

Technical Report:



**Optimized
transformer
designs which yield
significant production
cost reductions.**

Those seeking increased coil life ...

Those needing greater product performance and reliability ...

And those striving for lower total production costs ...

can achieve all three by utilizing optimized coil designs as demonstrated in this report.



INTRODUCTION

Substantial manufacturing cost reductions may be achieved through optimized transformer designs that incorporate the superior qualities of IPT electrical insulation materials.

It is a well-established fact that, in addition to being less costly, IPT inorganic-based papers outperform aramid papers in thermal conductivity, long-term voltage endurance, and resistance to moisture absorption.

The purpose of this study, conducted by Optimized Program Service, Inc. of Berea, Ohio, is to demonstrate that core and/or conductor costs can also be reduced significantly by optimizing transformer design to take advantage of the high thermal conductivity exhibited by IPT materials.

STUDY PROCEDURE

The study was conducted by using the TOPT program. TOPT employs advanced non-linear mathematical routines to arrive at the lowest cost designs for each material combination selected. In this particular study, the total costs shown were the summation of costs for core, conductor, and insulation. TOPT produces a blend of these three components of cost that gives the lowest total cost for designs meeting constraints such as temperature rise, regulation, window fill, etc.

The major factor influencing the transformer designs in this study is the thermal conductivity of the materials considered. Thermal conductivity values used in this study were taken from a technical report on a study performed by an independent laboratory. Values of thermal conductivities used are shown in Table I. The values shown in Table I are used without modification. Some of these values may increase for certain materials when properly impregnated with varnish.

<u>Material Type</u>	<u>Thermal Conductivity*</u>	
	<u>155°C</u>	<u>190°C</u>
Aramid paper	.079	.085
CeQUIN® I	.098	.1085
TufQUIN®	.1103	.1175

*BTU • ft / hr • °F • ft²

RESULTS

Each comparison contains the optimized system design and indicates the type of material used. Also shown are the thicknesses used in each system. Thicknesses shown were selected on the basis of judgment and observed practices in the field.

DESCRIPTION

TRANSFORMER TYPE: Dry Type Distribution, 225 KVA
 TEMPERATURE CLASS: 220C
 CONDUCTOR TYPE: Aluminum Strip
 COMPARISON BETWEEN: CeQUIN I®
 Primary layer insulation thickness: .005"
 Secondary layer insulation thickness: .007"
 Barrier insulation thickness: .030"

COST COMPARISONS

INSULATION TYPE	CORE	CONDUCTOR	INSULATION	TOTAL
Aramid paper	1137.76	150.00	141.89	1429.65
CeQUIN I	978.27	191.17	84.92	1254.36
Difference	-159.49	+41.17	-56.97	-175.29
% SAVINGS				12.3%

OPTIMUM DESIGN*

	Aramid paper	CeQUIN I®
TEMP	= 149.9525	149.9545
% REG	= 2.4492	2.5445
% IMP	= 4.5470	4.8465
% BUILD	= 79.9881	79.9405
WATTS	= 6913.4554	6881.0933
FE WATTS	= 1568.0998	1348.2895
LENGTH	= 43.0049	38.9907
DEPTH	= 17.1484	19.7801
HEIGHT	= 21.2911	19.2727
COND	= 150.0039	191.1681
CORE	= 1137.7595	978.2727
LAYER	= 97.6387	73.2455
SECTION	= 30.4223	13.7735

