaclad A," marked AC-A, Anamag. 2. "Anaclad A(AL)," marked AC-A(AL), Anamag. 3. "Anaclad-MR," marked AC-MR, Anamag. 4. "Anaclad-MR(AL)," marked AC-MR(AL), Anamag. 5. "Anamid-A," marked A-A, Anamag. 6. "Polyester Imide," marked HPI or SPI, Chicago Magnet Wire Corp. 7. "GP-200," marked GP-200, Essex Group 8. "MR-200," marked MR-200, Essex Group. 9. "Esterimide/Al," General Electric. 10. "Armored Poly-Thermaleze 2000," marked APTZ or Armored APTZ or Armored Poly-Thermaleze 2000, Phelps Dodge Magnet Wire Co. 11. "M/R Thermaleze," marked M/R TZ, Phelps Dodge Magnet Wire Co. 12. "Therm-Aimid," marked TAI, Rea Magnet Wire Co. 13. "Super Hyslik 200," marked TAIH, Rea Magnet Wire Co. 14. "Polyklad II," marked PK II, Westinghouse Electric Corp.

Table continued.

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Insulation Function		Insulating Material
	15.	"Omagaklad," marked OK, Westinghouse Electr Corp.
	16.	"Hydroshield" marked OHS, Westinghouse Electric Corp.
	17.	"Omagaklad II," marked OK II, Westinghouse Electric Corp.
	18.	"Hydroshield II," marked OHS II, Westinghouse Electric Corp.
3. Ground and Interwinding Insulation	A.	Aramid paper, 10 mils nominal, 8.5 mils minimum thickness, "Nomex 410, 411, 414, 418, 424, 425 and E59", aramid pressboards, "Nomex E93 and E94," Du Pont.
	B.	Moldable polyethylene terephthalate, 40 mils minimum thickness, "Rynite FR-530", Du Pont.
4. Layer Insulation	A.	Series 2100-Friction coated polyester films (2100-FCF), Chase Foster, Keene Corp.
	B.	Series 2000-Estermat 02F-353 (2000-DMD), saturated polyester mat laminated to polyester film, Chase Foster, Keene Corp.
	C.	Series 5000-Estermat 03K-454 (5000-K CMC), Cal-glass laminated to polyester film, Chase Foster, Keene Corp.
	D.	Series 4000-Astromat IV: 04J-353, nonwoven aramid mat laminated to polyester film, Chase Foster, Keene Corp.
	E.	Mica No. 77520, NEMA Grade 6, flexible mica plate with epoxy binders, G.E.
	F.	Copaco 125, cotton rag - no binders, Cottrell Paper Co.

Table continued.

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ATTACHMENT A-2 4 pages

1

ESSEX
GP-200
PRODUCT AND APPLICATION DATA

SECTION B

PAGE 1

Class 200
Copper or Aluminum;
Round, Square or Rectangular Conductors;
Polyester/polyamide imide coated magnet wire

