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Revision 0

Transformer Efficiency Assessment – Okinawa, Japan

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EXECUTIVE SUMMARY

The US Army Engineering & Support Center, Huntsville (USAESCH), and the US Marine Corps Base (MCB), Okinawa, Japan retained Idaho National Laboratory (INL) to conduct a Transformer Efficiency Assessment of "key" transformers located at multiple military bases in Okinawa, Japan. The purpose of this assessment is to support the Marine Corps Base, Okinawa in evaluating medium voltage distribution transformers for potential efficiency upgrades. The original scope of work included the MCB providing actual transformer nameplate data, manufacturer's factory test sheets, electrical system data (kWh), demand data (kWd), power factor data, and electricity cost data. Unfortunately, the MCB's actual data is not available and therefore making it necessary to de-scope the original assessment. Note: Any similar nameplate data, photos of similar transformer nameplates, and basic electrical details from one-line drawings (provided by MCB) are not a replacement for actual load loss test data. It is recommended that load measurements are performed on the high and low sides of transformers to better quantify actual load losses, demand data, and power factor data. We also recommend that actual data, when available, be inserted by MCB Okinawa where assumptions have been made and then the LCC analysis updated. This report covers a generalized assessment of modern U.S. transformers in a three level efficiency category, Low-Level efficiency, Medium-Level efficiency, and High-Level efficiency.

There were 18 Energy Conservation Investment Program (ECIP) LCC analysis scenarios ran for this project. Some of the assumptions utilized for the ECIP LCC analyses and project construction cost estimates include: an operating period of 30 years, on-line date of 1/1/13, discount rate of 3%, other rates and factors given by 2012 FEMP rates, 100% government funded, base energy rates of $0.229 per kWh, and install and removal costs at approximately $25,000. Note: Transformer prices, base energy rates, and removal/install costs could vary significantly depending on the situation, so any approximations used in this report should be refined for better matching to actual project details of future transformer replacements. Low-level transformers while being the least expensive to purchase would not be the best option for the long term. This transformer would only be an option if initial price was the only factor for purchasing transformers and the losses experienced over the life of the transformer did not matter. The medium-level transformers have a better efficiency percentage than the assumed Okinawa transformers, although it is only slightly better. The High-Level transformers have the highest efficiency percentages and will have the greatest energy savings.

The LCC analysis brought to light several facts. Running transformers at small loads, such as the 20% load analyzed, makes any transformer efficiency upgrade hard to justify because the Simple Payback Periods (SPP) are greater than the 30 year life expectancy of the transformer. Even at 60% loaded there are only two transformers (750 High & 1000 High) that have payback periods within the life term of the transformer. It is noted that if at all possible, transformers should be loaded to at least 35%.

We also looked at the differences between selecting the Medium-level or the High-level for upgrading Okinawa's transformers. We took the 1000 KVA transformer and compared the Total Costs and the Total Discounted Operational Savings. Table 5 (on Page 18 in the report below) shows that the

1000 KVA High-level transformer costs $24,438 more than the 1000 KVA Medium-level one. However, over the 30 year life term of these transformers the 1000 KVA will have $34,647 more in savings. By looking closer, we took the Total Discounted Operational Savings (TDOS) difference and divided by the 30 year life term to get a yearly approximation of the extra savings associated with the High-level transformer. We then took the difference in Price and divided it by the TDOS difference yearly amount and were able to determine that by upgrading with the High-Level Transformer instead of the Medium-Level; the difference in price will be made up in roughly 21.16 years. The 750 KVA and 500 KVA were also examined with the 750 KVA taking approximately 24.75 years and the 500 KVA taking 28.05 years. In all three examples, it would be justified to use High-Level transformers for upgrades instead of the Medium-Level ones but it is noted that even with the High-Level transformers it would be best to not replace existing transformers before they need be replaced.

The LCC analysis above has been applied to the 46 Key Transformers (26-500 KVA, 16-750 KVA, 4-1000 KVA) located at the military camps (Foster, Hansen, & Kinser). Table 7 (on Page 20) shows the costs/savings for the 46 transformers in the key transformer lists if Okinawa transformers were replaced with High-Level transformers.

We believe that under the current market conditions, several manufacturers/models of transformers could respond to a contracting/procurement process to supply transformer to this proposed project. The energy savings by installing a higher efficient transformer would not justify replacing a lower efficient transformer before the end of its life. If electrical energy savings are the primary goal, then greater savings would be achieved by considering building efficiency upgrades such as insulation, lights, windows, doors, appliances, smart-grid meters, micro-grid control systems, etc.

CONTENTS

FIGURES

TABLES

EQUATIONS

ACRONYMS

AIRR:	Adjusted Internal Rate of Return
DC:	Design Cost
DOE:	Department of Energy
ECIP:	Energy Conservation Investment Program
EOL:	End of Life
EULA:	End User Lease Agreement
ESPC:	Energy Savings Performance Contract
INL:	Idaho National Laboratory
KVA:	Kilovolt-Ampere
kW:	Kilowatt
kWd:	Kilowatt-demand
kWh:	Kilowatt-hour
LCC:	Life cycle cost
MCB:	Marine Corps Base
PF:	Power Factor
SIOH:	Supervision, Inspection, & Overhead
SIR:	Savings to Investment Ratio
SOW:	Statement of Work
SPP:	Simple Payback Period
TDOL:	Total Discounted Operational Loss
TDOS:	Total Discounted Operational Savings
UESC:	Utility Energy Service Contract
VAR:	Volt-amperes reactive power
XFMR:	Transformer

Transformer Efficiency Assessment – Okinawa, Japan

1. Introduction

The purpose of this assessment is to support the Marine Corps Base (MCB), Okinawa in evaluating medium voltage distribution transformers for potential efficiency upgrades. The original statement of work (SOW) included using actual transformer nameplate data, manufacturer's factory test sheets, electrical system data (kWh), demand data (kWd), power factor data, and electricity cost data. Unfortunately, the MCB's actual data is not available and therefore making it necessary to de-scope the original assessment. Note: Any similar nameplate data, photos of similar transformer nameplates, and basic electrical details from one-line drawings (provided by MCB) are not a replacement for actual load loss test data. It is recommended that load measurements are performed on the high and low sides of transformers to better quantify actual load losses, demand data, and power factor data. We also recommend that actual data, when available, be inserted by MCB Okinawa where assumptions have been made and the LCC analysis then updated. This report covers a generalized assessment of modern U.S. transformers in a three level efficiency category, low-level efficiency, medium-level efficiency, and high-level efficiency.

In the SOW's Appendix A (also **Appendix A** in this report) the MCB provided a list of 651 transformers in Japan. The amount of transformers was sorted and reduced to a more manageable list for this report. This was done by identifying transformers that were 10 years old or older and also by limiting transformers in the 500 KVA – 1000 KVA size range. This list was given to the MCB who then identified transformers on that list that were earmarked for replacement already. The remaining transformers make up the final list of key transformers used in this evaluation and is shown in Table 1.

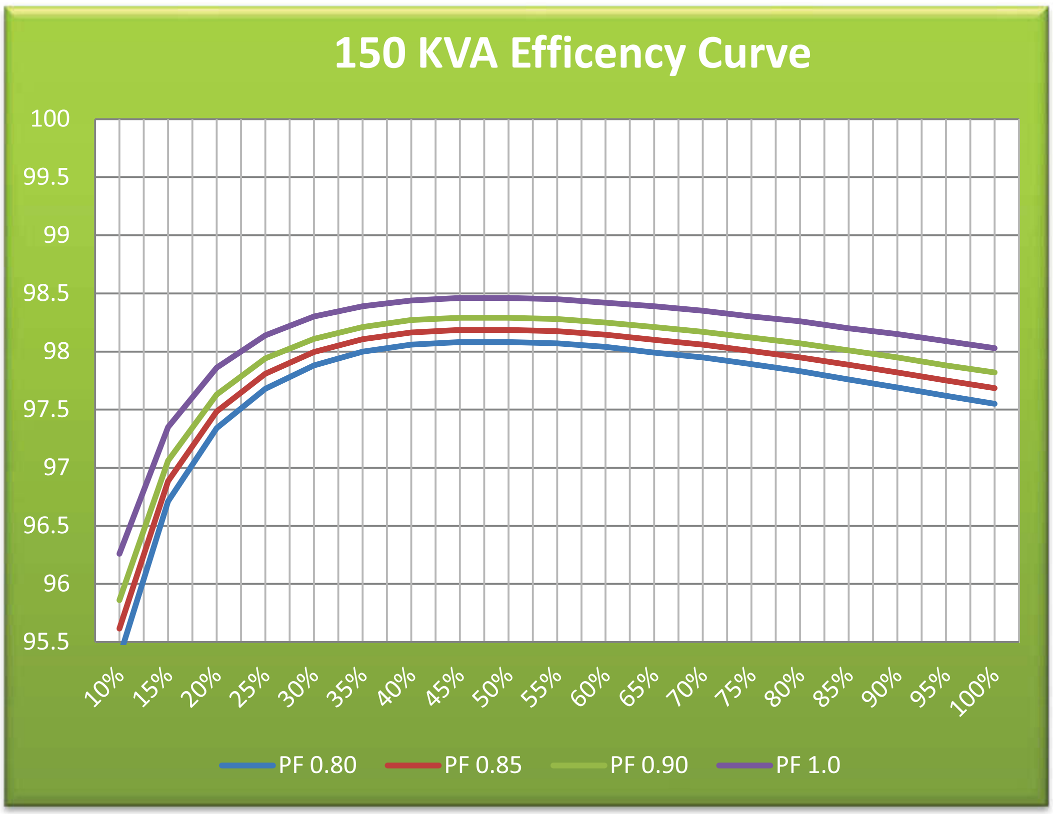
Table 1: Key Transformer List

CAMP	LOC	CAPACITY KVA	MANUFACT	MFR_DATE	Serial_ID	Type	#	#	#
FOSTER	5704 TS	500	AICHI	1989	892221701	Pad Mount	1		
FOSTER	5703 TS	500	AICHI	1989	892221702	Pad Mount	2		
FOSTER	478 TS	500	AICHI	1997	9721148	Pad Mount	3		
FOSTER	5696 TS	500	DAIHEN	1991	3SD1250A1	Pad Mount	4		
FOSTER	370 TS	500	DAIHEN	1991	3SD1253A1	Pad Mount	5		
FOSTER	481 TS	500	FUJI	1996	B50348AT1	Pad Mount	6		
FOSTER	445 TS	500	MEIDEN	1998	1N6330T1	Pad Mount	7		
FOSTER	490 TS	500	MITSUBISHI	1999	DD9891001	Pad Mount	8		
FOSTER	5670 TS	500	WESTING HOUSE	1989	89J495273	Pad Mount	9		
HANSEN	2860 TS	500	AICHI	1994	9421620	Pad Mount	10		
HANSEN	2519 TS	500	AICHI	1999	9821621	Pad Mount	11		
HANSEN	2622 TS	500	DAIHEN	1990	3SD1232A1	Pad Mount	12		
HANSEN	2665 TS	500	DAIHEN	1990	3SD1122A1	Pad Mount	13		
HANSEN	2530	500	DAIHEN	1992	3SD1424A1	Pad Mount	14		

	TS								
HANSEN	2340 TS	500	FUJI	1990	B90330A01	Pad Mount	15		
HANSEN	2441 TS	500	FUJI	1993	A24006T1	Pad Mount	16		
HANSEN	2141 TS	500	G.E.	1991	P817332TYF	Pad Mount	17		
HANSEN	2442 TS	500	MEIDEN	1990	1P9691T1	Pad Mount	18		
HANSEN	2221 TS	500	MEIDEN	1996	1T8311T1	Pad Mount	19		
HANSEN	2610 TS	500	MEIDEN	1999	1N6714T1	Pad Mount	20		
HANSEN	2165 TS	500	MITSUBISHI	1994	DH4649001	Pad Mount	21		
HANSEN	2518 TS	500	MITSUBISHI	1996	DN3220001	Pad Mount	22		
HANSEN	2245 TS	500	TOSHIBA	1999	99000692	Pad Mount	23		
KINSER	1225 TS	500	FUJI	1990	B00288A01	Pad Mount	24		
KINSER	616 TS	500	FUJI	1993	B30146A01	Pad Mount	25		
KINSER	99 TS	500	MITSUBISHI	1988	DM4692001	Pad Mount	26		
FOSTER	464 TS	750	ABB	1998	98J597224	Pad Mount	27	1	
FOSTER	5907 TS	750	AICHI	2001	1703349	Pad Mount	28	2	
FOSTER	11 TS	750	MEIDEN	2001	1P5419T1	Pad Mount	29	3	
FOSTER	480 TS	750	MITSUBISHI	1996	DM2743001	Pad Mount	30	4	
FOSTER	363 TS	750	MITSUBISHI	2001	DY1357001	Pad Mount	31	5	
HANSEN	2667 TS	750	AICHI	1993	9223017	Pad Mount	32	6	
HANSEN	2537 TS	750	DAIHEN	1992	3SD1429A1	Pad Mount	33	7	
HANSEN	2327 TS	750	DAIHEN	1993	3SD1605A1	Pad Mount	34	8	
HANSEN	2725 TS	750	FUJI	1992	B20168A01	Pad Mount	35	9	
HANSEN	2635 TS	750	HITACHI	1999	23339821	Pad Mount	36	10	
HANSEN	2893 TS	750	MEIDEN	1992	1R8626T1	Pad Mount	37	11	
KINSER	1202 TS	750	AICHI	1993	9222379	Pad Mount	38	12	
KINSER	1226 TS	750	DAIHEN	1991	3SD1272A1	Pad Mount	39	13	
KINSER	1210 TS	750	FUJI	1992	B10310A01	Pad Mount	40	14	
KINSER	104-A TS	750	FUJI	1993	A30954T1	Pad Mount	41	15	
KINSER	100 TS	750	MITSUBISHI	1989	DP3113001	Pad Mount	42	16	
FOSTER	1002 TS	1000	G.E.	1993	Q108279-TNI	Pad Mount	43		1
FOSTER	1004 TV	1000	WESTING HOUSE	1989	PAW4176-0101	Pad Mount	44		2
HANSEN	2365 TS	1000	FUJI	2001	B10215A01	Pad Mount	45		3
HANSEN	2654 TS	1000	TOSHIBA	2000	23589	Pad Mount	46		4

The transformers on this list are from 3 different camps (Foster, Hansen, & Kinser) and include 46 transformers (26-500 KVA, 16-750 KVA, 4-1000 KVA). The base actual loads for these transformers are an unknown and most likely vary per transformer. Original SOW called for analyzing base loads at 30% and 70%, however, at a closer look of transformer efficiencies, 30% and 70% are very similar on most transformers. It was determined that 20% and 60% would provide a better analysis that shows the differences in the smaller load and the larger load. Figure 1 shows an efficiency curve from Howard Transformers and an example of how similar 30% and 70% are in the curve.

Figure 1: 30% & 70% Efficiency Similarities



2. Efficiency Evaluation

2.1 U.S. Transformer Manufacturer Data

Several U.S. transformer manufacturers were contacted but due to the massive number of options available (more than 15,000 types, sizes and unique features of distribution transformers) and the reluctance of U.S. manufacturers to provide performance information, only Howard Transformers produced useful information. However, the Department of Energy (DOE) did provide a list of transformer standard efficiencies and a European standards list was also found and used for comparative analysis. The information obtained was enough to compile an analysis spreadsheet containing transformer efficiencies for low-level, medium-level, and high-level transformers in the 500 KVA, 750 KVA and 1000 KVA sizes. Some of the analysis involved using the Linear Interpolation formula as seen in Equation 1.

Equation 1: Linear Interpolation Formula

$$y_2 = \frac{(x_2 - x_1)(y_3 - y_1)}{(x_3 - x_1)} + y_1$$

Two other formulas were used; the second formula used was for determining the transformer's efficiency and a third formula was used for applying the Power Factor (PF) conversion and they are seen in Equation 2 and Equation 3. Note: Based on past experiences with military bases; a power factor of 0.85 has been assumed for the MCB Okinawa, Japan and used in the analysis and Life Cycle Cost analysis (LCC's) detailed in this report.

Equation 2: Transformer Efficiency Formula

$$Efficiency = \big((Power\ In - Total\ Losses) \div Power\ In\big) * 100$$

Equation 3: Power Factor Conversion Formula

$$PF\ Efficiency = \Big(\big((Power\ In * [PF]) - Total\ Losses\big) \div (Power\ In * [PF])\Big) * 100$$

2.1.1 Low-Level Efficient Transformers

The Low-Level transformers are the lowest efficient transformers with no extra features or options. These transformers have the poorest quality windings and therefore have the highest amount of both load losses and no-load losses. However, these transformers would be the cheapest priced on the market and should cost somewhere around $15,000 - $20,000 for a 500 KVA, $25,000-$30,000 for a 750 KVA, and $40,000-$45,000 for a 1000 KVA. Note: These prices vary depending on market fluctuations, manufacturer, windings type, options, etc… and could possibly be improved upon through a government contract bidding process. Figure 2 shows a chart of manufacturer listed prices for Low-Level Efficient G.E. Transformers. This price list was used in the report analysis and LCC's for Low-Level transformers.

Figure 2: Low-Level Price List

Figure 3 shows the Low-Level transformer efficiency percentages at the 0.85 power factor.

Figure 3: Low-Level Transformer Comparison

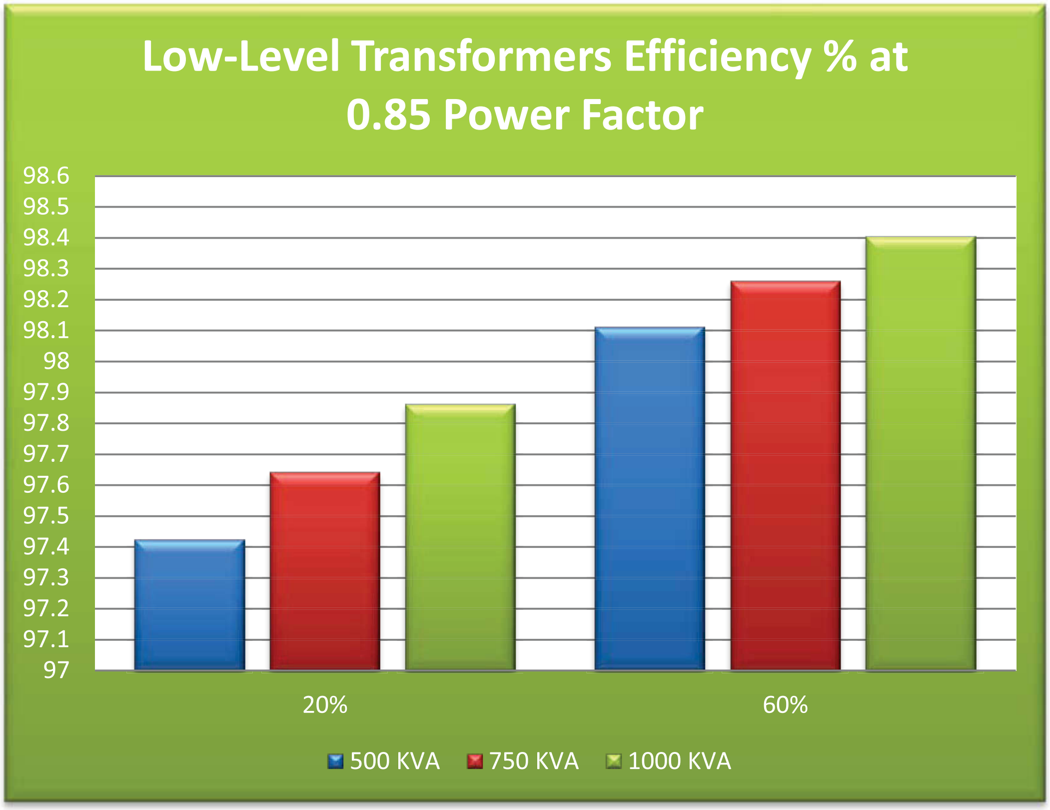
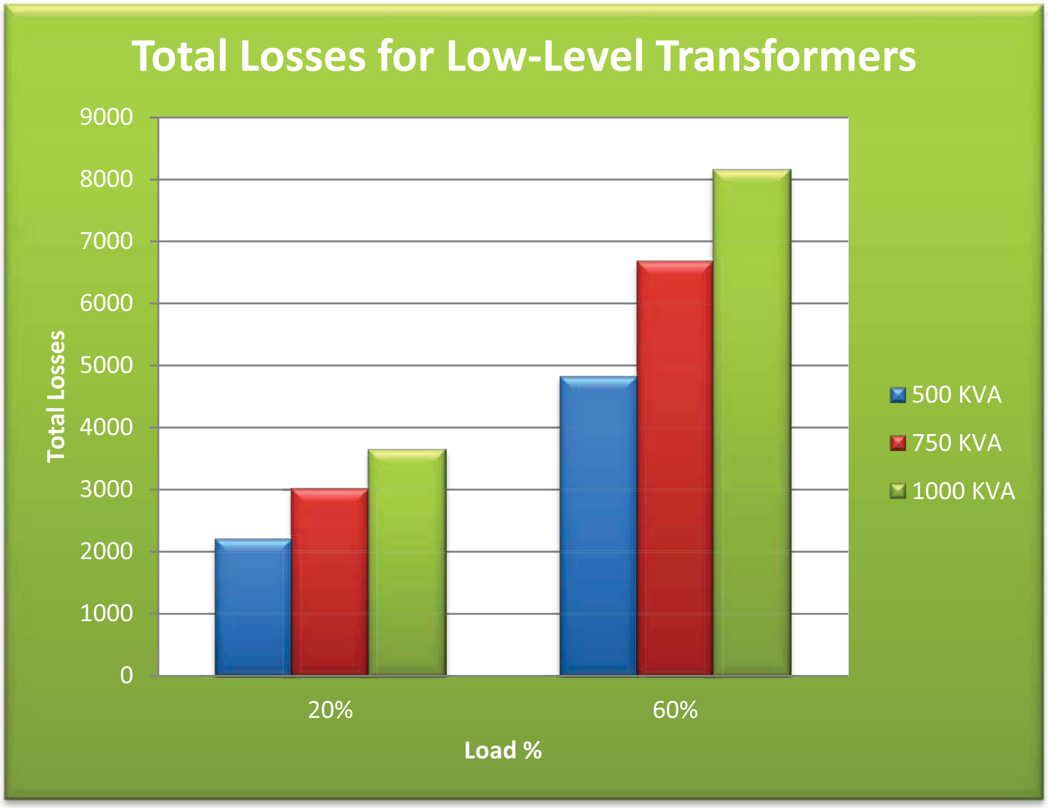


Figure 4 shows the Low-Level transformer total losses at the 0.85 power factor.

Figure 4: Low-Level Transformers Total Losses



2.1.2 Medium-Level Efficient Transformers

The Medium-Level transformers have better efficiencies than the lowest efficient transformers from section 2.1.1 but they are not as efficient as the High-Level transformers in section 2.1.3. These transformers tend to have improvements in winding material and therefore have slightly better load loss ratios than the Low-Level transformers. These transformers usually included extra features/options that also help improve transformer efficiency. However, these transformers are more expensive in price and should cost somewhere around \$30,000 - \$35,000 for a 500 KVA, \$40,000-\$45,000 for a 750 KVA, and \$60,000-\$65,000 for a 1000 KVA. Note: These prices also vary depending on market fluctuations, manufacturer, windings type, options, etc… and could possibly be improved upon through a government contract bidding process. Figure 5 shows a chart of manufacturer listed prices for Medium-Level Efficient G.E. Transformers. This price list was used in the report analysis and LCC's for Medium-Level transformers.

Figure 5: Medium-Level Price List

Figure 6 shows the Medium-Level transformer efficiency percentages at the 0.85 power factor.

Figure 6: Medium-Level Transformer Comparison

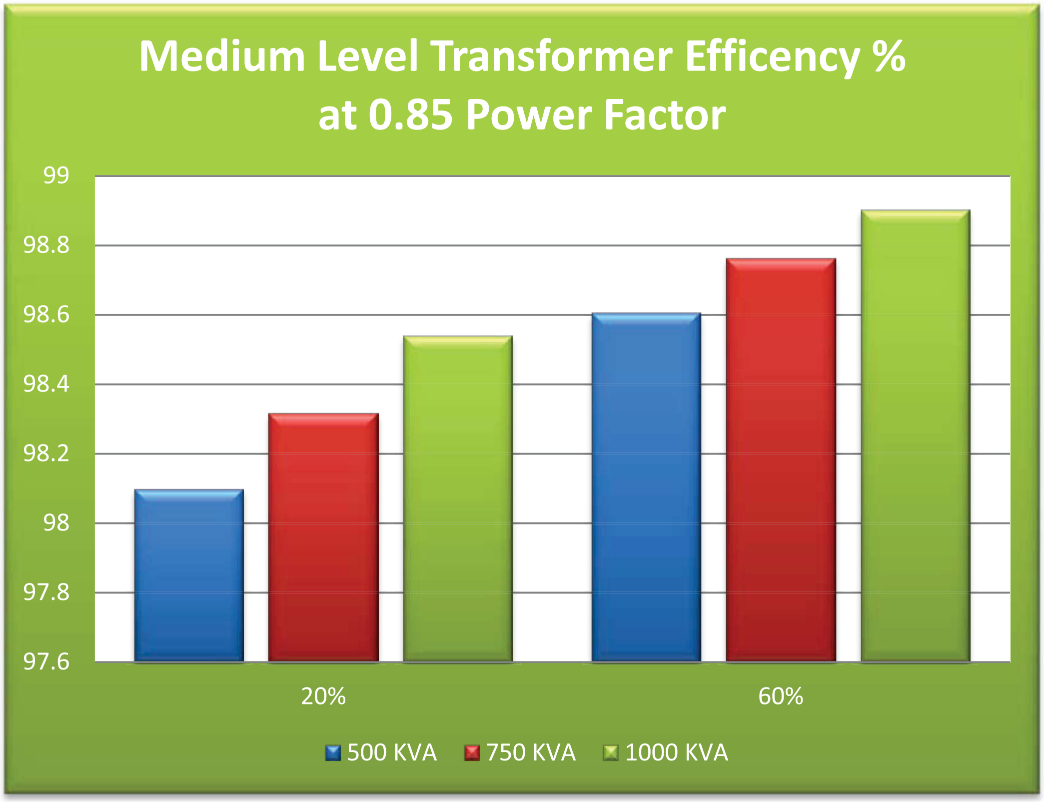
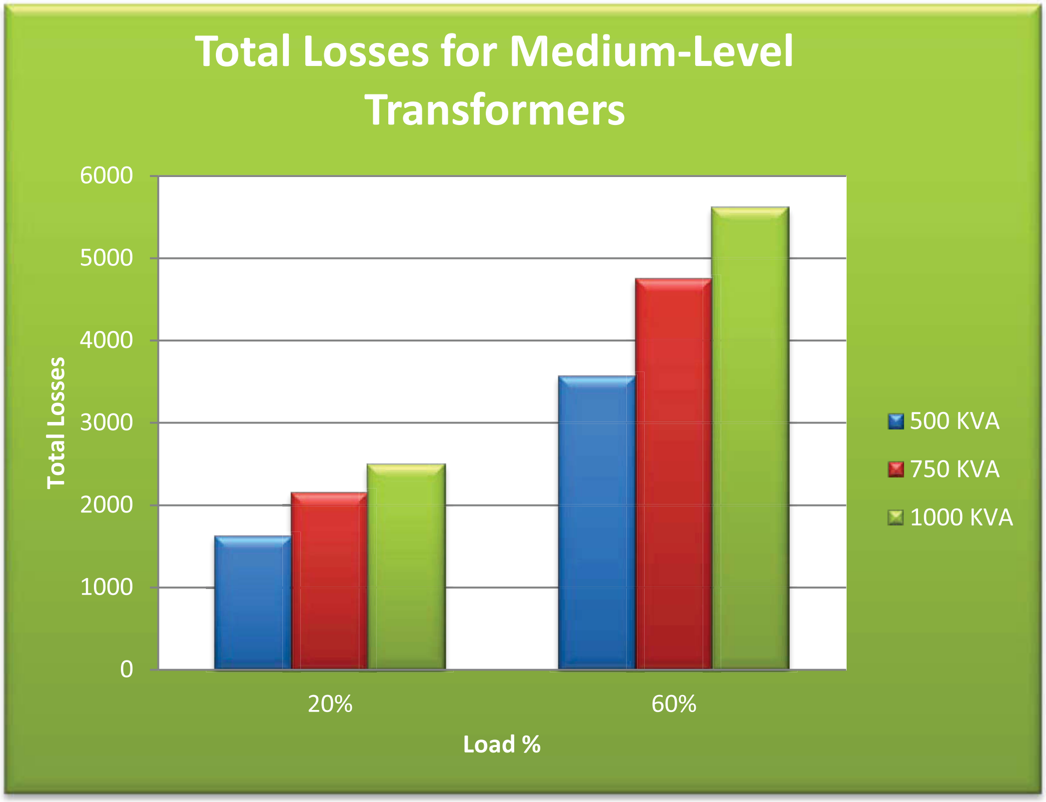


Figure 7 shows the Medium-Level transformer total losses at the 0.85 power factor.

Figure 7: Medium-Level Transformer Total Losses



2.1.3 High-Level Efficient Transformers

The High-Level transformers are the highest efficient transformers and have the best extra features or options for improving efficiency. These transformers have the highest quality winding material and therefore have the lowest amount of both load losses and no-load losses. However, these transformers are the most expensive and should cost somewhere around $55,000 - $60,000 for a 500 KVA, $65,000-$70,000 for a 750 KVA, and $80,000-$85,000 for a 1000 KVA. Note: These prices vary depending on market fluctuations, manufacturer, windings material, options, etc… and could possibly be improved upon through a government contract bidding process. Figure 8 shows a chart of manufacturer listed prices for High-Level Efficient G.E. Transformers. This price list was used in the report analysis and LCC's for High-Level transformers.

Figure 8: High-Level Price List

Figure 9 shows the High-Level transformer efficiency percentages at the 0.85 power factor.

Figure 9: High-Level Transformer Comparison

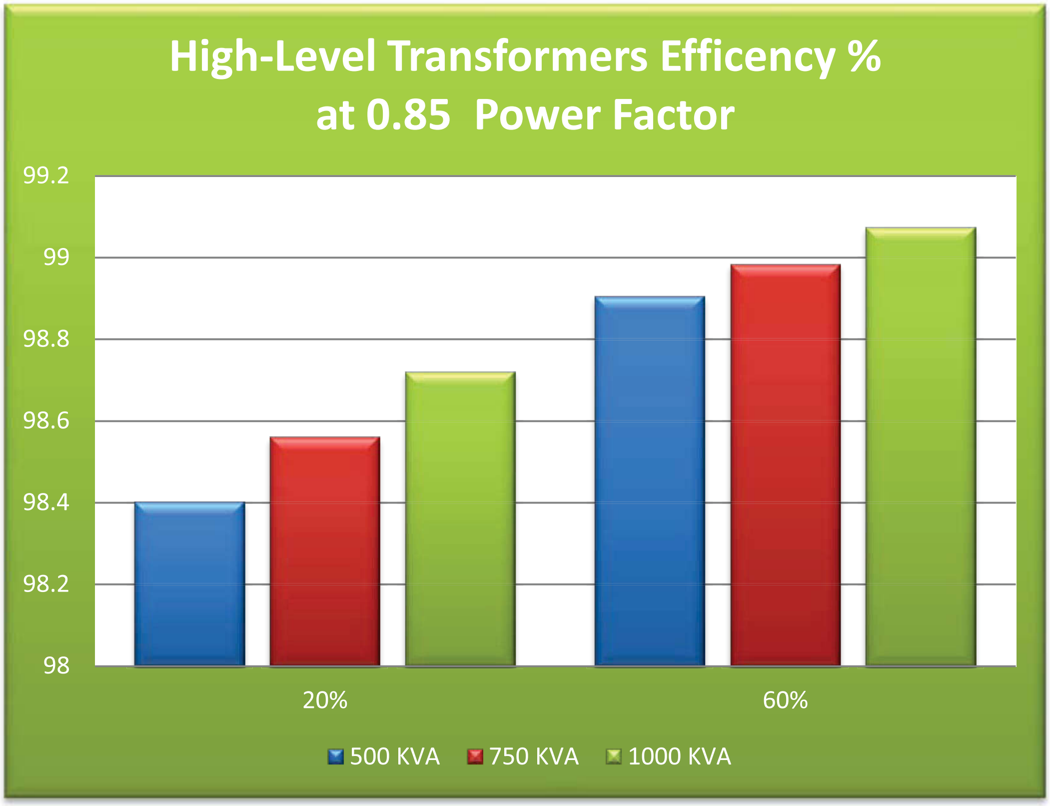
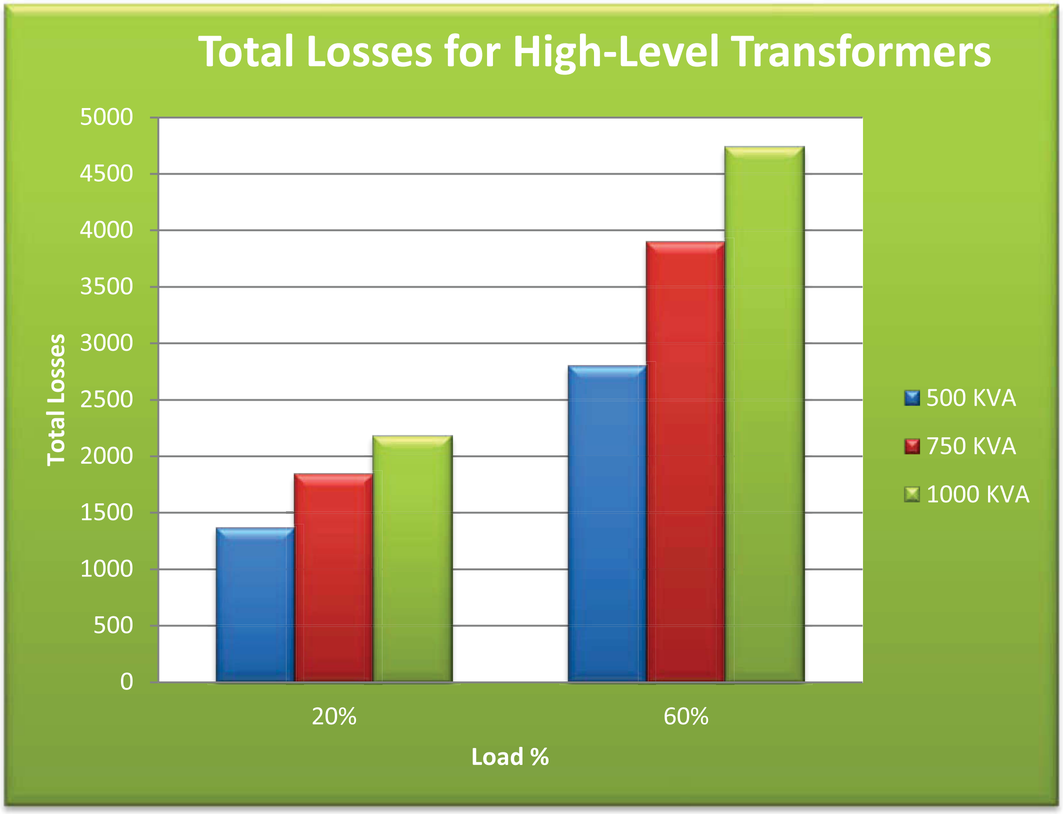


Figure 10 shows the High-Level transformer total losses at the 0.85 power factor.

Figure 10: High-Level Transformers Total Losses



2.2 Okinawa Transformer Assumptions

The transformers in Okinawa are assumed to be somewhere between Low and Medium Level efficient transformers and the age range for the transformers is between 11 and 24 years old. The efficiency curves from the 1980's Howard Transformers were used to represent the MCB transformer data. Figure 11 shows the Howard transformer efficiency percentages at the 0.85 power factor.

Figure 11: Okinawa Transformer Comparison

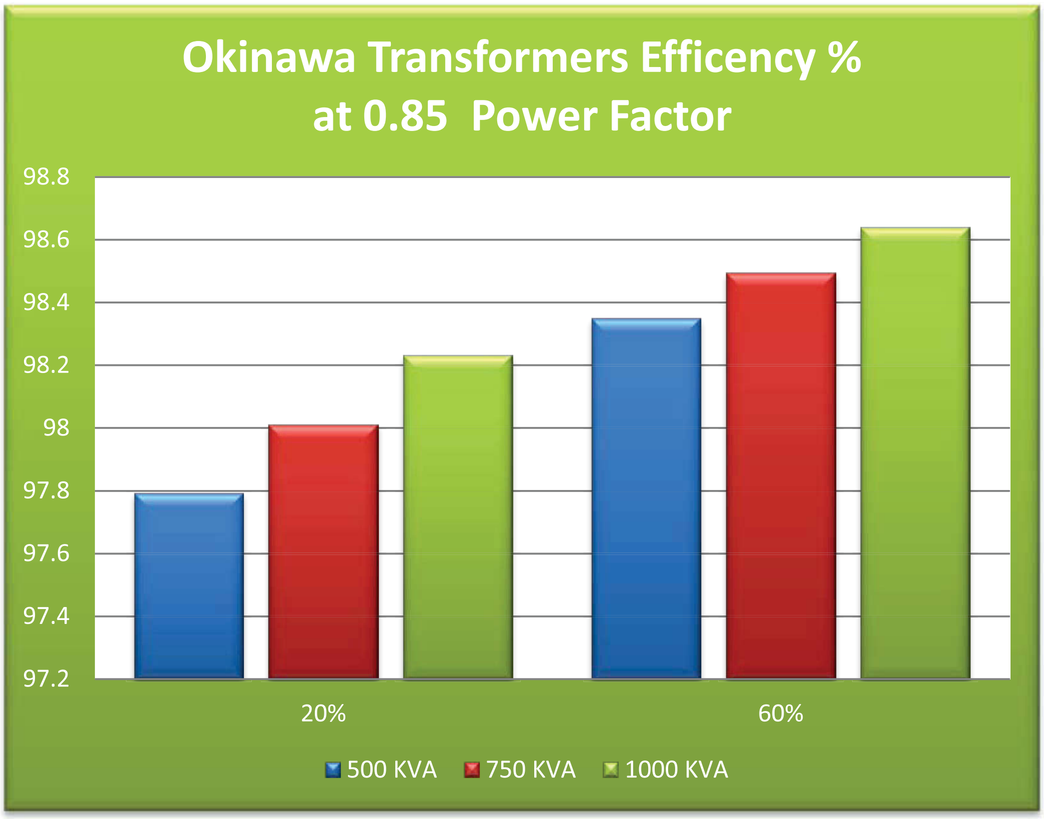
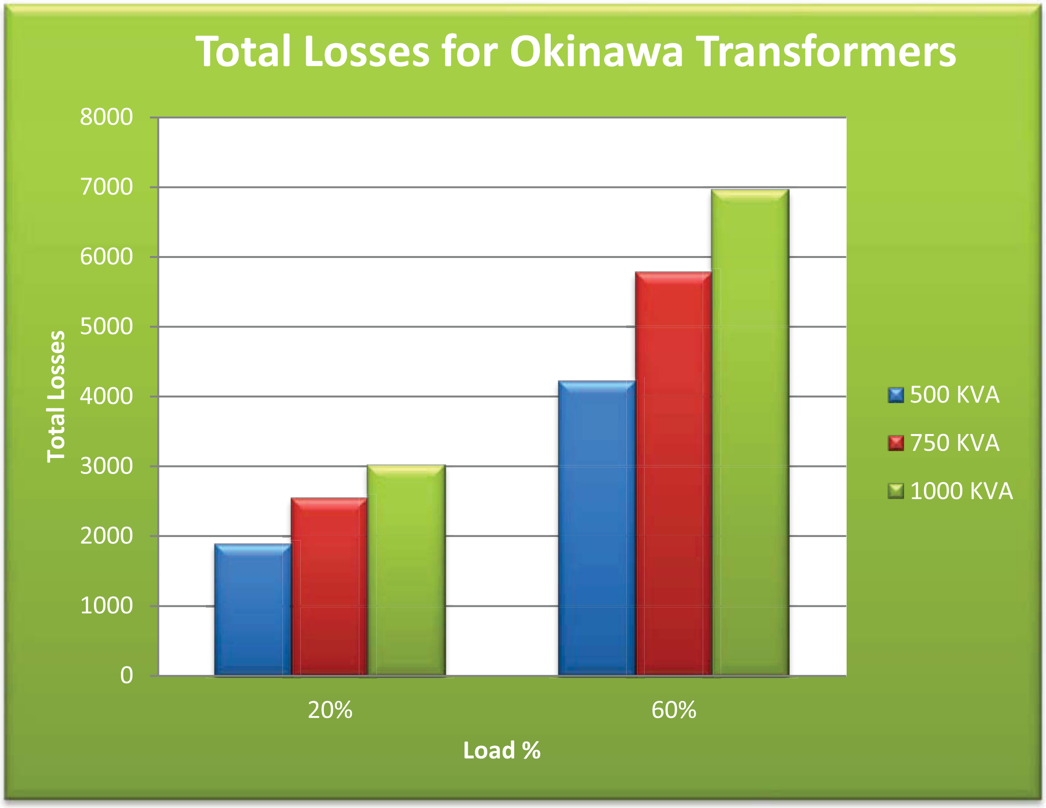


Figure 12 shows the assumed Okinawa transformer total losses at the 0.85 power factor.

Figure 12: Okinawa Transformers Total Losses



2.3 LCC Analysis

18 Energy Conservation Investment Program (ECIP) LCC analysis scenarios were run for this project. This analysis centered on construction of the potential project utilizing ECIP funding. Of course there are other ways to develop and finance this type of project, but it is estimated that ECIP funding enables the greatest benefit to the government when dealing with payback periods and accounting to meet energy goals. Other business and financing models can be run utilizing the energy production estimates above if other development scenarios are desired. However, those types of analyses will be left to others, or on request outside of the scope of this report. Other types of business models and financing for project development on federal land could include Utility Energy Service Contracts (UESC), Energy Savings Performance Contracts (ESPC), End User Lease Agreements (EULA), private financing and/or other options.

Some of the assumptions utilized for the ECIP LCC analyses and project construction cost estimates include: an operating period of 30 years, on-line date of 1/1/13, discount rate of 3%, other rates and factors given by 2012 FEMP rates, 100% government funded, base energy rates of $0.229 per kWh, and install and removal costs at approximately $25,000. Note: Removal/install costs, transformer prices, and base energy rates could vary significantly depending on the situation, so any approximations used in this report should be refined for better matching to actual project details of future transformer replacements. Table 2 below shows estimated project construction costs used for the LCC analyses, as well as a summary of results for transformers loaded to 20% loads. Table 3 contains the summary of results for transformers loaded to 60% loads.