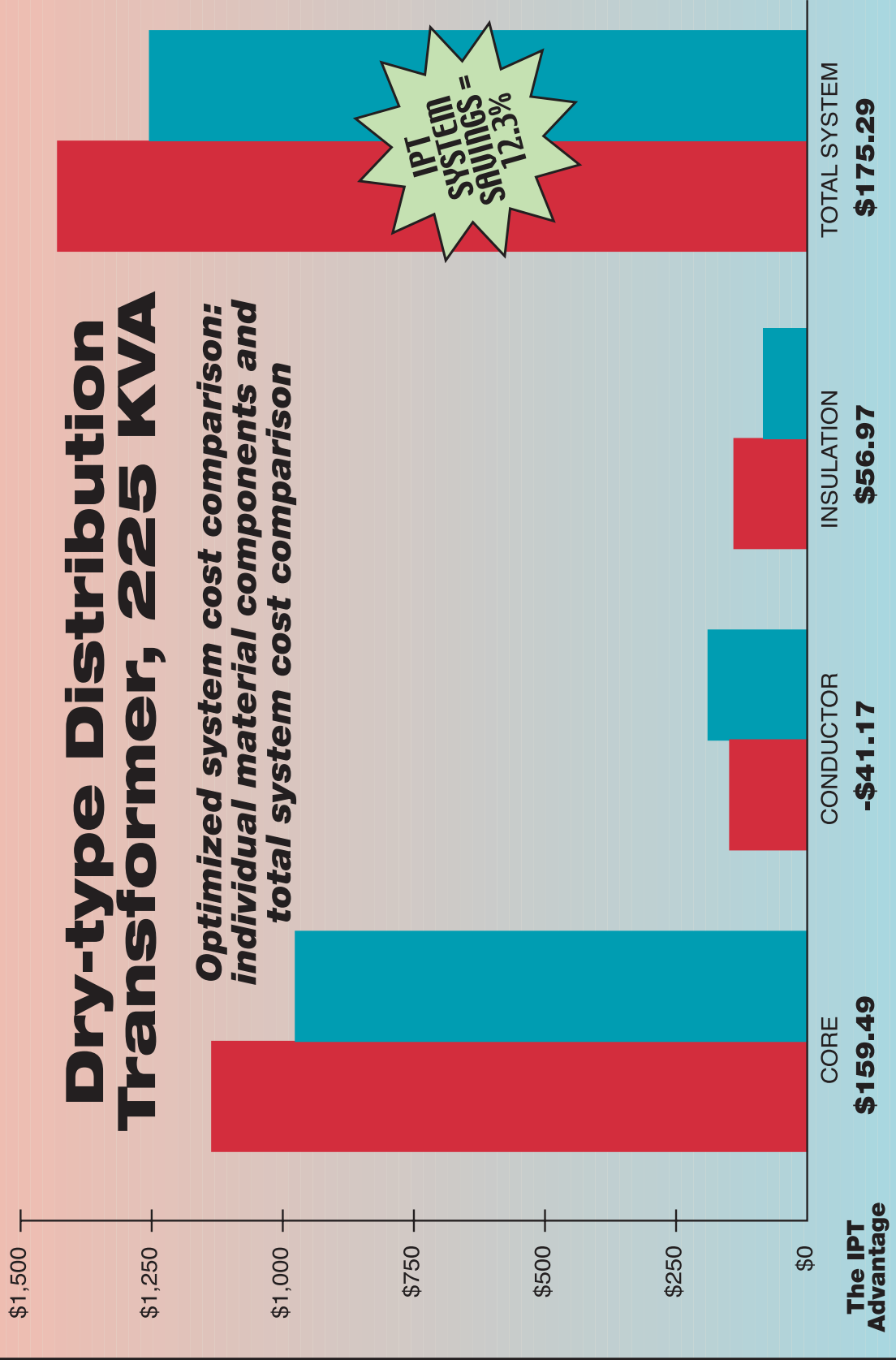
DESIGN VARIABLES

T	= 6.0000	4.3054
S	= 8.8134	11.0886
H	= 8.3350	8.6914
W	= 9.2911	10.6618
Jp	= 2.0226	1.8853
B	= 15.6888	15.6888
OBJECTIVE	= 1415.8244	1256.4597

*Design parameters and variables are defined in the appendix on page 8.

Dry-type Distribution Transformer, 225 KVA

*Optimized system cost comparison:
individual material components and
total system cost comparison*



Cost using aramid paper

Cost using CeQUIN® I

DESCRIPTION

TRANSFORMER TYPE: Dry Type Distribution, 45 KVA
 TEMPERATURE CLASS: 220C
 CONDUCTOR TYPE: Aluminum Foil 3 mil.
 COMPARISON BETWEEN: Aramid paper CeQUIN® 3000
 Primary layer insulation thickness: .003"
 Secondary layer insulation thickness: .003"
 Barrier insulation thickness: .020"

COST COMPARISONS

INSULATION TYPE	COST IN DOLLARS		
	CORE	CONDUCTOR	INSULATION TOTAL
Aramid paper	269.15	38.03	71.95
CeQUIN 3000	215.75	63.40	47.51
Difference	-53.40	+25.37	-27.44
% SAVINGS			13.8%

OPTIMUM DESIGN*

	Aramid paper	CeQUIN® 3000
TEMP	= 141.3761	143.0355
% REG	= 2.9972	3.0000
% IMP	= 3.3441	4.1040
% BUILD	= 79.9621	79.9499
WATTS	= 2212.7553	2028.6661
FE WATTS	= 868.1129	695.8780
LENGTH	= 20.4450	23.2388
DEPTH	= 13.0446	12.8362
HEIGHT	= 12.8777	13.0519
COND	= 38.0252	63.4029
CORE	= 269.1454	215.7465
LAYER	= 56.7902	44.2603
SECTION	= 8.4965	4.3197