← OPEN

Quality
ESSEX
Masters

Performance Data/ESSEX/GP-200 — #18AWG HEAVY BUILD

PROPERTY	DESCRIPTION OF TEST
THERMAL PROPERTIES	
Thermal Stability	NEMA — ASTM D2307 — Unvarnished specimens in air — 20,000 hours extrapolated endpoint with 5000 hours at 20°C above rating.
Thermoplastic Flow	NEMA — 2000 grams on crossed wires with 5°C/minute temperature rise.
Heat Shock Resistance	NEMA — Elongation and mandrel wrap. ½ hour bake at temperature.
Overload Resistance — Figure of Merit	NEMA — Stepwise current-time resistance heating of twisted pair.
— Rapid Collette	Resistance heating of bifilar collette with internal thermocouples.
— Hermetic Collette	Bifilar collette conditioned 72 hours in R-22, resistance heated to 300°C and tested for breakdown voltage.
PHYSICAL PROPERTIES	
Adhesion and Flexibility — NEMA	Elongation followed by mandrel wrap
— Slit Twist	Specimen twisted until film loses adhesion at slit down one side.
Abrasion Resistance — Unidirectional	NEMA — Scrape test with increasing load to penetration with a .009" needle.
— Single Scrape	Load on .05" needle necessary to penetrate film 8 times out of 10 at 12" per second.
Coefficient of Friction	Tentative NEMA — Dynamic Single Line Tester, 450gm load at 50 ft./min.
Springback	NEMA — Restoration on release in deg. per turn from 3¼" mandrel wrap.
Conductor Elongation	NEMA — Percent increase in length in 10" to break, at 12" per minute.
Conductor Tensile Strength	Stress to break specimen.
Conductor Yield Strength	Stress to cause permanent elongation at 0.2% offset.
ELECTRICAL PROPERTIES	
Dielectric Strength — Room Temperature	NEMA — Twisted pair breakdown voltage, rms AC.
— Rated Temperature	NEMA — Twisted pair breakdown at 200°C.
Continuity	NEMA — 1500VDC applied to 100 ft. wire length by grooved rollers.
CHEMICAL PROPERTIES	
Solvent Resistance — NEMA	30 minute immersion at 60°C in xylene, perchlorethylene, and 50/50 ethyl Cellosolve/xylene, followed by scrape with .016" needle.
— Other Solvents	Petroleum naphtha, 3° toluene, ethanol, 5% sulfuric acid, 1% potassium hydroxide, butyl acetate, acetone for 24 hours at room temperature.
Refrigerant Resistance — Extraction	NEMA — 6 hours reflux cycling in R-22, residue as percent of film weight.
— Blistering	R-22 conditioned specimens rapidly transferred to oven at 125°C for 10 min.
— Softening	16 hour immersion in liquid R-22 at room temp., scrape with .016"needle.
— Dielectric Strength	NEMA — Retention of dielectric strength after R-22 conditioning for 72 hours.
— Overload	See Hermetic Collette test listed with Thermal Properties above.
— Crazing	Specimens annealed after 8% elongation immersed 1 hour in liquid R-22 and 10 minutes in boiling R-113.

COPPER CONDUCTOR		ALUMINUM CONDUCTOR	
TYPICAL PERFORMANCE*	REQUIRED PERFORMANCE	TYPICAL PERFORMANCE*	REQUIRED PERFORMANCE
210°C	200°C, minimum†	220°C	200°C minimum†
340°C	300°C, minimum†	415°C	300°C minimum†
20%, 1X D no cracks	20%, 3X D, no cracks†	15%, 2X D, no cracks	15%, 3X D, no cracks†
8.5 Fig. of Merit	6.8 Fig. of Merit, minimum†	11.4 Fig. of Merit	6.8 Fig. of Merit, minimum
570°C	525°C, minimum	610°C	525°C minimum
4300 volts	2500 volts, minimum	6400 volts	2500 volts, minimum
20%, 1X D, no cracks	20%, 3XD, no cracks†	15%, 2X wrap	15%, 3X D, no cracks†
45 turns	35 turns, minimum	45 turns	35 turns, minimum
1300gm, avg.	980gm, minimum; 1150gm, minimum avg.†	1230gm, avg.	590gm, minimum; 690gm, minimum, avg.†
28 lbs.	20 lbs. minimum	Wire breaks before penetration	No req'mt. established
Oil: .13-.15	No req'mt. established	Oil: .14-.16	No req'mt. established
54 degrees	58 degrees, maximum†	38 degrees	58 degrees, maximum
38%	32%, minimum†	22%	15%, maximum†
35,900 psi, avg.	36,000 psi, maximum	16,500 psi, avg	15,000 psi, minimum
16,800 psi, avg.	21,000 psi, maximum	10,100 psi, avg	8,000 psi, minimum
15,700 volts, avg.	5,700 volts, minimum†	10,500 volts, avg.	5,700 volts, minimum†
8,850 volts, avg.	4,275 volts, minimum†	7,200 volts, avg.	4,275 volts, minimum†
No faults/100 ft.	5 faults/100 ft., maximum†	No faults/100 ft.	10 faults/100 ft. maximum†
Passes	580gm scrape, minimum†	Passes	340gm scrape, minimum†
Passes	580gm scrape, minimum	Passes	340gm scrape, minimum
0.07%	0.25%, maximum†	0.07%	0.25%, maximum†
Passes	No blistering	Passes	No blistering
Passes	580gm scrape, minimum	Passes	340gm scrape, minimum
12,300 volts	5,700 volts, minimum†	9,200 volts	5,700 volts, minimum
4,300 volts	2,500 volts, minimum	6,400 volts	2,500 volts, minimum
Passes	No crazing at 10X magnification	Passes	No crazing at 10X magnification