Table 2: Transformers Loaded at 20% LCC Results Summary

20% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR
500 Low	$27,569.00	$57,826.00	-$633.00	-91.30	-$12,429.00	-0.21	n/a
500 Med	$36,354.00	$64,894.00	$518.00	125.35	$10,159.00	0.16	-3.17%
500 High	$59,626.00	$93,089.00	$1,039.00	89.56	$20,395.00	0.22	-2.08%
750 Low	$36,354.00	$67,489.00	-$946.00	-71.33	-$18,567.00	-0.28	n/a
750 Med	$44,299.00	$76,229.00	$779.00	97.86	$15,285.00	0.2	-2.37%
750 High	$69,350.00	$103,785.00	$1,403.00	73.97	$27,531.00	0.27	-1.46%
1000 Low	$50,794.00	$83,373.00	-$1,256.00	-66.36	-$24,654.00	-0.3	n/a
1000 Med	$60,742.00	$94,316.00	$1,053.00	89.54	$20,670.00	0.22	-2.08%
1000 High	$82,958.00	$118,754.00	$1,674.00	70.95	$32,843.00	0.28	-1.32%

Table 3: Transformers Loaded at 60% LCC Results Summary

60% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR
500 Low	$27,569.00	$57,826.00	-$1,209.00	-47.85	-$23,716.00	-0.41	n/a

500 Med	$36,354.00	$64,894.00	$1,307.00	49.67	$25,638.00	0.4	-0.14%
500 High	$59,626.00	$93,089.00	$2,843.00	32.74	$55,795.00	0.6	1.26%
750 Low	$36,354.00	$67,489.00	-$1,801.00	-37.47	-$35,345.00	-0.52	n/a
750 Med	$44,299.00	$76,229.00	$2,056.00	37.07	$40,354.00	0.53	0.84%
750 High	$69,350.00	$103,785.00	$3,758.00	27.62	$73,746.00	0.71	1.83%
1000 Low	$50,794.00	$83,373.00	-$2,386.00	-34.94	-$46,822.00	-0.56	n/a
1000 Med	$60,742.00	$94,316.00	$2,692.00	35.04	$52,824.00	0.56	1.03%
1000 High	$82,958.00	$118,754.00	$4,458.00	26.64	$87,471.00	0.74	1.96%

2.3.1 Low-Level Transformers

We can see by the summary of LCC's above that the low-level transformers while being the least expensive to purchase would not be the best option for the long term. Based on our past experiences with military bases, it is our opinion that the transformers already in place at Okinawa are probably somewhere between the low-level and medium-level transformers. Table 3 shows a low-level 500 KVA transformer has a Total Discounted Operational Loss (as compared to the assumed Okinawa Transformers) of approximately $23,716 over the 30 year life bringing the real cost for this transformer to (Total Cost) $57,826 + (TDOL) $23,716 = (Real Cost) $81,542. This transformer would only be an option if initial price was the only factor for purchasing transformers and the losses experienced over the life of the transformer did not matter.

2.3.2 Medium-Level Transformers

The medium-level transformers have a better efficiency percentage than the assumed Okinawa transformers, although it is only slightly better. Looking at the 500 medium-level transformer analysis in Table 3, we see that the Total Discounted Operational Savings for this transformer is $25,638. Factor this with the Total cost ($64,894 - $25,638) and the real cost for these transformers would be $39,256.

2.3.3 High-Level Transformers

These transformers have the highest efficiency percentages and will have the greatest energy savings. Again, comparing these to the assumed Okinawa transformers, we look at Table 3 and see that the Total Cost of the 500 KVA high-level transformers is $93,089 and the Total Discounted Operational Savings is $55,795. This makes the real cost of the 500 KVA high-level transformers as $37,294 ($93,089 - $55,795).

3. Findings

By analyzing Table 2 & Table 3 we can see the difference between the two different load levels: 20% and 60%. Looking at the Simple Payback Periods (SPP) we can see that none of the low-level transformers have a payback period since their efficiency is worse than the assumed Okinawa transformers. Table 4 below represents the medium-level and high-level comparison for SPP.

Table 4: 20% & 60% Load SPP Comparison

	20% Load SPP	60% Load SPP
500 Med	125.35	49.67
500 High	89.56	32.74
750 Med	97.86	37.07
750 High	73.97	27.62
1000 Med	89.54	35.04

1000 High	70.95	26.64

By looking at this comparison of the SPP we can see that transformers loaded at only 20% would not have enough energy savings to pay for themselves. The 60% loaded transformers have slightly better energy savings but only two (750 High & 1000 High) have payback periods within the life term of the transformer.

We also looked at the differences between selecting the Medium-Level or the High-Level for upgrading Okinawa's transformers. We took the 1000 KVA transformer and compared the Total Costs and the Total Discounted Operational Savings. Table 5 shows that the 1000 KVA High-Level transformer costs $24,438 more than the 1000 KVA Medium-level one. However, over the 30 year life term of these transformers the 1000 KVA will have $34,647 more in savings.

Table 5: Medium-Level vs. High-Level Transformers

	Total Cost $	Total Discounted Operational Savings $
500 Med	$64,894.00	$25,638.00
500 High	$93,089.00	$55,795.00
Difference $	$28,195.00	$30,157.00
750 Med	$76,229.00	$40,354.00
750 High	$103,785.00	$73,746.00
Difference $	$27,556.00	$33,392.00
1000 Med	$94,316.00	$52,824.00
1000 High	$118,754.00	$87,471.00
Difference $	$24,438.00	$34,647.00

By looking closer, we took the TDOS difference and divided by 30 year life term to get a yearly approximation of the extra savings associated with the High-level transformer. We then took the difference in Price and divided it by the TDOS difference yearly amount and were able to determine that by upgrading with the High-Level Transformer instead of the Medium-Level; the difference in price will be made up in roughly 21.16 years. The 750 KVA and 500 KVA were also examined with the 750 KVA taking approximately 24.75 years and the 500 KVA taking 28.05 years. In all three examples, it would be justified to use High-Level transformers for upgrades instead of the Medium-Level ones but it is noted that even with the High-Level transformers it would be best to not replace existing transformers before they need be replaced. Simply put, the energy savings are not enough to justify the early replacements of any 500, 750 & 1000 KVA transformers.

3.1 Findings for Okinawa Camps

The LCC analysis above has been applied to the Key Transformers located at the military camps (Foster, Hansen, & Kinser). As stated earlier, there are three different camps (Foster, Hansen, & Kinser) and they consist of 46 key transformers (26-500 KVA, 16-750 KVA, 4-1000 KVA). Table 6 shows an End-of-Life (EOL) date for these key transformers and it identifies the time left before these transformers should be replaced.

Table 6: End-of-Life estimates for Key Transformers

CAMP	LOC	CAPACITY KVA	MFR_DATE	EOL Date	Years until EOL
KINSER	99 TS	500	1988	2018	6

FOSTER	5704 TS	500	1989	2019	7
FOSTER	5703 TS	500	1989	2019	7
FOSTER	5670 TS	500	1989	2019	7
FOSTER	1004 TV	1000	1989	2019	7
KINSER	100 TS	750	1989	2019	7
HANSEN	2622 TS	500	1990	2020	8
HANSEN	2665 TS	500	1990	2020	8
HANSEN	2340 TS	500	1990	2020	8
HANSEN	2442 TS	500	1990	2020	8
KINSER	1225 TS	500	1990	2020	8
FOSTER	5696 TS	500	1991	2021	9
FOSTER	370 TS	500	1991	2021	9
HANSEN	2141 TS	500	1991	2021	9
KINSER	1226 TS	750	1991	2021	9
HANSEN	2530 TS	500	1992	2022	10
HANSEN	2537 TS	750	1992	2022	10
HANSEN	2725 TS	750	1992	2022	10
HANSEN	2893 TS	750	1992	2022	10
KINSER	1210 TS	750	1992	2022	10
FOSTER	1002 TS	1000	1993	2023	11
HANSEN	2441 TS	500	1993	2023	11
HANSEN	2667 TS	750	1993	2023	11
HANSEN	2327 TS	750	1993	2023	11
KINSER	616 TS	500	1993	2023	11
KINSER	1202 TS	750	1993	2023	11
KINSER	104-A TS	750	1993	2023	11
HANSEN	2860 TS	500	1994	2024	12
HANSEN	2165 TS	500	1994	2024	12
FOSTER	481 TS	500	1996	2026	14
FOSTER	480 TS	750	1996	2026	14
HANSEN	2221 TS	500	1996	2026	14
HANSEN	2518 TS	500	1996	2026	14
FOSTER	478 TS	500	1997	2027	15
FOSTER	445 TS	500	1998	2028	16
FOSTER	464 TS	750	1998	2028	16
FOSTER	490 TS	500	1999	2029	17
HANSEN	2519 TS	500	1999	2029	17
HANSEN	2610 TS	500	1999	2029	17
HANSEN	2245 TS	500	1999	2029	17
HANSEN	2635 TS	750	1999	2029	17
HANSEN	2654 TS	1000	2000	2030	18
FOSTER	5907 TS	750	2001	2031	19
FOSTER	11 TS	750	2001	2031	19
FOSTER	363 TS	750	2001	2031	19
HANSEN	2365 TS	1000	2001	2031	19

Since actual load information and nameplate data is not available for each individual transformer, actual analysis for each transformer was not performed. However, the LCC results have been applied to the group of transformers using the assumed data. Table 7 below shows the costs/savings for the 46 transformers in the key transformer list, if Okinawa transformers were to be replaced with High-Level transformers.

Table 7: LCC Analysis for Key Transformers

	Total Cost	Annual Savings 20% Load	Annual Savings 60% Load	TDOS 20% Load	TDOS 60% Load
26 - 500 KVA	$2,420,314.00	$27,014.00	$73,918.00	$530,270.00	$1,450,670.00
16- 750 KVA	$1,660,560.00	$22,448.00	$60,128.00	$440,496.00	$1,179,936.00
4 - 1000 KVA	$475,016.00	$6,696.00	$17,832.00	$131,372.00	$349,884.00
Total:	$4,555,890.00	$56,158.00	$151,878.00	$1,102,138.00	$2,980,490.00

3.2 Recommendations

We believe that under the current market conditions, several manufacturers/models of transformers could respond to a contracting/procurement process to supply transformer to this proposed project. The transformers in the 1000 KVA size range will be the ones to see the greatest energy savings from efficiency improvements. Most sizes, especially the ones smaller than 1000 KVA, should not be upgraded unless the transformer they are replacing has reached its full life term. The energy savings by installing a higher efficient transformer would not justify replacing a lower efficient transformer before the end of its life. Market conditions should also continue to be monitored to determine if economy fluctuations and changes could affect the timing of the project and procurements.

If electrical energy savings are the primary goal, then greater savings would be achieved by considering building efficiency upgrades such as insulation, lights, windows, doors, appliances, smart-grid meters, micro-grid control systems, etc.

Appendix A

Military Base Transformer List

Page 1 of 24

APPENDIX A
Pad Mounted Transformer List

CAMP	LOC	CAPACITY KVA	MANUFACT	MFR_DATE	Serial_ID	Type
HANSEN	307Q-8 POLE	10 KVA	AICHI	2007	07211926	Pad Mount
CTNY	4354 TS	100 KVA	OSAKA	1985	3ND0577A1	Pad Mount
CTNY	4399 TS	100 KVA	MITSUBISHI	2005	DA3657001	Pad Mount
CTNY-TG	4137 TS	100 KVA	DAIHEN	1988	3ND0823A1	Pad Mount
FOSTER	5641 TS	100 KVA	AICHI	1993	9222477	Pad Mount
FOSTER	5970 TS	100 KVA	AICHI		9221168	Pad Mount
FOSTER	362 TS	100 KVA	AICHI	2000	0701085	Pad Mount
FOSTER	5666 TS	100 KVA	AICHI	2002	02704192	Pad Mount
FOSTER	497 TS	100 KVA	AICHI	1999	8960322	Pad Mount
FOSTER	5833 TS	100 KVA	AICHI	2000	0700486	Pad Mount
FOSTER-1	SHOP STOCK	100 KVA	FUJI	93 JUN	A30946T1	Pad Mount
FOSTER-1	SHOP STOCK	100 KVA	DAIHEN	1994	2TF436801	Pad Mount
HANSEN	2346 TS	100 KVA	AICHI	1992	9220879	Pad Mount
HANSEN	2653 TS	100 KVA	MEIDEN	JUN 1992	1R8544T1	Pad Mount
HANSEN	2609 TS	100 KVA	MITSUBISHI	1993	DF0790001	Pad Mount
HANSEN	2175 TS	100 KVA	HITACHI	2002	24614221	Pad Mount
HANSEN	2174 TS	100 KVA	AICHI	2005	05207302	Pad Mount
HANSEN	2464 TS	100 KVA	TOSHIBA	2002	02011230	Pad Mount
HANSEN	2715 TS	100 KVA	FUJI	DEC 1996	B60382A01	Pad Mount
HANSEN	2474 TS	100 KVA	AICHI	2008	08213938	Pad Mount
HANSEN	2439 TS	100 KVA	FUJI	1990 JUN	A01329T 1-1	Pad Mount
HANSEN	2240 TS	100 KVA	FUJI	1991 FEB	B00364A01	Pad Mount
KINSER	104-C TS	100 KVA	DAIHEN	OCT 1986	3ND0657A1	Pad Mount

APPENDIX A
Pad Mounted Transformer List

CAMP	LOC	CAPACITY KVA	MANUFACT	MFR_DATE	Serial_ID	Type
HANSEN	307Q-8 POLE	10 KVA	AICHI	2007	07211926	Pad Mount
CTNY	4354 TS	100 KVA	OSAKA	1985	3ND0577A1	Pad Mount
CTNY	4399 TS	100 KVA	MITSUBISHI	2005	DA3657001	Pad Mount
CTNY-TG	4137 TS	100 KVA	DAIHEN	1988	3ND0823A1	Pad Mount
FOSTER	5641 TS	100 KVA	AICHI	1993	9222477	Pad Mount
FOSTER	5970 TS	100 KVA	AICHI		9221168	Pad Mount
FOSTER	362 TS	100 KVA	AICHI	2000	0701085	Pad Mount
FOSTER	5666 TS	100 KVA	AICHI	2002	02704192	Pad Mount
FOSTER	497 TS	100 KVA	AICHI	1999	8960322	Pad Mount
FOSTER	5833 TS	100 KVA	AICHI	2000	0700486	Pad Mount
FOSTER-1	SHOP STOCK	100 KVA	FUJI	93 JUN	A30946T1	Pad Mount
FOSTER-1	SHOP STOCK	100 KVA	DAIHEN	1994	2TF436801	Pad Mount
HANSEN	2346 TS	100 KVA	AICHI	1992	9220879	Pad Mount
HANSEN	2653 TS	100 KVA	MEIDEN	JUN 1992	1R8544T1	Pad Mount
HANSEN	2609 TS	100 KVA	MITSUBISHI	1993	DF0790001	Pad Mount
HANSEN	2175 TS	100 KVA	HITACHI	2002	24614221	Pad Mount
HANSEN	2174 TS	100 KVA	AICHI	2005	05207302	Pad Mount
HANSEN	2464 TS	100 KVA	TOSHIBA	2002	02011230	Pad Mount
HANSEN	2715 TS	100 KVA	FUJI	DEC 1996	B60382A01	Pad Mount
HANSEN	2474 TS	100 KVA	AICHI	2008	08213938	Pad Mount
HANSEN	2439 TS	100 KVA	FUJI	1990 JUN	A01329T 1-1	Pad Mount
HANSEN	2240 TS	100 KVA	FUJI	1991 FEB	B00364A01	Pad Mount
KINSER	104-C TS	100 KVA	DAIHEN	OCT 1986	3ND0657A1	Pad Mount

KINSER	424 TS	100 KVA	AICHI	1986	8622191	Pad Mount
KINSER	520 TS	100 KVA	DAIHEN		3SD146001	Pad Mount
KINSER	1305-A TS	100 KVA	AICHI	SEP 1992	9123095	Pad Mount
KINSER	611 TS	100 KVA	AICHI	1999	9860231	Pad Mount
KINSER	5-E TS	100 KVA	JIMELCO	1991 MAR	AA00201406	Pad Mount
MCAS	681 TS	100 KVA	DAIHEN	1992	3SD1209A1	Pad Mount
MCAS	687 TS	100 KVA	DAIHEN		3SD1206A2	Pad Mount
MCAS	675 TS	100 KVA	DAIHEN		3ND0819A1	Pad Mount
MCAS	683 TS	100 KVA	AICHI		8820697	Pad Mount
FOSTER	5972 TV	1000 KVA	AICHI		9221416	Pad Mount
FOSTER	1004 TV	1000 KVA	WESTING HOUSE	OCT 1989	PAW4176-0101	Pad Mount
FOSTER	1002 TS	1000 KVA	G.E.	JUN 1993	Q108279-TNI	Pad Mount
FOSTER	122-F TS	1000 KVA	MITSUBISHI		D52035001	Pad Mount
FOSTER	148-B TS	1000 KVA	DAIHEN	1988	2TE141401	Pad Mount
FOSTER	5866 TS	1000 KVA	VANTRAN		90V6400	Pad Mount
FOSTER	5718 TS	1000 KVA	COOPER	JUL 2008	0850011715	Pad Mount
FOSTER-1	SHOP STOCK	1000 KVA	COOPER	2005 JAN	0526000153	Pad Mount
HANSEN	2365 TS	1000 KVA	FUJI	2001 JUN	B10215A01	Pad Mount
HANSEN	2654 TS	1000 KVA	TOSHIBA	2000	00023589	Pad Mount
HENOKO	1024 TS	1000 KVA	DAIHEN		3SD145701	Pad Mount
KINSER	831 TS	1000 KVA	MITSUBISHI		DB5361001	Pad Mount
KINSER	107 TV	1000 KVA	SIEMENS		PYG-0619	Pad Mount
KINSER	67-C TS	1000 KVA	RTE		886000358	Pad Mount
KINSER	107 TS	1000 KVA	SIEMENS		PZE-0484	Pad Mount
KINSER	301 TS	1000 KVA	COOPER	2005 FEB	0537003818	Pad Mount
MCAS	633 TS	1000 KVA	FUJI		B50328A01	Pad Mount
MCAS	49-A-2 TS	1000 KVA	WESTING HOUSE	APR 1989	89J385097	Pad Mount
MCAS	505 TS	1000 KVA	COOPER	JUN 2007	0759001399	Pad Mount

CTNY	4352 TS	112.5 KVA	HOWARD		2252112195	Pad Mount
CTNY	4206 TS	112.5 KVA	COOPER	2005 FEB	0537004313	Pad Mount
CTNY	4436 TS	112.5 KVA	VANTRAN		05V6858	Pad Mount
CTNY-TG	4108 TS	112.5 KVA	RTE		896003384	Pad Mount
FOSTER	13-A TS	112.5 KVA	ABB	JAN 1991	91J817095	Pad Mount
FOSTER	301-C TS	112.5 KVA	COOPER	NOV 1995	959006282	Pad Mount
FOSTER	33-D TS	112.5 KVA	PAUWELS	NOV 2004	04J129802	Pad Mount
FOSTER	371R TS	112.5 KVA	COOPER	AUG 2008	0850013516	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	ABB	DEC 2008	08J162068	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	AUG 2008	0850012805	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	APR 2009	0950003921	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	2005 FEB	0537003338	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	PAUWELS	NOV 2004	04J129805	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	2005 FEB	0537003337	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	SEP 2007	0750017354	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	G	FEB 2010	20111020441	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	JAN 2010	1050000517	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	JUL 2009	0950006596	Pad Mount
FOSTER-1	SHOP STOCK	112.5 KVA	COOPER	DEC 2009	0950011341	Pad Mount
HANSEN	2406 TS	112.5 KVA	COOPER	2006 SEP	0650016683	Pad Mount
HANSEN	2892 TS	112.5 KVA	COOPER	FEB 2005	0537004310	Pad Mount
HANSEN	2435 TS	112.5 KVA	COOPER	2005 FEB	0537004314	Pad Mount
HANSEN	2139 TS	112.5 KVA	COOPER	MAY 2008	0850007604	Pad Mount
HANSEN	2887 TS	112.5 KVA	COOPER	2007 MAY	0750009544	Pad Mount
HANSEN	2171 TS	112.5 KVA	COOPER	2008 JAN	0850000733	Pad Mount
HANSEN	2523 TS	112.5 KVA	COOPER	AUG 2007	0750015787	Pad Mount
HANSEN	2538 TS	112.5 KVA	ABB	DEC 2008	08J162067	Pad Mount
HENOKO	1 TS	112.5 KVA	ABB		98J584270	Pad Mount

HENOKO	5 TS	112.5 KVA	VANTRAN		03V6401-1	Pad Mount
HENOKO	2 TS	112.5 KVA	VANTRAN		03V6401-2	Pad Mount
HENOKO	6 TS	112.5 KVA	COOPER		0437009015	Pad Mount
HENOKO	9-A TS	112.5 KVA	PAUWELS	SEP 2003	03G122433	Pad Mount
HENOKO	4 TS	112.5 KVA	VANTRAN		03V6401-3	Pad Mount
KINSER	30-A TS	112.5 KVA	COOPER		929000640	Pad Mount
MCAS	33-A TS	112.5 KVA	COOPER	2008 FEB	0850003442	Pad Mount
MCAS	38 TS	112.5 KVA	WESTING HOUSE		88JB100180	Pad Mount
MCAS	11-C TS	112.5 KVA	COOPER		959006334	Pad Mount
MCAS	667 TS	112.5 KVA	WESTING HOUSE		88J246046	Pad Mount
MCAS	416 TS	112.5 KVA	COOPER	2005 FEB	0537004311	Pad Mount
MCAS	690 TS	112.5 KVA	PAUWELS	APR 2007	20060002086	Pad Mount
MCAS	11-B1 TS	112.5 KVA	PAUWELS		20060002087	Pad Mount
MCAS	2B-3 TS	112.5 KVA	COOPER	MAY 2008	0850007605	Pad Mount
MCAS	13-4 TS	112.5 KVA	WESTING HOUSE		80JG262280	Pad Mount
MCAS	435 TS	112.5 KVA	COOPER	DEC 2003	0326002279	Pad Mount
KINSER	202 TS	1200 KVA	FUJI	1993 DEC	B30228A01	Pad Mount
MCAS	518 TV	15 KW	COOPER		2209	Pad Mount
CTNY	4233 TS	150 KVA	DAIHEN	1985	3ND0760A1	Pad Mount
CTNY	4444 TS	150 KVA	MEIDEN		1N8218T1	Pad Mount
CTNY	4438 TS	150 KVA	PAUWELS	OCT 2005	05G135695	Pad Mount
CTNY	4344 TS	150 KVA	VANTRAN		05V6855	Pad Mount
CTNY	4412 TS	150 KVA	AICHI	2004	04205391	Pad Mount
CTNY	4411 TS	150 KVA	CUTLER-HAMMER	OCT 2003	03J908112	Pad Mount
CTNY-TG	4135 TS	150 KVA	COOPER	SEP 2003	0337014224	Pad Mount
FOSTER	1005 TS	150 KVA	AICHI	1997	9720755	Pad Mount
FOSTER	371S TS	150 KVA	COOPER		0326000060	Pad Mount
FOSTER	5821 TS	150 KVA	AICHI	1999	9960222	Pad Mount

FOSTER	14 TS	150 KVA	ABB	JAN 1991	91J817147	Pad Mount
FOSTER	7-E TS	150 KVA	ABB	NOV 2003	03J924313	Pad Mount
FOSTER	5838 TS	150 KVA	DAIHEN	2000	KSB0151B1	Pad Mount
FOSTER	5968 TS	150 KVA	MITSUBISHI		AM6336001	Pad Mount
FOSTER	5655 TS	150 KVA	FUJI	1997	B70345AT1	Pad Mount
FOSTER	151B TH	150 KVA	AICHI		03203947	Pad Mount
FOSTER	355 TS	150 KVA	MITSUBISHI	2005	DA3627001	Pad Mount
FOSTER	1006 TS	150 KVA	HITACHI	2004	23011421	Pad Mount
FOSTER	215 TS	150 KVA	DAIHEN		3SD1083A1	Pad Mount
FOSTER	5969 TS	150 KVA	DAIHEN		3SD1433A1	Pad Mount
FOSTER	1620 TS	150 KVA	DAIHEN	1992	3SD1434A1	Pad Mount
FOSTER	455 TS	150 KVA	DAIHEN	1992	3SD1519A1	Pad Mount
FOSTER	206 TS	150 KVA	HITACHI	2003	24615221	Pad Mount
FOSTER	12 TS	150 KVA	WESTING HOUSE		85JJ513092	Pad Mount
FOSTER	264-A TS	150 KVA	WESTING HOUSE		87JC873224	Pad Mount
FOSTER	5631 TS	150 KVA	COOPER	JUL 2009	0950006597	Pad Mount
FOSTER	5668 TS	150 KVA	AICHI		06208829	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	1995 MAR	959001470	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	MITSUBISHI	1993	D90879004	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	PAUWELS	OCT 2005	05G135694	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	2005 FEB	0537004315	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	2005 FEB	0537003967	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	2005 FEB	0537003964	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	PAUWELS	NOV 2004	04J129804	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	2005 FEB	0537003966	Pad Mount
FOSTER-1	SHOP STOCK	150 KVA	COOPER	SEP 09	0950008496	Pad Mount
HANSEN	SHOP STOCK	150 KVA	PAUWELS	2007 JUN	20110703497	Pad Mount
HANSEN	2354 TS	150 KVA	COOPER	JUN 2007	0750011232	Pad Mount

HANSEN	2440 TS	150 KVA	HOWARD		1312150504	Pad Mount
HANSEN	2137 TS	150 KVA	VANTRAN		92V8997	Pad Mount
HANSEN	2859 TS	150 KVA	MEIDEN	DEC 1995	1T8309T1	Pad Mount
HANSEN	2418 TS	150 KVA	MITSUBISHI	1994	DH8709001	Pad Mount
HANSEN	2148 TS	150 KVA	MOLONEY	JUN 1964	2055688	Pad Mount
HANSEN	2485-A TS	150 KVA	BALTEAU		PZB-0165	Pad Mount
HANSEN	2143 TS	150 KVA	AICHI	2002	02704781	Pad Mount
HANSEN	2451 TS	150 KVA	DAIHEN	1989	3SD1027A1	Pad Mount
HANSEN	2208 TS	150 KVA	VANTRAN		88V3331	Pad Mount
HANSEN	2376 TS	150 KVA	PAUWELS	JUN 2007	200110703497	Pad Mount
HANSEN	R4 TS	150 KVA	AICHI	2007	07211925	Pad Mount
HANSEN	2484 TS	150 KVA	AICHI	2006	06210656	Pad Mount
HANSEN	2140 TS	150 KVA	COOPER	SEP 2007	0750017355	Pad Mount
HANSEN	2864 TS	150 KVA	WESTING HOUSE		87JK022149	Pad Mount
HANSEN	2901-A TS	150 KVA	VANTRAN		04V6756	Pad Mount
HANSEN	2885 TS	150 KVA	AICHI	2005	05207424	Pad Mount
KINSER	54-D TS	150 KVA	DAIHEN	1987	3ND0696A1	Pad Mount
KINSER	73-A TS	150 KVA	DAIHEN	1986	3ND0612A1	Pad Mount
KINSER	90-B TS	150 KVA	DAIHEN	AUG 1986	3ND063501	Pad Mount
KINSER	864 TS	150 KVA	DAIHEN	1995	3SD1867B1	Pad Mount
KINSER	64-A TS	150 KVA	HOWARD		4423985003	Pad Mount
KINSER	27-A TS	150 KVA	SIERRA		9476-1	Pad Mount
KINSER	114 TS	150 KVA	AICHI		9221897	Pad Mount
KINSER	1040R TS	150 KVA	COOPER		0326000061	Pad Mount
KINSER	79 TH	150 KVA	MGM TRANSFORMER		03-02-02-10569A	Pad Mount
KINSER	13-C TH	150 KVA	H. K.PORTER		W-228059	Pad Mount
KINSER	1052 TS	150 KVA	PAUWELS		05E134380	Pad Mount
MCAS	2A-5 TS	150 KVA	VANTRAN		88V4357	Pad Mount

MCAS	77 TS	150 KVA	PAUWELS		06F142079	Pad Mount
MCAS	38-J1 TS	150 KVA	COOPER	2008 MAR	0850004240	Pad Mount
MCAS	2B-1 TS	150 KVA	PAUWELS	OCT 2005	05G135693	Pad Mount
MCAS	682 TS	150 KVA	AICHI		9222794	Pad Mount
MCAS	8-6 TS	150 KVA	MITSUBISHI		D5147901	Pad Mount
MCAS	461 TS	150 KVA	PAUWELS	JUL 2005	05E134378	Pad Mount
MCAS	220 TS	150 KVA	COOPER	2005 FEB	0537003965	Pad Mount
MCAS	438 TS	150 KVA	COOPER	DEC 2008	0850020422	Pad Mount
MCAS	444 TS	150 KVA	COOPER	DEC 2008	0850020421	Pad Mount
MCAS	11-A1 TS	150 KVA	AICHI	1986	8621626	Pad Mount
MCAS	49-A-1 TS	150 KVA	RTE		866005009	Pad Mount
MCAS	13-1B TS	150 KVA	PAUWELS	2007 MAR	20060001660	Pad Mount
MCAS	38-N TS	150 KVA	WESTING HOUSE		87JH983095	Pad Mount
MCAS	505-B TS	150 KVA	BALTEAN		PUK-0972	Pad Mount
FOSTER	5675 TS	1500 KVA	ABB		96J031306	Pad Mount
FOSTER	480A TS	1500 KVA	TAKAOKA	2004	03011288	Pad Mount
HANSEN	2419 TS	1500 KVA	HOWARD		3630173005	Pad Mount
KINSER	618 TS	1500 KVA	TOSHIBA	2002	01057451	Pad Mount
KINSER	425 TS	1500/1725 KV	COOPER		9926000262	Pad Mount
CTNY	4456 TS	200 KVA	FUJI	JAN 1990	B-90404A01	Pad Mount
CTNY	4453 TS	200 KVA	MITSUBISHI		DM0852001	Pad Mount
CTNY-TG	4119 TS	200 KVA	AICHI	1985	8521470	Pad Mount
CTNY-TG	4149 TS	200 KVA	MITSUBISHI	1988	DM4693001	Pad Mount
FOSTER	5665 TS	200 KVA	AICHI	2003	03203998	Pad Mount
FOSTER	150 TS	200 KVA	FUJI		A30947T1	Pad Mount
FOSTER	302-F3 TS	200 KVA	JIMELCO	MAR 1991	AA00201411	Pad Mount
FOSTER	5971 TS	200 KVA	FUJI		B10285A01	Pad Mount
FOSTER	5626 TS	200 KVA	AICHI	1993	9221396	Pad Mount

FOSTER	97-A TS	200 KVA	MITSUBISHI	1978	D51836001	Pad Mount
FOSTER	130-B TS	200 KVA	MITSUBISHI	1978	D51838001	Pad Mount
FOSTER	129-K TS	200 KVA	DAIHEN	1995	3SD1834B1	Pad Mount
FOSTER	5831 TS	200 KVA	MEIDEN	DEC 1991	1Q9558T1	Pad Mount
FOSTER	496 TS	200 KVA	MEIDEN	NOV 1992	1R8668T1	Pad Mount
FOSTER-1	SHOP STOCK	200 KVA	MITSUBISHI		D52039001	Pad Mount
HANSEN	2533 TS	200 KVA	AICHI	2005	05207386	Pad Mount
HANSEN	2865 TS	200 KVA	DAIHEN	1995	3SD1947B1	Pad Mount
HANSEN	2821 TS	200 KVA	MITSUBISHI	2000	DN9113001	Pad Mount
HANSEN	2241 TS	200 KVA	AICHI	1994	9420698	Pad Mount
HANSEN	2138 TS	200 KVA	HITACHI	2003	024670321	Pad Mount
HANSEN	2489-E TS	200 KVA	AICHI	2009	0921447	Pad Mount
HANSEN	2183 TS	200 KVA	AICHI	2004	04206635	Pad Mount
HANSEN	2457 TS	200 KVA	TOSHIBA	2002	02028889	Pad Mount
HANSEN	2858 TS	200 KVA	AICHI	2006	06208938	Pad Mount
KINSER	5G TS	200 KVA	DAIHEN		3SD0927A1	Pad Mount
KINSER	52-A TH	200 KVA	AICHI		8421663	Pad Mount
KINSER	90-C TS	200 KVA	AICHI	1993	92231117	Pad Mount
KINSER	104-B TS	200 KVA	AICHI	1978	8922063	Pad Mount
KINSER	415 TS	200 KVA	HITACHI		24754321	Pad Mount
MCAS	261 TS	200 KVA	AICHI		9222795	Pad Mount
MCAS	685 TS	200 KVA	DAIHEN		3SD1123A1	Pad Mount
MCAS	646 TS	200 KVA	MEIDEN	NOV 1993	1R9946T1	Pad Mount
CTNY	4234 TS	225 KVA	WESTING HOUSE		87JA840043	Pad Mount
CTNY	4218 TS	225 KVA	ABB		96J164212	Pad Mount
CTNY	4300 TS	225 KVA	B&B		0505920	Pad Mount
CTNY	4320 TS	225 KVA	PAUWELS	OCT 2005	05G135691	Pad Mount
CTNY-TG	4123 TS	225 KVA	COOPER	FEB 2006	0650003885	Pad Mount

FOSTER	330 TS	225 KVA	COOPER		969002966	Pad Mount
FOSTER	320 TS	225 KVA	COOPER	JAN2005	0537000671	Pad Mount
FOSTER	5-B TS	225 KVA	COOPER	FEB2005	0537000672	Pad Mount
FOSTER	183-A TS	225 KVA	WESTING HOUSE		79JH038017	Pad Mount
FOSTER	33-C TS	225 KVA	COOPER		906008978	Pad Mount
FOSTER	95-C TS	225 KVA	PAUWELS		20110704947	Pad Mount
FOSTER	89-C TS	225 KVA	PAUWELS	NOV 2004	20110704948	Pad Mount
FOSTER	5699 TS	225 KVA	COOPER	APR 2008	0850006947	Pad Mount
FOSTER	264-C TS	225 KVA	PAUWELS	2007 MAR	20060001856	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER	JUN 2008	0850010005	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER	MAY 2008	0850007864	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	PAUWELS	JUN 2007	20110703029	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER	DEC2004	0437020478	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER	DEC2004	0437020477	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER		0537005787	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	B&B	N/A	1215981	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	COOPER	DEC 2004	0437020880	Pad Mount
FOSTER-1	SHOP STOCK	225 KVA	ABB	JUL 2002	02J602094	Pad Mount
HANSEN	2206 TS	225 KVA	COOPER	AUG 2007	0750016080	Pad Mount
HANSEN	2444 TS	225 KVA	COOPER	2007 AUG	0750015008	Pad Mount
HANSEN	2617 TS	225 KVA	COOPER	FEB 2005	0537000623	Pad Mount
HANSEN	2618 TS	225 KVA	COOPER	FEB 2005	0537000624	Pad Mount
HANSEN	2510 TS	225 KVA	COOPER	FEB 2005	0537000625	Pad Mount
HANSEN	2460 TS	225 KVA	COOPER	JUN 2005	0537000670	Pad Mount
HANSEN	2449 TS	225 KVA	COOPER	DEC 2004	0537000622	Pad Mount
HANSEN	2631 TS	225 KVA	PAUWELS	JUL 2005	05E134081	Pad Mount
HANSEN	2148-A TS	225 KVA	VANTRAN		88V3333	Pad Mount
HANSEN	2728 TS	225 KVA	VANTRAN		88V3332	Pad Mount

HANSEN	2176 TS	225 KVA	PAUWELS	APR 2005	05C132897	Pad Mount
HANSEN	2407 TS	225 KVA	ABB	OCT 2003	03J898241	Pad Mount
HANSEN	2149 TS	225 KVA	ABB	2007 FEB	07J716216	Pad Mount
HANSEN	2620 TS	225 KVA	COOPER	OCT 2007	0750020176	Pad Mount
HANSEN	2857 TS	225 KVA	COOPER	MAY 2007	0750010141	Pad Mount
KINSER	1202-A TS	225 KVA	ABB	DEC 2008	08J162069	Pad Mount
KINSER	40-D TS	225 KVA	COOPER	JUN 2009	0950005374	Pad Mount
KINSER	37-A TS	225 KVA	VANTRAN		88V3352	Pad Mount
KINSER	42-A TS	225 KVA	VANTRAN		88V3351	Pad Mount
KINSER	1216 TS	225 KVA	PAUWELS		05E134080	Pad Mount
KINSER	40-B TS	225 KVA	SIERRA		9104-1	Pad Mount
MCAS	15 TS	225 KVA	CUTLER-HAMMER	OCT 2003	03J908084	Pad Mount
MCAS	38-BA TS	225 KVA	ABB	MAY 1996	96J094049	Pad Mount
MCAS	13-2 TS	225 KVA	ABB		96J067063	Pad Mount
MCAS	71B TS	225 KVA	ABB	NOV 2003	03J914087	Pad Mount
MCAS	665-A TS	225 KVA	COOPER	DEC2004	0437020474	Pad Mount
MCAS	17-B2 TS	225 KVA	COOPER	DEC2004	0437020475	Pad Mount
MCAS	11-E TS	225 KVA	COOPER	DEC2004	0437020476	Pad Mount
MCAS	2A-1 TS	225 KVA	ABB		91J822137	Pad Mount
MCAS	14 TS	225 KVA	ABB	1991 FEB	91J824197	Pad Mount
MCAS	17-B1 TS	225 KVA	COOPER		04J102349	Pad Mount
MCAS	39-A TS	225 KVA	COOPER		959006283	Pad Mount
MCAS	539 TS	225 KVA	COOPER	DEC 2007	0750023420	Pad Mount
MCAS	13-1 TS	225 KVA	PAUWELS	2007 MAR	20060001855	Pad Mount
CTNY	4446 TS	250 KVA	MITSUBISHI	2005	DA3652001	Pad Mount
CTNY	4224 TS	250 KVA	OSAKA	1985	3ND0487A1	Pad Mount
CTNY-TG	4118 TS	250 KVA	AICHI	1985	8521471	Pad Mount
HANSEN	2123 TS	250 KVA	DAIHEN	1988	2TE140701	Pad Mount

CTNY	4217 TS	30 KVA	MITSUBISHI	1978	D51789001	Pad Mount
FOSTER-1	SHOP STOCK	30 KVA	DAIHEN		3SD1766B1	Pad Mount
FOSTER-1	SHOP STOCK	30 KVA	ABB	NOV 2003	03J924055	Pad Mount
KINSER	54-A TH	30 KVA	DAIHEN		2TF909101	Pad Mount
MCAS	47A-5 POLE	30 KVA	AICHI		8622697	Pad Mount
FOSTER	129 RH	30 KW	WESTING HOUSE		1PXB09073	Pad Mount
FOSTER	129 RH	30 KW	WESTING HOUSE		1PXB13074	Pad Mount
CTNY	4419 TS	300 KVA	PAUWELS		20110703034	Pad Mount
CTNY	4231 TS	300 KVA	AICHI		9222797	Pad Mount
CTNY	4440 TS	300 KVA	MEIDEN	JAN 2004	4A5588TP1	Pad Mount
CTNY	4405 TS	300 KVA	TOSHIBA	1997	97060796	Pad Mount
CTNY	4451 TS	300 KVA	FUJI		A24004T1	Pad Mount
CTNY	4409 TS	300 KVA	COOPER	OCT 2005	0559002005	Pad Mount
CTNY	4316 TS	300 KVA	COOPER	2005 FEB	0537001402	Pad Mount
CTNY	4335 TS	300 KVA	COOPER	2005 JAN	0537001397	Pad Mount
FOSTER	5624 TS	300 KVA	AICHI	1997 AUG	9720746	Pad Mount
FOSTER	5618 TS	300 KVA	AICHI	2003	03204858	Pad Mount
FOSTER	91-A TS	300 KVA	COOPER	APR 1996	969002967	Pad Mount
FOSTER	5713 TS	300 KVA	AICHI	2004	04206081	Pad Mount
FOSTER	361 TS	300 KVA	AICHI		9420508	Pad Mount
FOSTER	5634 TS	300 KVA	MITSUBISHI	1990	DX3611001	Pad Mount
FOSTER	5835 TS	300 KVA	MITSUBISHI	2003	DJ7988001	Pad Mount
FOSTER	5949 TS	300 KVA	FUJI	2000 DEC	B00344A01	Pad Mount
FOSTER	437 TS	300 KVA	HITACHI	APR 2004	23012421	Pad Mount
FOSTER	14 TS	300 KVA	DAIHEN		3SD2084B1	Pad Mount
FOSTER	371 TS	300 KVA	COOPER	2005 JAN	0537001399	Pad Mount
FOSTER	5679 TS	300 KVA	AICHI		9023259	Pad Mount
FOSTER	5900 TS	300 KVA	WESTING HOUSE		83JB885015	Pad Mount

FOSTER	4 TS	300 KVA	CUTLER-HAMMER	AUG 2004	04J102272	Pad Mount
FOSTER	499 TS	300 KVA	AICHI	FEB 1989	8822210	Pad Mount
FOSTER	5910 TS	300 KVA	COOPER		0850016223	Pad Mount
FOSTER	16C TS	300 KVA	ABB	SEP 2007	07J872209	Pad Mount
FOSTER	1017 TS	300 KVA	ALSTOM	JUN 2003	PIF-0427	Pad Mount
FOSTER	90 TS	300 KVA	COOPER	OCT 2007	0759002459	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	VANTRAN	N/A	96-6655	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	PAUWELS	SEP 2008	20110811295	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	ABB	JUN 98	98J505238	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	OCT 06	0650019150	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	DEC2004	0437020529	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	JAN 05	0437020528	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	MAY 2010	1050004104	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	MAY 2010	1050004102	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	PAUWELS	NOV 2004	04J129803	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	AUG 2004	0437014260	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	NOV 2009	0950010824	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	MAY 2010	1050004105	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	AICHI	2003	03203801	Pad Mount
FOSTER-1	SHOP STOCK	300 KVA	COOPER	JUL 2009	0950006598	Pad Mount
HANSEN	2215 TS	300 KVA	COOPER	2007 JUL	0750014503	Pad Mount
HANSEN	2534 TS	300 KVA	AICHI	2005	05207385	Pad Mount
HANSEN	2867 TS	300 KVA	MITSUBISHI		L24257121	Pad Mount
HANSEN	2386 TS	300 KVA	HITACHI	2000	23601921	Pad Mount
HANSEN	2134 TS	300 KVA	AICHI	1992	9221188	Pad Mount
HANSEN	2130 TS	300 KVA	COOPER	2005 FEB	0537001398	Pad Mount
HANSEN	2505 TS	300 KVA	PAUWELS	APR 2005	05C132898	Pad Mount
HANSEN	2142 TS	300 KVA	COOPER	JUY 2009	0950005375	Pad Mount