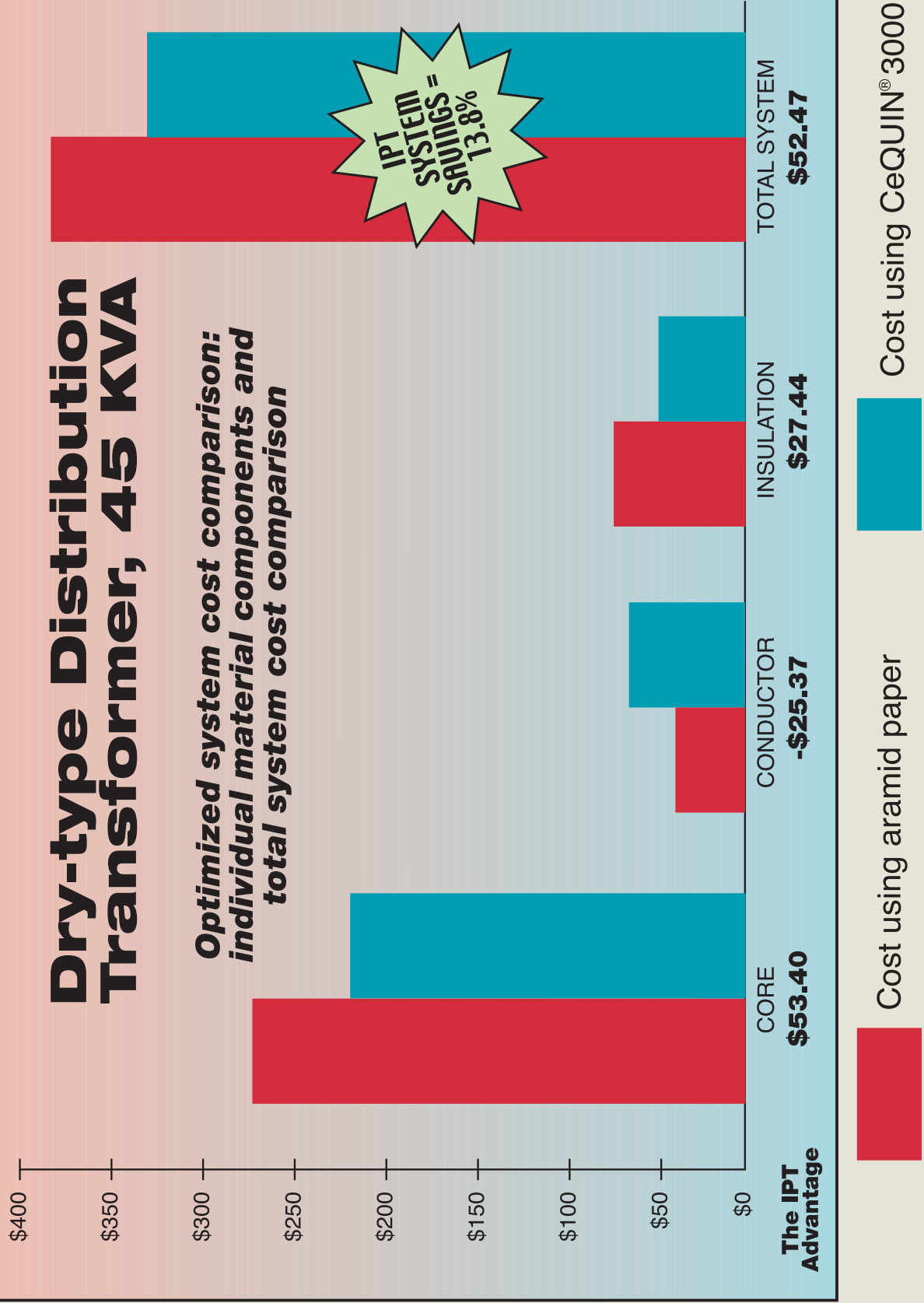
DESIGN VARIABLES

T	= 4.1701	3.8788
S	= 6.3997	4.9687
H	= 2.6449	3.8675
W	= 4.5375	5.2943
Jp	= 1.8869	1.4571
B	= 15.9720	15.9720
OBJECTIVE	= 372.4573	327.7294

*Design parameters and variables are defined in the appendix on page 8.