* The values shown represent typical average results and are not intended to be used as design data or specification limits.
†Requirements of NEMA MW 1000; Section MW 25-C, MW 35-A, or MW 73-C, as applicable.

PRODUCT AND APPLICATION DATA

GP-200

APPLICATION

GP-200 is recommended for all applications where modified polyester, polyester-imide or polyester-amide-imide wires have been used and in hermetic applications where an improved construction over the hermetic grade Formvar is desirable.

The improved thermal characteristics of GP-200 have proven most beneficial in extreme duty applications such as power tool armatures.

Windability of GP-200, as predicted by the Essex Needle Test and verified by years of experience on high speed stator and armature winders, is excellent. No winding application is too tough for Essex GP-200.

GP-200 is recommended for various end uses as follows:

Rotating Machines
- Fractional and Integral HP Motors
- Hermetic Motors
- DC Motors
- Power Tools
- Automotive Alternators and Generators

Transformers
- All dry type, Class 105 through 200
- Control type

Electronics
- All types of coils, Class 105 through 200

ENGINEERING HIGHLIGHTS

1. What is the thermal rating of GP-200? Extrapolated ASTM-D-2307 data yields a temperature of 210°C for copper conductor and 230°C on aluminum conductor at 20,000 hours, the NEMA classifications for the constructions are Class 200 and Class 220 respectively. However, most high temperature applications have been limited to Class 180 because of total systems capability.

2. What improvement has been realized in the heat shock? GP-200, stretched 20%, then wound on a 3X diameter mandrel not heat shock at temperatures as great as 250°C (456°F). GP-200 has been improved by nearly 100°C over modified polyesters with regard to heat shock.

3. Is the thermoplastic flow resistance of GP-200 substantial? The thermoplastic flow point of GP-200 as determined by constant pressure and increasing temperature methods has been found to be nearly 30° higher than modified polyester and approximately 100°C higher than Formvar.

At a constant temperature of 250°C and an increasing load, GP-200 and polyester will flow at a loading of 36 pounds; Formvar flows at 8 pounds.

4. What does GP-200 offer in the area of burnout? Burnout is a result of high temperatures and exposure time to these temperatures. Laboratory testing of single twisted pairs, bifilar twisted pairs and coils have shown that GP-200 is 50% better than modified polyester and 100% better than Formvar in burnout resistance.

5. Why should GP-200 be considered for hermetic applications? GP-200 has a lower extractable level in R-22 as compared to formvar. Also, laboratory testing has shown that pre-annealing of GP-200 eliminates R-22 blister problems when the wire is heated either internally or externally after exposure to the refrigerant. The R-22 resistance of GP-200 coupled with the first four properties discussed have correctly predicted its widespread use in hermetic applications.

6. Can GP-200 be wound on automatic equipment? The Essex Needle Test has indicated this construction to be one of the most windable magnet wires available today. This laboratory data has been substantiated by day-in-day-out use of GP-200 on the very latest high speed automatic winding equipment.

7. Does GP-200 resist hydrolysis? After four hours at 180°C in a sealed tube containing three parts of water to one part of film insulation by weight, GP-200 retains a dielectric strength of 3000 volts per mil, and does not soften, expand or tube.