HANSEN	2716 TS	300 KVA	DAIHEN	2000	KNB0165B1	Pad Mount
HANSEN	2616 TS	300 KVA	MITSUBISHI	1994	DH8717001	Pad Mount
HANSEN	2455 TS	300 KVA	AICHI	1999	9821620	Pad Mount
HANSEN	2383 TS	300 KVA	COOPER	NOV 2006	0650021781	Pad Mount
HANSEN	2420 TS	300 KVA	AICHI	2006	06210657	Pad Mount
HANSEN	2345 TS	300 KVA	MEIDEN	2004 JAN	4A5611TP1	Pad Mount
HANSEN	2397 TS	300 KVA	ABB	APR 2002	02J544290	Pad Mount
HANSEN	2375 TS	300 KVA	AICHI	2000	0700900	Pad Mount
HANSEN	2323 TS	300 KVA	FUJI	2001 MAY	B00422A01	Pad Mount
HANSEN	2828 TS	300 KVA	AICHI	2006	06208939	Pad Mount
HANSEN	2814 TS	300 KVA	AICHI	1995	9522553	Pad Mount
HANSEN	2818 TS	300 KVA	AICHI	2005	05207530	Pad Mount
HANSEN	2627 TS	300 KVA	HITACHI	2002	24257121	Pad Mount
HANSEN-1	SHOP STOCK	300 KVA	COOPER	JUL 2010	1050006856	Pad Mount
HENOKO	10 TS	300 KVA	VANTRAN		88V3350	Pad Mount
KINSER	1229 TS	300 KVA	DAIHEN		3ND0859A1	Pad Mount
KINSER	708 TS	300 KVA	HITACHI	2001	I24255121	Pad Mount
KINSER	18 TS	300 KVA	G.E.		L190261T73AA	Pad Mount
KINSER	26-A TS	300 KVA	COOPER	DEC2004	0437020530	Pad Mount
KINSER	202 TS	300 KVA	FUJI	1993 DEC	B30228A02	Pad Mount
KINSER	5-E TS	300 KVA	FUJI	1983 DEC	B30119A01	Pad Mount
KINSER	M-21 TS	300 KVA	COOPER	DEC2004	0437020533	Pad Mount
KINSER	1307 TS	300 KVA	FUJI ELECTRIC	1995 FEB	B40194A01	Pad Mount
KINSER	1220 TS	300 KVA	AICHI	1997	9720757	Pad Mount
KINSER	92-A TS	300 KVA	AICHI	1989	8822081	Pad Mount
KINSER	4-A TS	300 KVA	MITSUBISHI	1981	DA3057001	Pad Mount
KINSER	21-A TS	300 KVA	SIERRA		9004-1	Pad Mount
MCAS	13-3 TS	300 KVA	ABB	SEP 2003	03J872095	Pad Mount

MCAS	42 TS	300 KVA	ABB	OCT 2003	03J913182	Pad Mount
MCAS	539A TS	300 KVA	COOPER	DEC 2007	0750023250	Pad Mount
MCAS	633 TS	300 KVA	FUJI		A53659T1	Pad Mount
MCAS	2A-TR	300 KVA	VANTRAN		01V5667	Pad Mount
MCAS	6-C TS	300 KVA	ABB	JAN 2002	02J582146	Pad Mount
MCAS	684 TS	300 KVA	VANTRAN		04V6815	Pad Mount
MCAS	11-3 TS	300 KVA	COOPER		0526000267	Pad Mount
MCAS	676 TS	300 KVA	MITSUBISHI		DC6959001	Pad Mount
MCAS	77-A TS	300 KVA	COOPER	APR 2005	0526000429	Pad Mount
MCAS	159 TS	300 KVA	DAIHEN		3SD1831B1	Pad Mount
MCAS	20-C TS	300 KVA	G.E.		E-693088	Pad Mount
MCAS	546 TS	300 KVA	DAIHEN		3SD1330A1	Pad Mount
MCAS	20-G TS	300 KVA	SUNBELT		3279783104	Pad Mount
MCAS	429 TS	300 KVA	COOPER	NOV 2009	0950010825	Pad Mount
FOSTER	104 TS	3000 KVA	NIAGARA		60310	Pad Mount
FOSTER	104 TS	3000 KVA	NIAGARA		50309	Pad Mount
CTNY	4213 TS	350 KVA	OSAKA	1985	3ND0539A-1	Pad Mount
HANSEN	2495 TS	350 KVA	MITSUBISHI	1992	D90879003	Pad Mount
MCAS	518 TV	37.5 KW	COOPER		4153	Pad Mount
MCAS	518 TV	37.5 KW	COOPER		4152	Pad Mount
MCAS	518 TV	4 KW	COOPER		1485	Pad Mount
MCAS	518 TV	4 KW	COOPER		1480	Pad Mount
MCAS	518 TV	4 KW	COOPER		1479	Pad Mount
MCAS	518 TV	4 KW	COOPER		1481	Pad Mount
MCAS	518 TV	4 KW	COOPER		1484	Pad Mount
MCAS	518 TV	4 KW	COOPER		1487	Pad Mount
MCAS	518 TV	4 KW	COOPER		1483	Pad Mount
MCAS	518 TV	4 KW	COOPER		1482	Pad Mount

MCAS	518 TV	4 KW	COOPER		1486	Pad Mount
FOSTER	131-B1 TS	400 KVA	MEIDEN	NOV 1986	1M9301T2	Pad Mount
FOSTER	132-A TS	400 KVA	MEIDEN	NOV 1986	1M9301T1	Pad Mount
FOSTER-1	SHOP STOCK	400 KVA	AICHI		8421351	Pad Mount
HANSEN	2888 TS	400 KVA	OSAKA	1981	3D0134A01	Pad Mount
HANSEN	2820 TS	400 KVA	MEIDEN	OCT 1984	1K8888T1	Pad Mount
HANSEN	2655 TS	400 KVA	MEIDEN	OCT 1984	1K8890T1	Pad Mount
MCAS	9-D TS	400 KVA	OSAKA	OCT 1984	3ND0499A1	Pad Mount
HANSEN	2601 TV	400A OS	G&W		799-216	Pad Mount
HANSEN	2663 TV	400A OS	G&W		799-238	Pad Mount
KINSER	831 (B) SW	400A VS	MITSUBISHI	1998 MAR	ID507102	Pad Mount
KINSER	831 (A) SW	400A VS	MITSUBISHI	1998 MAR	ID507101	Pad Mount
CTNY	4209 TS	45 KVA	VANTRAN		03V6460	Pad Mount
CTNY-TG	6E TS	45 KVA	COOPER	DEC 2007	0859000030	Pad Mount
FOSTER	1013 TS	45 KVA	SUNBELT		3297723104	Pad Mount
FOSTER	7 TS	45 KVA	PAUWELS	JUN 2007	20110703032	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	PAUWELS	JUN 2009	20110916859	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	COOPER	N/A	949002952	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	COOPER	MAY 2008	0850007946	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	PAUWELS	JUN 2007	20110703033	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	COOPER	2005 FEB	0537003791	Pad Mount
FOSTER-1	SHOP STOCK	45 KVA	VANTRAN	N/A	03V6541-3	Pad Mount
KINSER	54-A TH	45 KVA	MITSUBISHI		AZ0970001	Pad Mount
KINSER	66-F TS	45 KVA	VANTRAN		03V6541-1	Pad Mount
KINSER	106 TS	45 KVA	COOPER	AUG 2006	0650016474	Pad Mount
MCAS	64-B TS	45 KVA	PAUWELS	2008 FEB	20110708373	Pad Mount
MCAS	48-B TS	45 KVA	ABB	JUN 2003	03J806149	Pad Mount
MCAS	656 TS	45 KVA	ABB	FEB 1997	97J284026	Pad Mount

MCAS	503 TS	45 KVA	COOPER	2005 FEB	0537003495	Pad Mount
MCAS	37-A TS	45 KVA	PAUWELS		93F51772	Pad Mount
MCAS	151 TS	45 KVA	PAUWELS	APR 2005	05C132899	Pad Mount
MCAS	46-A TS	45 KVA	VANTRAN		03V6541-4	Pad Mount
MCAS	112 TS	45 KVA	VANTRAN		03V6546-1	Pad Mount
MCAS	120 TS	45 KVA	VANTRAN		03V6546-2	Pad Mount
MCAS	125 TS	45 KVA	VANTRAN		03V6546-3	Pad Mount
MCAS	44 TS	45 KVA	VANTRAN		03V6541-5	Pad Mount
MCAS	9-7C TS	45 KVA	PAUWELS		06J144236	Pad Mount
MCAS	501 TS	45 KVA	VANTRAN		87V2308	Pad Mount
CTNY	4425 TS	50 KVA	DAIHEN	1997	3SD2138R1	Pad Mount
FOSTER	TAKE TO 5609	50 KVA	H. K.PORTER		W-237186	Pad Mount
FOSTER	151B TH	50 KVA	AICHI		03101481	Pad Mount
FOSTER	27 POLE	50 KVA	DAIHEN		QNB399701	Pad Mount
FOSTER-1	SHOP STOCK	50 KVA	MITSUBISHI		DZ3922001	Pad Mount
FOSTER-1	SHOP STOCK	50 KVA	DAIHEN	2002	GNB399701	Pad Mount
HANSEN	264C POLE	50 KVA	DAIHEN	1994	2TF52570	Pad Mount
HANSEN	2385 TS	50 KVA	DAIHEN	1994	3SD1715B1	Pad Mount
HANSEN	2200 TS	50 KVA	JIMELCO	MAR 0991	AA000201412	Pad Mount
HANSEN	2498 TS	50 KVA	FUJI	1993 FEB	A24005T1	Pad Mount
HANSEN	2453 TS	50 KVA	AICHI	2008	08212761	Pad Mount
HENOKO	18 TS	50 KVA	ABB		02J643186	Pad Mount
KINSER	1205 TS	50 KVA	AICHI	1993	9320747	Pad Mount
CTNY	4433 TS	500 KVA	MITSUBISHI		DX3707001	Pad Mount
CTNY	4228 TS	500 KVA	HOWARD		3770674895	Pad Mount
CTNY	4219 TS	500 KVA	COOPER	NOV 2007	0759001145	Pad Mount
CTNY-TG	4102 TS	500 KVA	COOPER	2008 JAN	0750024439	Pad Mount
CTNY-TG	4131 TS	500 KVA	MEIDEN	AUG 1987	1M9938T1	Pad Mount

CTNY-TG	4148 TS	500 KVA	HITACHI	2003	24645221	Pad Mount
FOSTER	445 TS	500 KVA	MEIDEN	1998 DEC	1N6330T1	Pad Mount
FOSTER	478 TS	500 KVA	AICHI	1997 AUG	9721148	Pad Mount
FOSTER	217 TS	500 KVA	FUJI		A30952T1	Pad Mount
FOSTER	494 TS	500 KVA	AICHI	2004	04206082	Pad Mount
FOSTER	1 TV	500 KVA	MOLONEY		1934243	Pad Mount
FOSTER	359 TS	500 KVA	HITACHI	JULY 2004	23013421	Pad Mount
FOSTER	TAKE TO 5609	500 KVA	G.E.		Q112067-TRH	Pad Mount
FOSTER	220 TS	500 KVA	AICHI		9122773	Pad Mount
FOSTER	481 TS	500 KVA	FUJI	JAN 1996	B50348AT1	Pad Mount
FOSTER	5973 TS	500 KVA	AICHI	2006	06209924	Pad Mount
FOSTER	1000 TS	500 KVA	COOPER	AUG 2002	0237013493	Pad Mount
FOSTER	222 TS	500 KVA	MITSUBISHI		DC1671001	Pad Mount
FOSTER	490 TS	500 KVA	MITSUBISHI	1999	DD9891001	Pad Mount
FOSTER	495 TS	500 KVA	AICHI	2002	02704123	Pad Mount
FOSTER	5903 TS	500 KVA	MITSUBISHI	1988	DM9906001	Pad Mount
FOSTER	5822 TS	500 KVA	HITACHI	2003 APR	24751321	Pad Mount
FOSTER	5644 TS	500 KVA	HITACHI	2004	23062421	Pad Mount
FOSTER	5696 TS	500 KVA	DAIHEN	1991	3SD1250A1	Pad Mount
FOSTER	5670 TS	500 KVA	WESTING HOUSE	OCT 1989	89J495273	Pad Mount
FOSTER	5704 TS	500 KVA	AICHI	1989	892221701	Pad Mount
FOSTER	5703 TS	500 KVA	AICHI	1989	892221702	Pad Mount
FOSTER	5836 TS	500 KVA	HITACHI	2003	24820321	Pad Mount
FOSTER	9 TS	500 KVA	COOPER		0526001680	Pad Mount
FOSTER	131-E TS	500 KVA	AICHI	1988	8721968	Pad Mount
FOSTER	38 TS	500 KVA	VANTRAN		07V8039	Pad Mount
FOSTER	370 TS	500 KVA	DAIHEN	1991	3SD1253A1	Pad Mount
FOSTER	5906 TS	500 KVA	COOPER	SEP 2008	0850014636	Pad Mount

FOSTER-1	SHOP STOCK	500 KVA	COOPER	MAR 2009	0950003263	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	DAIHEN	1988	3ND0754A1	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	DAIHEN	1991	3SD1254A1	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	FUJI		A30951T1	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	COOPER	MAY 2009	0950005190	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	MITSUBISHI	2005	DA3633001	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	COOPER	MAY 2006	0650008288	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	COOPER	NOV 2007	0750021298	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	MITSUBISHI	2005	DA3631001	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	COOPER	JUN 2010	1050006859	Pad Mount
FOSTER-1	SHOP STOCK	500 KVA	ABB	SEP 2003	03J871119	Pad Mount
HANSEN	2441 TS	500 KVA	FUJI	1993 MAR	A24006T1	Pad Mount
HANSEN	2205 TS	500 KVA	AICHI	1997	9721571	Pad Mount
HANSEN	2819 TS	500 KVA	TOSHIBA	2003	02033660	Pad Mount
HANSEN	2610 TS	500 KVA	MEIDEN	JUL 1999	1N6714T1	Pad Mount
HANSEN	2519 TS	500 KVA	AICHI	1999	9821621	Pad Mount
HANSEN	2729 TS	500 KVA	AICHI	2002	02704782	Pad Mount
HANSEN	2221 TS	500 KVA	MEIDEN	1996 JAN	1T8311T1	Pad Mount
HANSEN	2518 TS	500 KVA	MITSUBISHI	1996	DN3220001	Pad Mount
HANSEN	2445 TS	500 KVA	MITSUBISHI	1988	DM1953001	Pad Mount
HANSEN	2141 TS	500 KVA	G.E.	1991 NOV	P817332TYF	Pad Mount
HANSEN	2431 TS	500 KVA	DAIHEN	1992	3SD153501	Pad Mount
HANSEN	2530 TS	500 KVA	DAIHEN	1992	3SD1424A1	Pad Mount
HANSEN	2442 TS	500 KVA	MEIDEN	1990 DEC	1P9691T1	Pad Mount
HANSEN	2622 TS	500 KVA	DAIHEN	1990	3SD1232A1	Pad Mount
HANSEN	2665 TS	500 KVA	DAIHEN	1990	3SD1122A1	Pad Mount
HANSEN	2339 TS	500 KVA	HITACHI	2003	024775321	Pad Mount
HANSEN	2245 TS	500 KVA	TOSHIBA	1999	99000692	Pad Mount

HANSEN	2872 TS	500 KVA	AICHI	2003	03204219	Pad Mount
HANSEN	2165 TS	500 KVA	MITSUBISHI	1994	DH4649001	Pad Mount
HANSEN	2860 TS	500 KVA	AICHI	1994	9421620	Pad Mount
HANSEN	2814-A TS	500 KVA	VANTRAN		00V5179	Pad Mount
HANSEN	2416 TS	500 KVA	COOPER	2007 JAN	0750002595	Pad Mount
HANSEN	2340 TS	500 KVA	FUJI	1990 JAN	B90330A01	Pad Mount
KINSER	401 TV	500 KVA	G.E.		M154620	Pad Mount
KINSER	51-H TS	500 KVA	COOPER	DEC2004	0437020881	Pad Mount
KINSER	99 TS	500 KVA	MITSUBISHI	1988	DM4692001	Pad Mount
KINSER	616 TS	500 KVA	FUJI ELECTRIC	NOV 1993	B30146A01	Pad Mount
KINSER	1225 TS	500 KVA	FUJI	DEC 1990	B00288A01	Pad Mount
KINSER	618 TS	500 KVA	TOSHIBA	2002	01057452	Pad Mount
KINSER	29-A TH	500 KVA	JIMELCO		AA00201407	Pad Mount
KINSER	208 TS	500 KVA	COOPER	SEP2004	0437015743	Pad Mount
KINSER	24-D TS	500 KVA	COOPER	APR 2008	0850007597	Pad Mount
MCAS	433-A TS	500 KVA	COOPER	2007 OCT	0759002306	Pad Mount
MCAS	36-B TS	500 KVA	ABB	1997 FEB	97J269325	Pad Mount
MCAS	64-A TS	500 KVA	AICHI	1990	8922620	Pad Mount
MCAS	433 TS	500 KVA	COOPER	2007 OCT	0759002435	Pad Mount
MCAS	219 TS	500 KVA	ABB	JUN 2005	05J319105	Pad Mount
MCAS	39 TV	500 KVA	JIMELCO		AA00201410	Pad Mount
MCAS	4-A TV	500 KVA	JIMELCO	MAR 1991	AA00201409	Pad Mount
MCAS	633A TS	500 KVA	VANTRAN		01V5700	Pad Mount
MCAS	417 TS	500 KVA	ABB		03J767219	Pad Mount
MCAS	509 TS	500 KVA	COOPER	NOV 2007	0750022806	Pad Mount
MCAS	223 TS	500 KVA	AICHI		9222303	Pad Mount
MCAS	525 TS	500 KVA	AICHI	1991	9023315	Pad Mount
MCAS	218 TS	500 KVA	COOPER		0537015240	Pad Mount

MCAS	4-B TS	500 KVA	H. K.PORTER		W224357	Pad Mount
MCAS	740 TS	500 KVA	MEIDEN	SEP 1991	1Q8154T1	Pad Mount
MCAS	505-A TS	500 KVA	ABB	DEC 2008	08J163083	Pad Mount
MCAS	229 TS	500 KVA	MEIDEN	1994 NOV	1R9945T1	Pad Mount
MCAS	3 TS	500 KVA	BALTEAU		PYB-0143	Pad Mount
MCAS	6-B TS	500 KVA	COOPER	MAY 2008	0850007611	Pad Mount
N.T.A	502 TS	500 KVA	COOPER	JUL 2007	0750013417	Pad Mount
FOSTER	21 GS	600 A	G&W (SF6)		625-00-0162	Pad Mount
FOSTER-1	SHOP STOCK	600 A	G&W		626-02-0016	Pad Mount
FOSTER-1	SHOP STOCK	600 A	G&W	OCT 2007	627-07-0962	Pad Mount
FOSTER-1	SHOP STOCK	600 A	G&W	APR 2000	625-00-0184	Pad Mount
FOSTER-1	SHOP STOCK	600 A	G&W	APR 2000	622-00-0013	Pad Mount
CTNY	4229 TS	75 KVA	AICHI	1986	8622045	Pad Mount
CTNY	4467 TS	75 KVA	MEIDEN	1978	1T8016T1	Pad Mount
CTNY	4496 TS	75 KVA	MEIDEN	OCT 1988	1N8922T1	Pad Mount
CTNY	4331 TS	75 KVA	COOPER	2000 FEB	0037003186	Pad Mount
CTNY	4423 TS	75 KVA	COOPER	SEP 1995	959004585	Pad Mount
CTNY	4460 TS	75 KVA	FUJI		A01329T1-1	Pad Mount
CTNY	4227 TS	75 KVA	PAUWELS		05J136842	Pad Mount
CTNY	4461 TS	75 KVA	PAUWELS	OCT 2005	05G135692	Pad Mount
CTNY	4204 TS	75 KVA	COOPER	SEP 04	0437014505	Pad Mount
CTNY	4408 TS	75 KVA	PAUWELS	NOV 2004	04J129806	Pad Mount
CTNY-TG	4151 TS	75 KVA	AICHI	1993	9320157	Pad Mount
FOSTER	546 TS	75 KVA	CUTLER-HAMMER	OCT 2003	03J907081	Pad Mount
FOSTER	267-B2 TS	75 KVA	RTE		896005650	Pad Mount
FOSTER	262 TS	75 KVA	AICHI	2001	01703756	Pad Mount
FOSTER	5608 TS	75 KVA	MITSUBISHI	1988	DM0066001	Pad Mount
FOSTER	5606 TS	75 KVA	DAIHEN	1988	35SD0926A1	Pad Mount

FOSTER	154-D TS	75 KVA	COOPER	FEB2005	0537000684	Pad Mount
FOSTER	456 TS	75 KVA	COOPER	AUG 2004	043701514	Pad Mount
FOSTER	5828 TS	75 KVA	COOPER	SEP 2004	0437014506	Pad Mount
FOSTER	5638 TS	75 KVA	MEIDEN	JUL 1994	1S8380T1	Pad Mount
FOSTER	146-B TS	75 KVA	RTE		866001907	Pad Mount
FOSTER	267-B1 TS	75 KVA	WESTING HOUSE		86JC624058	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	PAUWELS	AUG 2008	20110811454	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	COOPER	SEP 2006	0650016411	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	COOPER	SEP 2004	0437015140	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	PAUWELS	JUL 2005	05E134381	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	COOPER	2005 FEB	0537003657	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	COOPER	2005 FEB	0537003658	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	HOWARD		2212572195	Pad Mount
FOSTER-1	SHOP STOCK	75 KVA	COOPER	AUG 2006	0650016412	Pad Mount
HANSEN	124 POLE	75 KVA	FUJI	JUN 1999	A90889T1	Pad Mount
HANSEN	2113 TS	75 KVA	COOPER	2005 FEB	0537003793	Pad Mount
HANSEN	2425 TS	75 KVA	COOPER	SEP 2007	0750017628	Pad Mount
HANSEN	2386 TS	75 KVA	HITACHI	2000	23601911	Pad Mount
HANSEN	2895 TS	75 KVA	RTE		886006888	Pad Mount
HANSEN	2448 TS	75 KVA	OSAKA	1983	3D0332A01	Pad Mount
HANSEN	2663 TS	75 KVA	PAUWELS	2008 FEB	20110708980	Pad Mount
HANSEN	2203 TS	75 KVA	SUNBELT	AUG 1982	ST029756407	Pad Mount
HANSEN	261-B POLE	75 KVA	FUJI	JUN 1993	A30945T1	Pad Mount
HANSEN	2542 TS	75 KVA	ABB	AUG 1997	97J406217	Pad Mount
HANSEN	2206 TS	75 KVA	ABB	1997 FEB	97J284160	Pad Mount
HANSEN	2395-A TS	75 KVA	COOPER	DEC 2007	0859000042	Pad Mount
HANSEN	2395 TS	75 KVA	COOPER	MAR 2010	1050002252	Pad Mount
HANSEN	2466 TS	75 KVA	MEIDEN	1999 JUN	1N6648T1	Pad Mount

HENOKO	1020 TS	75 KVA	DAIHEN		3SD2137B1	Pad Mount
HENOKO	19 TS	75 KVA	PAUWELS		99C79864	Pad Mount
KINSER	626 TS	75 KVA	DAIHEN	1993	3SD162401	Pad Mount
KINSER	407 TS	75 KVA	AICHI	1993	9320156	Pad Mount
KINSER	79-B TS	75 KVA	MITSUBISHI		DZ8626001	Pad Mount
KINSER	204 TS	75 KVA	AICHI		017003828	Pad Mount
MCAS	12-B TS	75 KVA	FUJI		B70346AT1	Pad Mount
MCAS	53-A TS	75 KVA	ABB	SEP 2002	02J648031	Pad Mount
MCAS	553 TS	75 KVA	COOPER	NOV 1995	959006333	Pad Mount
MCAS	202 TS	75 KVA	COOPER	NOV 2007	0750022395	Pad Mount
MCAS	538 TS	75 KVA	COOPER	2007 JAN	0759000112	Pad Mount
MCAS	450 TS	75 KVA	COOPER	APR 2009	0950003759	Pad Mount
MCAS	38-L TS	75 KVA	PAUWELS		20110703031	Pad Mount
MCAS	13 TS	75 KVA	DAIHEN	1999	KSB0141B1	Pad Mount
MCAS	57-A TS	75 KVA	HOWARD		3005213694	Pad Mount
MCAS	553A TS	75 KVA	COOPER	OCT 2008	0850016308	Pad Mount
MCAS	44A TS	75 KVA	WESTING HOUSE		86JH733156	Pad Mount
MCAS	665 TS	75 KVA	PAUWELS	JUN 2008	20110810763	Pad Mount
N.T.A	532 TS	75 KVA	JIMELCO	1991 MAR	AA00201414	Pad Mount
CTNY	4417 TS	750 KVA	FUJI	2002 NOV	A20021	Pad Mount
CTNY	4225 TS	750 KVA	COOPER	AUG 03	0326001576	Pad Mount
CTNY	4211 TS	750 KVA	HOWARD		1530390804	Pad Mount
CTNY-TG	4132 TS	750 KVA	PAUWELS	AUG 2006	06C140508	Pad Mount
FOSTER	464 TS	750 KVA	ABB	1998 JUN	98J597224	Pad Mount
FOSTER	11 TS	750 KVA	MEIDEN	2001 AUG	1P5419T1	Pad Mount
FOSTER	5907 TS	750 KVA	AICHI	2001	01703349	Pad Mount
FOSTER	363 TS	750 KVA	MITSUBISHI	2001	DY1357001	Pad Mount
FOSTER	480 TS	750 KVA	MITSUBISHI	1996	DM2743001	Pad Mount

FOSTER	5966 TS	750 KVA	HITACHI	2004	23014421	Pad Mount
FOSTER	5902 TS	750 KVA	AICHI	2005	05206083	Pad Mount
FOSTER	460 TS	750 KVA	ABB	DEC 2004	04J185376	Pad Mount
FOSTER	5906 TS	750 KVA	COOPER	SEP 2008	0850014902	Pad Mount
FOSTER-1	SHOP STOCK	750 KVA	AICHI	1997	9623180	Pad Mount
FOSTER-1	SHOP STOCK	750 KVA	COOPER	AUG 2010	1050008156	Pad Mount
FOSTER-1	SHOP STOCK	750 KVA	COOPER	NOV 2009	0950010955	Pad Mount
HANSEN	2635 TS	750 KVA	HITACHI	1999	23339821	Pad Mount
HANSEN	2447 TS	750 KVA	COOPER	2005 FEB	0537004265	Pad Mount
HANSEN	2667 TS	750 KVA	AICHI	1993	9223017	Pad Mount
HANSEN	2893 TS	750 KVA	MEIDEN	OCT 1992	1R8626T1	Pad Mount
HANSEN	2327 TS	750 KVA	DAIHEN	1993	3SD1605A1	Pad Mount
HANSEN	2537 TS	750 KVA	DAIHEN	1992	3SD1429A1	Pad Mount
HANSEN	2450 TS	750 KVA	COOPER	DEC 2008	085002123	Pad Mount
HANSEN	2825 TS	750 KVA	AICHI	2002	02704784	Pad Mount
HANSEN	2153 TS	750 KVA	AICHI	2005	05208270	Pad Mount
HANSEN	2725 TS	750 KVA	FUJI	SEP 1992	B20168A01	Pad Mount
HANSEN	2118 TS	750 KVA	AICHI	2007	07211927	Pad Mount
HANSEN	2443 TS	750 KVA	VANTRAN		06V7282	Pad Mount
KINSER	100 TS	750 KVA	MITSUBISHI	1989	DP3113001	Pad Mount
KINSER	66-H TS	750 KVA	COOPER	OCT 2008	0850017701	Pad Mount
KINSER	300 TS	750 KVA	COOPER	MAY 2008	0850008332	Pad Mount
KINSER	1226 TS	750 KVA	DAIHEN	1991	3SD1272A1	Pad Mount
KINSER	1202 TS	750 KVA	AICHI	1993	9222379	Pad Mount
KINSER	1210 TS	750 KVA	FUJI	MAR 1992	B10310A01	Pad Mount
KINSER	40-E TS	750 KVA	PAUWELS		00A101228	Pad Mount
KINSER	104-A TS	750 KVA	FUJI	1993 JUN	A30954T1	Pad Mount
KINSER	502 TS	750 KVA	COOPER	2005 FEB	0537003496	Pad Mount

KINSER	29-F TS	750 KVA	COOPER		0537007394	Pad Mount
KINSER	41-A TH	750 KVA	COOPER	APR 2010	1050003055	Pad Mount
KINSER	18 TS	750 KVA	RTE		906008395	Pad Mount
MCAS	400 TS	750 KVA	COOPER	JAN 2007	0759000102	Pad Mount
MCAS	2B-4A TS	750 KVA	COOPER	NOV 2007	0759001159	Pad Mount
MCAS	548 TS	750 KVA	MITSUBISHI		D28363001	Pad Mount
MCAS	510 TS	750 KVA	ABB	SEP 2005	05J388001	Pad Mount
MCAS	562 TS	750 KVA	MITSUBISHI		DP1479001	Pad Mount
MCAS	20-B2 TS	750 KVA	COOPER	APR 2008	0850007313	Pad Mount
MCAS	443 TS	750 KVA	COOPER	DEC 2008	0850020328	Pad Mount
MCAS	439 TS	750 KVA	COOPER	DEC 2008	0850020568	Pad Mount
HANSEN	2493 TS	850 KVA	AICHI	1985	8521374	Pad Mount

END

CAMP	LOC	CAPACITY KVA	MFR_DATE	MANUFACT	Serial_ID	Type	#	#	#	Age
FOSTER	5704 TS	500	1989	AICHI	892221701	Pad Mount	1			23
FOSTER	5703 TS	500	1989	AICHI	892221702	Pad Mount	2			23
FOSTER	478 TS	500	1997	AICHI	9721148	Pad Mount	3			15
FOSTER	5696 TS	500	1991	DAIHEN	3SD1250A1	Pad Mount	4			21
FOSTER	370 TS	500	1991	DAIHEN	3SD1253A1	Pad Mount	5			21
FOSTER	481 TS	500	1996	FUJI	B50348AT1	Pad Mount	6			16
FOSTER	445 TS	500	1998	MEIDEN	1N6330T1	Pad Mount	7			14
FOSTER	490 TS	500	1999	MITSUBISHI	DD9891001	Pad Mount	8			13
FOSTER	5670 TS	500	1989	WESTING HOUSE	89J495273	Pad Mount	9			23
HANSEN	2860 TS	500	1994	AICHI	9421620	Pad Mount	10			18
HANSEN	2519 TS	500	1999	AICHI	9821621	Pad Mount	11			13
HANSEN	2622 TS	500	1990	DAIHEN	3SD1232A1	Pad Mount	12			22
HANSEN	2665 TS	500	1990	DAIHEN	3SD1122A1	Pad Mount	13			22
HANSEN	2530 TS	500	1992	DAIHEN	3SD1424A1	Pad Mount	14			20
HANSEN	2340 TS	500	1990	FUJI	B90330A01	Pad Mount	15			22
HANSEN	2441 TS	500	1993	FUJI	A24006T1	Pad Mount	16			19
HANSEN	2141 TS	500	1991	G.E.	P817332TYF	Pad Mount	17			21
HANSEN	2442 TS	500	1990	MEIDEN	1P9691T1	Pad Mount	18			22
HANSEN	2221 TS	500	1996	MEIDEN	1T8311T1	Pad Mount	19			16
HANSEN	2610 TS	500	1999	MEIDEN	1N6714T1	Pad Mount	20			13
HANSEN	2165 TS	500	1994	MITSUBISHI	DH4649001	Pad Mount	21			18
HANSEN	2518 TS	500	1996	MITSUBISHI	DN3220001	Pad Mount	22			16
HANSEN	2245 TS	500	1999	TOSHIBA	99000692	Pad Mount	23			13
KINSER	1225 TS	500	1990	FUJI	B00288A01	Pad Mount	24			22
KINSER	616 TS	500	1993	FUJI	B30146A01	Pad Mount	25			19
KINSER	99 TS	500	1988	MITSUBISHI	DM4692001	Pad Mount	26			24
FOSTER	464 TS	750	1998	ABB	98J597224	Pad Mount	27	1		14
FOSTER	5907 TS	750	2001	AICHI	1703349	Pad Mount	28	2		11
FOSTER	11 TS	750	2001	MEIDEN	1P5419T1	Pad Mount	29	3		11
FOSTER	480 TS	750	1996	MITSUBISHI	DM2743001	Pad Mount	30	4		16
FOSTER	363 TS	750	2001	MITSUBISHI	DY1357001	Pad Mount	31	5		11
HANSEN	2667 TS	750	1993	AICHI	9223017	Pad Mount	32	6		19
HANSEN	2537 TS	750	1992	DAIHEN	3SD1429A1	Pad Mount	33	7		20
HANSEN	2327 TS	750	1993	DAIHEN	3SD1605A1	Pad Mount	34	8		19
HANSEN	2725 TS	750	1992	FUJI	B20168A01	Pad Mount	35	9		20
HANSEN	2635 TS	750	1999	HITACHI	23339821	Pad Mount	36	10		13
HANSEN	2893 TS	750	1992	MEIDEN	1R8626T1	Pad Mount	37	11		20
KINSER	1202 TS	750	1993	AICHI	9222379	Pad Mount	38	12		19
KINSER	1226 TS	750	1991	DAIHEN	3SD1272A1	Pad Mount	39	13		21
KINSER	1210 TS	750	1992	FUJI	B10310A01	Pad Mount	40	14		20
KINSER	104-A TS	750	1993	FUJI	A30954T1	Pad Mount	41	15		19
KINSER	100 TS	750	1989	MITSUBISHI	DP3113001	Pad Mount	42	16		23
FOSTER	1002 TS	1000	1993	G.E.	Q108279-TNI	Pad Mount	43		1	19
FOSTER	1004 TV	1000	1989	WESTING HOUSE	PAW4176-0101	Pad Mount	44		2	23
HANSEN	2365 TS	1000	2001	FUJI	B10215A01	Pad Mount	45		3	11
HANSEN	2654 TS	1000	2000	TOSHIBA	23589	Pad Mount	46		4	12

Age Sort
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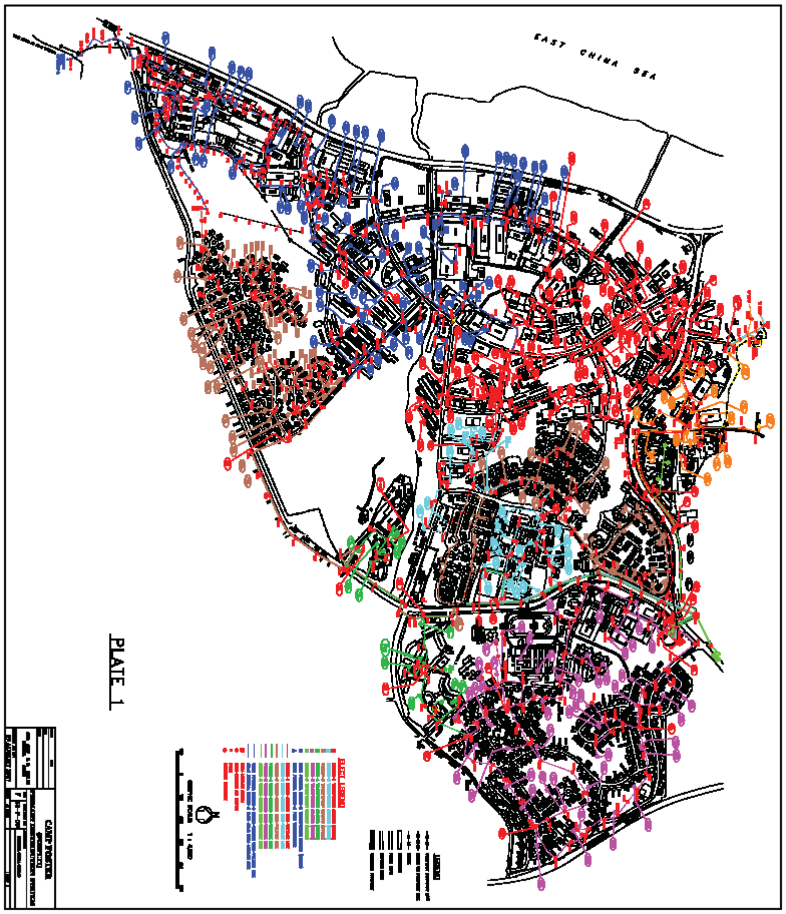
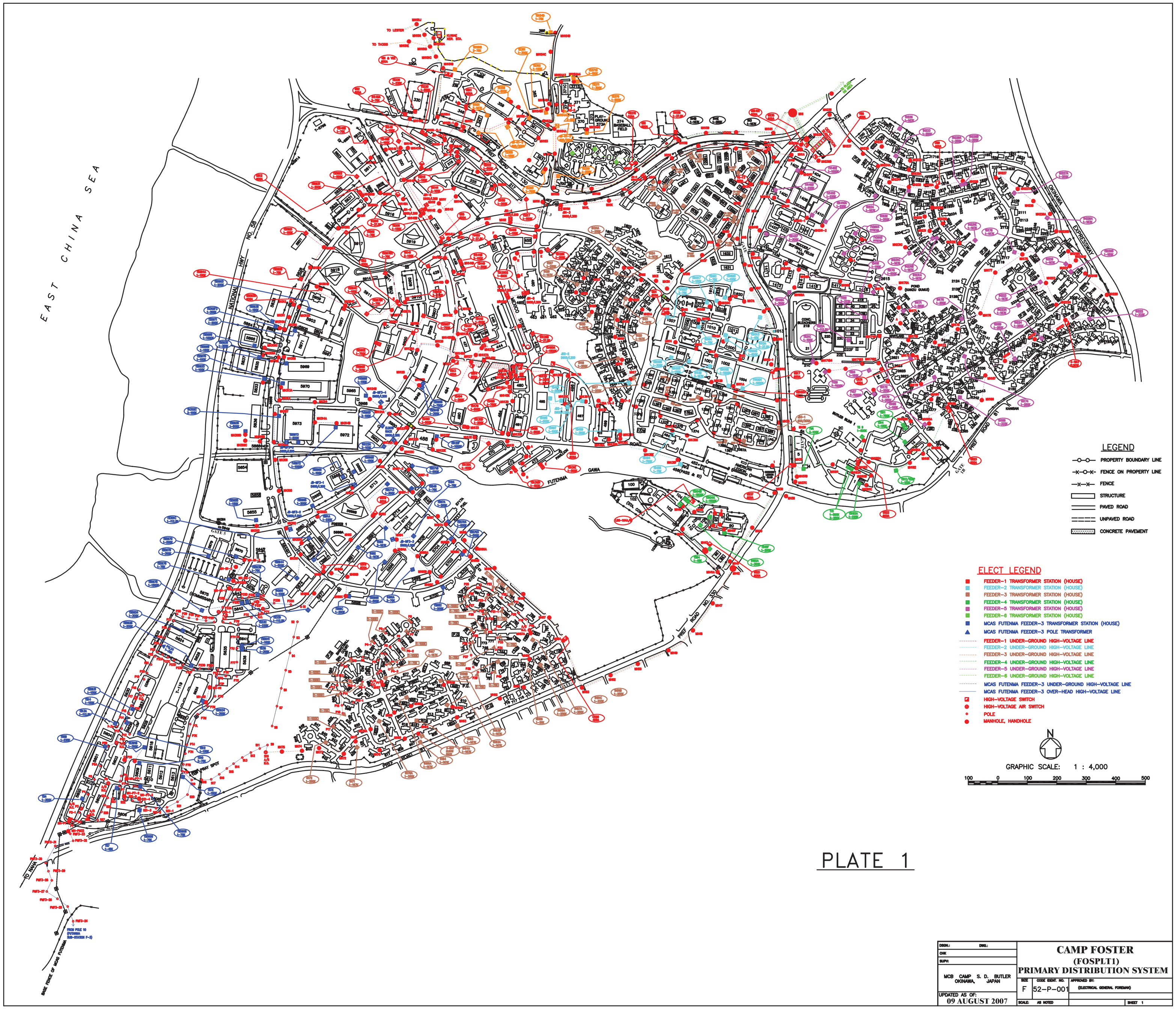
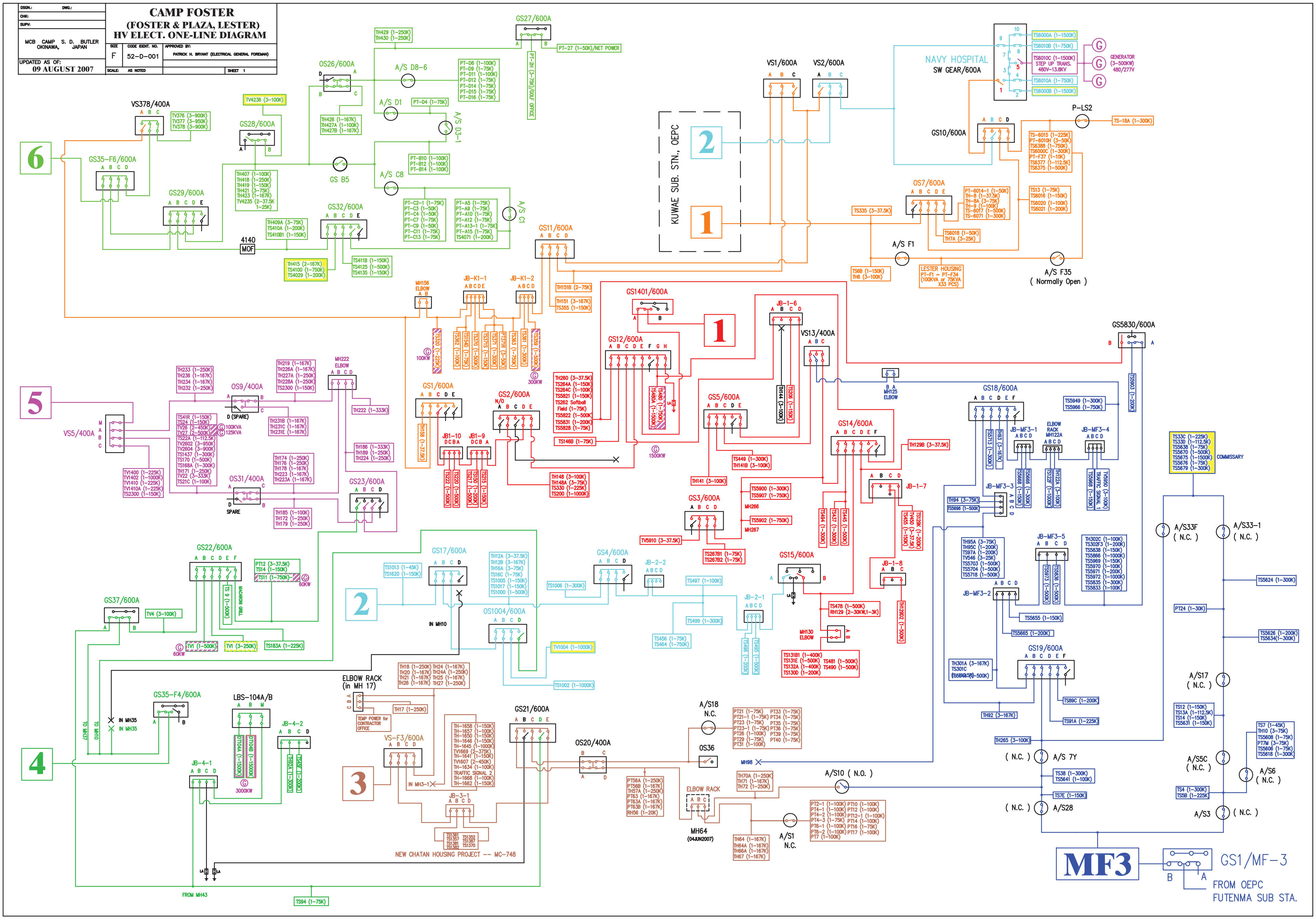
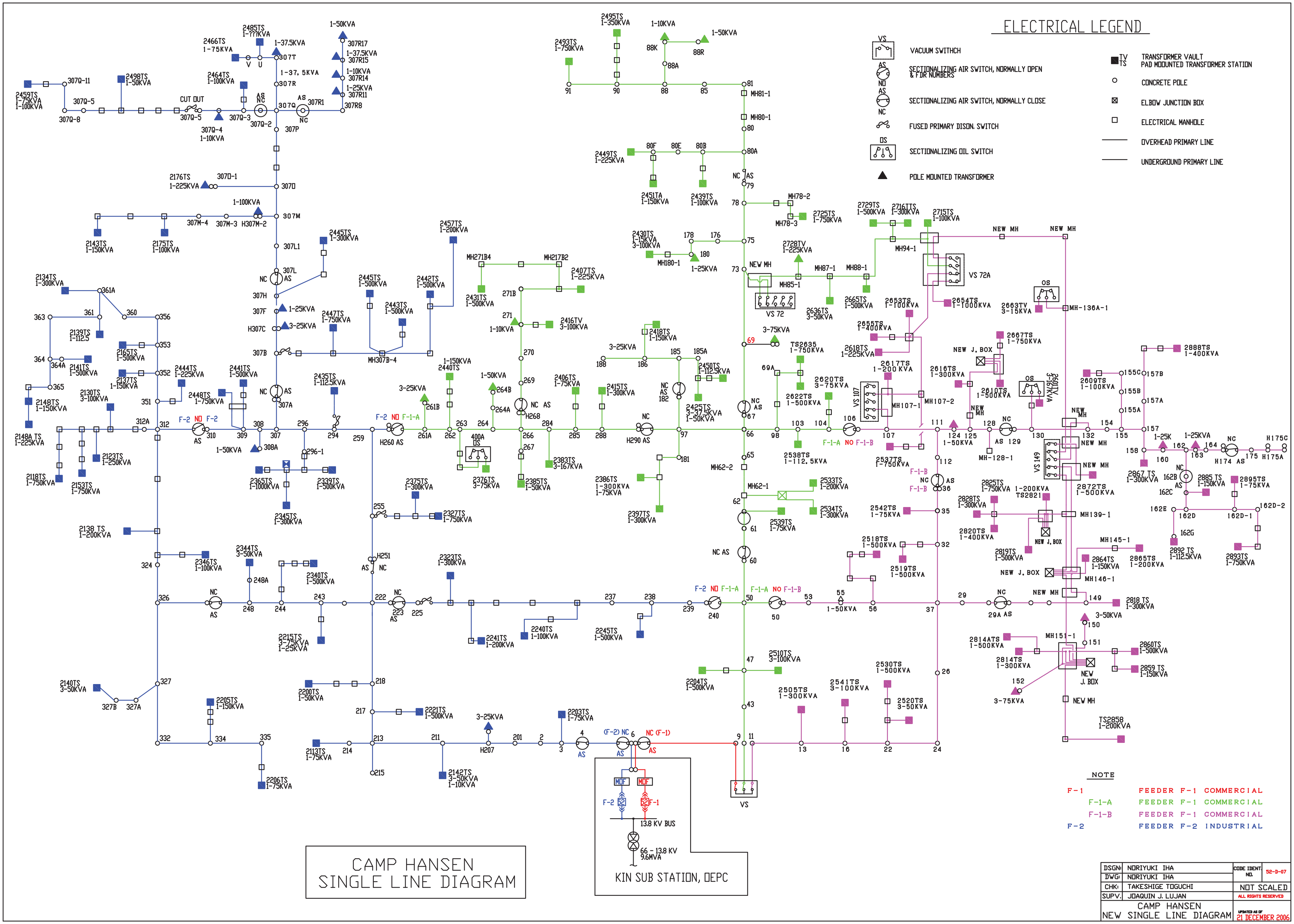
Appendix B