Dry-type Distribution Transformer, 45 KVA

*Optimized system cost comparison:
individual material components and
total system cost comparison*



DESCRIPTION

TRANSFORMER TYPE: Battery Charger
 TEMPERATURE CLASS: 180C
 CONDUCTOR TYPE: Copper Wire
 COMPARISON BETWEEN: Aramid paper TufQUIN® 110
 Primary layer insulation thickness: .010"
 Secondary layer insulation thickness: .010"
 Barrier insulation thickness: .020"

COST COMPARISONS

INSULATION TYPE	COST IN DOLLARS			TOTAL
	CORE	CONDUCTOR	INSULATION	
Aramid paper	61.20	36.65	12.92	110.77
TufQUIN	55.91	33.99	7.27	97.17
Difference	-5.29	-2.66	-5.65	-13.60
% SAVINGS				12.3%

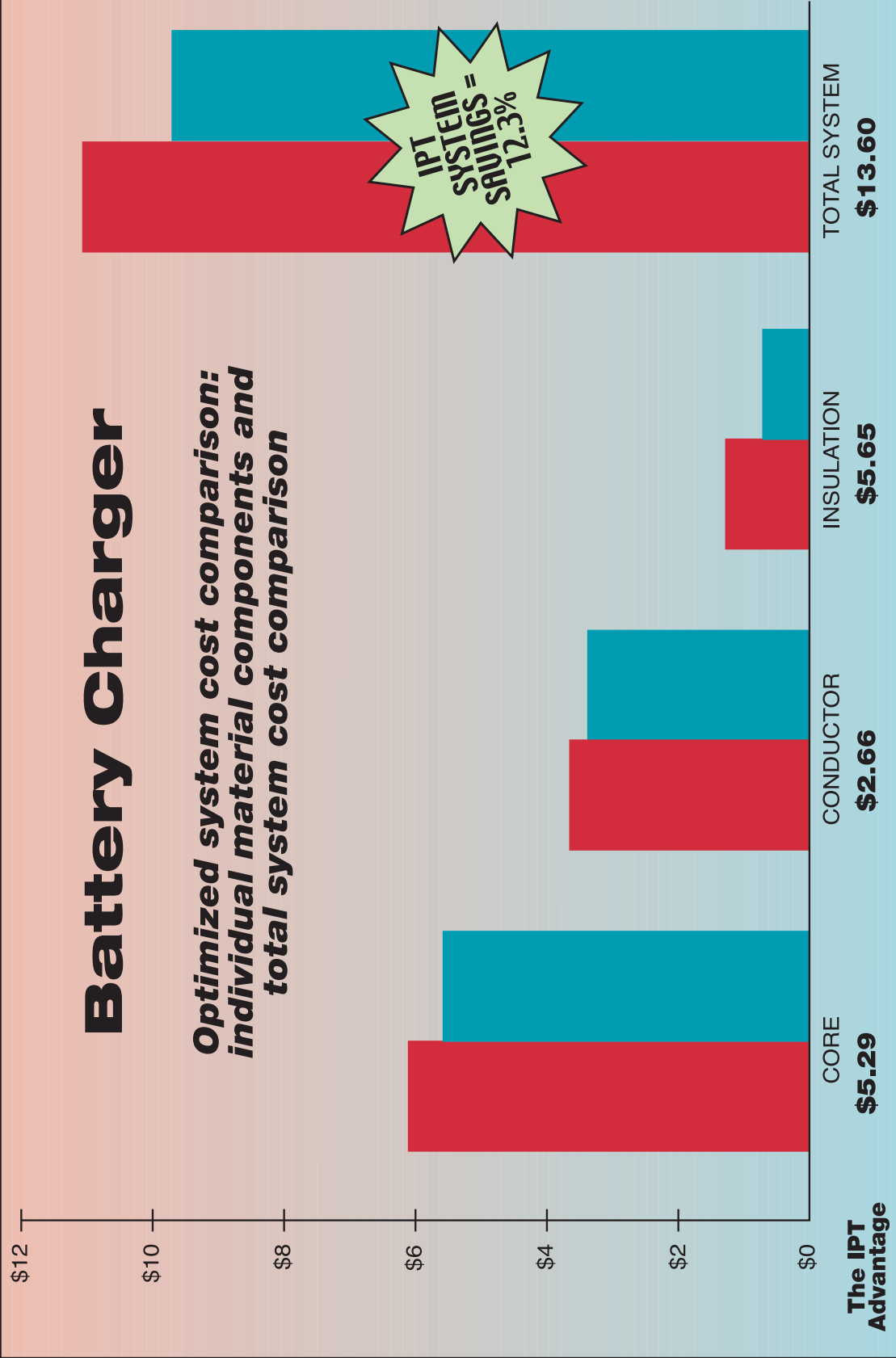
OPTIMUM DESIGN*

	Aramid paper	TufQUIN® 110
TEMP	= 109.8770	109.9694
% REG	= 2.9995	3.4995
% IMP	= 3.0200	3.5206
% BUILD	= 79.9805	79.9591
WATTS	= 345.1137	371.8845
FE WATTS	= 121.3718	110.8746
LENGTH	= 11.9268	11.6141
DEPTH	= 4.9559	4.7633
HEIGHT	= 9.8309	9.6983
COND	= 36.6536	33.9895
CORE	= 61.2051	55.9116
LAYER	= 5.4548	3.4982
SECTION	= 6.2104	3.9185
DESIGN VARIABLES		
T	= 2.4471	2.3786
S	= 3.4277	3.2710
H	= 1.5286	1.4930
W	= 4.9368	4.9411
Jp	= 2.2104	2.4791
B	= 15.0000	15.0000
OBJECTIVE	= 109.5239	97.3178

*Design parameters and variables are defined in the appendix on page 8.

Battery Charger

**Optimized system cost comparison:
individual material components and
total system cost comparison**



**IPT
SYSTEM
SAVINGS =
12.3%**

Cost using aramid paper Cost using TufQUIN®

APPENDIX

DESCRIPTIONS OF DESIGNS

A brief description of the designs used in this study follows:

A. Dry-Type Distribution Transformer

This is a 225 KVA, 3 phase distribution transformer operating off a 480V line and producing an output of 208/120 volts at 60HZ.

The aluminum foil strip-wound design compares aramid paper with CeQUIN I in a Class 220(R) insulation system.

B. Dry-Type Distribution Transformer

The model chosen for this comparison was a 45 KVA, industrial dry-type isolation transformer operating at 60 HZ off of a 480 volt line and producing an output of 208/120 three phase.

The aluminum foil strip-wound design compares aramid paper with CeQUIN 3000 in a Class 220(R) insulation system.