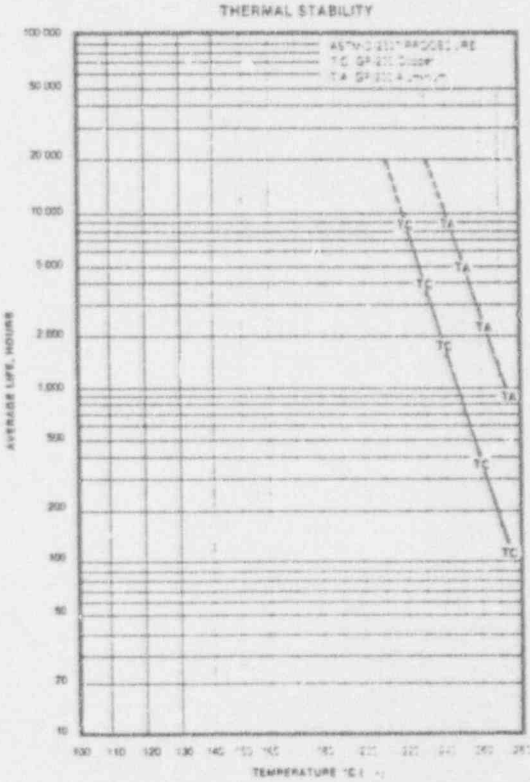
8. Can GP-200 be used in existing insulation systems? In application, the thermal rating of the system will be established by the total system specified. For operation at Class 200 temperatures, the components of the system must match the rating of the wire.

For lower temperature systems, where GP-200 is specified for added safety, materials of the desired thermal rating may be used.

9. How can GP-200 be connected? Insulation piercing terminals, hot staking and direct flame welding processes can all be used with GP-200. If the connection is to be soldered, the insulation must be removed prior to soldering. It is recommended that mechanical methods be used to remove or strip GP-200.

10. Will GP-200 be adaptable to oil filled transformers? Laboratory tests have indicated this material does possess the required performance characteristics in oil filled applications. However caution must be used. If the outer topcoat of amide-imide is fractured or scraped off as may occur in winding, the base polyester is exposed to whatever elements of degradation may be present in the system.

THERMAL STABILITY



MAGNET WIRE & INSULATION DIVISION 1510 WALL STREET FORT WAYNE, IN 46804

Attachment B-1 Reproduced from *Design Shortcuts and Procedures for Electronic Power Transformers and Inductors* ©1975 Harris Publishing Co.

One other method often used and to be considered for the subject of ΔT is:

$$\Delta T = \frac{K\,(\text{Cu losses} + .65\ \text{fe losses})}{Ac_1\sqrt{\frac{Ac_2}{Ac_1}}} + 1.5$$