Military Base Drawings

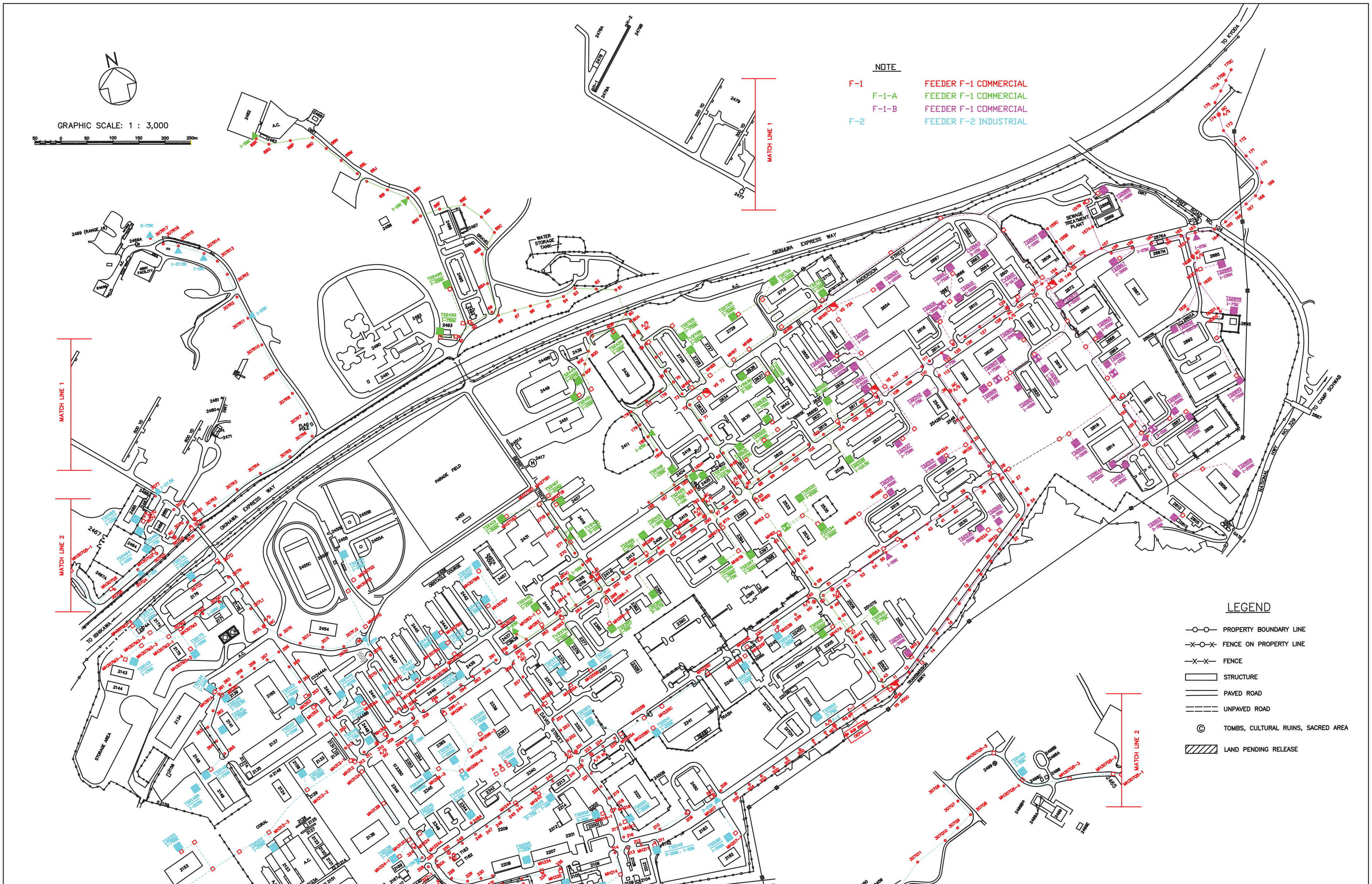



EAST CHINA SEA
NATIONAL HWY NO. 58
FUTENMA GAWA
OKINAWA EXPRESSWAY
LEGEND
PROPERTY BOUNDARY LINE
FENCE ON PROPERTY LINE
FENCE
STRUCTURE
PAVED ROAD
UNPAVED ROAD
CONCRETE PAVEMENT
ELECT LEGEND
FEEDER-1 TRANSFORMER STATION (HOUSE)
FEEDER-2 TRANSFORMER STATION (HOUSE)
FEEDER-3 TRANSFORMER STATION (HOUSE)
FEEDER-4 TRANSFORMER STATION (HOUSE)
FEEDER-5 TRANSFORMER STATION (HOUSE)
FEEDER-6 TRANSFORMER STATION (HOUSE)
MCAS FUTENMA FEEDER-3 TRANSFORMER STATION (HOUSE)
MCAS FUTENMA FEEDER-3 POLE TRANSFORMER
FEEDER-1 UNDER-GROUND HIGH-VOLTAGE LINE
FEEDER-2 UNDER-GROUND HIGH-VOLTAGE LINE
FEEDER-3 UNDER-GROUND HIGH-VOLTAGE LINE
FEEDER-4 UNDER-GROUND HIGH-VOLTAGE LINE
FEEDER-5 UNDER-GROUND HIGH-VOLTAGE LINE
FEEDER-6 UNDER-GROUND HIGH-VOLTAGE LINE
MCAS FUTENMA FEEDER-3 UNDER-GROUND HIGH-VOLTAGE LINE
MCAS FUTENMA FEEDER-3 OVER-HEAD HIGH-VOLTAGE LINE
HIGH-VOLTAGE SWITCH
HIGH-VOLTAGE AIR SWITCH
POLE
MANHOLE, HANDHOLE
N
GRAPHIC SCALE: 1 : 4,000
100 0 100 200 300 400 500
PLATE 1
CAMP FOSTER
(FOSPLT1)
PRIMARY DISTRIBUTION SYSTEM
MCB CAMP S. D. BUTLER OKINAWA, JAPAN
UPDATED AS OF:
09 AUGUST 2007
F
52-P-001
SHEET 1


CAMP FOSTER
(FOSTER & PLAZA, LESTER)
HV ELECT. ONE-LINE DIAGRAM
MCB CAMP S. D. BUTLER OKINAWA, JAPAN
UPDATED AS OF: 09 AUGUST 2007
SIZE F
CODE IDENT. NO. 52-D-001
APPROVED BY: PATRICK H. BRYANT (ELECTRICAL GENERAL FOREMAN)
SCALE: AS NOTED
SHEET 1
KUWAE SUB. STN., OEPC
NAVY HOSPITAL SW GEAR/600A
GENERATOR (3-500KW) 480/277V
MF3
GS1/MF-3
FROM OEPC FUTENMA SUB STA.
NEW CHATAN HOUSING PROJECT -- MC-748
COMMISSARY
ELBOW RACK (in MH 17)
VS1/600A
VS2/600A
VS5/400A
VS13/400A
VS378/400A
GS1/600A
GS2/600A
GS3/600A
GS4/600A
GS5/600A
GS10/600A
GS11/600A
GS12/600A
GS14/600A
GS15/600A
GS17/600A
GS18/600A
GS19/600A
GS21/600A
GS22/600A
GS23/600A
GS26/600A
GS27/600A
GS28/600A
GS29/600A
GS32/600A
GS35-F4/600A
GS35-F6/600A
GS37/600A
GS1401/600A
GS5830/600A
OS7/600A
OS9/400A
OS20/400A
OS31/400A
OS1004/600A
VS-F3/600A
LBS-104A/B



ELECTRICAL LEGEND
VS VACUUM SWITHCH
SECTIONALIZING AIR SWITCH, NORMALLY OPEN & FDR NUMBERS
SECTIONALIZING AIR SWITCH, NORMALLY CLOSE
FUSED PRIMARY DISCN. SWITCH
SECTIONALIZING OIL SWITCH
POLE MOUNTED TRANSFORMER
TV TS TRANSFORMER VAULT PAD MOUNTED TRANSFORMER STATION
CONCRETE POLE
ELBOW JUNCTION BOX
ELECTRICAL MANHOLE
OVERHEAD PRIMARY LINE
UNDERGROUND PRIMARY LINE
NOTE
F-1 FEEDER F-1 COMMERCIAL
F-1-A FEEDER F-1 COMMERCIAL
F-1-B FEEDER F-1 COMMERCIAL
F-2 FEEDER F-2 INDUSTRIAL
CAMP HANSEN
SINGLE LINE DIAGRAM
13.8 KV BUS
66 - 13.8 KV 9.6MVA
KIN SUB STATION, DEPC
DSGN: NORIYUKI IHA
DWG: NORIYUKI IHA
CHK: TAKESHIGE TOGUCHI
SUPV. JOAQUIN J. LUJAN
CAMP HANSEN
NEW SINGLE LINE DIAGRAM
CODE IDENT NO. 52-D-07
NOT SCALED
ALL RIGHTS RESERVED
UPDATED AS OF 21 DECEMBER 2006



CAMP HANSEN

ELECT. DISTRIBUTION SYS. MAP

MCB CAMP S. D. BUTLER
OKINAWA, JAPAN

UPDATED AS OF:
21 DECEMBER 2006

SIZE	CODE IDENT. NO.	APPROVED BY:
F		

SCALE: AS NOTED — SHEET 1 OF 1

DWG:

MCB CAMP S. D. BUTLER
OKINAWA, JAPAN

UPDATED AS OF:
01 NOVEMBER 2007

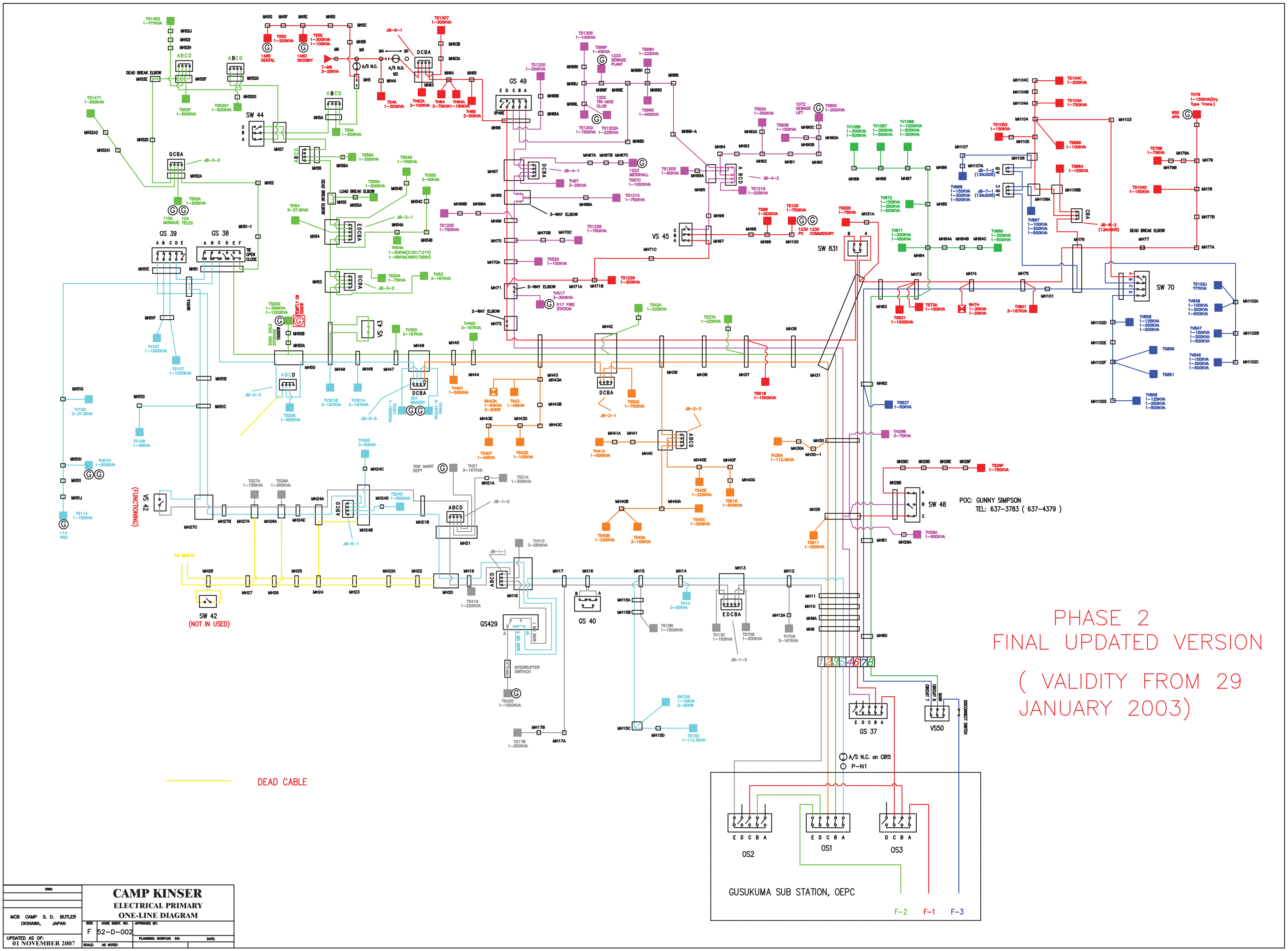
CAMP KINSER
ELECTRICAL PRIMARY DISTRIBUTION SYSTEM MAP

SIZE	CODE IDENT. NO.	APPROVED BY:
F	52-P-002	

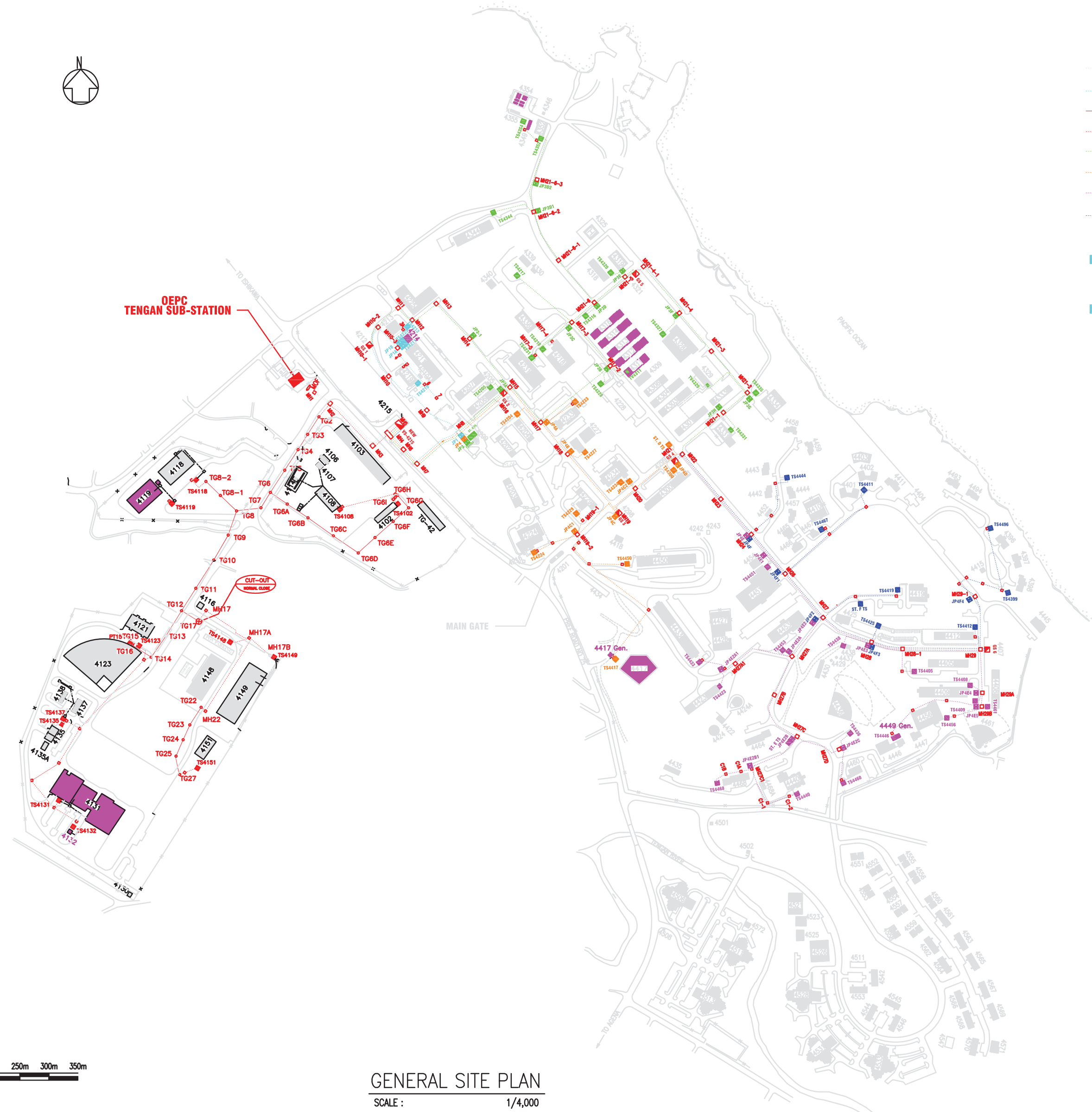
SCALE: AS NOTED

DATE:

SHEET 1 OF 1



PHASE 2
FINAL UPDATED VERSION
(VALIDITY FROM 29 JANUARY 2003)
DEAD CABLE
POC: GUNNY SIMPSON
TEL: 637-3783 (637-4379)
GUSUKUMA SUB STATION, OEPC
OS1
OS2
OS3
F-2
F-1
F-3
GS 37
VS50
A/S N.C. on CIR5
P-N1
GS 38
GS 39
GS 40
GS 49
GS429
SW 42
(NOT IN USED)
VS 42
(FUNCTIONING)
SW 44
VS 43
VS 45
SW 48
SW 70
SW 831
CAMP KINSER
ELECTRICAL PRIMARY
ONE-LINE DIAGRAM
MCB CAMP S. D. BUTLER
OKINAWA, JAPAN
F
52-D-002
UPDATED AS OF:
01 NOVEMBER 2007



ELECT. LEGEND

- F-2, MAIN UNDERGROUND PRIMARY LINE
- CIR 1, UNDERGROUND PRIMARY LINE
- CIR 2, OVERHEAD PRIMARY LINE
- CIR 2, UNDERGROUND PRIMARY LINE
- CIR 3, UNDERGROUND PRIMARY LINE
- CIR 4, UNDERGROUND PRIMARY LINE
- CIR 4, GS 4-E, UNDERGROUND PRIMARY LINE
- CIR 4, GS 4-F, UNDERGROUND PRIMARY LINE
- CIR 2, POLE MOUNTED TRANSFORMER STATION
- CIR 1, 2, 3, 4, 4-E, 4-F, TRANSFORMER HOUSE OR STATION
- SWITCH HOUSE
- CIR 1, 2, 3, 4, 4-E, 4-F, JUNCTION PEDESTAL BOX
- MH/HH MANHOLE OR HANDHOLE
- GENERATOR RM or GEN. BACK UP BLDG.

GRAPHIC SCALES

1/4000 50m 0 50m 100m 150m 200m 250m 300m 350m

GENERAL SITE PLAN

SCALE : 1/4,000

CMAP BUTLER
OKINAWA, JAPAN

ELECTRICAL PRIMARY DISTRIBUTION SYSTEM MAP CAMP COURTNEY

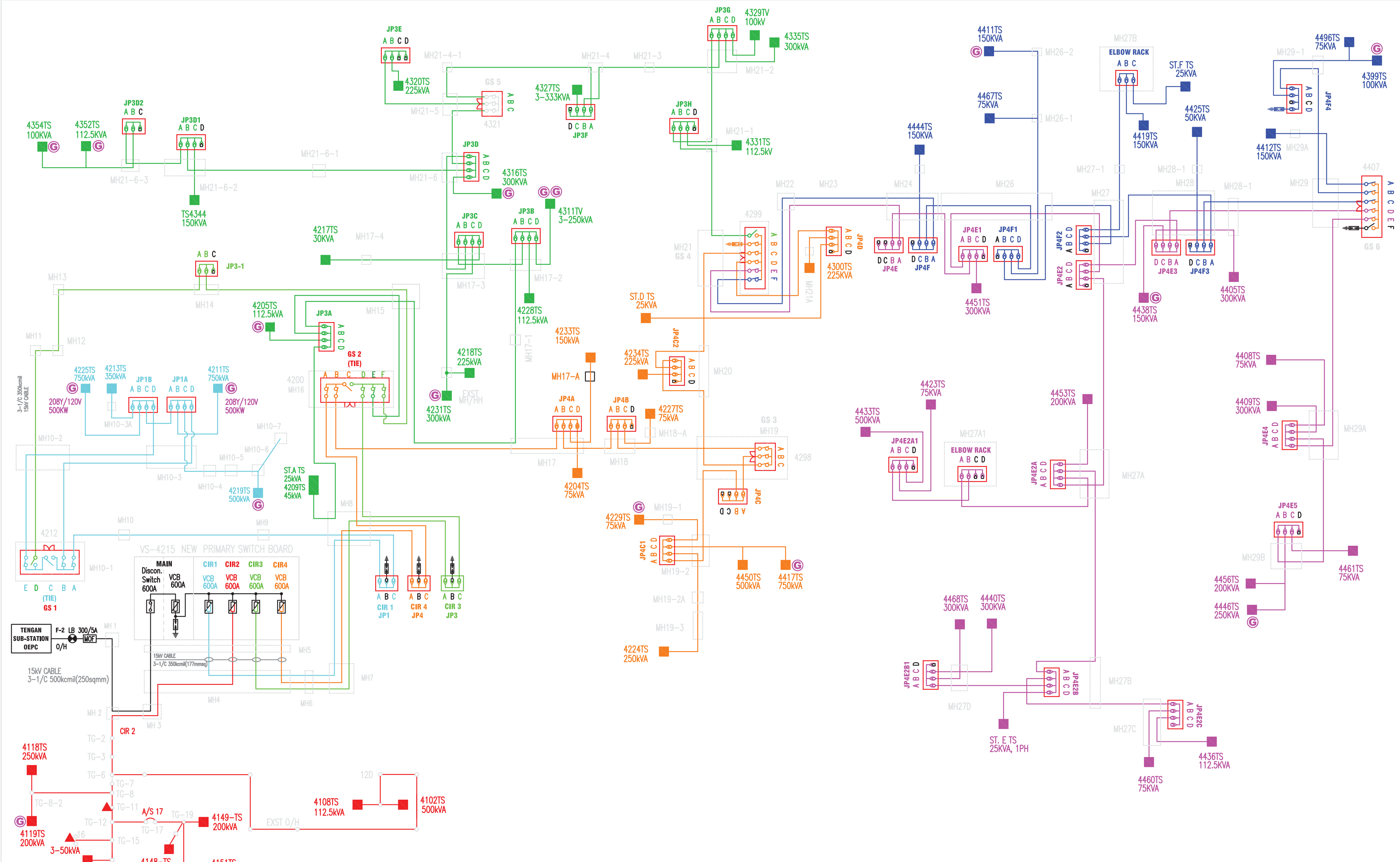
OKINAWA, JAPAN

SCALE :1/4,000

UPDATED AS OF:
05 September 2007

CODE ID.:

SHEET 1 OF 1



NEW ELECTRICAL SINGLE LINE DIAGRAM

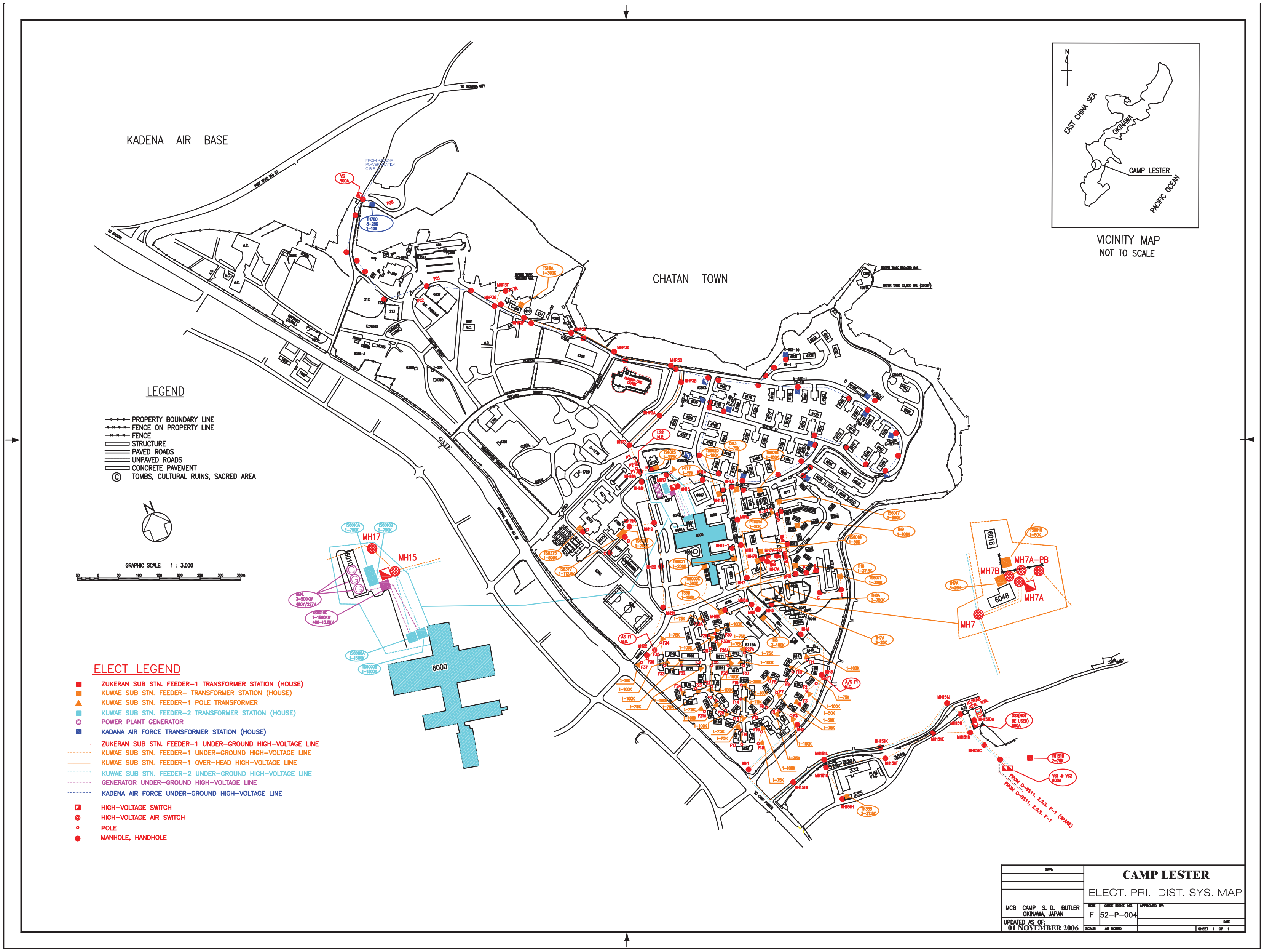
NOT TO SCALE

DRAWN ON 03 MARCH 2006

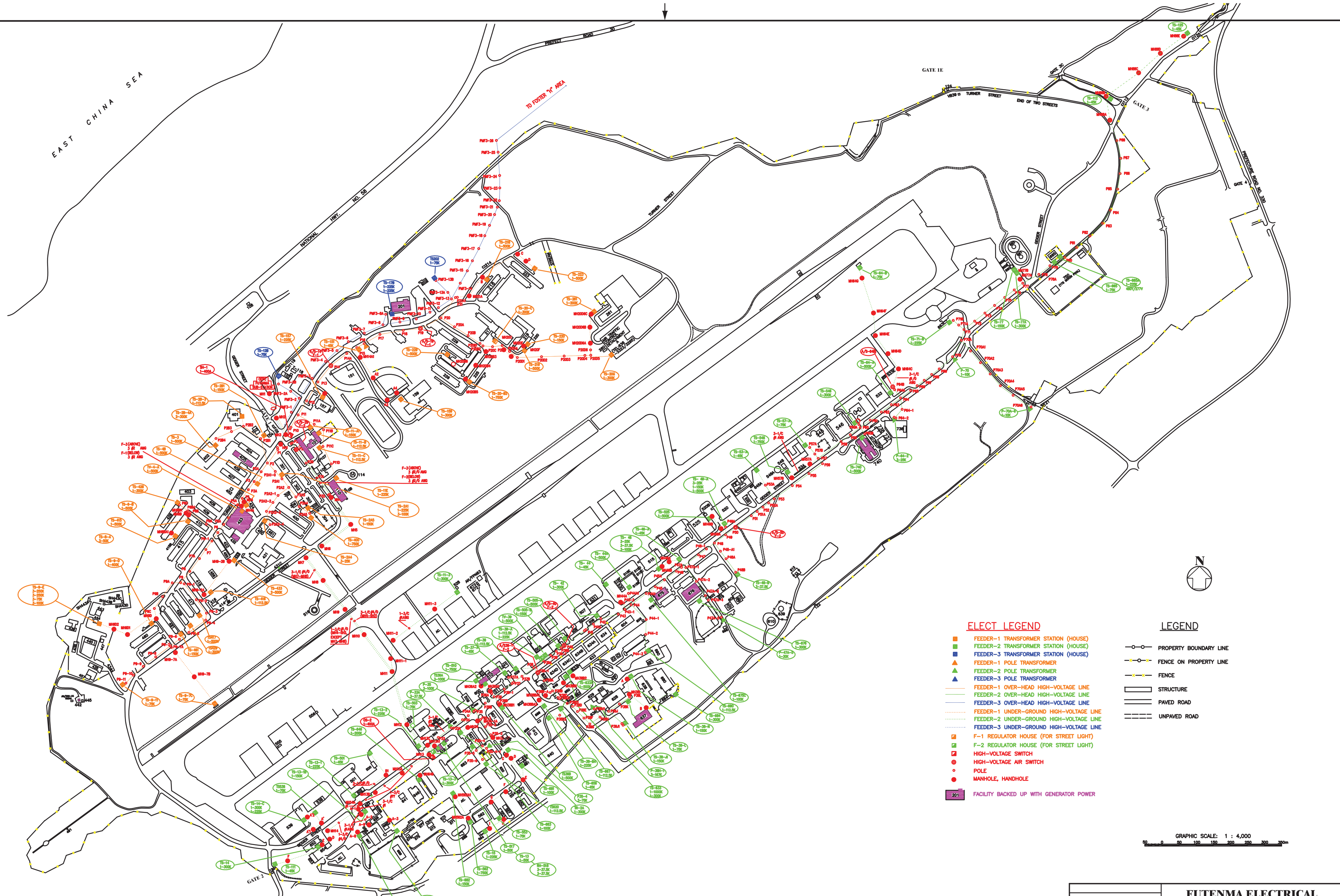
NEW POWER SINGLE LINE DIAGRAM

CAMP COURTNEY

ELECTRICAL (Updated as of 05 September 2007)



UPDATING DISTRIBUTION SYSTEM MAP



ELECT LEGEND

- FEEDER–1 TRANSFORMER STATION (HOUSE)
- FEEDER–2 TRANSFORMER STATION (HOUSE)
- FEEDER–3 TRANSFORMER STATION (HOUSE)
- FEEDER–1 POLE TRANSFORMER
- FEEDER–2 POLE TRANSFORMER
- FEEDER–3 POLE TRANSFORMER
- FEEDER–1 OVER–HEAD HIGH–VOLTAGE LINE
- FEEDER–2 OVER–HEAD HIGH–VOLTAGE LINE
- FEEDER–3 OVER–HEAD HIGH–VOLTAGE LINE
- FEEDER–1 UNDER–GROUND HIGH–VOLTAGE LINE
- FEEDER–2 UNDER–GROUND HIGH–VOLTAGE LINE
- FEEDER–3 UNDER–GROUND HIGH–VOLTAGE LINE
- F–1 REGULATOR HOUSE (FOR STREET LIGHT)
- F–2 REGULATOR HOUSE (FOR STREET LIGHT)
- HIGH–VOLTAGE SWITCH
- HIGH–VOLTAGE AIR SWITCH
- POLE
- MANHOLE, HANDHOLE
- 201 FACILITY BACKED UP WITH GENERATOR POWER

LEGEND

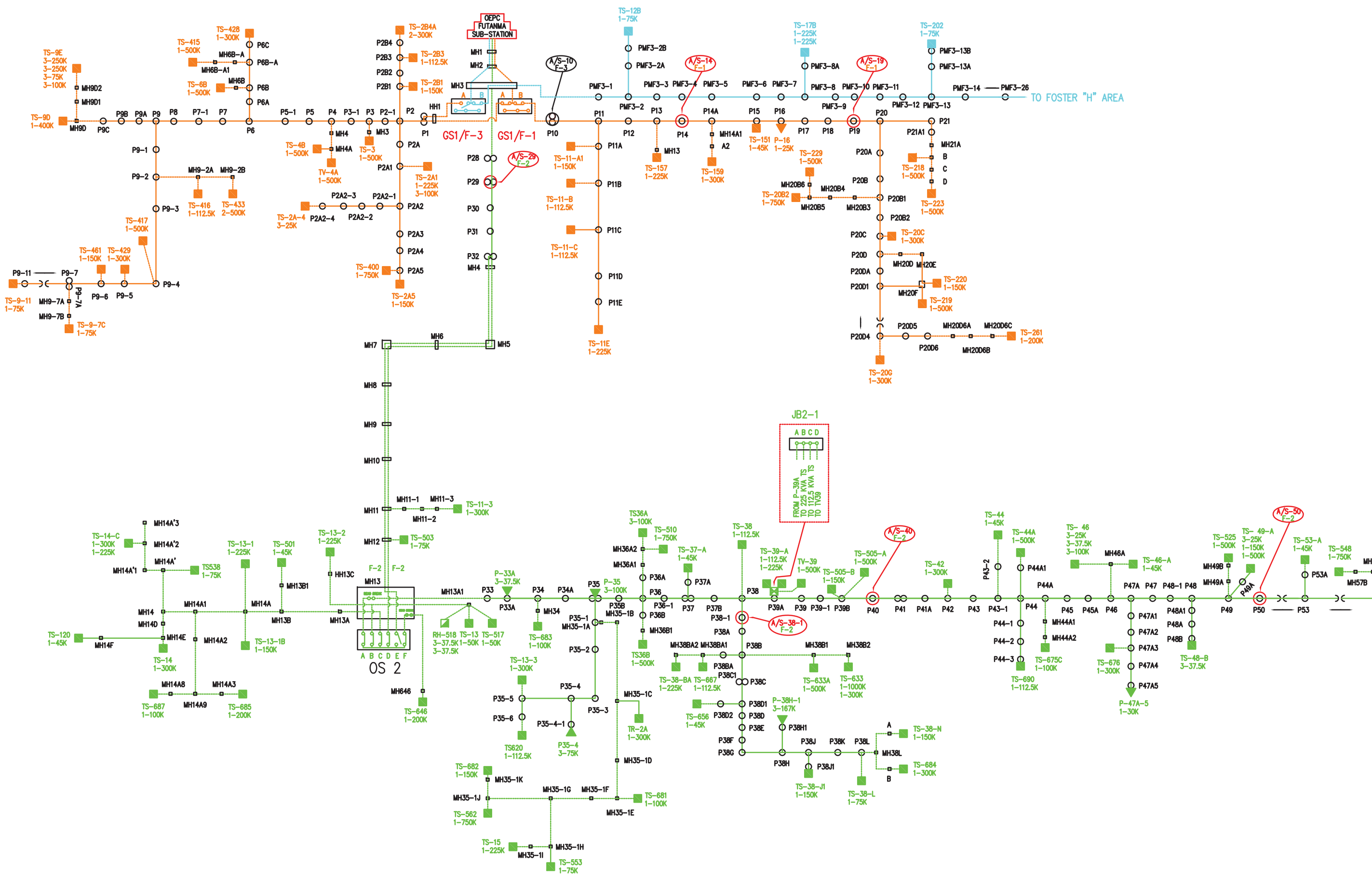
- PROPERTY BOUNDARY LINE
- FENCE ON PROPERTY LINE
- FENCE
- STRUCTURE
- PAVED ROAD
- UNPAVED ROAD

GRAPHIC SCALE: 1 : 4,000

50 0 50 100 150 200 250 300 350m

FUTENMA ELECTRICAL PRIMARY DISTRIBUTION SYSTEM MAP

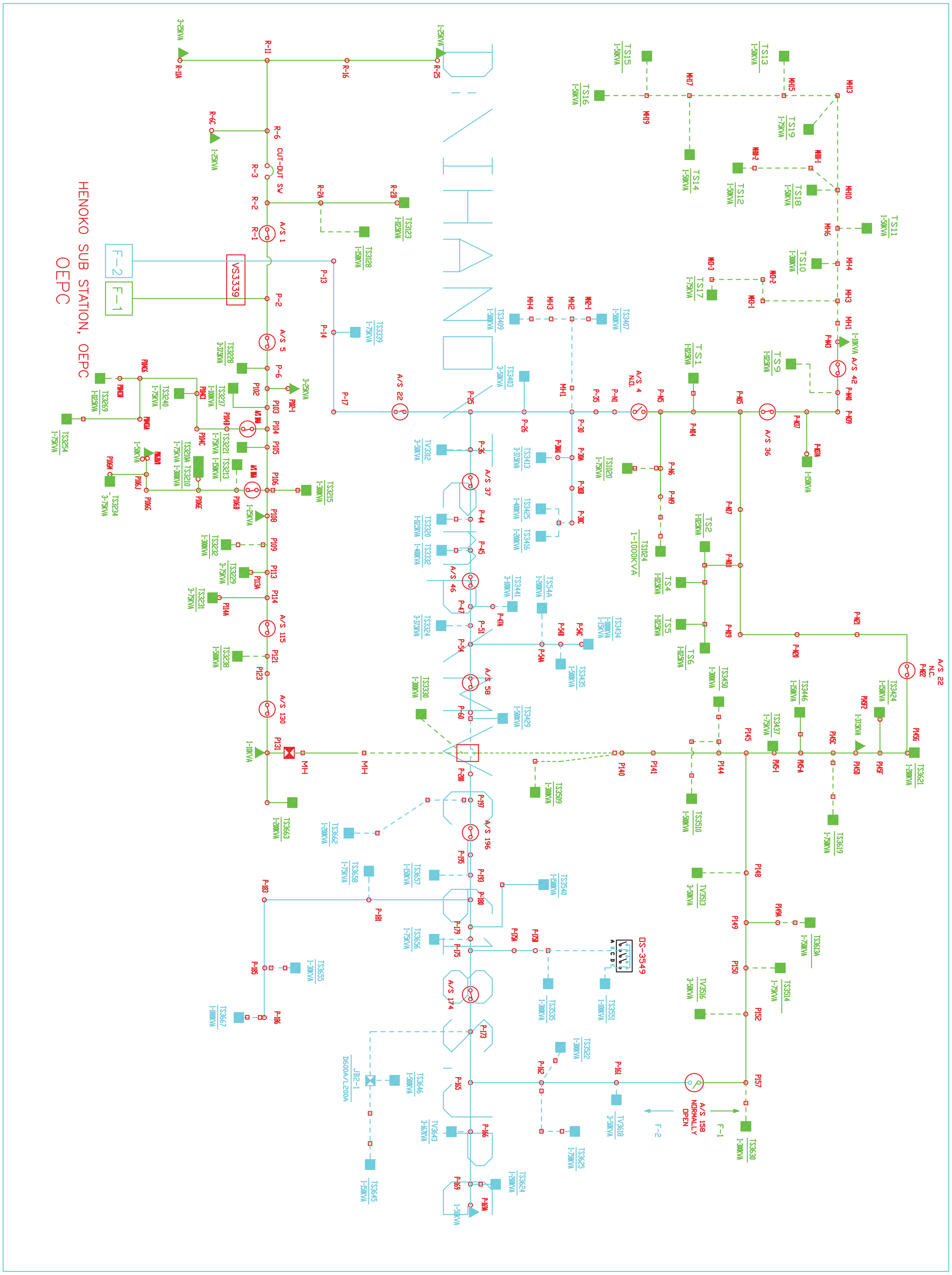
MCB CAMP S. D. BUTLER OKINAWA, JAPAN	SIZE: F	CODE IDENT. NO.: 0001052
UPDATED AS OF: 05 OCTOBER 2007	SCALE: AS NOTED	APPROVED BY:
		SHEET 1 OF 1