C. Battery Charger

This transformer is used in conjunction with electronic controls for an 18-cell, 850 ampere hour 3-phase industrial-type battery charger.

The copper wire-wound design compares aramid paper with TufQUIN 110 in a Class 180(H) insulation system.

DEFINITION OF TERMS

(Costs are in dollars)

OPTIMUM DESIGN

TEMP	=	Avg. temperature rise in degrees C
% REG	=	% voltage regulation
% IMP	=	% impedance
% BUILD	=	Measure of fill in the core window
WATTS	=	Sum of core and conductor loss
FE WATTS	=	Core loss only
LENGTH	=	Length of core-coil assembly
DEPTH	=	Depth of core-coil assembly
HEIGHT	=	Height of core-coil assembly
COND	=	Cost of conductor material
CORE	=	Cost of core material
LAYER	=	Cost of layer insulation
SECTION	=	Cost of barrier insulation

DESIGN VARIABLES

T	=	Core strip width
S	=	Core stack height
H	=	Core window dimension
W	=	Core window dimension
Jp	=	Current density in primary winding in kilo-amperes per sq. inch
B	=	Flux density in the core in kilo-gausses
OBJECTIVE	=	Sum of core, conductor, and insulation costs.

The % difference of the total system cost shown in each comparison is based on the dollar savings using IPT materials in the optimized design versus the total cost of the aramid paper optimized design. Dollar values were based on available material list prices. For current cost savings, contact IPT.

COMPETITIVE ADVANTAGES OF SPECIFYING IPT MATERIALS

- ◆ Superior thermal conductivity
- ◆ Resistance to moisture absorption
- ◆ Long-term voltage endurance
- ◆ Cost-effective materials
- ◆ Optimized design reduces system cost
- ◆ UL® Systems recognition
- ◆ CSA Component acceptance



INNOVATIVE PAPER TECHNOLOGIES, LLC

TYPICAL APPLICATIONS FOR DRY TYPE TRANSFORMER DESIGNS

- ◆ Core wrap insulation
- ◆ Ground insulation
- ◆ Phase insulation
- ◆ Barrier insulation
- ◆ End fill
- ◆ Interwinding for strip-wound coils



INNOVATIVE PAPER TECHNOLOGIES, LLC

Innovative Paper Technologies, LLC
P.O. Box 739 • Tilton, New Hampshire USA 03276-0739
Toll-Free: 866-357-2737 • Fax: 603 286-4859
www.iptllc.net • info@iptllc.net