Where Ac_1 = Area of square core stack in CM^2

Where Ac_2 = Area of actual core stack in CM^2

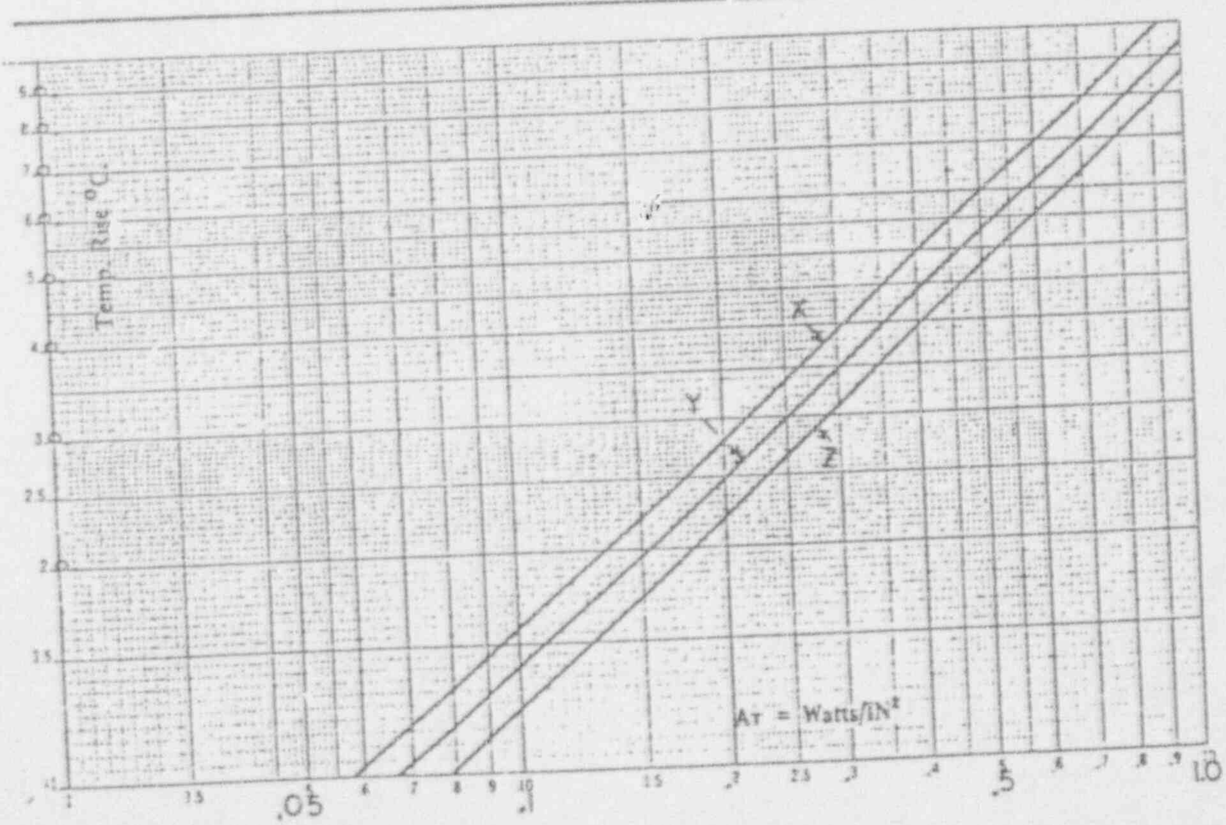
Where Cu losses = Conductor losses at amb. temp.

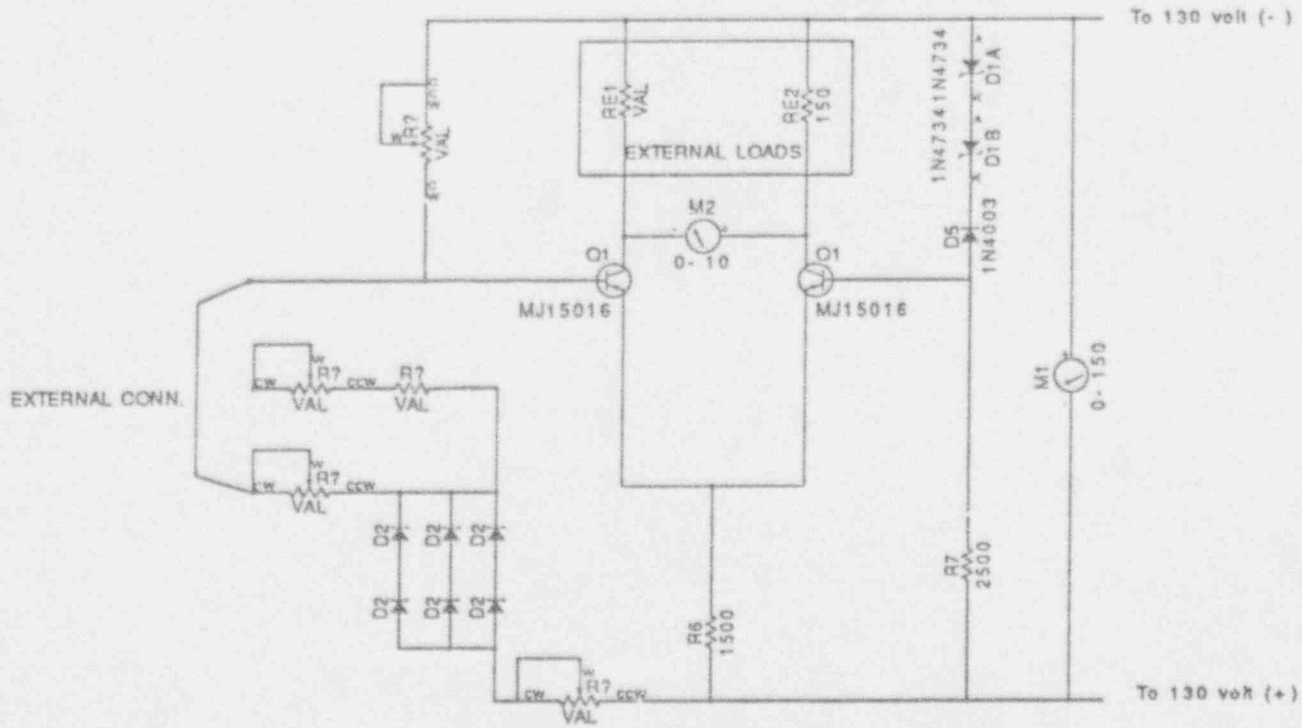
Where K = Constant for type construction, impregnation, encapsulation and physical size of lamination with level ranging from 30 to 58.