ELECT LEGEND

- FEEDER-1 TRANSFORMER STATION (HOUSE)
- FEEDER-2 TRANSFORMER STATION (HOUSE)
- FEEDER-3 TRANSFORMER STATION (HOUSE)
- FEEDER-1 POLE TRANSFORMER
- FEEDER-2 POLE TRANSFORMER
- FEEDER-3 POLE TRANSFORMER
- FEEDER-1 OVER-HEAD HIGH-VOLTAGE LINE
- FEEDER-2 OVER-HEAD HIGH-VOLTAGE LINE
- FEEDER-3 OVER-HEAD HIGH-VOLTAGE LINE
- FEEDER-1 UNDER-GROUND HIGH-VOLTAGE LINE
- FEEDER-2 UNDER-GROUND HIGH-VOLTAGE LINE
- FEEDER-3 UNDER-GROUND HIGH-VOLTAGE LINE
- F-1 REGULATOR HOUSE (FOR STREET LIGHT)
- F-2 REGULATOR HOUSE (FOR STREET LIGHT)
- HIGH-VOLTAGE AIR SWITCH
- POLE
- MANHOLE, HANDHOLE

MCB CAMP S. D. BUTLER OKINAWA, JAPAN	FUTENMA ELECTRICAL PRIMARY ONE-LINE DIAGRAM
UPDATED AS OF: 05 OCTOBER 2007	SIZE: F · CODE IDENT. NO.: 52-D-003 · APPROVED BY:
	SCALE: AS NOTED · SHEET 1 OF 1



SINGLE LINE DIAGRAM
ELECTRICAL
CAMP SCHWAB

OKINAWA, JAPAN

OKINAWA, JAPAN

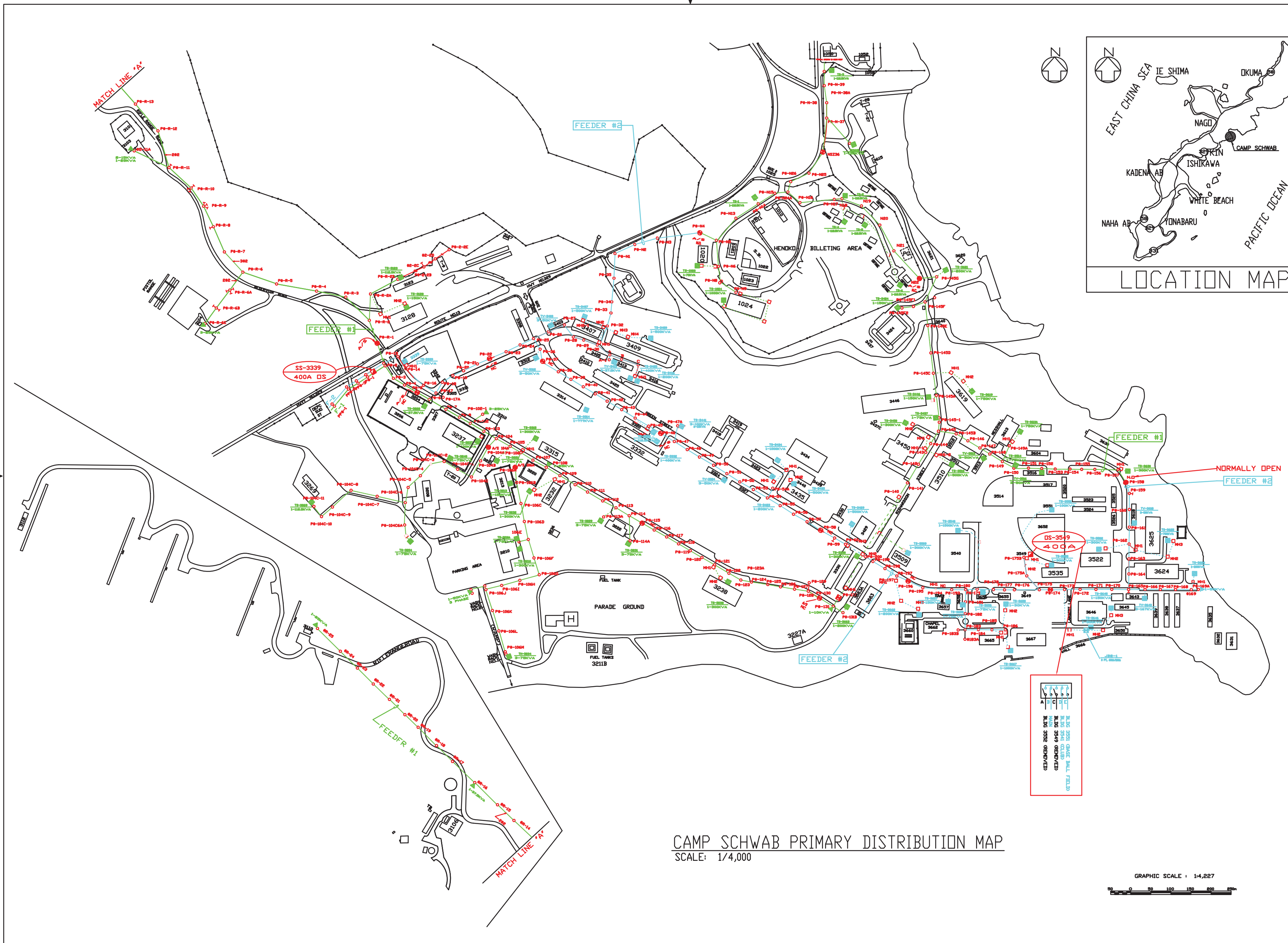
APPROVED:

NOT SCALED

UPDATED AS OF: 28 JULY 2006

CODE ID: 52-D-06

SHEET 1 OF 1



OKINAWA, JAPAN

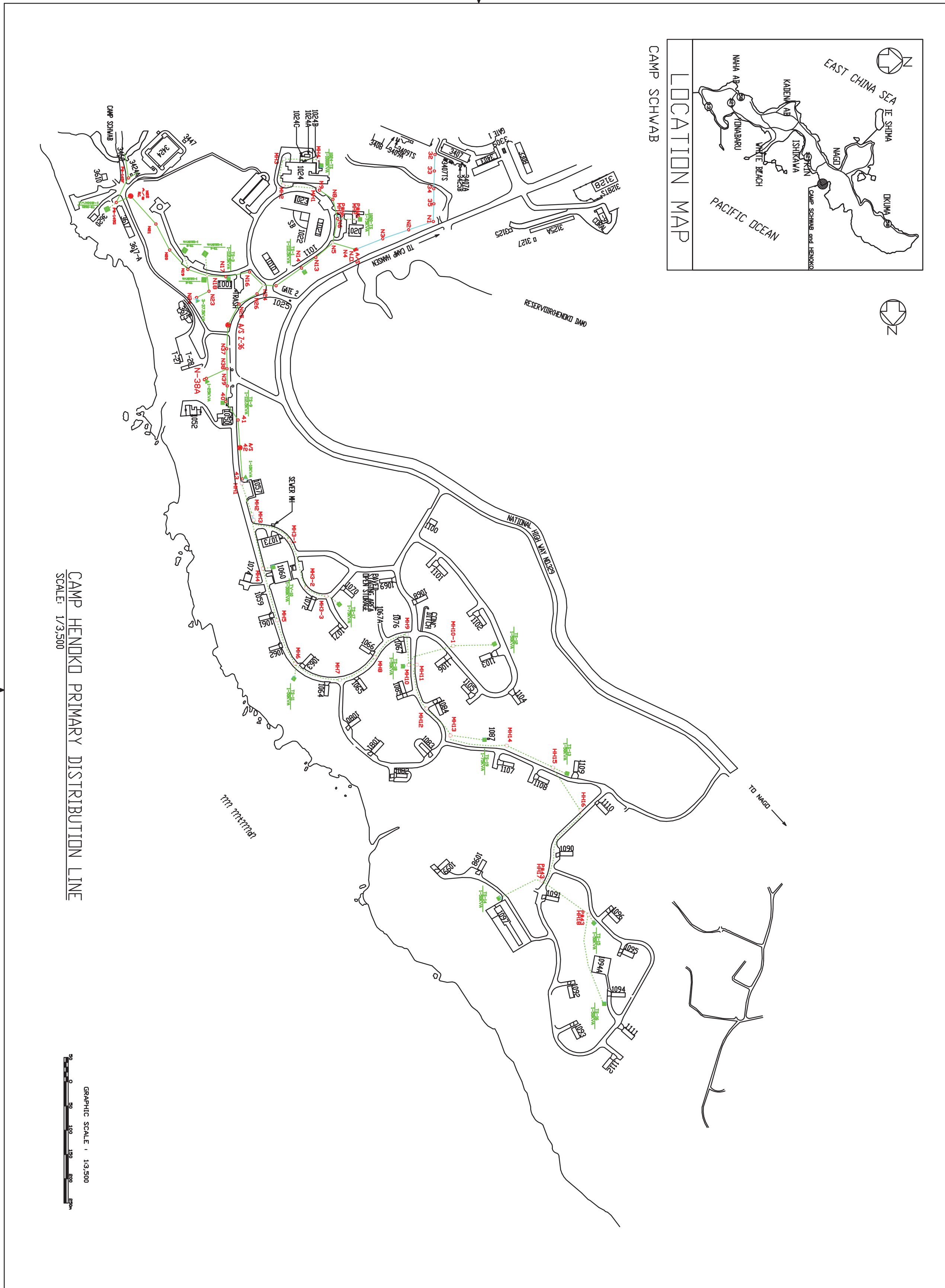
PRIMARY DISTRIBUTION SYSTEM MAP
ELECTRICAL
CAMP SCHWAB
OKINAWA, JAPAN

SCALE :1/4,000

UPDATED AS OF: 28 JULY 2006

CODE ID: 52-P-06

SHEET 1 OF 1

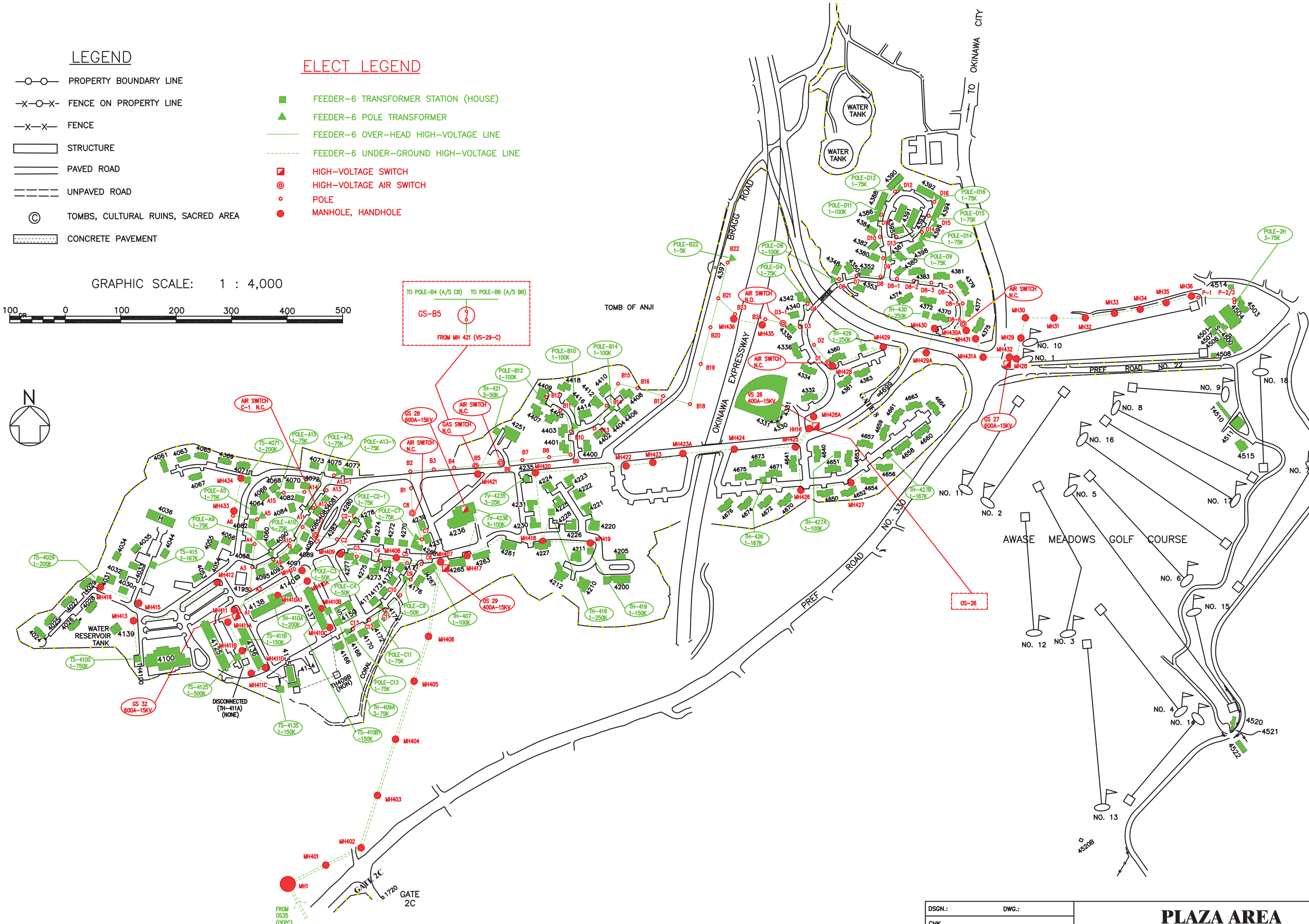


SCALE: 1/4,000	PRIMARY DISTRIBUTION SYSTEM MAP ELECTRICAL HENOKO OF CAMP SCHWAB, OKINAWA, JAPAN	OKINAWA, JAPAN APPROVED:

UPDATED AS OF: 08 JUNE 2004

CODE ID: 52-D-06

SHEET 1 OF 1



DSGN.:	DWG.:
CHK	
SUPV	

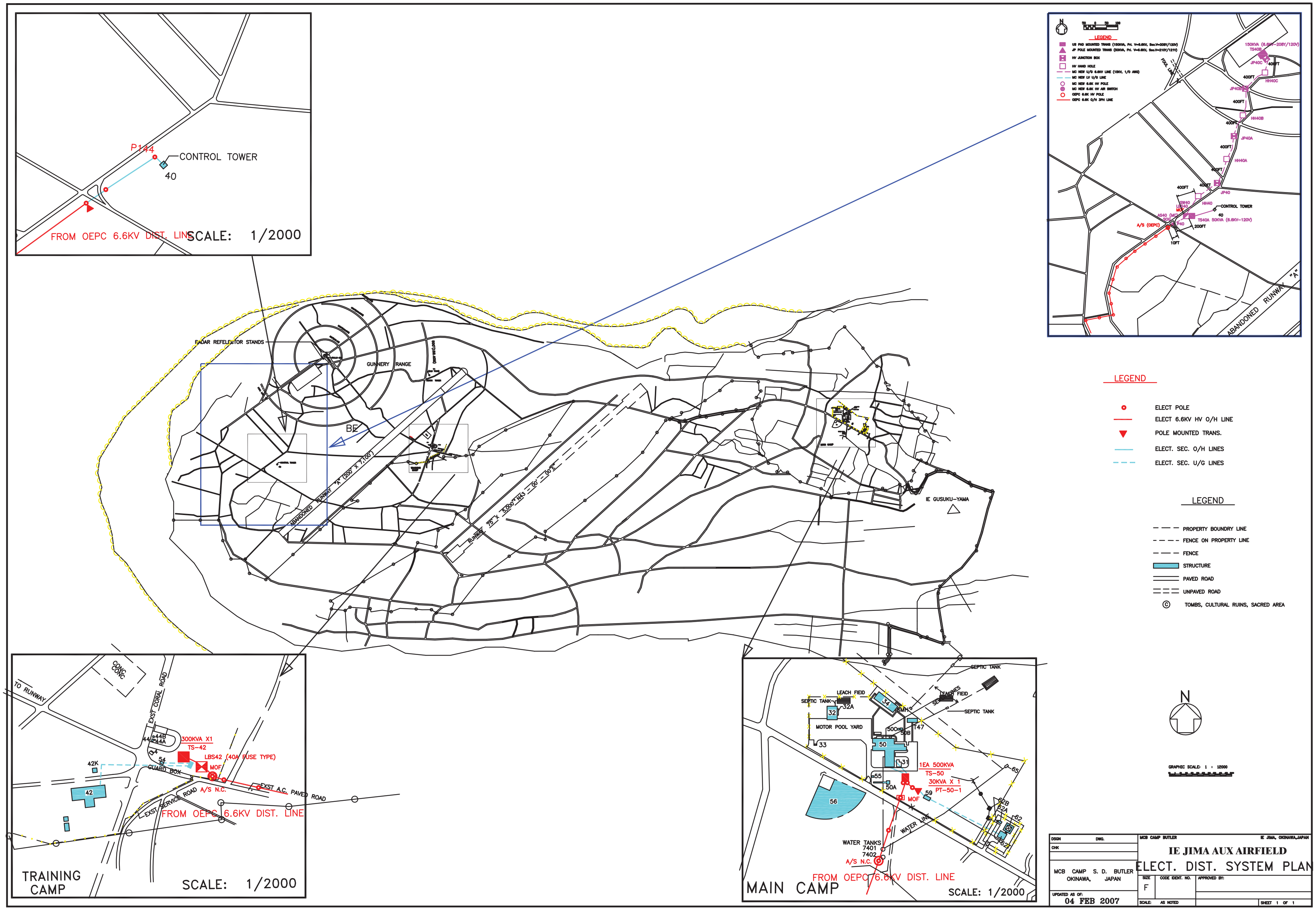
MCB CAMP S. D. BUTLER
OKINAWA, JAPAN

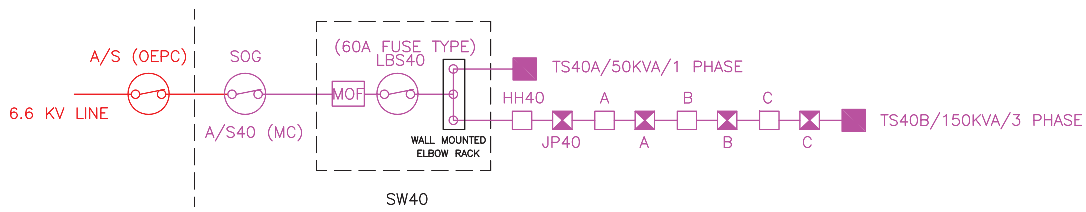
UPDATED AS OF:
25 September 2007

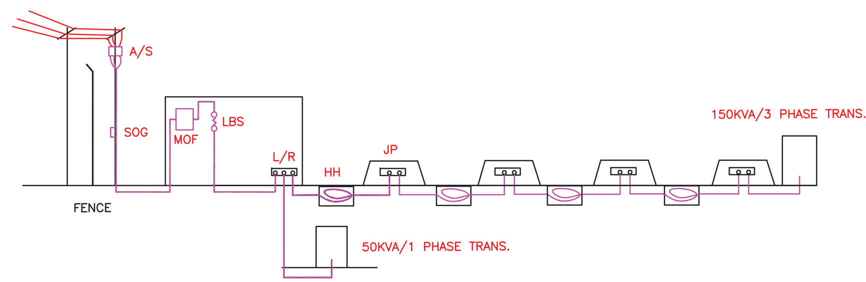
PLAZA AREA
(FOSPLT2)
PRIMARY DISTRIBUTION SYSTEM

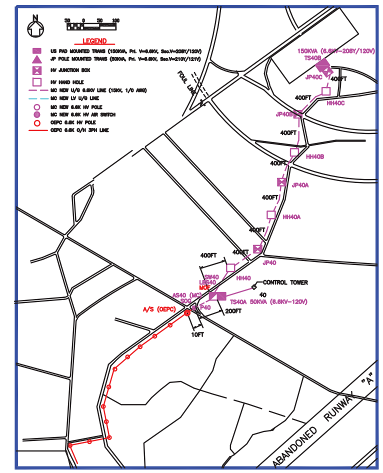
SIZE	CODE IDENT. NO.	APPROVED BY:
F		

SCALE:	AS NOTED		SHEET 1


CONTROL TOWER
P144
40
FROM OEPC 6.6KV DIST. LINE
SCALE: 1/2000
RADAR REFLECTOR STANDS
GUNNERY RANGE
BE
ABANDONED RUNWAY "A" (200' X 7,100')
RUNWAY "B" 75' X 5,000' (N43°-00'-00"E)
IE GUSUKU-YAMA
TO RUNWAY
CONC
EXST CORAL ROAD
300KVA X1
TS-42
LBS42 (40A FUSE TYPE)
MOF
GUARD BOX
42K
42
44B
44A
54
A/S N.C.
EXST SERVICE ROAD
EXST A.C. PAVED ROAD
FROM OEPC 6.6KV DIST. LINE
TRAINING CAMP
SCALE: 1/2000
SEPTIC TANK
LEACH FIELD
32
32A
34
MH5
MOTOR POOL YARD
33
50
50C
50B
47
31
55
50A
56
1EA 500KVA
TS-50
30KVA X 1
PT-50-1
59
MOF
WATER TANKS
7401
7402
A/S N.C.
WATER LINE
62
62A
62B
65
FROM OEPC 6.6KV DIST. LINE
MAIN CAMP
SCALE: 1/2000
LEGEND
ELECT POLE
ELECT 6.6KV HV O/H LINE
POLE MOUNTED TRANS.
ELECT. SEC. O/H LINES
ELECT. SEC. U/G LINES
LEGEND
PROPERTY BOUNDRY LINE
FENCE ON PROPERTY LINE
FENCE
STRUCTURE
PAVED ROAD
UNPAVED ROAD
TOMBS, CULTURAL RUINS, SACRED AREA
N
GRAPHIC SCALE: 1 : 12000
LEGEND
150KVA (6.6KV-208Y/120V)
TS40B
JP40C
HH40C
JP40B
HH40B
JP40A
HH40A
JP40
HH40
CONTROL TOWER
40
TS40A 50KVA (6.6KV-120V)
A/S (OEPC)
400FT
200FT
10FT
ABANDONED RUNWAY "A"
MCB CAMP BUTLER
IE JIMA, OKINAWA, JAPAN
IE JIMA AUX AIRFIELD
ELECT. DIST. SYSTEM PLAN
MCB CAMP S. D. BUTLER
OKINAWA, JAPAN
UPDATED AS OF:
04 FEB 2007
SIZE F
SCALE: AS NOTED
SHEET 1 OF 1


A/S (OEPC)
6.6 KV LINE
SOG
A/S40 (MC)
(60A FUSE TYPE)
LBS40
MOF
WALL MOUNTED
ELBOW RACK
SW40
TS40A/50KVA/1 PHASE
HH40
JP40
A
A
B
B
C
C
TS40B/150KVA/3 PHASE


A/S
SOG
MOF
LBS
L/R
HH
JP
FENCE
50KVA/1 PHASE TRANS.
150KVA/3 PHASE TRANS.


LEGEND
A/S (OEPC)
CONTROL TOWER
ABANDONED RUNWAY "A"

Appendix C

Analysis Spreadsheets & U.S. Manufacturer Data

20% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR			20% Load SPP	60% Load SPP
500 Low	$27,569.00	$57,826.00	-$633.00	-91.30	-$12,429.00	-0.21	n/a		500 Low	-91.30	-47.85
500 Med	$36,354.00	$64,894.00	$518.00	125.35	$10,159.00	0.16	-3.17%		500 Med	125.35	49.67
500 High	$59,626.00	$93,089.00	$1,039.00	89.56	$20,395.00	0.22	-2.08%		500 High	89.56	32.74
750 Low	$36,354.00	$67,489.00	-$946.00	-71.33	-$18,567.00	-0.28	n/a		750 Low	-71.33	-37.47
750 Med	$44,299.00	$76,229.00	$779.00	97.86	$15,285.00	0.2	-2.37%		750 Med	97.86	37.07
750 High	$69,350.00	$103,785.00	$1,403.00	73.97	$27,531.00	0.27	-1.46%		750 High	73.97	27.62
1000 Low	$50,794.00	$83,373.00	-$1,256.00	-66.36	-$24,654.00	-0.3	n/a		1000 Low	-66.36	-34.94
1000 Med	$60,742.00	$94,316.00	$1,053.00	89.54	$20,670.00	0.22	-2.08%		1000 Med	89.54	35.04
1000 High	$82,958.00	$118,754.00	$1,674.00	70.95	$32,843.00	0.28	-1.32%		1000 High	70.95	26.64
60% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR			Total Cost $	Total Discounted Operational Savings $
500 Low	$27,569.00	$57,826.00	-$1,209.00	-47.85	-$23,716.00	-0.41	n/a		500 Med	$64,894.00	$25,638.00
500 Med	$36,354.00	$64,894.00	$1,307.00	49.67	$25,638.00	0.4	-0.14%		500 High	$93,089.00	$55,795.00
500 High	$59,626.00	$93,089.00	$2,843.00	32.74	$55,795.00	0.6	1.26%		Difference $	$28,195.00	$30,157.00
750 Low	$36,354.00	$67,489.00	-$1,801.00	-37.47	-$35,345.00	-0.52	n/a		750 Med	$76,229.00	$40,354.00
750 Med	$44,299.00	$76,229.00	$2,056.00	37.07	$40,354.00	0.53	0.84%		750 High	$103,785.00	$73,746.00
750 High	$69,350.00	$103,785.00	$3,758.00	27.62	$73,746.00	0.71	1.83%		Difference $	$27,556.00	$33,392.00
1000 Low	$50,794.00	$83,373.00	-$2,386.00	-34.94	-$46,822.00	-0.56	n/a		1000 Med	$94,316.00	$52,824.00
1000 Med	$60,742.00	$94,316.00	$2,692.00	35.04	$52,824.00	0.56	1.03%		1000 High	$118,754.00	$87,471.00
1000 High	$82,958.00	$118,754.00	$4,458.00	26.64	$87,471.00	0.74	1.96%		Difference $	$24,438.00	$34,647.00
								500	TDOS/per yr	$1,005.23	
									Yrs to PD	28.04821434	
								750	TDOS/per yr	$1,113.07	
									Yrs to PD	24.75682798	
								1000	TDOS/per yr	$1,154.90	
									Yrs to PD	21.16027362	

20% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR			20% Load SPP	60% Load SPP
500 Low	$27,569.00	$57,826.00	-$633.00	-91.30	-$12,429.00	-0.21	n/a		500 Low	-91.30	-47.85
500 Med	$36,354.00	$64,894.00	$518.00	125.35	$10,159.00	0.16	-3.17%		500 Med	125.35	49.67
500 High	$59,626.00	$93,089.00	$1,039.00	89.56	$20,395.00	0.22	-2.08%		500 High	89.56	32.74
750 Low	$36,354.00	$67,489.00	-$946.00	-71.33	-$18,567.00	-0.28	n/a		750 Low	-71.33	-37.47
750 Med	$44,299.00	$76,229.00	$779.00	97.86	$15,285.00	0.2	-2.37%		750 Med	97.86	37.07
750 High	$69,350.00	$103,785.00	$1,403.00	73.97	$27,531.00	0.27	-1.46%		750 High	73.97	27.62
1000 Low	$50,794.00	$83,373.00	-$1,256.00	-66.36	-$24,654.00	-0.3	n/a		1000 Low	-66.36	-34.94
1000 Med	$60,742.00	$94,316.00	$1,053.00	89.54	$20,670.00	0.22	-2.08%		1000 Med	89.54	35.04
1000 High	$82,958.00	$118,754.00	$1,674.00	70.95	$32,843.00	0.28	-1.32%		1000 High	70.95	26.64
60% Load	XFMR Price$	Total Cost $ (includes install/removal, SIOH, & DC)	Annual Savings $	SPP	Total Discounted Operational Savings $	SIR	AIRR			Total Cost $	Total Discounted Operational Savings $
500 Low	$27,569.00	$57,826.00	-$1,209.00	-47.85	-$23,716.00	-0.41	n/a		500 Med	$64,894.00	$25,638.00
500 Med	$36,354.00	$64,894.00	$1,307.00	49.67	$25,638.00	0.4	-0.14%		500 High	$93,089.00	$55,795.00
500 High	$59,626.00	$93,089.00	$2,843.00	32.74	$55,795.00	0.6	1.26%		Difference $	$28,195.00	$30,157.00
750 Low	$36,354.00	$67,489.00	-$1,801.00	-37.47	-$35,345.00	-0.52	n/a		750 Med	$76,229.00	$40,354.00
750 Med	$44,299.00	$76,229.00	$2,056.00	37.07	$40,354.00	0.53	0.84%		750 High	$103,785.00	$73,746.00
750 High	$69,350.00	$103,785.00	$3,758.00	27.62	$73,746.00	0.71	1.83%		Difference $	$27,556.00	$33,392.00
1000 Low	$50,794.00	$83,373.00	-$2,386.00	-34.94	-$46,822.00	-0.56	n/a		1000 Med	$94,316.00	$52,824.00
1000 Med	$60,742.00	$94,316.00	$2,692.00	35.04	$52,824.00	0.56	1.03%		1000 High	$118,754.00	$87,471.00
1000 High	$82,958.00	$118,754.00	$4,458.00	26.64	$87,471.00	0.74	1.96%		Difference $	$24,438.00	$34,647.00
								500	TDOS/per yr	$1,005.23	
									Yrs to PD	28.04821434	
								750	TDOS/per yr	$1,113.07	
									Yrs to PD	24.75682798	
								1000	TDOS/per yr	$1,154.90	
									Yrs to PD	21.16027362	

Older XFMR

Load %	Load Efficiency at 0.85 PF 500 KVA	750 KVA	1000 KVA	Load KVA 500 KVA	750 KVA	1000 KVA	% Loss 500 KVA	750 KVA	1000 KVA
20%	97.79093	98.00944	98.22796	100	150	200	2.209074	1.990556	1.772037
30%	98.23222	98.40167	98.57111	150	225	300	1.767778	1.598333	1.428889
60%	98.34722	98.49167	98.63611	300	450	600	1.652778	1.508333	1.363889
70%	98.26611	98.41333	98.56056	350	525	700	1.733889	1.586667	1.439444

	500 KVA	750 KVA	1000 KVA
20%	97.79093	98.00944	98.22796
60%	98.34722	98.49167	98.63611

	500 KVA	750 KVA	1000 KVA
20%	1877.75	2537.99	3012.35
60%	4214.56	5769.42	6956.08

100000	1877.75	20%	97.79088	97.79093
300000	4214.56	60%	98.34723	98.34722

150000	2537.99	20%	98.00942	98.00944
450000	5769.42	60%	98.49165	98.49167

200000	3012.35	20%	98.22803	98.22796
600000	6956.08	60%	98.63606	98.63611

Modern XFMR — Low Level

Load %	Load Efficiency at 0.85 PF 500 KVA	750 KVA	1000 KVA	Load KVA 500 KVA	750 KVA	1000 KVA	% Loss 500 KVA	750 KVA	1000 KVA	Total Losses (w) 500 KVA	750 KVA	1000 KVA
20%	97.41947	97.63951	97.85956	100	150	200	2.580529	2.360486	2.140441	2193.45	3009.58	3638.75
30%	97.91927	98.0892	98.25914	150	225	300	2.080729	1.910803	1.740863	2652.85	3654.52	4439.2
60%	98.11096	98.25692	98.40289	300	450	600	1.889043	1.743077	1.597114	4817.25	6667.21	8145.28
70%	98.02811	98.17625	98.3244	350	525	700	1.971889	1.823747	1.675598	5866.37	8138.53	9969.81

	500 KVA	750 KVA	1000 KVA
20%	2193.45	3009.58	3638.75
60%	4817.25	6667.21	8145.28

Modern XFMR — Medium Level

Load %	Load Efficiency at 0.85 PF 500 KVA	750 KVA	1000 KVA	Load KVA 500 KVA	750 KVA	1000 KVA	% Loss 500 KVA	750 KVA	1000 KVA	Total Losses (w) 500 KVA	750 KVA	1000 KVA
20%	98.09453	98.31398	98.53684	100	150	200	1.905468	1.686016	1.463165	1619.648	2149.67	2487.38
30%	98.52512	98.70572	98.8673	150	225	300	1.47488	1.29428	1.132702	1880.472	2475.31	2888.39
60%	98.60263	98.75968	98.89923	300	450	600	1.397371	1.240322	1.100769	3563.296	4744.23	5613.92
70%	98.53362	98.68884	98.83547	350	525	700	1.466377	1.311164	1.164534	4362.472	5851.07	6928.98

	500 KVA	750 KVA	1000 KVA
20%	1619.648	2149.67	2487.38
60%	3563.296	4744.23	5613.92

Modern XFMR — High Level

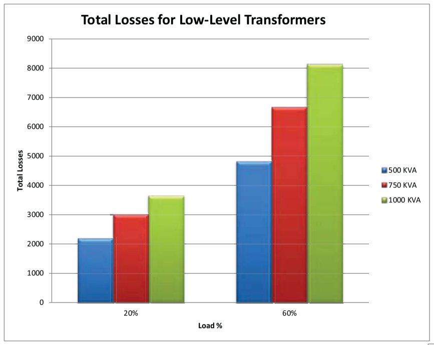
Load %	Load Efficiency at 0.85 PF 500 KVA	750 KVA	1000 KVA	Load KVA 500 KVA	750 KVA	1000 KVA	% Loss 500 KVA	750 KVA	1000 KVA	Total Losses (w) 500 KVA	750 KVA	1000 KVA
20%	98.40047	98.55799	98.71874	100	150	200	1.599529	1.442013	1.281259	1359.6	1838.567	2178.14
30%	98.80557	98.90711	99.02251	150	225	300	1.194431	1.09289	0.97749	1522.9	2090.153	2492.6
60%	98.90306	98.98144	99.07181	300	450	600	1.096941	1.018556	0.928188	2797.2	3895.975	4733.76
70%	98.82541	98.91168	99.00008	350	525	700	1.174588	1.088319	0.999924	3494.4	4856.625	5949.55

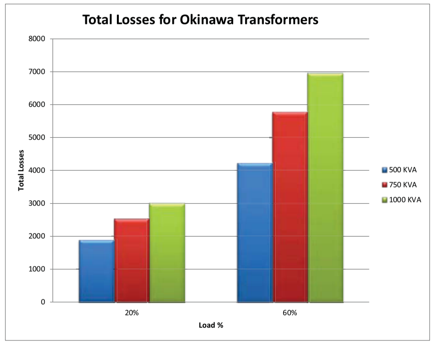
	500 KVA	750 KVA	1000 KVA
20%	1359.6	1838.567	2178.14
60%	2797.2	3895.975	4733.76

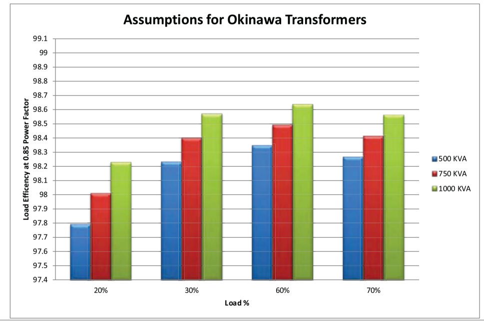
Load %	Low 500 KVA	Med 500 KVA	High 500 KVA
20%	97.41947	98.09453	98.40047
30%	97.91927	98.52512	98.80557
60%	98.11096	98.60263	98.90306
70%	98.02811	98.53362	98.82541

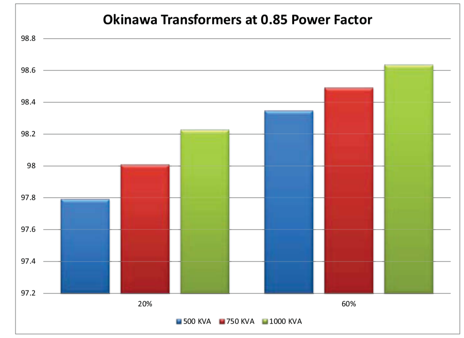
Load %	Low 750 KVA	Med 750 KVA	High 750 KVA
20%	97.63951	98.31398	98.55799
30%	98.0892	98.70572	98.90711
60%	98.25692	98.75968	98.98144
70%	98.17625	98.68884	98.91168

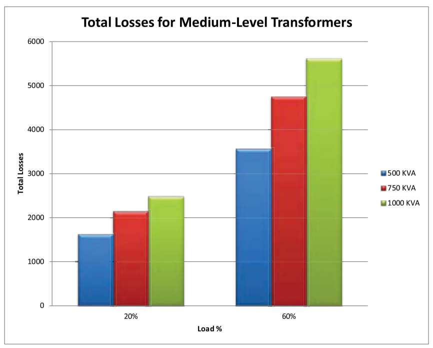
Load %	Low 1000 KVA	Med 1000 KVA	High 1000 KVA
20%	97.85956	98.53684	98.71874
30%	98.25914	98.8673	99.02251
60%	98.40289	98.89923	99.07181
70%	98.3244	98.83547	99.00008

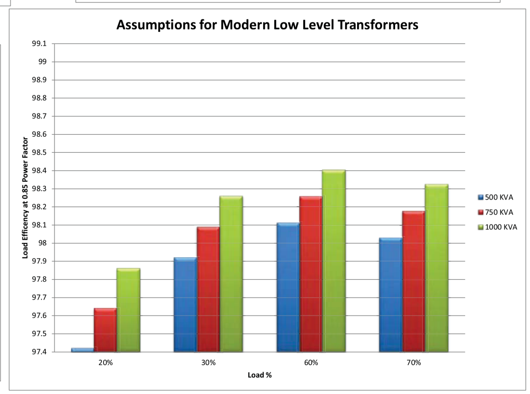

Total Losses for Low-Level Transformers
Total Losses
Load %
20%
60%
500 KVA
750 KVA
1000 KVA

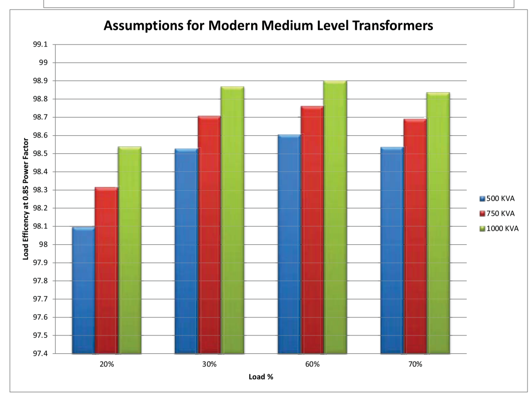

Total Losses for Okinawa Transformers
Total Losses
Load %
20%
60%
500 KVA
750 KVA
1000 KVA

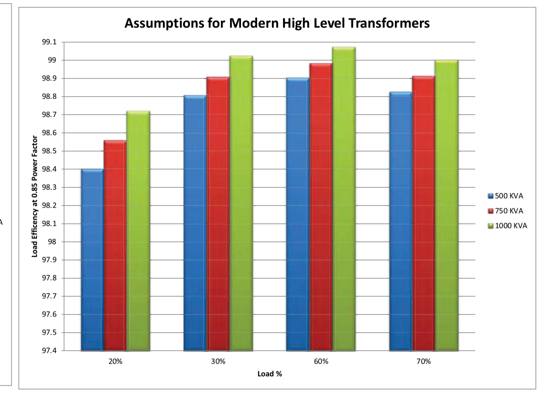

Assumptions for Okinawa Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
500 KVA
750 KVA
1000 KVA

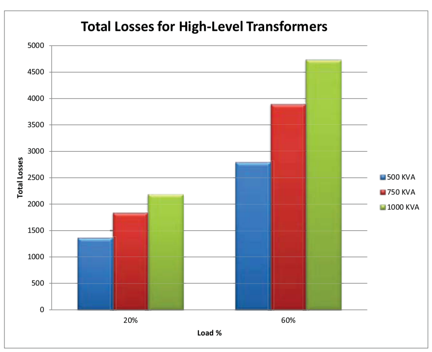

Okinawa Transformers at 0.85 Power Factor
20%
60%
500 KVA
750 KVA
1000 KVA

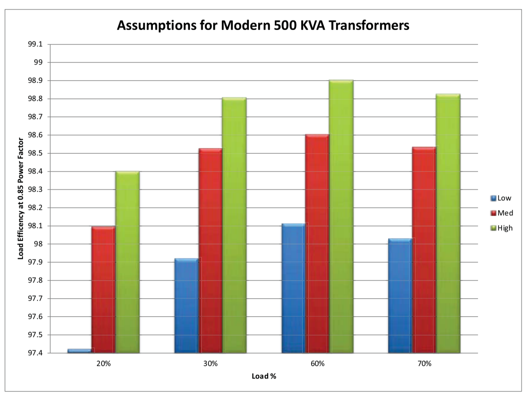

Total Losses for Medium-Level Transformers
Total Losses
Load %
20%
60%
500 KVA
750 KVA
1000 KVA

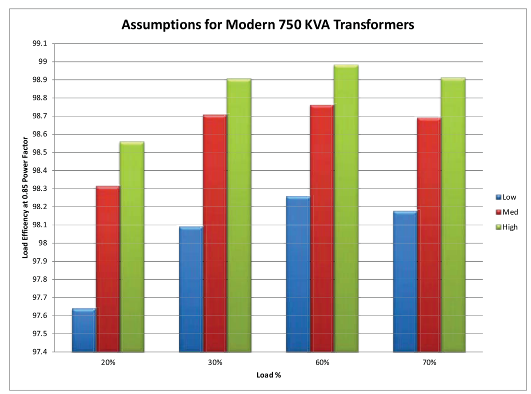

Assumptions for Modern Low Level Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
500 KVA
750 KVA
1000 KVA

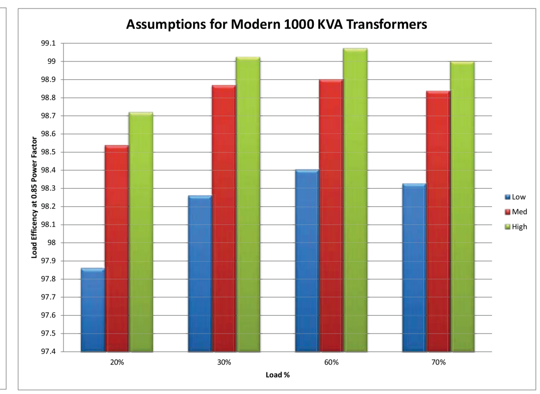

Assumptions for Modern Medium Level Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
500 KVA
750 KVA
1000 KVA


Assumptions for Modern High Level Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
500 KVA
750 KVA
1000 KVA

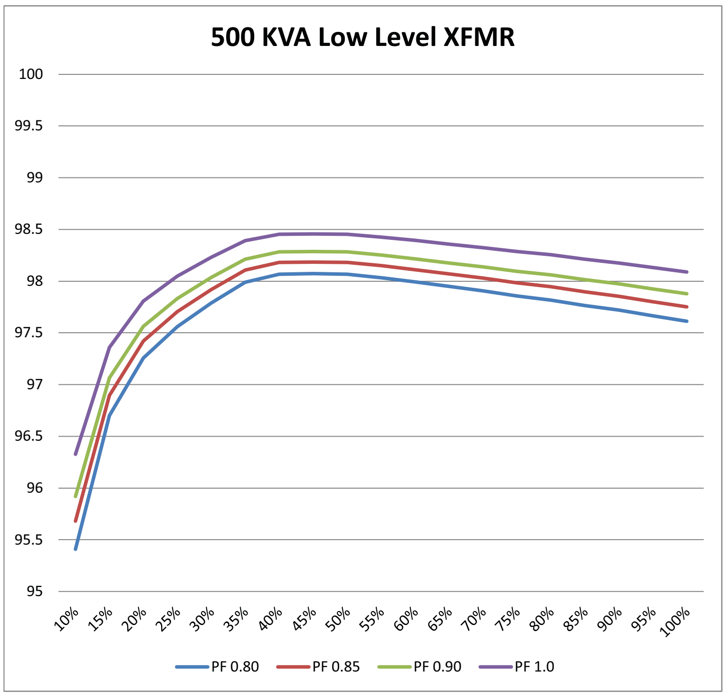

Total Losses for High-Level Transformers
Total Losses
Load %
20%
60%
500 KVA
750 KVA
1000 KVA


Assumptions for Modern 500 KVA Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
Low
Med
High

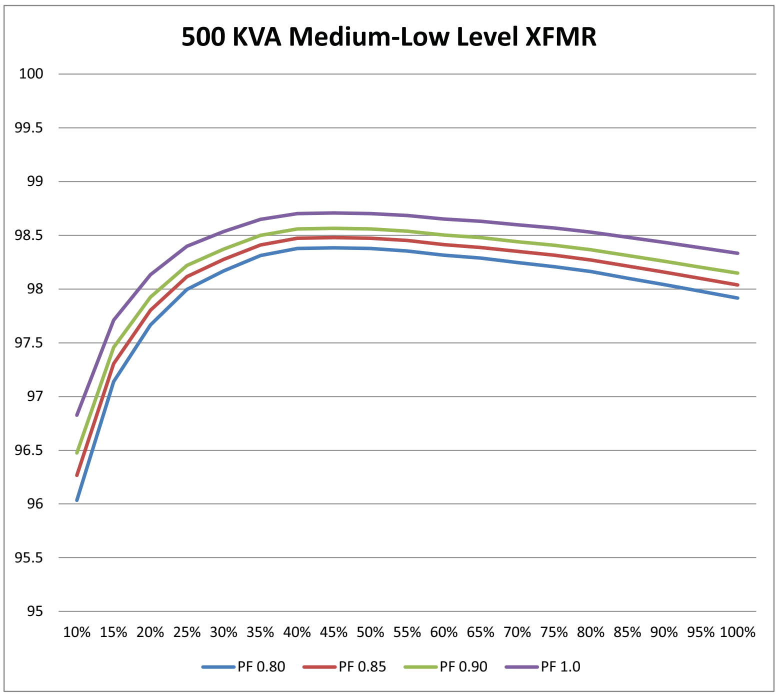

Assumptions for Modern 750 KVA Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
Low
Med
High


Assumptions for Modern 1000 KVA Transformers
Load Efficency at 0.85 Power Factor
Load %
20%
30%
60%
70%
Low
Med
High

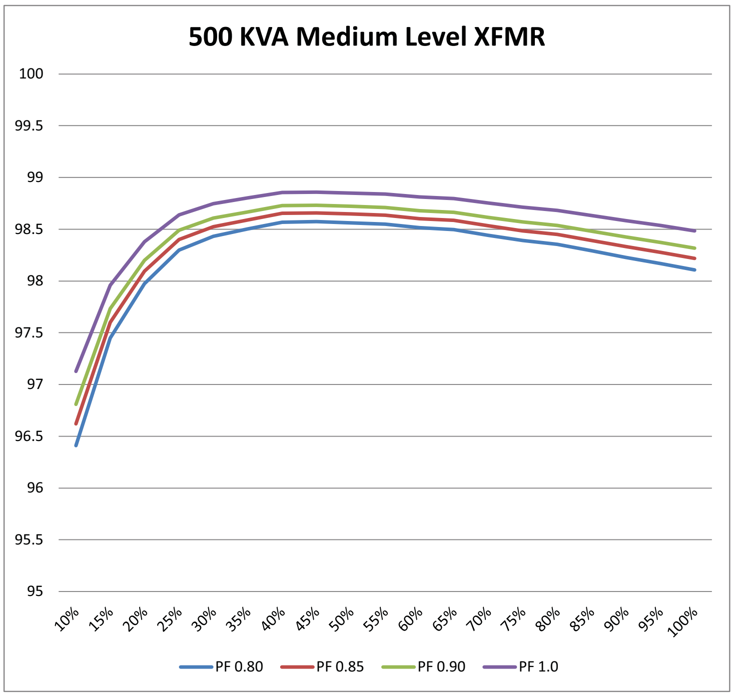
Load VA	Low Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1836.37	10%	95.40908	95.67913	95.91918	96.32726
75000	1980.18	15%	96.6997	96.89384	97.0664	97.35976
100000	2193.45	20%	97.25819	97.41947	97.56283	97.80655
125000	2439.2	25%	97.5608	97.70428	97.83182	98.04864
150000	2652.93	30%	97.78923	97.91927	98.03487	98.23138
175000	2816.82	35%	97.98799	98.10634	98.21154	98.39039
200000	3092.61	40%	98.06712	98.18082	98.28188	98.4537
225000	3470.3	45%	98.07206	98.18546	98.28627	98.45764
250000	3864.84	50%	98.06758	98.18125	98.28229	98.45406
275000	4326.42	55%	98.03345	98.14913	98.25195	98.42676
300000	4817.06	60%	97.99289	98.11096	98.2159	98.39431
325000	5334.22	65%	97.94838	98.06906	98.17634	98.3587
350000	5866.37	70%	97.90487	98.02811	98.13766	98.32389
375000	6428.88	75%	97.85704	97.9831	98.09515	98.28563
400000	6984.9	80%	97.81722	97.94562	98.05975	98.25378
425000	7598.96	85%	97.76501	97.89648	98.01334	98.21201
450000	8211.43	90%	97.71905	97.85322	97.97249	98.17524
475000	8874.89	95%	97.6645	97.80188	97.924	98.1316
500000	9551.69	100%	97.61208	97.75254	97.8774	98.08966



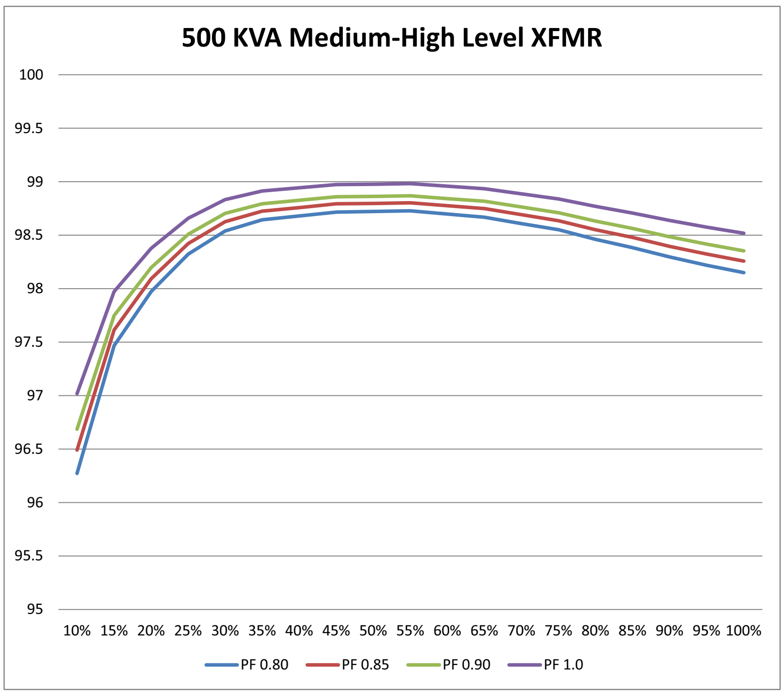
Load VA	Medium-Low Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1586.805	10%	96.03299	96.26634	96.47377	96.82639
75000	1717.03	15%	97.13828	97.30662	97.45625	97.71063
100000	1867.68	20%	97.6654	97.80273	97.9248	98.13232
125000	2004.59	25%	97.99541	98.11333	98.21814	98.39633
150000	2197.75	30%	98.16854	98.27627	98.37204	98.53483
175000	2366.35	35%	98.30975	98.40918	98.49756	98.6478
200000	2595.79	40%	98.37763	98.47306	98.55789	98.70211
225000	2910.33	45%	98.38315	98.47826	98.5628	98.70652
250000	3246.91	50%	98.37655	98.47204	98.55693	98.70124
275000	3620.94	55%	98.35412	98.45093	98.53699	98.68329
300000	4045.74	60%	98.31428	98.41344	98.50158	98.65142
325000	4456.23	65%	98.28607	98.38689	98.4765	98.62885
350000	4912.6	70%	98.2455	98.34871	98.44044	98.5964
375000	5375.99	75%	98.208	98.31341	98.40711	98.5664
400000	5884.94	80%	98.16096	98.26914	98.36529	98.52877
425000	6459.03	85%	98.10029	98.21203	98.31136	98.48023
450000	7050.73	90%	98.04146	98.15667	98.25908	98.43317
475000	7688.17	95%	97.9768	98.09581	98.2016	98.38144
500000	8335.38	100%	97.91616	98.03873	98.14769	98.33292



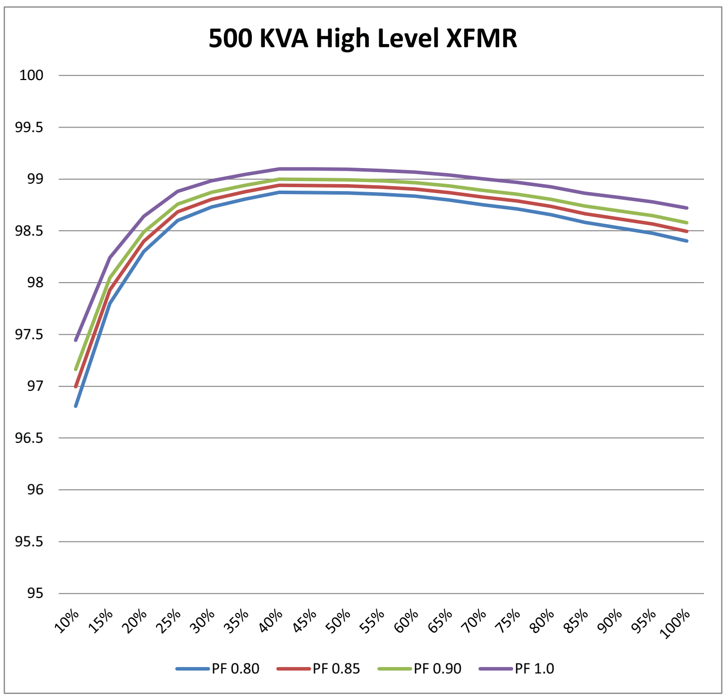
Load VA	Medium Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1436.15	10%	96.40963	96.62082	96.80856	97.1277
75000	1529.774	15%	97.45038	97.60035	97.73367	97.9603
100000	1619.648	20%	97.97544	98.09453	98.20039	98.38035
125000	1699.906	25%	98.30009	98.40009	98.48897	98.64008
150000	1880.472	30%	98.43294	98.52512	98.60706	98.74635
175000	2097.884	35%	98.50151	98.58966	98.66801	98.80121
200000	2290.296	40%	98.56857	98.65277	98.72761	98.85485
225000	2567.708	45%	98.5735	98.65741	98.732	98.8588
250000	2874.12	50%	98.56294	98.64747	98.72261	98.85035
275000	3191.708	55%	98.54922	98.63456	98.71042	98.83938
300000	3563.296	60%	98.51529	98.60263	98.68026	98.81223
325000	3907.884	65%	98.49697	98.58538	98.66397	98.79757
350000	4362.472	70%	98.44197	98.53362	98.61509	98.75358
375000	4827.06	75%	98.39098	98.48563	98.56976	98.71278
400000	5269.648	80%	98.35324	98.4501	98.53621	98.68259
425000	5806.236	85%	98.29228	98.39274	98.48203	98.63383
450000	6380.824	90%	98.22755	98.33181	98.42449	98.58204
475000	6955.412	95%	98.16963	98.2773	98.373	98.5357
500000	7571.358	100%	98.10716	98.2185	98.31748	98.48573



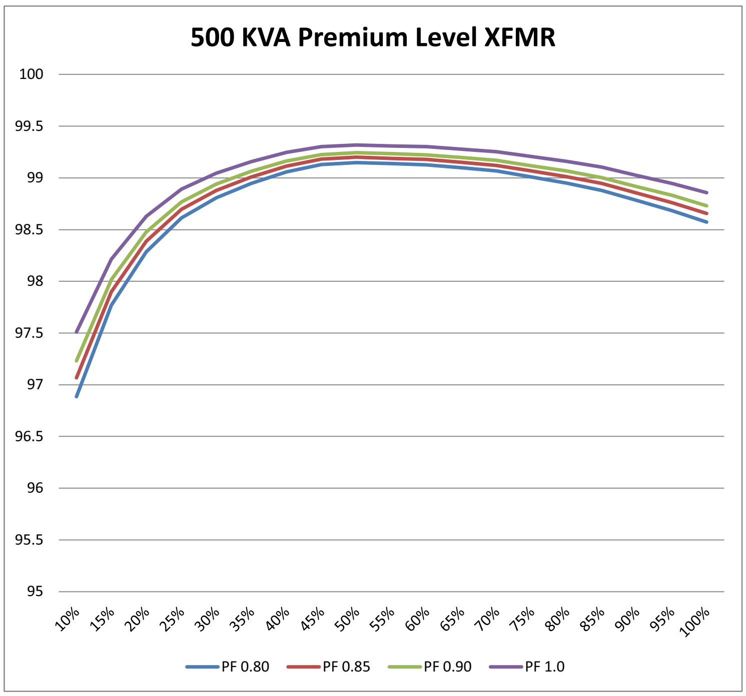
Load VA	Medium-High Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1490.824	10%	96.27294	96.49218	96.68706	97.01835
75000	1520.236	15%	97.46627	97.61532	97.7478	97.97302
100000	1621.648	20%	97.97294	98.09218	98.19817	98.37835
125000	1677.06	25%	98.32294	98.42159	98.50928	98.65835
150000	1750.472	30%	98.54127	98.62708	98.70335	98.83302
175000	1897.884	35%	98.64437	98.72411	98.79499	98.91549
200000	2110.296	40%	98.68107	98.75865	98.82761	98.94485
225000	2307.708	45%	98.71794	98.79336	98.86039	98.97435
250000	2554.12	50%	98.72294	98.79806	98.86484	98.97835
275000	2798.708	55%	98.72786	98.80269	98.86921	98.98229
300000	3123.296	60%	98.69863	98.77518	98.84322	98.9589
325000	3457.884	65%	98.67004	98.74828	98.81782	98.93604
350000	3892.472	70%	98.60983	98.69161	98.76429	98.88787
375000	4347.06	75%	98.55098	98.63622	98.71198	98.84078
400000	4921.648	80%	98.46199	98.55246	98.63288	98.76959
425000	5496.236	85%	98.38346	98.47855	98.56308	98.70677
450000	6130.824	90%	98.29699	98.39717	98.48622	98.63759
475000	6765.412	95%	98.21963	98.32436	98.41745	98.5757
500000	7401.358	100%	98.14966	98.2585	98.35525	98.51973



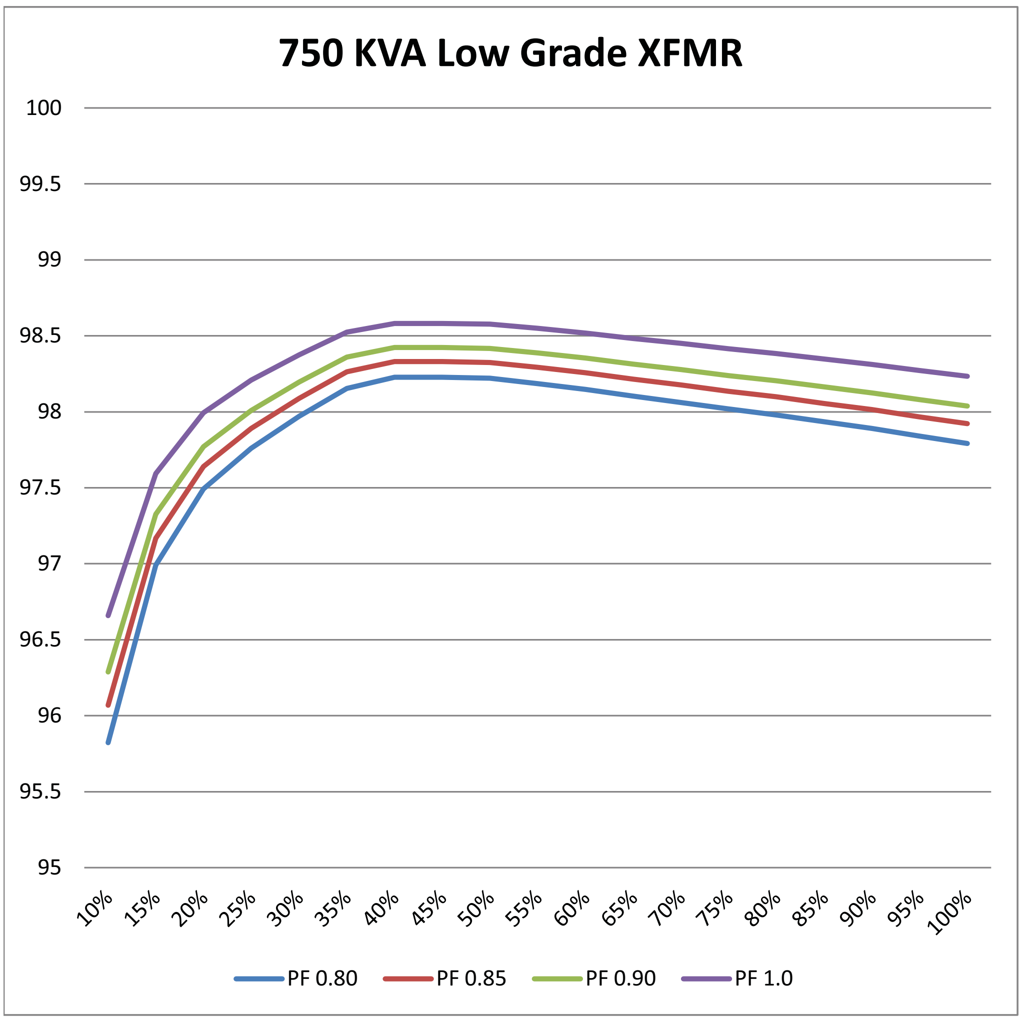
Load VA	High Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1277.3	10%	96.80675	96.99459	97.16156	97.4454
75000	1319.45	15%	97.80092	97.93027	98.04526	98.24073
100000	1359.6	20%	98.3005	98.40047	98.48933	98.6404
125000	1398.75	25%	98.60125	98.68353	98.75667	98.881
150000	1522.9	30%	98.73092	98.80557	98.87193	98.98473
175000	1668.05	35%	98.80854	98.87862	98.94092	99.04683
200000	1802.475	40%	98.87345	98.93972	98.99863	99.09876
225000	2033.1	45%	98.8705	98.93694	98.996	99.0964
250000	2265.5	50%	98.86725	98.93388	98.99311	99.0938
275000	2519.35	55%	98.85484	98.9222	98.98208	99.08387
300000	2797.2	60%	98.8345	98.90306	98.964	99.0676
325000	3122.3	65%	98.79912	98.86976	98.93255	99.03929
350000	3494.4	70%	98.752	98.82541	98.89067	99.0016
375000	3864.5	75%	98.71183	98.78761	98.85496	98.96947
400000	4300.6	80%	98.65606	98.73512	98.80539	98.92485
425000	4826.7	85%	98.58038	98.66389	98.73812	98.86431
450000	5297.51	90%	98.52847	98.61503	98.69197	98.82278
475000	5792.321	95%	98.47571	98.56537	98.64507	98.78056
500000	6391.8421	100%	98.40204	98.49604	98.57959	98.72163



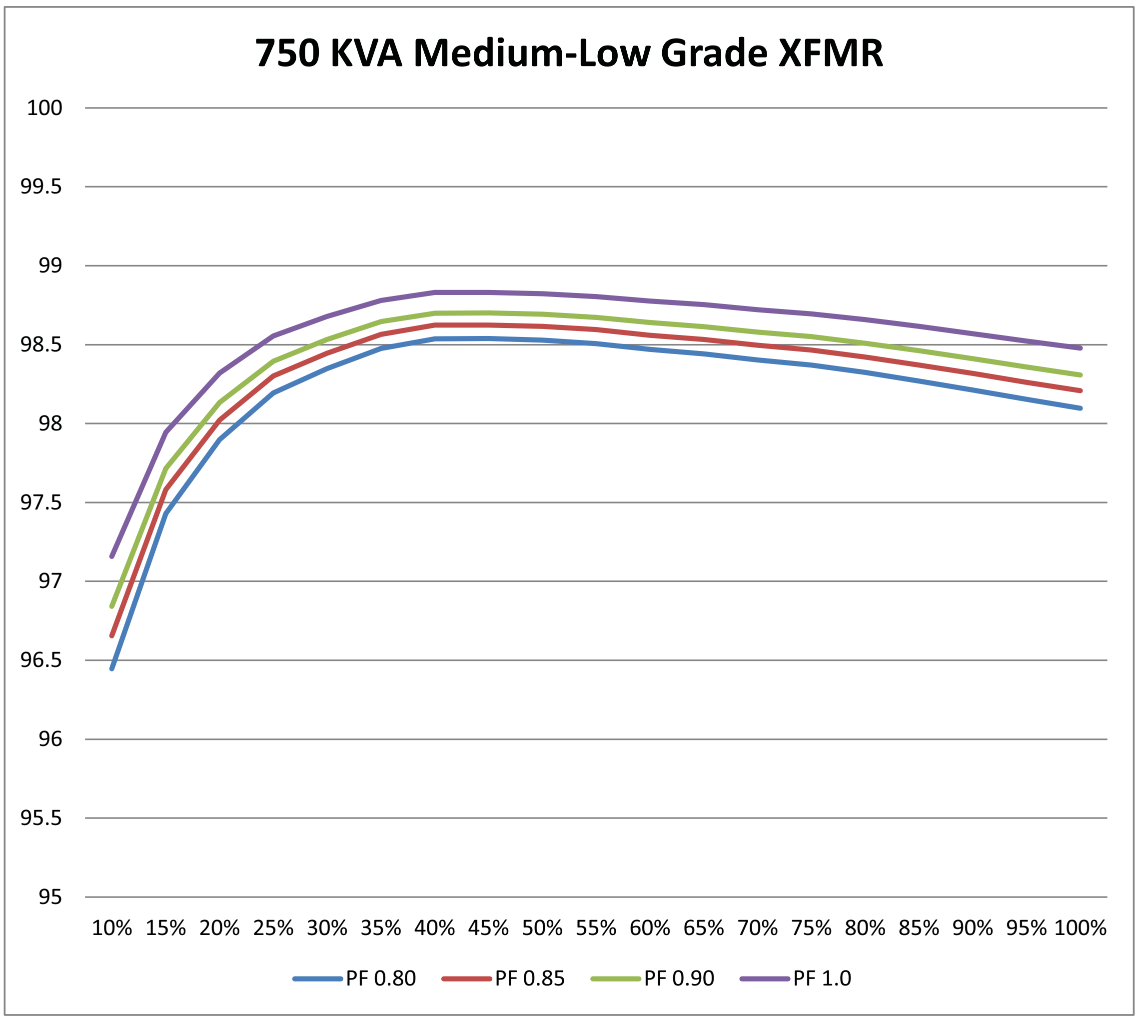
Load VA	Premium Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1246.133	10%	96.88467	97.06792	97.23082	97.50773
75000	1339.203	15%	97.768	97.89929	98.016	98.2144
100000	1370.742	20%	98.28657	98.38736	98.47695	98.62926
125000	1385.974	25%	98.61403	98.69555	98.76802	98.89122
150000	1430.632	30%	98.80781	98.87794	98.94027	99.04625
175000	1472.545	35%	98.94818	99.01005	99.06505	99.15855
200000	1505.166	40%	99.05927	99.11461	99.1638	99.24742
225000	1566.435	45%	99.12976	99.18095	99.22645	99.30381
250000	1701.728	50%	99.14914	99.19919	99.24368	99.31931
275000	1897.225	55%	99.13763	99.18835	99.23344	99.3101
300000	2096.43	60%	99.12649	99.17787	99.22354	99.30119
325000	2344.56	65%	99.09825	99.15129	99.19844	99.2786
350000	2615.0332	70%	99.06606	99.121	99.16983	99.25285
375000	2975.879	75%	99.00804	99.06639	99.11826	99.20643
400000	3358.0789	80%	98.9506	99.01233	99.0672	99.16048
425000	3809.554	85%	98.87954	98.94545	99.00404	99.10363
450000	4385.114	90%	98.78191	98.85356	98.91726	99.02553
475000	4997.32	95%	98.68492	98.76227	98.83104	98.94793
500000	5711.986	100%	98.572	98.656	98.73067	98.8576



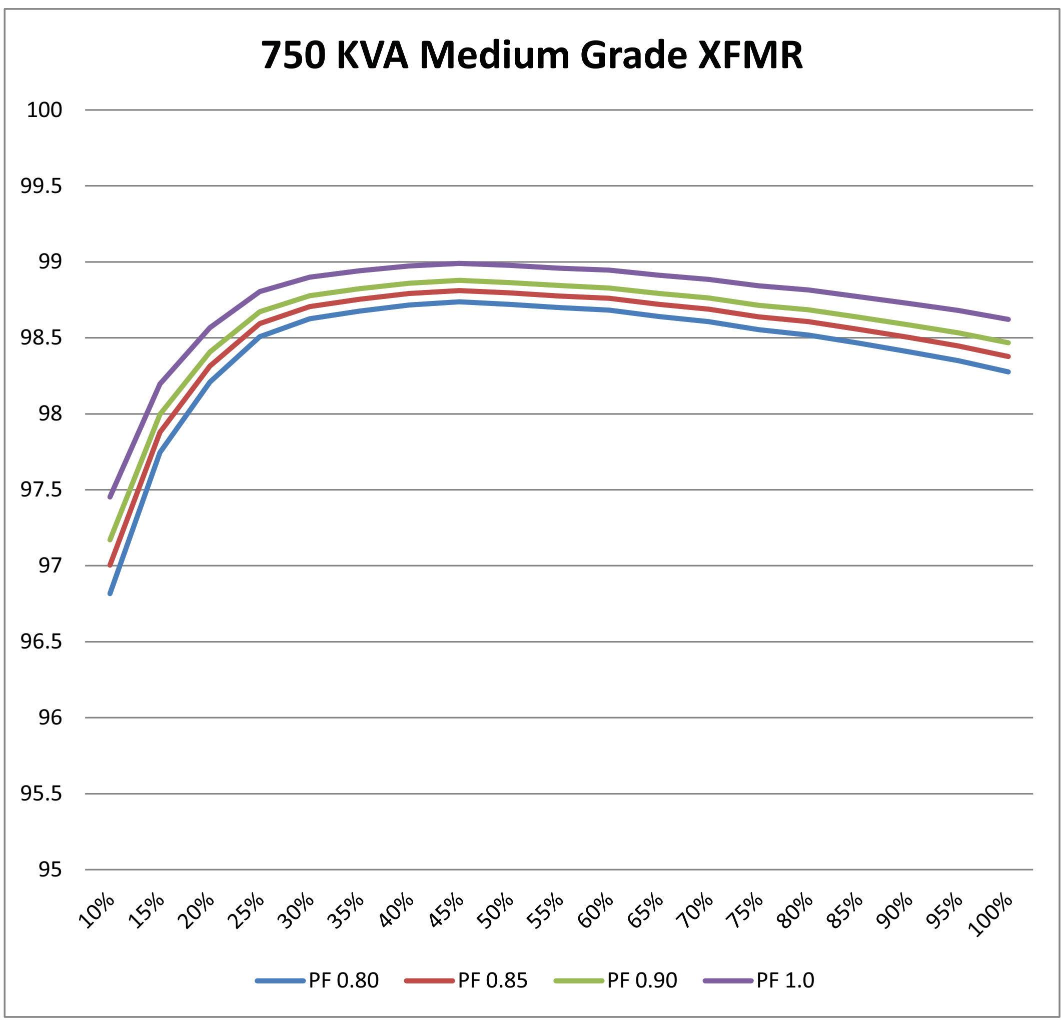
Load VA	Low Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	2505.948	10%	95.82342	96.0691	96.28748	96.65874
112500	2707.77	15%	96.99137	97.16835	97.32566	97.59309
150000	3009.62	20%	97.49198	97.63951	97.77065	97.99359
187500	3360.18	25%	97.75988	97.89165	98.00878	98.2079
225000	3654.41	30%	97.96977	98.0892	98.19535	98.37582
262500	3875.24	35%	98.15465	98.2632	98.35969	98.52372
300000	4255.56	40%	98.22685	98.33115	98.42387	98.58148
337500	4786.71	45%	98.22714	98.33143	98.42413	98.58172
375000	5338.96	50%	98.22035	98.32503	98.41809	98.57628
412500	5985.46	55%	98.18622	98.29292	98.38775	98.54898
450000	6667.27	60%	98.14798	98.25692	98.35376	98.51838
487500	7396.43	65%	98.10348	98.21504	98.3142	98.48278
525000	8138.47	70%	98.06227	98.17625	98.27757	98.44982
562500	8914.15	75%	98.01908	98.1356	98.23918	98.41526
600000	9699.56	80%	97.97926	98.09813	98.20379	98.38341
637500	10536.67	85%	97.93399	98.05552	98.16354	98.34719
675000	11392.08	90%	97.89036	98.01445	98.12476	98.31228
712500	12309.53	95%	97.84043	97.96747	98.08039	98.27235
750000	13244.19	100%	97.79264	97.92248	98.0379	98.23411



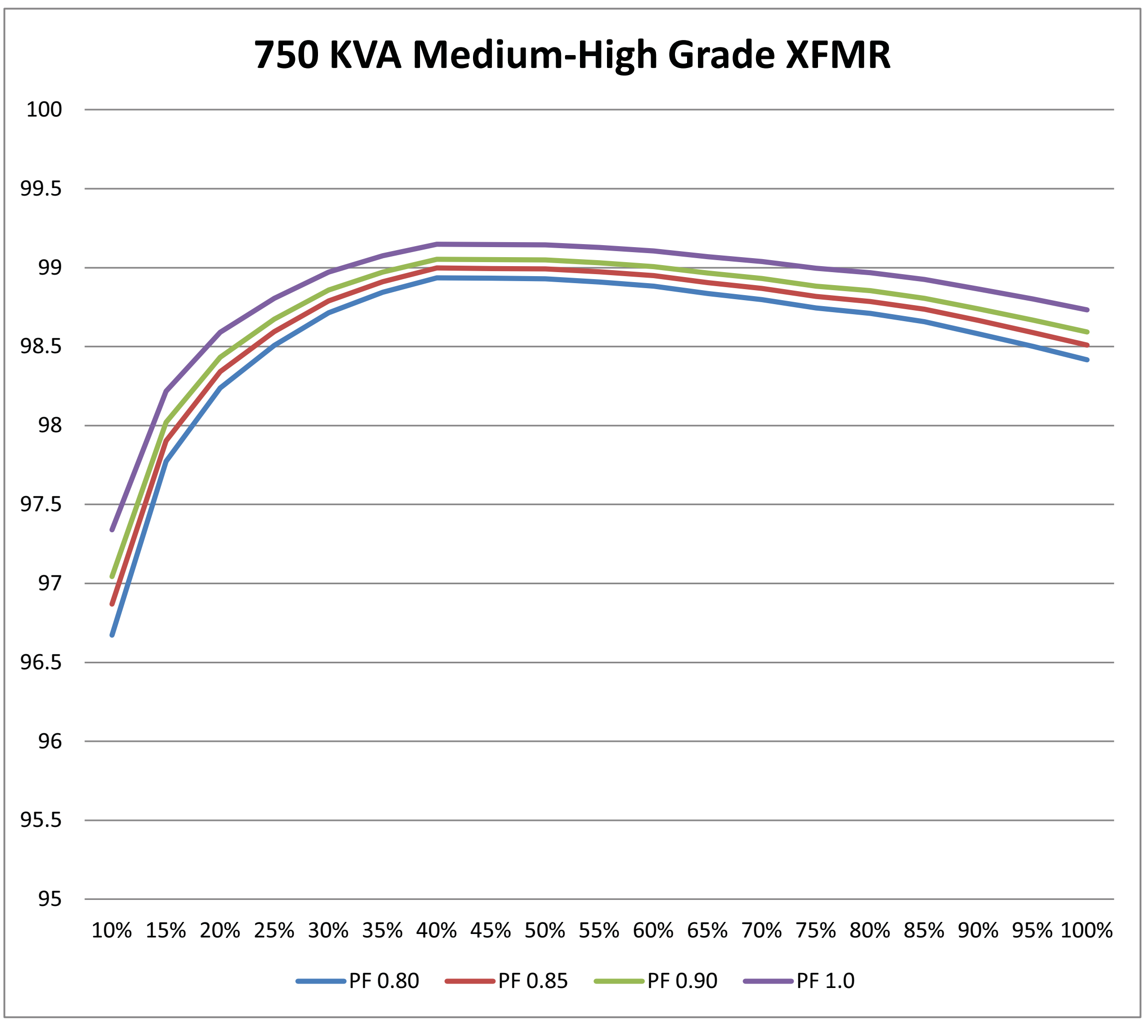
Load VA	Medium-Low Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	2131.6	10%	96.44733	96.65631	96.84207	97.15787
112500	2313.03	15%	97.42997	97.58115	97.71553	97.94397
150000	2520.97	20%	97.89919	98.02277	98.13261	98.31935
187500	2708.27	25%	98.19449	98.30069	98.3951	98.55559
225000	2971.64	30%	98.34909	98.4462	98.53252	98.67927
262500	3199.52	35%	98.47642	98.56604	98.64571	98.78114
300000	3510.34	40%	98.53736	98.6234	98.69987	98.82989
337500	3946.75	45%	98.53824	98.62423	98.70066	98.83059
375000	4412	50%	98.52933	98.61584	98.69274	98.82347
412500	4927.27	55%	98.50689	98.59472	98.67279	98.80551
450000	5510.27	60%	98.46937	98.55941	98.63944	98.7755
487500	6079.5	65%	98.44115	98.53285	98.61436	98.75292
525000	6707.81	70%	98.4029	98.49685	98.58036	98.72232
562500	7334.84	75%	98.37004	98.46592	98.55114	98.69603
600000	8049.59	80%	98.323	98.42165	98.50934	98.6584
637500	8826.78	85%	98.26926	98.37107	98.46156	98.61541
675000	9651.18	90%	98.21274	98.31788	98.41133	98.5702
712500	10529.46	95%	98.15273	98.26139	98.35798	98.52218
750000	11419.69	100%	98.09672	98.20868	98.30819	98.47737



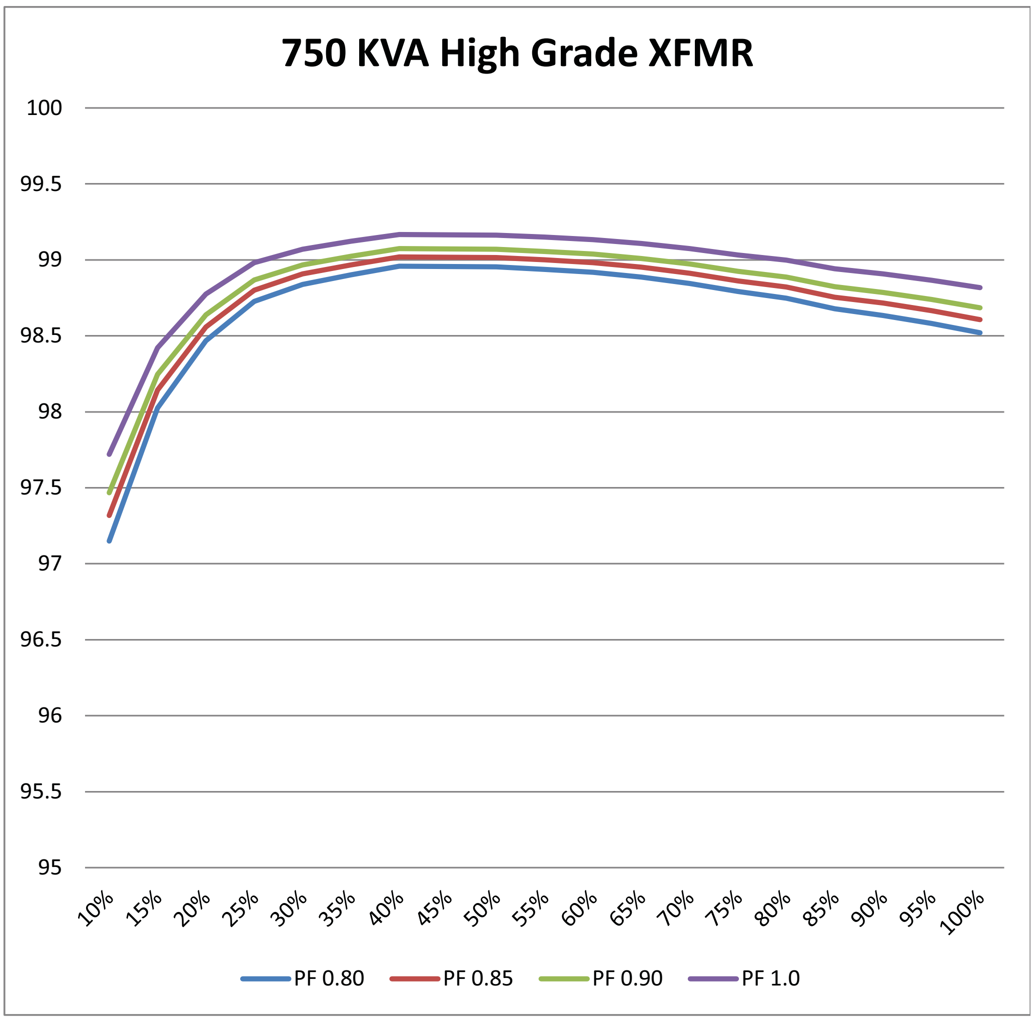
Load VA	Medium Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1909.99	10%	96.81668	97.00394	97.17039	97.45335
112500	2028.85	15%	97.74572	97.87833	97.9962	98.19658
150000	2149.67	20%	98.20861	98.31398	98.40765	98.56689
187500	2239.99	25%	98.50667	98.59452	98.6726	98.80534
225000	2475.31	30%	98.62483	98.70572	98.77762	98.89986
262500	2781.13	35%	98.67565	98.75356	98.8228	98.94052
300000	3081.95	40%	98.71585	98.79139	98.85854	98.97268
337500	3408.77	45%	98.73749	98.81176	98.87777	98.98999
375000	3838.59	50%	98.72047	98.79574	98.86264	98.97638
412500	4292.41	55%	98.69927	98.77578	98.8438	98.95942
450000	4744.23	60%	98.68216	98.75968	98.82859	98.94573
487500	5302.05	65%	98.6405	98.72047	98.79156	98.9124
525000	5851.07	70%	98.60689	98.68884	98.76168	98.88551
562500	6506.09	75%	98.5542	98.63925	98.71485	98.84336
600000	7107.76	80%	98.51922	98.60632	98.68375	98.81537
637500	7829.43	85%	98.46482	98.55512	98.63539	98.77185
675000	8591.1	90%	98.40906	98.50264	98.58583	98.72724
712500	9406.77	95%	98.34969	98.44677	98.53306	98.67975
750000	10342.44	100%	98.27626	98.37766	98.46779	98.62101