Examples for K:

38 for epoxy or polyester encapsulation
43 to 50 for EI-1″ to EI-1.5″ core and coil impregnation
46 to 58 for EI-1.75″ to 2.25″ core and coil impregnation

K levels may be established from pertinent types of construction and impregnation used from experience and practices.





ATTACHMENT D- 1

STONE AND WEBSTER P/ O 02268.5004

DESCRIPTION OF CHANGE PER ECO NO.	
ENGINEER JTM ENG.	power conversion products inc crystal lake, illinois 60014 (800) 435- 4872
DRAFTER DRAWN	
APPROVED	TANGO SCHEMATIC VERSION 1.2
	SCHEMATIC TEST CKT FOR MAGAMP CONTROL
	DRAWING ISSUED DATE
	PAGE OF / REV
	DRAWING NUMBER

ATTACHMENT 2 TO JPN-93-019

Documentation of Changes to Analysis

PAGE/LOCATION	CHANGE	REMARKS
NYPA Cover Sheet	New	Provides documentation of NYPA approval and NYPA Transmittal Number
Title Page	Revision History	Editorial change
Title Page	Deletion of "©" and "All Rights Reserved" statement	Deleted to allow placement of analysis in NRC PDR
Title Page	Deletion of documentation of NYPA approval	Now provided on NYPA Cover Sheet
Index (2 pages)	All	Editorial changes
Section 4, Page 3, First Paragraph	Addition of first two lines	First two lines inadvertently left out in Revision 2
Section 8, Pages 3 and 4	All	Editorial changes
Appendix D, Section 1, Page 1, Second Paragraph	Deletion of description of silicon devices	Editorial change, description of silicon devices immaterial to discussion of test
Appendix D, Section 2, Page 1	Deletion of "Digital Thermometer"	Editorial change, thermometer is part of the environmental test chamber
Appendix D, Section 4, Page 1	Section 4 moved forward from Page 2	Editorial change
Appendix D, Section 4, Page 2	All	Providing calibration information, remainder of changes are editorial
Appendix F, Attachment 1	Deletion of title	Editorial change
Appendix F, Attachment 4	Deletion of title	Editorial change
Appendix F, Attachment A-1, Pages 1 through 4	Modification of title	Editorial changes
Appendix F, Attachment A-2, Pages 1 through 4	Modification/deletion of title	Editorial changes
Appendix F, Attachment B-1	Replacement page	Wrong page provided in Revision 2