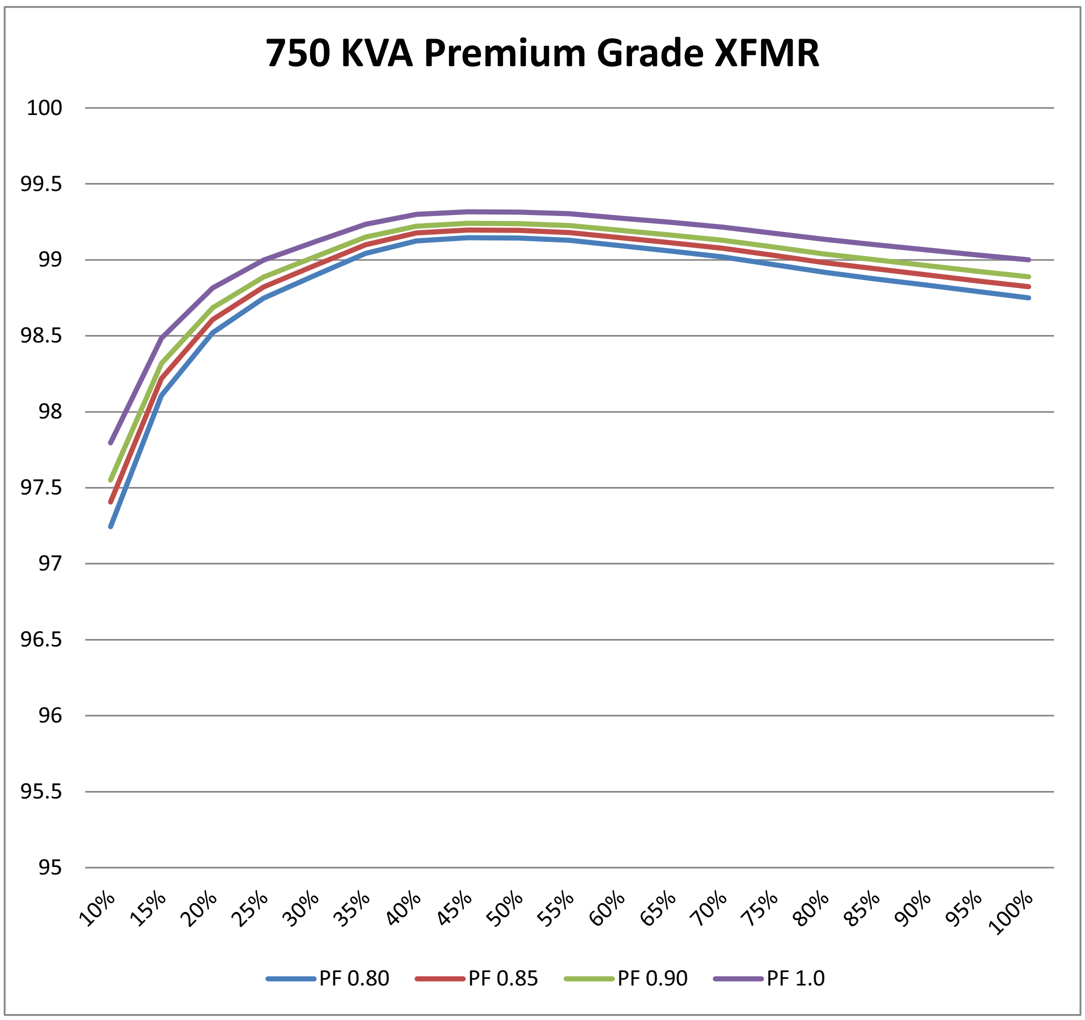
Load VA	Medium-High Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1995.934	10%	96.67344	96.86912	97.04306	97.33875
112500	2004.271	15%	97.77303	97.90403	98.02047	98.21843
150000	2115.608	20%	98.23699	98.3407	98.43288	98.58959
187500	2238.945	25%	98.50737	98.59517	98.67322	98.8059
225000	2314.282	30%	98.71429	98.78992	98.85714	98.97143
262500	2429.619	35%	98.84304	98.9111	98.97159	99.07443
300000	2556.956	40%	98.9346	98.99727	99.05298	99.14768
337500	2883.293	45%	98.93211	98.99493	99.05077	99.14569
375000	3213.63	50%	98.92879	98.9918	99.04781	99.14303
412500	3600.967	55%	98.9088	98.97299	99.03004	99.12704
450000	4022.304	60%	98.88269	98.94842	99.00684	99.10615
487500	4540.941	65%	98.83566	98.90415	98.96503	99.06852
525000	5050.578	70%	98.79748	98.86822	98.93109	99.03799
562500	5653.215	75%	98.74373	98.81763	98.88332	98.99498
600000	6190.852	80%	98.71024	98.78611	98.85355	98.96819
637500	6849.489	85%	98.65696	98.73597	98.80619	98.92557
675000	7662.126	90%	98.58109	98.66455	98.73874	98.86487
712500	8546.763	95%	98.50057	98.58877	98.66717	98.80045
750000	9506	100%	98.41567	98.50886	98.5917	98.73253



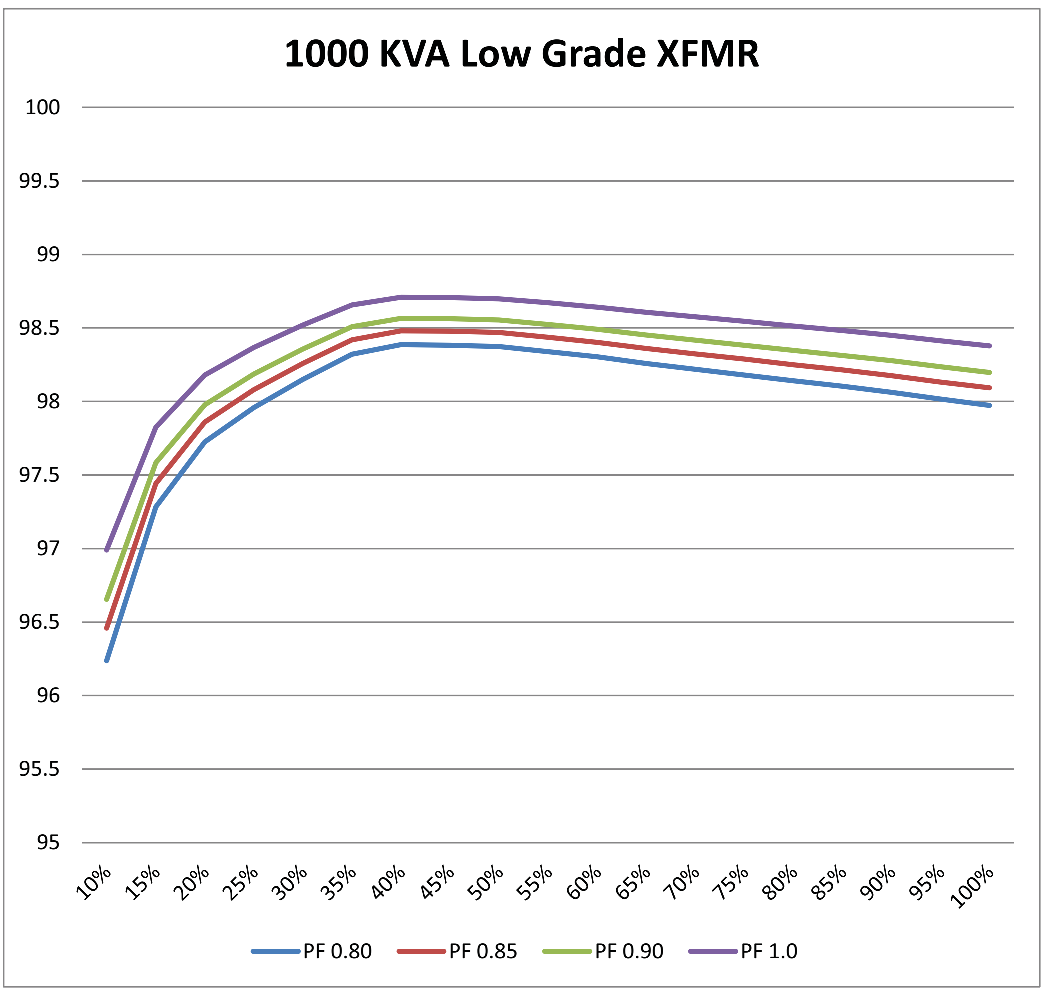
Load VA	High Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1709.981	10%	97.15003	97.31768	97.46669	97.72003
112500	1776.274	15%	98.02636	98.14246	98.24566	98.42109
150000	1838.567	20%	98.46786	98.55799	98.6381	98.77429
187500	1910.86	25%	98.72609	98.80103	98.86764	98.98087
225000	2090.153	30%	98.8388	98.90711	98.96783	99.07104
262500	2305.446	35%	98.90217	98.96675	99.02415	99.12173
300000	2498.139	40%	98.95911	99.02034	99.07476	99.16729
337500	2820.232	45%	98.95547	99.01691	99.07153	99.16438
375000	3139.325	50%	98.95356	99.01511	99.06983	99.16285
412500	3505.65	55%	98.93768	99.00017	99.05572	99.15015
450000	3895.975	60%	98.91778	98.98144	99.03803	99.13423
487500	4344.3	65%	98.88608	98.9516	99.00985	99.10886
525000	4856.625	70%	98.84366	98.91168	98.97214	99.07493
562500	5439.95	75%	98.79112	98.86223	98.92544	99.0329
600000	6010.275	80%	98.74786	98.82151	98.88699	98.99829
637500	6745.6	85%	98.67733	98.75514	98.8243	98.94187
675000	7370.925	90%	98.63501	98.71531	98.78668	98.90801
712500	8086.25	95%	98.58136	98.66481	98.73899	98.86509
750000	8875.78	100%	98.5207	98.60772	98.68507	98.81656



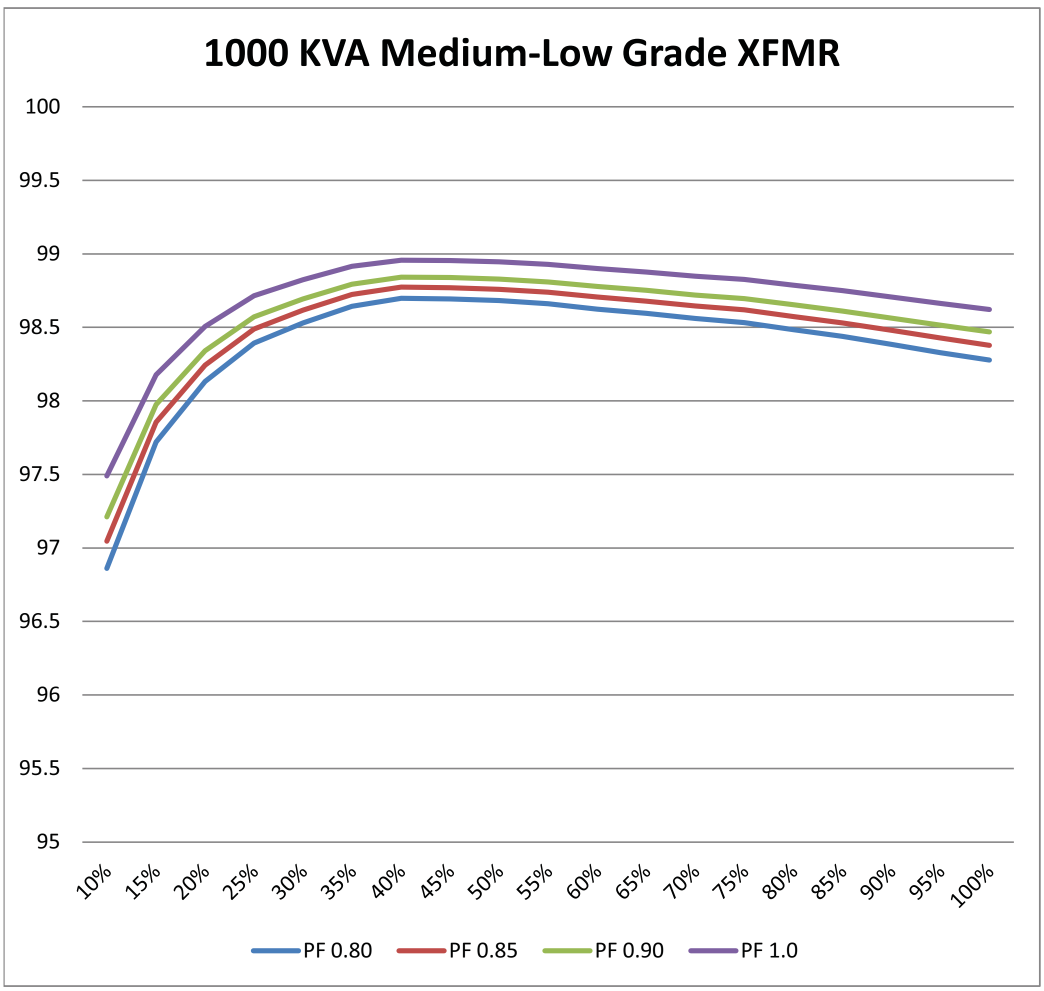
Load VA	Premium Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1652.99	10%	97.24502	97.40707	97.55113	97.79601
112500	1703.85	15%	98.10683	98.2182	98.31719	98.48547
150000	1775.67	20%	98.52028	98.60732	98.68469	98.81622
187500	1878.99	25%	98.74734	98.82103	98.88652	98.99787
225000	1985.31	30%	98.89705	98.96193	99.0196	99.11764
262500	2009.13	35%	99.04327	99.09955	99.14957	99.23462
300000	2099.15	40%	99.12535	99.1768	99.22254	99.30028
337500	2307.77	45%	99.14527	99.19555	99.24024	99.31622
375000	2567.59	50%	99.14414	99.19448	99.23923	99.31531
412500	2875.41	55%	99.12866	99.17992	99.22548	99.30293
450000	3264.23	60%	99.09327	99.14661	99.19402	99.27462
487500	3676.05	65%	99.05742	99.11287	99.16215	99.24594
525000	4118.07	70%	99.01951	99.07718	99.12845	99.21561
562500	4636.09	75%	98.96976	99.03036	99.08423	99.17581
600000	5192.76	80%	98.91818	98.98181	99.03838	99.13454
637500	5737.43	85%	98.87501	98.94119	99.00001	99.10001
675000	6299.1	90%	98.8335	98.90212	98.96311	99.0668
712500	6890.77	95%	98.79109	98.86221	98.92542	99.03287
750000	7502.44	100%	98.74959	98.82315	98.88853	98.99967



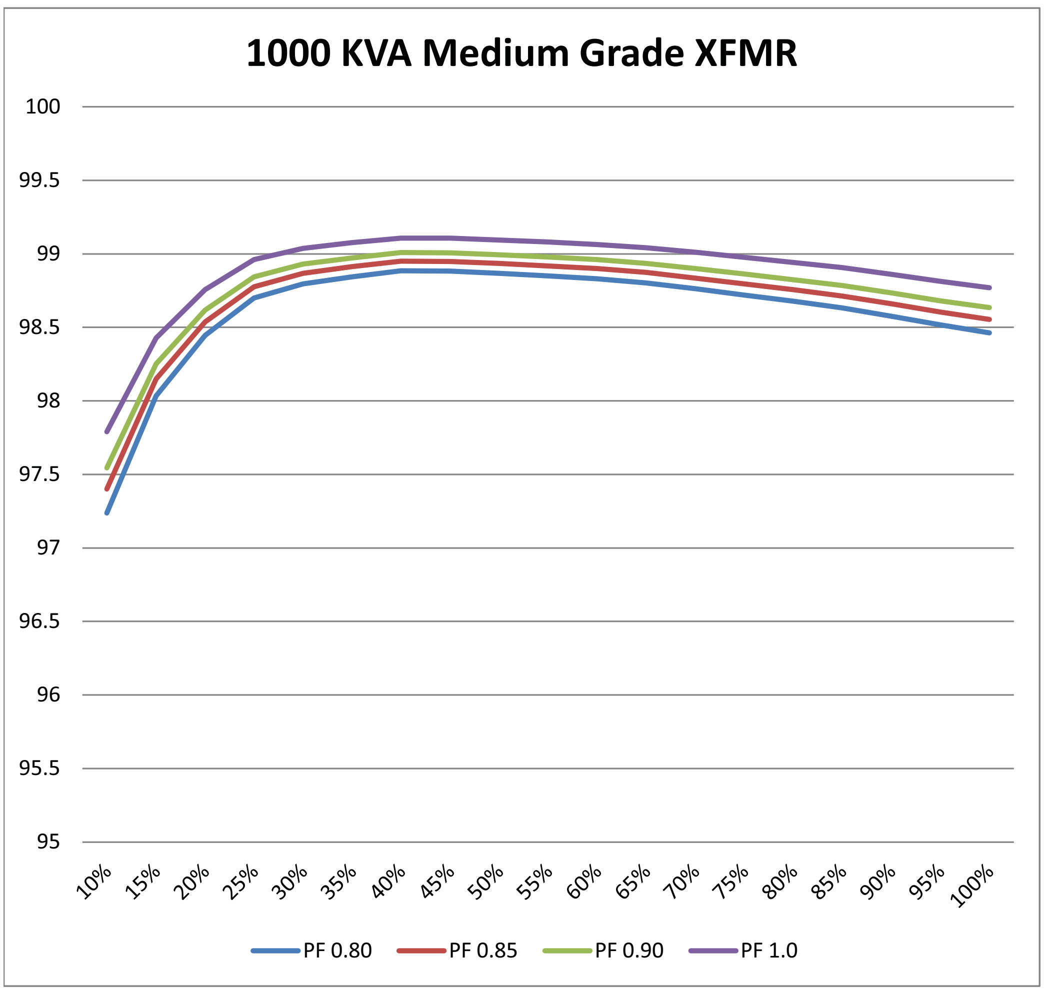
Load VA	Low Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	3009.78	10%	96.23778	96.45908	96.6558	96.99022
150000	3260.36	15%	97.28303	97.44285	97.58492	97.82643
200000	3638.75	20%	97.72578	97.85956	97.97847	98.18063
250000	4082.11	25%	97.95895	98.07901	98.18573	98.36716
300000	4439.2	30%	98.15033	98.25914	98.35585	98.52027
350000	4700.31	35%	98.32132	98.42006	98.50784	98.65705
400000	5162.98	40%	98.38657	98.48148	98.56584	98.70926
450000	5823.94	45%	98.38224	98.4774	98.56199	98.70579
500000	6507.48	50%	98.37313	98.46883	98.55389	98.6985
550000	7308.39	55%	98.339	98.43671	98.52356	98.6712
600000	8145.28	60%	98.30307	98.40289	98.49161	98.64245
650000	9055.47	65%	98.25856	98.361	98.45206	98.60685
700000	9969.81	70%	98.21968	98.3244	98.41749	98.57574
750000	10913.34	75%	98.18111	98.2881	98.38321	98.54489
800000	11895.68	80%	98.1413	98.25064	98.34782	98.51304
850000	12899.78	85%	98.10297	98.21456	98.31375	98.48238
900000	13956.18	90%	98.06164	98.17566	98.27701	98.44931
950000	15075.68	95%	98.01636	98.13304	98.23676	98.41309
1000000	16214.47	100%	97.97319	98.09242	98.19839	98.37855



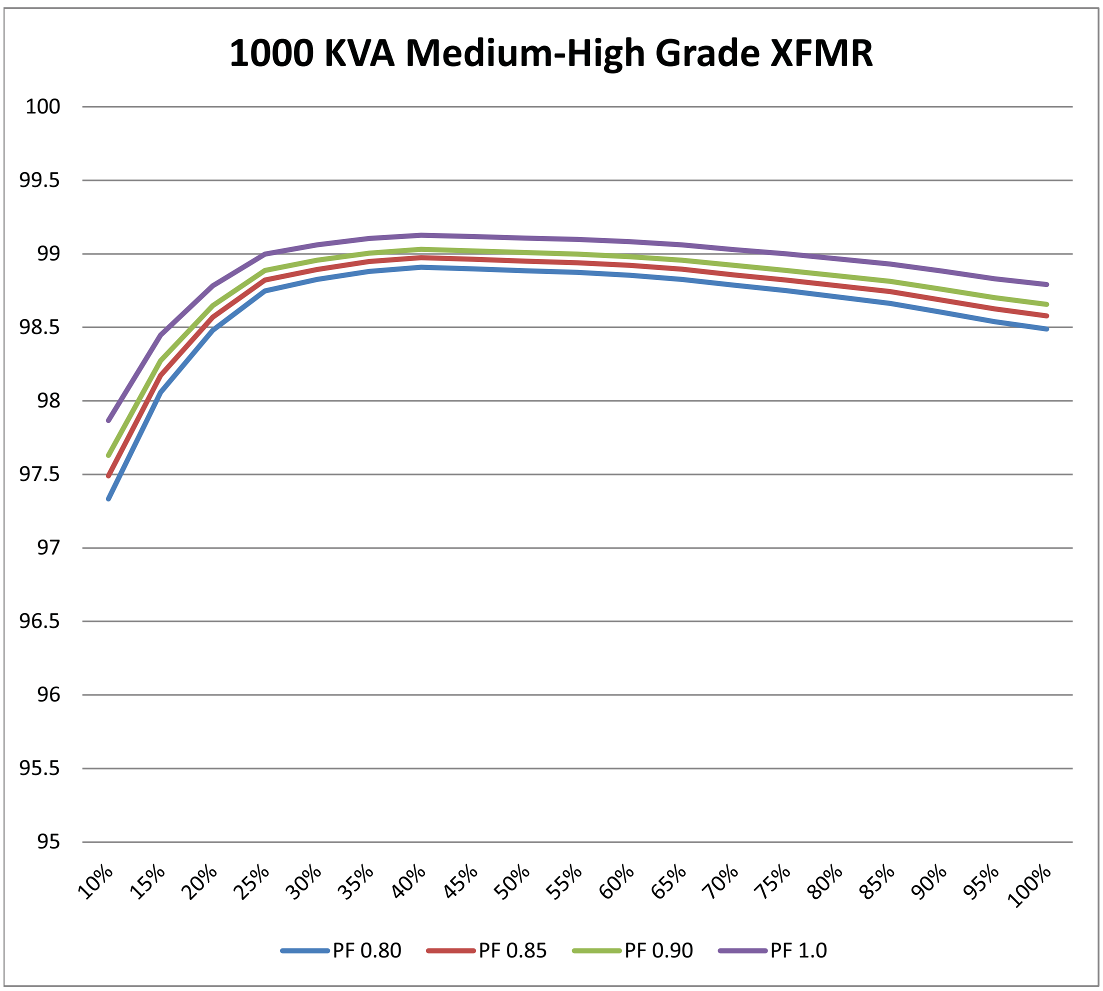
Load VA	Medium-Low Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	2510.65	10%	96.86169	97.04629	97.21039	97.48935
150000	2734.05	15%	97.72163	97.85565	97.97478	98.1773
200000	2987.22	20%	98.13299	98.24281	98.34043	98.50639
250000	3212.87	25%	98.39357	98.48806	98.57206	98.71485
300000	3528.85	30%	98.52965	98.61614	98.69302	98.82372
350000	3799.35	35%	98.64309	98.72291	98.79386	98.91447
400000	4169.32	40%	98.69709	98.77373	98.84186	98.95767
450000	4703.99	45%	98.69334	98.7702	98.83852	98.95467
500000	5271.56	50%	98.68211	98.75963	98.82854	98.94569
550000	5897.46	55%	98.65967	98.73851	98.80859	98.92773
600000	6602.57	60%	98.62446	98.70538	98.7773	98.89957
650000	7299.54	65%	98.59624	98.67882	98.75222	98.87699
700000	8062.27	70%	98.56031	98.645	98.72027	98.84825
750000	8807.59	75%	98.53207	98.61842	98.69517	98.82565
800000	9695.76	80%	98.48504	98.57415	98.65337	98.78803
850000	10619.92	85%	98.43825	98.53011	98.61178	98.7506
900000	11634.83	90%	98.38405	98.47911	98.5636	98.70724
950000	12702.21	95%	98.32866	98.42697	98.51436	98.66293
1000000	13781.87	100%	98.27727	98.3786	98.46868	98.62181



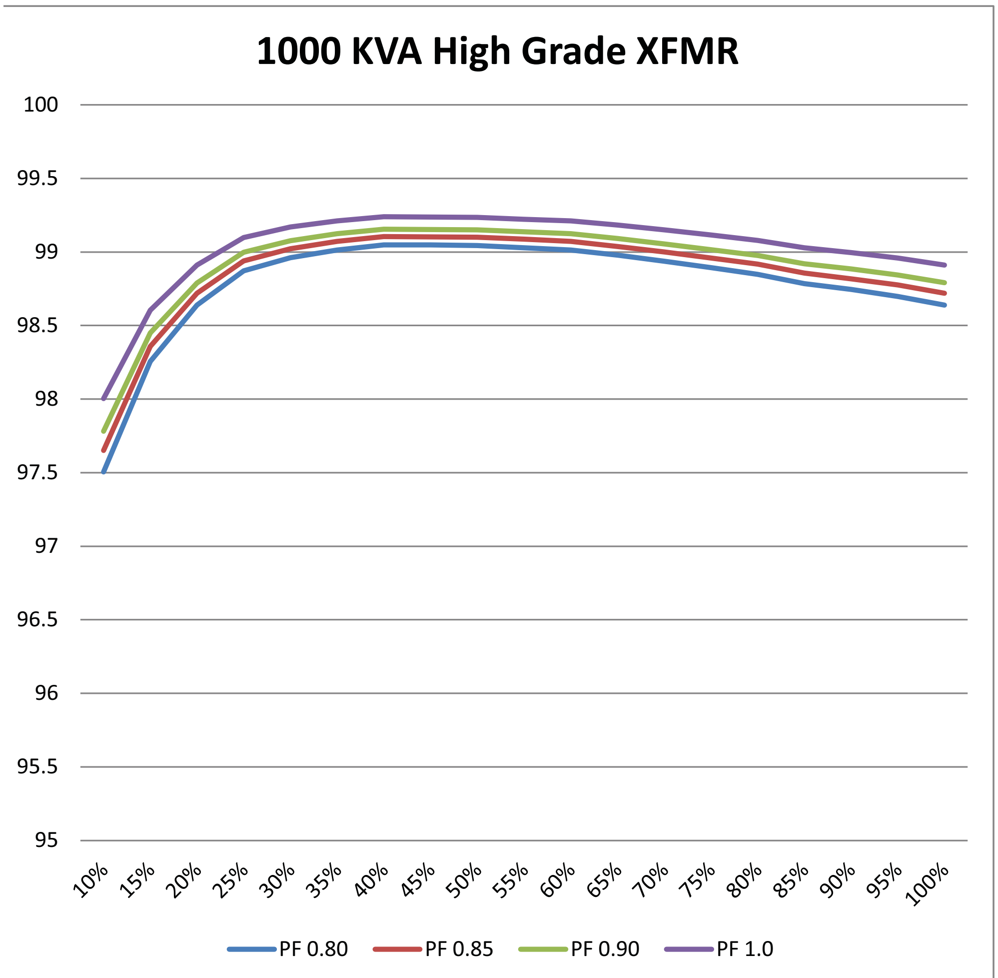
Load VA	Medium Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	2209.34	10%	97.23833	97.40078	97.54518	97.79066
150000	2359.55	15%	98.03371	98.14937	98.25219	98.42697
200000	2487.38	20%	98.44539	98.53684	98.61812	98.75631
250000	2599.77	25%	98.70012	98.77658	98.84455	98.96009
300000	2888.39	30%	98.7965	98.8673	98.93023	99.0372
350000	3235.12	35%	98.8446	98.91256	98.97298	99.07568
400000	3571.56	40%	98.88389	98.94954	99.0079	99.10711
450000	4021.03	45%	98.88305	98.94875	99.00715	99.10644
500000	4525.86	50%	98.86854	98.93509	98.99425	99.09483
550000	5059.23	55%	98.85018	98.91781	98.97793	99.08014
600000	5613.92	60%	98.83043	98.89923	98.96039	99.06435
650000	6225.45	65%	98.8028	98.87322	98.93582	99.04224
700000	6928.98	70%	98.76268	98.83547	98.90016	99.01015
750000	7677.27	75%	98.72046	98.79572	98.86263	98.97636
800000	8461.54	80%	98.67788	98.75566	98.82479	98.94231
850000	9292.81	85%	98.63341	98.7138	98.78525	98.90673
900000	10247.33	90%	98.57676	98.66048	98.7349	98.86141
950000	11275.71	95%	98.51635	98.60363	98.6812	98.81308
1000000	12295.23	100%	98.4631	98.5535	98.63386	98.77048



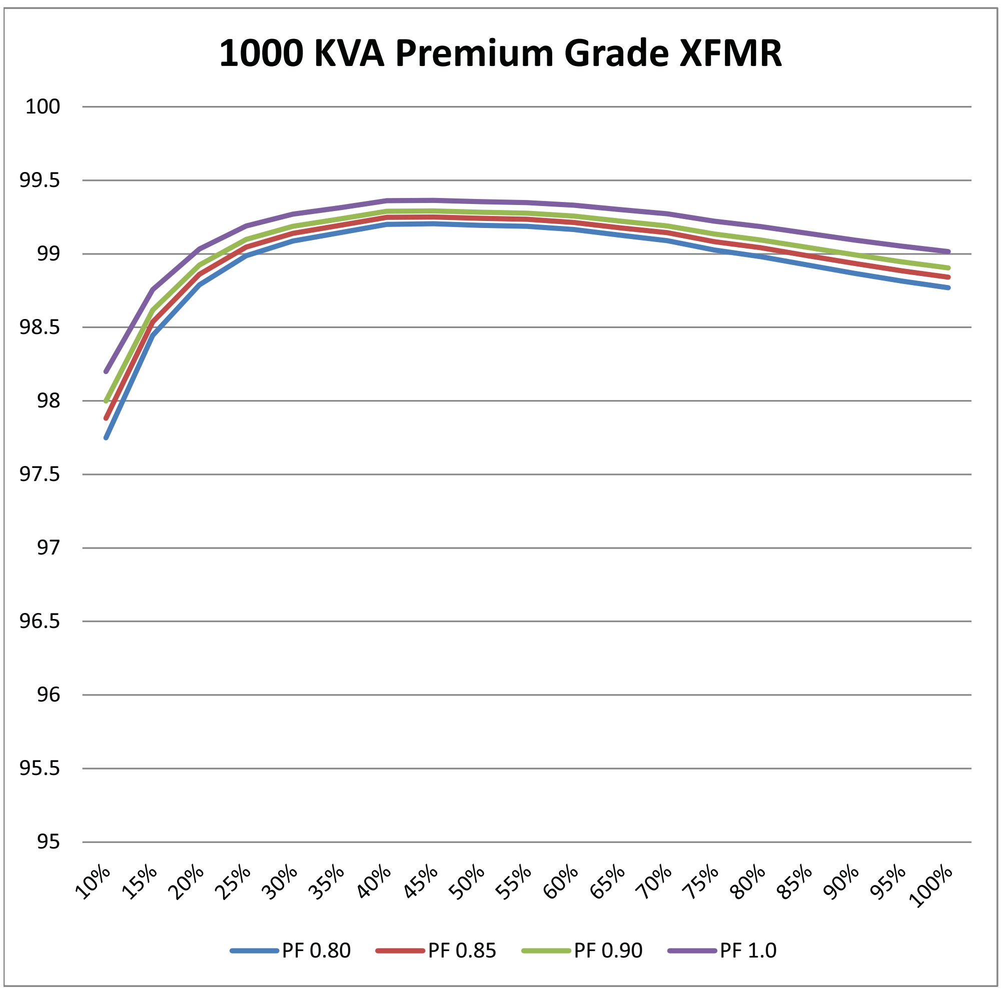
Load VA	Medium-High Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	2133.08	10%	97.33365	97.49049	97.62991	97.86692
150000	2329.78	15%	98.05852	98.17272	98.27424	98.44681
200000	2433.23	20%	98.47923	98.56869	98.64821	98.78339
250000	2503.59	25%	98.74821	98.82184	98.88729	98.99856
300000	2818.82	30%	98.82549	98.89458	98.95599	99.06039
350000	3132.44	35%	98.88127	98.94708	99.00557	99.10502
400000	3491.25	40%	98.90898	98.97316	99.03021	99.12719
450000	3968.03	45%	98.89777	98.96261	99.02024	99.11822
500000	4463.67	50%	98.88408	98.94972	99.00807	99.10727
550000	4958.73	55%	98.87302	98.93931	98.99824	99.09841
600000	5502.12	60%	98.85373	98.92115	98.98109	99.08298
650000	6102.86	65%	98.82637	98.89541	98.95678	99.0611
700000	6798.99	70%	98.78589	98.85731	98.9208	99.02872
750000	7505.45	75%	98.74909	98.82267	98.88808	98.99927
800000	8275.72	80%	98.70692	98.78298	98.85059	98.96554
850000	9085.11	85%	98.66395	98.74255	98.8124	98.93116
900000	10058.52	90%	98.60298	98.68516	98.75821	98.88239
950000	11100.73	95%	98.53938	98.6253	98.70167	98.8315
1000000	12085.76	100%	98.48928	98.57815	98.65714	98.79142



Load VA	High Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	1996.31	10%	97.50461	97.6514	97.78188	98.00369
150000	2093.2	15%	98.25567	98.35827	98.44948	98.60453
200000	2178.14	20%	98.63866	98.71874	98.78992	98.91093
250000	2256.13	25%	98.87194	98.93829	98.99728	99.09755
300000	2492.6	30%	98.96142	99.02251	99.07681	99.16913
350000	2760.49	35%	99.01411	99.0721	99.12365	99.21129
400000	3043.86	40%	99.04879	99.10475	99.15448	99.23904
450000	3429.97	45%	99.04723	99.10328	99.15309	99.23778
500000	3825.76	50%	99.04356	99.09982	99.14983	99.23485
550000	4272.11	55%	99.02907	99.08618	99.13695	99.22325
600000	4733.76	60%	99.0138	99.07181	99.12338	99.21104
650000	5314.42	65%	98.978	99.03811	99.09155	99.1824
700000	5949.55	70%	98.93758	99.00008	99.05563	99.15006
750000	6639.98	75%	98.89334	98.95843	99.0163	99.11467
800000	7367.75	80%	98.84879	98.91651	98.9767	99.07903
850000	8259.47	85%	98.78537	98.85682	98.92033	99.0283
900000	9039.29	90%	98.74454	98.81839	98.88404	98.99563
950000	9889.6	95%	98.69874	98.77528	98.84332	98.95899
1000000	10887.32	100%	98.63909	98.71914	98.7903	98.91127



Load VA	Premium Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	1800.775	10%	97.74903	97.88144	97.99914	98.19923
150000	1865.332	15%	98.44556	98.53699	98.61827	98.75645
200000	1935.876	20%	98.79008	98.86125	98.92451	99.03206
250000	2026.76	25%	98.98662	99.04623	99.09922	99.1893
300000	2192.92	30%	99.08628	99.14003	99.18781	99.26903
350000	2398.745	35%	99.14331	99.1937	99.23849	99.31464
400000	2558.113	40%	99.20059	99.24761	99.28941	99.36047
450000	2865.309	45%	99.20408	99.2509	99.29252	99.36326
500000	3221.786	50%	99.19455	99.24193	99.28405	99.35564
550000	3579.656	55%	99.18644	99.2343	99.27684	99.34915
600000	4009.5	60%	99.16469	99.21382	99.2575	99.33175
650000	4544.992	65%	99.12596	99.17738	99.22308	99.30077
700000	5099.695	70%	99.08934	99.14291	99.19052	99.27147
750000	5840.88	75%	99.02652	99.08378	99.13468	99.22122
800000	6517.557	80%	98.98163	99.04154	99.09478	99.18531
850000	7311.227	85%	98.92482	98.98807	99.04428	99.13986
900000	8150.349	90%	98.86801	98.93459	98.99378	99.09441
950000	9009.818	95%	98.8145	98.88423	98.94622	99.0516
1000000	9850.02	100%	98.76875	98.84117	98.90555	99.015

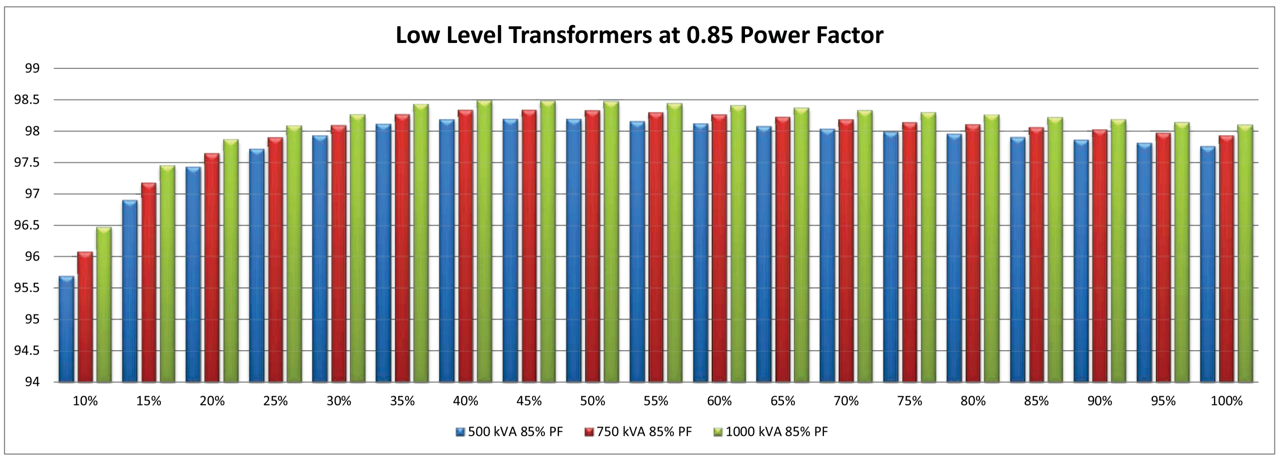


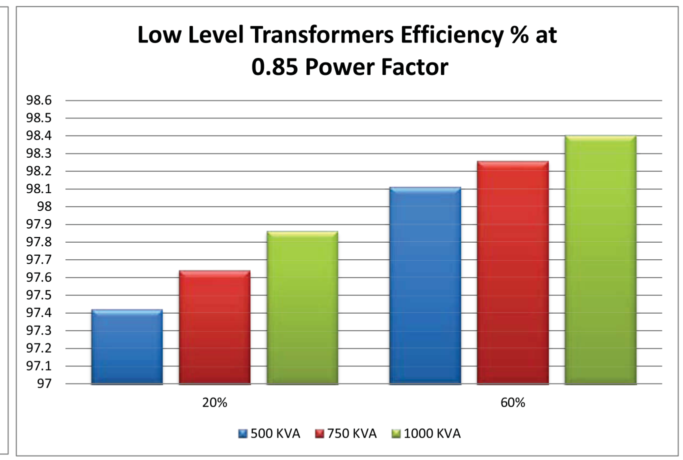
Load VA	Low Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1836.37	10%	95.40908	95.67913	95.91918	96.32726
75000	1980.18	15%	96.6997	96.89384	97.0664	97.35976
100000	2193.45	20%	97.25819	97.41947	97.56283	97.80655
125000	2439.19	25%	97.5608	97.70428	97.83182	98.04864
150000	2652.85	30%	97.78923	97.91927	98.03487	98.23138
175000	2816.77	35%	97.98799	98.10634	98.21154	98.39039
200000	3092.52	40%	98.06712	98.18082	98.28188	98.4537
225000	3470.45	45%	98.07206	98.18546	98.28627	98.45764
250000	3864.72	50%	98.06758	98.18125	98.28229	98.45406
275000	4326.24	55%	98.03345	98.14913	98.25195	98.42676
300000	4817.25	60%	97.99289	98.11096	98.2159	98.39431
325000	5334.22	65%	97.94838	98.06906	98.17634	98.3587
350000	5866.37	70%	97.90487	98.02811	98.13766	98.32389
375000	6429.06	75%	97.85704	97.9831	98.09515	98.28563
400000	6984.95	80%	97.81722	97.94562	98.05975	98.25378
425000	7598.99	85%	97.76501	97.89648	98.01334	98.21201
450000	8211.52	90%	97.71905	97.85322	97.97249	98.17524
475000	8874.77	95%	97.6645	97.80188	97.924	98.1316
500000	9551.36	100%	97.61208	97.75254	97.8774	98.08966

Load VA	Low Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	2505.99	10%	95.82342	96.0691	96.28748	96.65874
112500	2707.75	15%	96.99137	97.16835	97.32566	97.59309
150000	3009.58	20%	97.49198	97.63951	97.77065	97.99359
187500	3360.1	25%	97.75988	97.89165	98.00878	98.2079
225000	3654.52	30%	97.96977	98.0892	98.19535	98.37582
262500	3875.41	35%	98.15465	98.2632	98.35969	98.52372
300000	4255.49	40%	98.22685	98.33115	98.42387	98.58148
337500	4786.74	45%	98.22714	98.33143	98.42413	98.58172
375000	5339	50%	98.22035	98.32503	98.41809	98.57628
412500	5985.19	55%	98.18622	98.29292	98.38775	98.54898
450000	6667.21	60%	98.14798	98.25692	98.35376	98.51838
487500	7396.41	65%	98.10348	98.21504	98.3142	98.48278
525000	8138.53	70%	98.06227	98.17625	98.27757	98.44982
562500	8913.82	75%	98.01908	98.1356	98.23918	98.41526
600000	9699.59	80%	97.97926	98.09813	98.20379	98.38341
637500	10536.67	85%	97.93399	98.05552	98.16354	98.34719
675000	11391.65	90%	97.89036	98.01445	98.12476	98.31228
712500	12309.55	95%	97.84043	97.96747	98.08039	98.27235
750000	13244.59	100%	97.79264	97.92248	98.0379	98.23411

Load VA	Low Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	3009.78	10%	96.23778	96.45908	96.6558	96.99022
150000	3260.36	15%	97.28303	97.44285	97.58492	97.82643
200000	3638.75	20%	97.72578	97.85956	97.97847	98.18063
250000	4082.11	25%	97.95895	98.07901	98.18573	98.36716
300000	4439.2	30%	98.15033	98.25914	98.35585	98.52027
350000	4700.31	35%	98.32132	98.42006	98.50784	98.65705
400000	5162.98	40%	98.38657	98.48148	98.56584	98.70926
450000	5823.94	45%	98.38224	98.4774	98.56199	98.70579
500000	6507.48	50%	98.37313	98.46883	98.55389	98.6985
550000	7308.39	55%	98.339	98.43671	98.52356	98.6712
600000	8145.28	60%	98.30307	98.40289	98.49161	98.64245
650000	9055.47	65%	98.25856	98.361	98.45206	98.60685
700000	9969.81	70%	98.21968	98.3244	98.41749	98.57574
750000	10913.34	75%	98.18111	98.2881	98.38321	98.54489
800000	11895.68	80%	98.1413	98.25064	98.34782	98.51304
850000	12899.78	85%	98.10297	98.21456	98.31375	98.48238
900000	13956.18	90%	98.06164	98.17566	98.27701	98.44931
950000	15075.68	95%	98.01636	98.13304	98.23676	98.41309
1000000	16214.469	100%	97.97319	98.09242	98.19839	98.37855

	500 KVA	750 KVA	1000 KVA
20%	97.41947	97.63951	97.85956
60%	98.11096	98.25692	98.40289



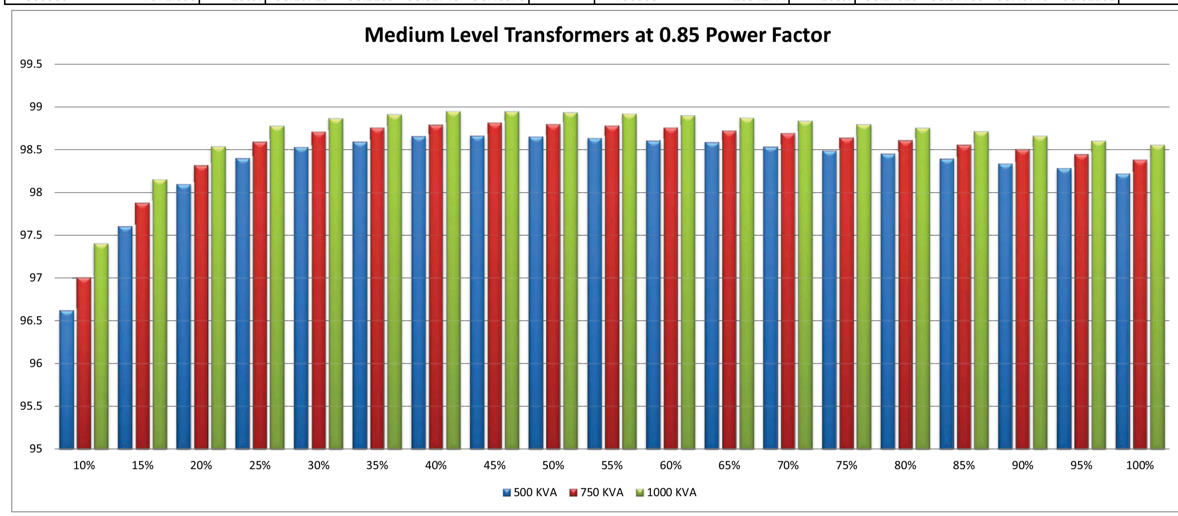


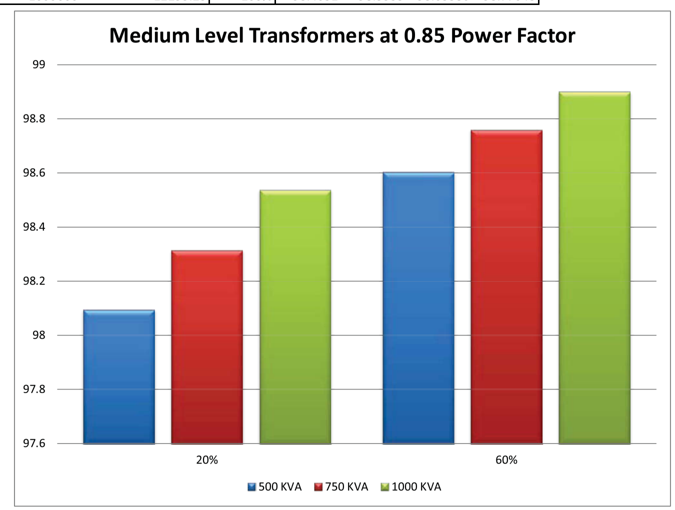
Load VA	Medium Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1436.15	10%	96.40963	96.62082	96.80856	97.1277
75000	1529.774	15%	97.45038	97.60035	97.73367	97.9603
100000	1619.648	20%	97.97544	98.09453	98.20039	98.38035
125000	1699.906	25%	98.30009	98.40009	98.48897	98.64008
150000	1880.472	30%	98.43294	98.52512	98.60706	98.74635
175000	2097.884	35%	98.50151	98.58966	98.66801	98.80121
200000	2290.296	40%	98.56857	98.65277	98.72761	98.85485
225000	2567.708	45%	98.5735	98.65741	98.732	98.8588
250000	2874.12	50%	98.56294	98.64747	98.72261	98.85035
275000	3191.708	55%	98.54922	98.63456	98.71042	98.83938
300000	3563.296	60%	98.51529	98.60263	98.68026	98.81223
325000	3907.884	65%	98.49697	98.58538	98.66397	98.79757
350000	4362.472	70%	98.44197	98.53362	98.61509	98.75358
375000	4827.06	75%	98.39098	98.48563	98.56976	98.71278
400000	5269.648	80%	98.35324	98.4501	98.53621	98.68259
425000	5806.236	85%	98.29228	98.39274	98.48203	98.63383
450000	6380.824	90%	98.22755	98.33181	98.42449	98.58204
475000	6955.412	95%	98.16963	98.2773	98.373	98.5357
500000	7571.358	100%	98.10716	98.2185	98.31748	98.48573

Load VA	Medium Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1909.99	10%	96.81668	97.00394	97.17039	97.45335
112500	2028.85	15%	97.74572	97.87833	97.9962	98.19658
150000	2149.67	20%	98.20861	98.31398	98.40765	98.56689
187500	2239.99	25%	98.50667	98.59452	98.6726	98.80534
225000	2475.31	30%	98.62483	98.70572	98.77762	98.89986
262500	2781.13	35%	98.67565	98.75356	98.8228	98.94052
300000	3081.95	40%	98.71585	98.79139	98.85854	98.97268
337500	3408.77	45%	98.73749	98.81176	98.87777	98.98999
375000	3838.59	50%	98.72047	98.79574	98.86264	98.97638
412500	4292.41	55%	98.69927	98.77578	98.8438	98.95942
450000	4744.23	60%	98.68216	98.75968	98.82859	98.94573
487500	5302.05	65%	98.6405	98.72047	98.79156	98.9124
525000	5851.07	70%	98.60689	98.68884	98.76168	98.88551
562500	6506.09	75%	98.5542	98.63925	98.71485	98.84336
600000	7107.76	80%	98.51922	98.60632	98.68375	98.81537
637500	7829.43	85%	98.46482	98.55512	98.63539	98.77185
675000	8591.1	90%	98.40906	98.50264	98.58583	98.72724
712500	9406.77	95%	98.34969	98.44677	98.53306	98.67975
750000	10342.44	100%	98.27626	98.37766	98.46779	98.62101

Load VA	Medium Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	2209.34	10%	97.23833	97.40078	97.54518	97.79066
150000	2359.55	15%	98.03371	98.14937	98.25219	98.42697
200000	2487.38	20%	98.44539	98.53684	98.61812	98.75631
250000	2599.77	25%	98.70012	98.77658	98.84455	98.96009
300000	2888.39	30%	98.7965	98.8673	98.93023	99.0372
350000	3235.12	35%	98.8446	98.91256	98.97298	99.07568
400000	3571.56	40%	98.88389	98.94954	99.0079	99.10711
450000	4021.03	45%	98.88305	98.94875	99.00715	99.10644
500000	4525.86	50%	98.86854	98.93509	98.99425	99.09483
550000	5059.23	55%	98.85018	98.91781	98.97793	99.08014
600000	5613.92	60%	98.83043	98.89923	98.96039	99.06435
650000	6225.45	65%	98.8028	98.87322	98.93582	99.04224
700000	6928.98	70%	98.76268	98.83547	98.90016	99.01015
750000	7677.27	75%	98.72046	98.79572	98.86263	98.97636
800000	8461.54	80%	98.67788	98.75566	98.82479	98.94231
850000	9292.81	85%	98.63341	98.7138	98.78525	98.90673
900000	10247.33	90%	98.57676	98.66048	98.7349	98.86141
950000	11275.71	95%	98.51635	98.60363	98.6812	98.81308
1000000	12295.23	100%	98.4631	98.5535	98.63386	98.77048

	500 KVA	750 KVA	1000 KVA
20%	98.09453	98.31398	98.53684
60%	98.60263	98.75968	98.89923



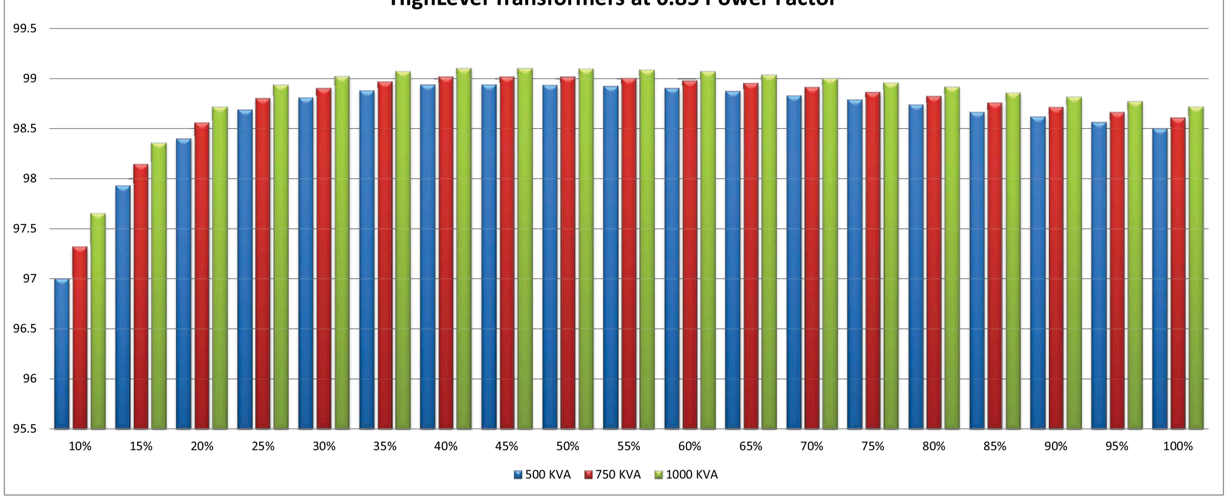


Load VA	High Total Losses	500 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
50000	1277.3	10%	96.80675	96.99459	97.16156	97.4454
75000	1319.45	15%	97.80092	97.93027	98.04526	98.24073
100000	1359.6	20%	98.3005	98.40047	98.48933	98.6404
125000	1398.75	25%	98.60125	98.68353	98.75667	98.881
150000	1522.9	30%	98.73092	98.80557	98.87193	98.98473
175000	1668.05	35%	98.80854	98.87862	98.94092	99.04683
200000	1802.475	40%	98.87345	98.93972	98.99863	99.09876
225000	2033.1	45%	98.8705	98.93694	98.996	99.0964
250000	2265.5	50%	98.86725	98.93388	98.99311	99.0938
275000	2519.35	55%	98.85484	98.9222	98.98208	99.08387
300000	2797.2	60%	98.8345	98.90306	98.964	99.0676
325000	3122.3	65%	98.79912	98.86976	98.93255	99.03929
350000	3494.4	70%	98.752	98.82541	98.89067	99.0016
375000	3864.5	75%	98.71183	98.78761	98.85496	98.96947
400000	4300.6	80%	98.65606	98.73512	98.80539	98.92485
425000	4826.7	85%	98.58038	98.66389	98.73812	98.86431
450000	5297.51	90%	98.52847	98.61503	98.69197	98.82278
475000	5792.321	95%	98.47571	98.56537	98.64507	98.78056
500000	6391.842	100%	98.40204	98.49604	98.57959	98.72163

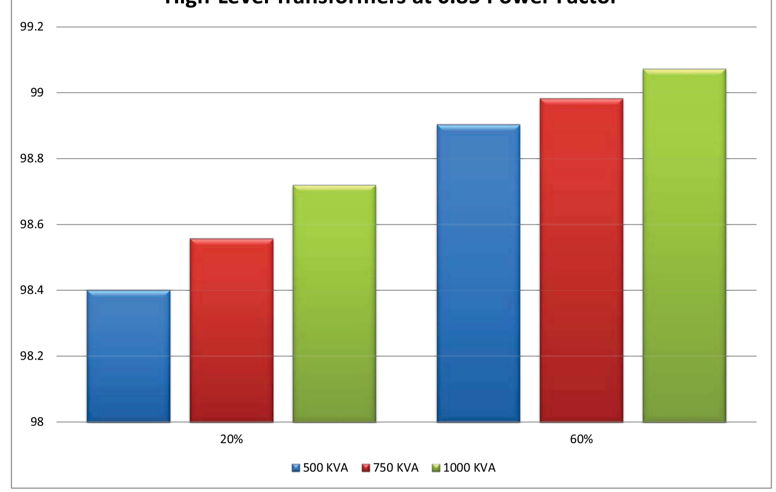
Load VA	High Total Losses	750 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
75000	1709.981	10%	97.15003	97.31768	97.46669	97.72003
112500	1776.274	15%	98.02636	98.14246	98.24566	98.42109
150000	1838.567	20%	98.46786	98.55799	98.6381	98.77429
187500	1910.86	25%	98.72609	98.80103	98.86764	98.98087
225000	2090.153	30%	98.8388	98.90711	98.96783	99.07104
262500	2305.446	35%	98.90217	98.96675	99.02415	99.12173
300000	2498.139	40%	98.95911	99.02034	99.07476	99.16729
337500	2820.232	45%	98.95547	99.01691	99.07153	99.16438
375000	3139.325	50%	98.95356	99.01511	99.06983	99.16285
412500	3505.65	55%	98.93768	99.00017	99.05572	99.15015
450000	3895.975	60%	98.91778	98.98144	99.03803	99.13423
487500	4344.3	65%	98.88608	98.9516	99.00985	99.10886
525000	4856.625	70%	98.84366	98.91168	98.97214	99.07493
562500	5439.95	75%	98.79112	98.86223	98.92544	99.0329
600000	6010.275	80%	98.74786	98.82151	98.88699	98.99829
637500	6745.6	85%	98.67733	98.75514	98.8243	98.94187
675000	7370.925	90%	98.63501	98.71531	98.78668	98.90801
712500	8086.25	95%	98.58136	98.66481	98.73899	98.86509
750000	8875.78	100%	98.5207	98.60772	98.68507	98.81656

Load VA	High Total Losses	1000 KVA Load %	PF 0.80 Eff%	PF 0.85 Eff%	PF 0.90 Eff%	PF 1.0 Eff%
100000	1996.31	10%	97.50461	97.6514	97.78188	98.00369
150000	2093.2	15%	98.25567	98.35827	98.44948	98.60453
200000	2178.14	20%	98.63866	98.71874	98.78992	98.91093
250000	2256.13	25%	98.87194	98.93829	98.99728	99.09755
300000	2492.6	30%	98.96142	99.02251	99.07681	99.16913
350000	2760.49	35%	99.01411	99.0721	99.12365	99.21129
400000	3043.86	40%	99.04879	99.10475	99.15448	99.23904
450000	3429.97	45%	99.04723	99.10328	99.15309	99.23778
500000	3825.76	50%	99.04356	99.09982	99.14983	99.23485
550000	4272.11	55%	99.02907	99.08618	99.13695	99.22325
600000	4733.76	60%	99.0138	99.07181	99.12338	99.21104
650000	5314.42	65%	98.978	99.03811	99.09155	99.1824
700000	5949.55	70%	98.93758	99.00008	99.05563	99.15006
750000	6639.98	75%	98.89334	98.95843	99.0163	99.11467
800000	7367.75	80%	98.84879	98.91651	98.9767	99.07903
850000	8259.47	85%	98.78537	98.85682	98.92033	99.0283
900000	9039.29	90%	98.74454	98.81839	98.88404	98.99563
950000	9889.6	95%	98.69874	98.77528	98.84332	98.95899
1000000	10887.32	100%	98.63909	98.71914	98.7903	98.91127

	500 KVA	750 KVA	1000 KVA
20%	98.40047	98.55799	98.71874
60%	98.90306	98.98144	99.07181

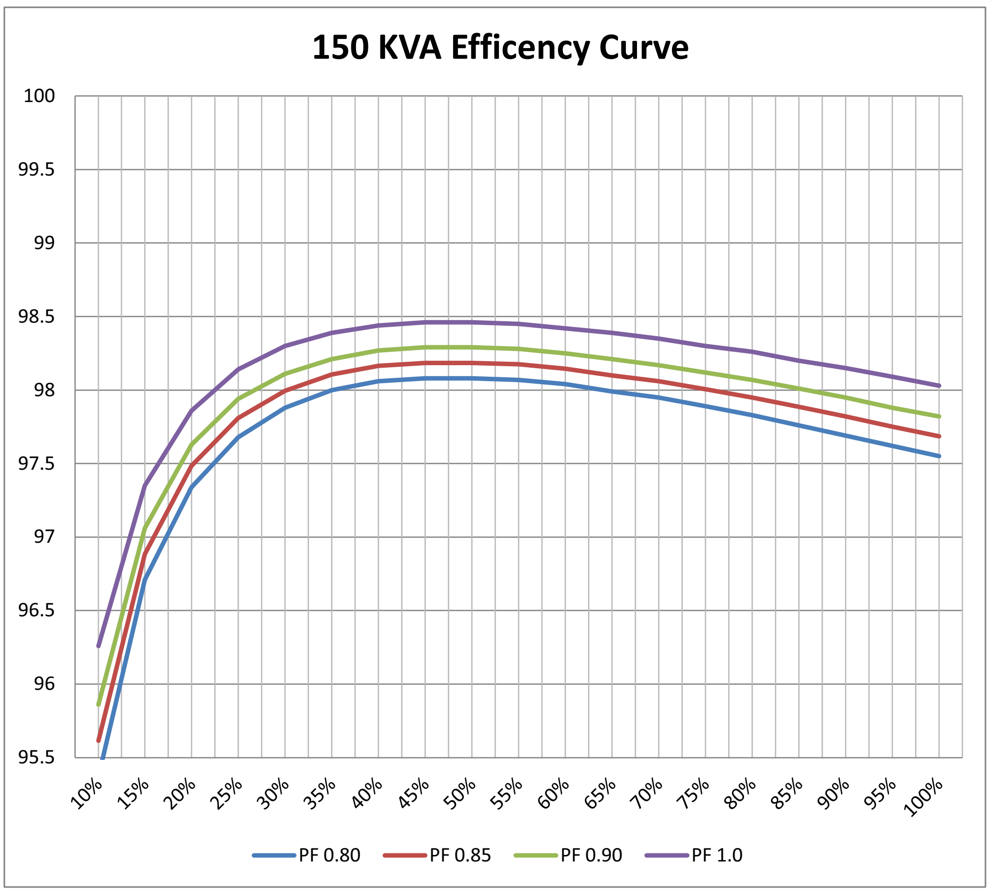


HighLevel Transformers at 0.85 Power Factor

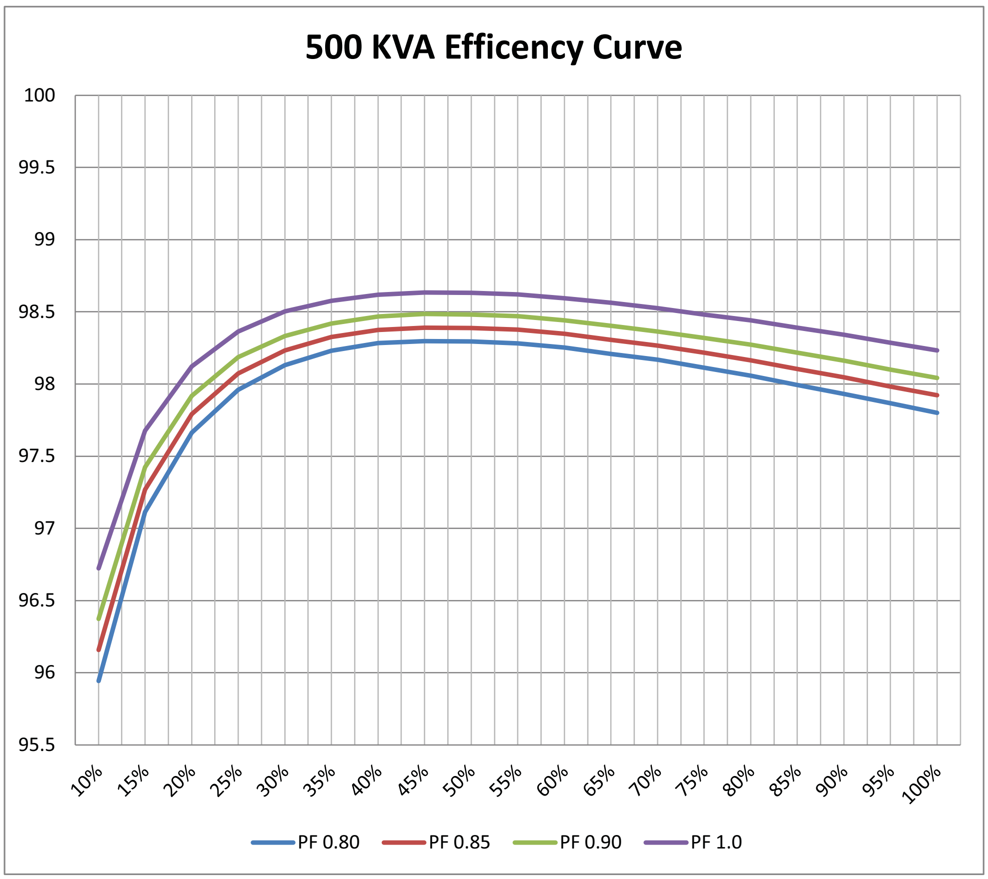


High-Level Transformers at 0.85 Power Factor

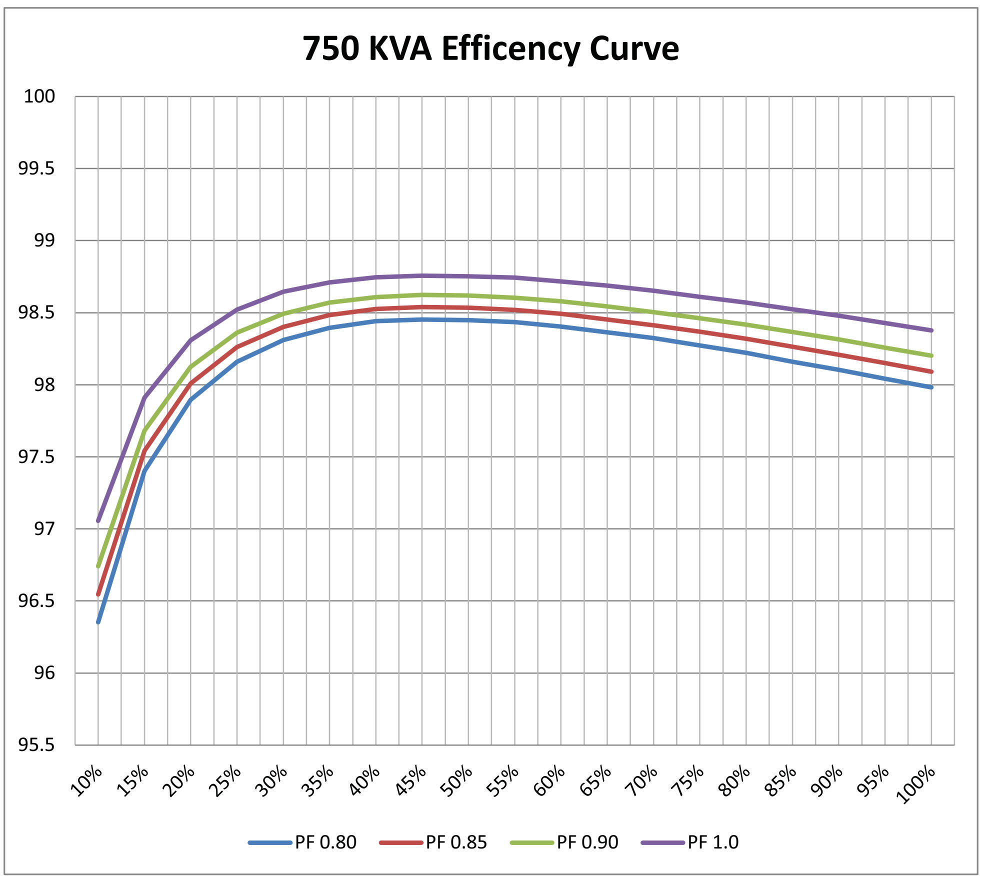
150kva Load %	PF 0.80 Eff %	PF 0.85 Eff %	PF 0.90 Eff %	PF 1.0 Eff %
10%	95.37	95.615	95.86	96.26
15%	96.71	96.885	97.06	97.35
20%	97.34	97.485	97.63	97.86
25%	97.68	97.81	97.94	98.14
30%	97.88	97.995	98.11	98.3
35%	98	98.105	98.21	98.39
40%	98.06	98.165	98.27	98.44
45%	98.08	98.185	98.29	98.46
50%	98.08	98.185	98.29	98.46
55%	98.07	98.175	98.28	98.45
60%	98.04	98.145	98.25	98.42
65%	97.99	98.1	98.21	98.39
70%	97.95	98.06	98.17	98.35
75%	97.89	98.005	98.12	98.3
80%	97.83	97.95	98.07	98.26
85%	97.76	97.885	98.01	98.2
90%	97.69	97.82	97.95	98.15
95%	97.62	97.75	97.88	98.09
100%	97.55	97.685	97.82	98.03



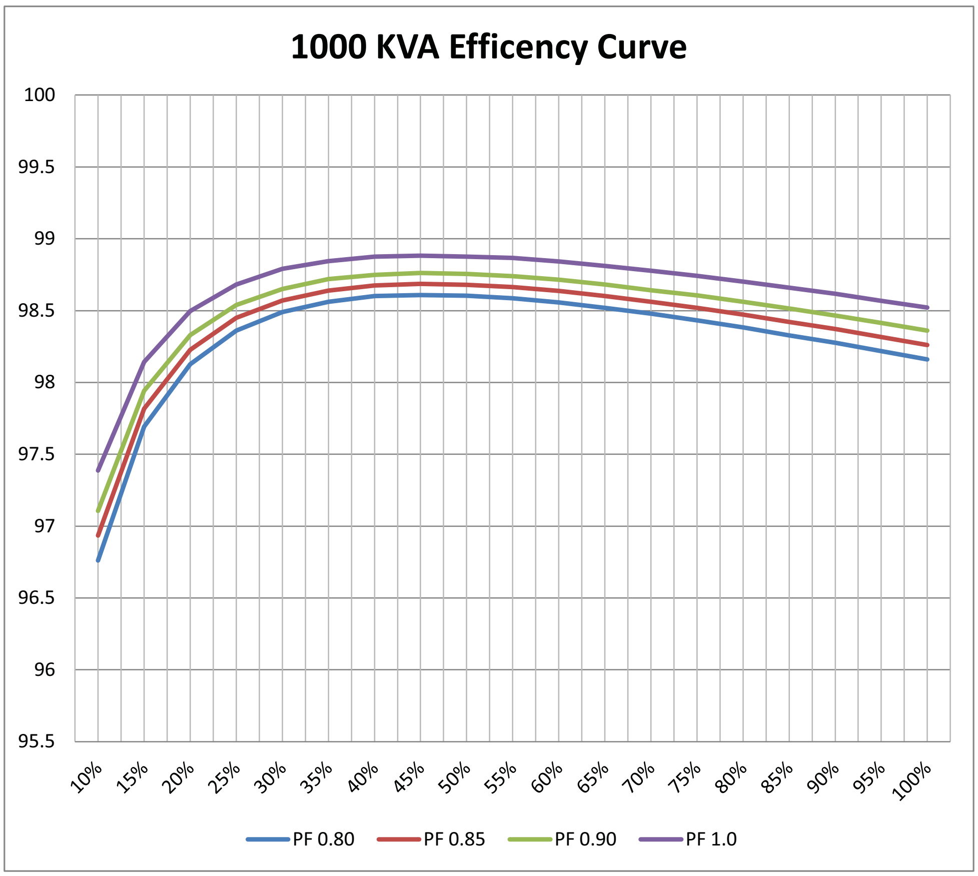
500 KVA	PF 0.80	PF 0.85	PF 0.90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
10%	95.94296	96.15815	96.37333	96.72407
15%	97.11444	97.2687	97.42296	97.67667
20%	97.66407	97.79093	97.91778	98.12185
25%	97.96	98.07315	98.1863	98.36296
30%	98.13148	98.23222	98.33296	98.50222
35%	98.23074	98.32537	98.42	98.57667
40%	98.28296	98.375	98.46704	98.61889
45%	98.29778	98.39111	98.48444	98.6337
50%	98.29519	98.38852	98.48185	98.63111
55%	98.28259	98.37593	98.46926	98.62111
60%	98.25259	98.34722	98.44185	98.5937
65%	98.20778	98.30611	98.40444	98.5637
70%	98.16778	98.26611	98.36444	98.5263
75%	98.11296	98.2163	98.31963	98.48148
80%	98.05815	98.16519	98.27222	98.44148
85%	97.99333	98.10537	98.21741	98.38926
90%	97.93111	98.04685	98.16259	98.34185
95%	97.8663	97.98333	98.10037	98.28704
100%	97.80148	97.92222	98.04296	98.23222



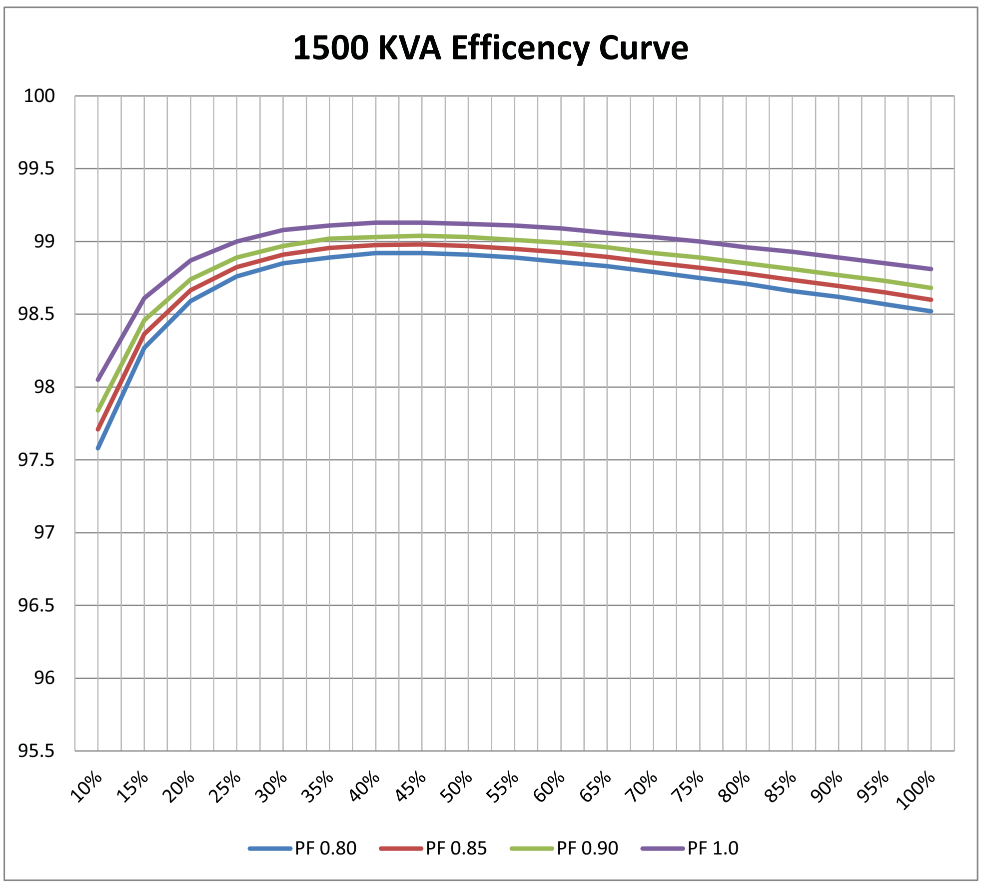
750 KVA	PF 0.80	PF 0.85	PF 0.90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
10%	96.35222	96.54611	96.74	97.05556
15%	97.40333	97.54278	97.68222	97.91
20%	97.89556	98.00944	98.12333	98.30889
25%	98.16	98.26111	98.36222	98.52222
30%	98.31111	98.40167	98.49222	98.64667
35%	98.39556	98.48278	98.57	98.71
40%	98.44222	98.525	98.60778	98.74667
45%	98.45333	98.53833	98.62333	98.75778
50%	98.44889	98.53389	98.61889	98.75333
55%	98.43444	98.51944	98.60444	98.74333
60%	98.40444	98.49167	98.57889	98.71778
65%	98.36333	98.45333	98.54333	98.68778
70%	98.32333	98.41333	98.50333	98.65222
75%	98.27222	98.36722	98.46222	98.61111
80%	98.22111	98.31889	98.41667	98.57111
85%	98.16	98.26278	98.36556	98.52444
90%	98.10333	98.20889	98.31444	98.47889
95%	98.04222	98.15	98.25778	98.42778
100%	97.98111	98.09167	98.20222	98.37667



1000 KVA	PF 0.80	PF 0.85	PF 0.90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
10%	96.76148	96.93407	97.10667	97.38704
15%	97.69222	97.81685	97.94148	98.14333
20%	98.12704	98.22796	98.32889	98.49593
25%	98.36	98.44907	98.53815	98.68148
30%	98.49074	98.57111	98.65148	98.79111
35%	98.56037	98.64019	98.72	98.84333
40%	98.60148	98.675	98.74852	98.87444
45%	98.60889	98.68556	98.76222	98.88185
50%	98.60259	98.67926	98.75593	98.87556
55%	98.5863	98.66296	98.73963	98.86556
60%	98.5563	98.63611	98.71593	98.84185
65%	98.51889	98.60056	98.68222	98.81185
70%	98.47889	98.56056	98.64222	98.77815
75%	98.43148	98.51815	98.60481	98.74074
80%	98.38407	98.47259	98.56111	98.70074
85%	98.32667	98.42019	98.5137	98.65963
90%	98.27556	98.37093	98.4663	98.61593
95%	98.21815	98.31667	98.41519	98.56852
100%	98.16074	98.26111	98.36148	98.52111

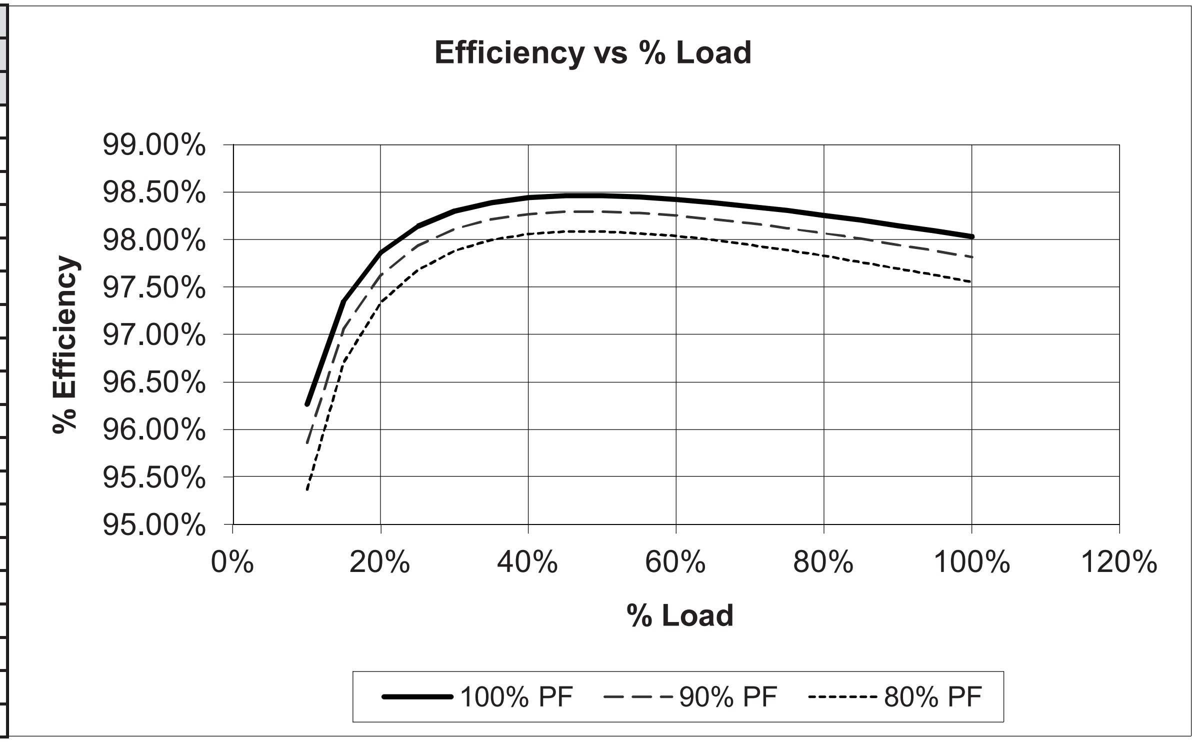


1500kva Load %	PF 0.80 Eff %	PF 0.85 Eff %	PF 0.90 Eff %	PF 1.0 Eff %
10%	97.58	97.71	97.84	98.05
15%	98.27	98.365	98.46	98.61
20%	98.59	98.665	98.74	98.87
25%	98.76	98.825	98.89	99
30%	98.85	98.91	98.97	99.08
35%	98.89	98.955	99.02	99.11
40%	98.92	98.975	99.03	99.13
45%	98.92	98.98	99.04	99.13
50%	98.91	98.97	99.03	99.12
55%	98.89	98.95	99.01	99.11
60%	98.86	98.925	98.99	99.09
65%	98.83	98.895	98.96	99.06
70%	98.79	98.855	98.92	99.03
75%	98.75	98.82	98.89	99
80%	98.71	98.78	98.85	98.96
85%	98.66	98.735	98.81	98.93
90%	98.62	98.695	98.77	98.89
95%	98.57	98.65	98.73	98.85
100%	98.52	98.6	98.68	98.81



Serial No.	131215-0504
kVA	150
No Load Loss*	558
Load Loss*	2457

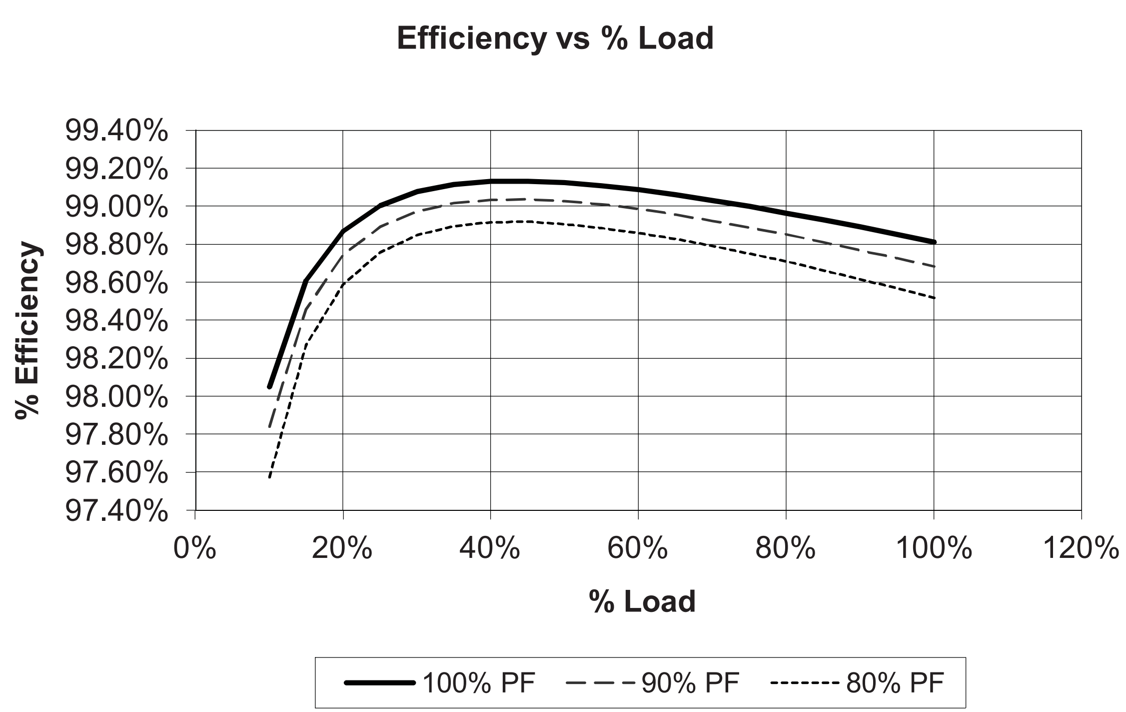
	Power Factor		
	100%	90%	80%
% Load	%Eff	%Eff	%Eff
10%	96.26%	95.86%	95.37%
15%	97.35%	97.06%	96.71%
20%	97.86%	97.63%	97.34%
25%	98.14%	97.94%	97.68%
30%	98.30%	98.11%	97.88%
35%	98.39%	98.21%	98.00%
40%	98.44%	98.27%	98.06%
45%	98.46%	98.29%	98.08%
50%	98.46%	98.29%	98.08%
55%	98.45%	98.28%	98.07%
60%	98.42%	98.25%	98.04%
65%	98.39%	98.21%	97.99%
70%	98.35%	98.17%	97.95%
75%	98.30%	98.12%	97.89%
80%	98.26%	98.07%	97.83%
85%	98.20%	98.01%	97.76%
90%	98.15%	97.95%	97.69%
95%	98.09%	97.88%	97.62%
100%	98.03%	97.82%	97.55%



* Losses are based on design data at 85 degrees Celsius.

Serial No.	3630173005
kVA	1500
No Load Loss*	2830
Load Loss*	15210

	Power Factor		
	100%	90%	80%
% Load	%Eff	%Eff	%Eff
10%	98.05%	97.84%	97.58%
15%	98.61%	98.46%	98.27%
20%	98.87%	98.74%	98.59%
25%	99.00%	98.89%	98.76%
30%	99.08%	98.97%	98.85%
35%	99.11%	99.02%	98.89%
40%	99.13%	99.03%	98.92%
45%	99.13%	99.04%	98.92%
50%	99.12%	99.03%	98.91%
55%	99.11%	99.01%	98.89%
60%	99.09%	98.99%	98.86%
65%	99.06%	98.96%	98.83%
70%	99.03%	98.92%	98.79%
75%	99.00%	98.89%	98.75%
80%	98.96%	98.85%	98.71%
85%	98.93%	98.81%	98.66%
90%	98.89%	98.77%	98.62%
95%	98.85%	98.73%	98.57%
100%	98.81%	98.68%	98.52%



* Losses are based on design data at 85 degrees Celsius.

Manufacturer	Model #	Size	Quality	Windings	List Price $	Sale Price $	
GE	9T40G0009	500		Aluminum	$38,930.00	$13,859.00	
GE	9T40G0109	500		Aluminum	$59,626.00	$53,663.00	
GE	9T40G0009G81	500		Aluminum	$61,750.00	$21,983.00	
GE	9T40G0009G51	500		Aluminum	$68,175.00	$20,589.00	
GE	9T44G0009G03	500		Aluminum	$69,996.00	$17,569.00	
GE	9T44G0009G53	500		Aluminum	$82,958.00	$20,822.00	
GE	9T44G0009G83	500		Aluminum	$93,328.00	$23,425.00	
GE	9T45G0009	500		Copper	$52,819.00	$22,501.00	
GE	9T45G0009G51	500		Copper	$60,742.00	$25,876.00	
GE	9T45G0009G81	500		Copper	$66,025.00	$28,127.00	
GE	9T45G0109	500		Copper	$82,958.00	$74,662.00	
GE	9T49G0009G03	500		Copper	$101,105.00	$34,679.00	
GE	9T46G0009G03	500		Copper	$106,290.00	$36,457.00	
GE	9T49G0009G53	500		Copper	$114,067.00	$39,125.00	
GE	9T46G0009G53	500		Copper	$119,251.00	$40,903.00	
GE	9T49G0009G83	500		Copper	$124,437.00	$42,681.00	
GE	9T40G0010	750		Aluminum	$69,350.00	$24,689.00	
GE	9T40G0010G51	750		Aluminum	$77,200.00	$23,314.00	
GE	9T44G0010G03	750		Aluminum	$104,994.00	$26,354.00	
GE	9T40G0010G81	750		Aluminum	$124,436.00	$44,299.00	
GE	9T45G0010	750		Copper	$79,800.00	$33,995.00	
GE	9T45G0010G51	750		Copper	$95,200.00	$40,555.00	
GE	9T45G0010G81	750		Copper	$147,768.00	$62,950.00	
GE	9T45G0011	1000		Copper	$95,760.00	$40,794.00	
GE	9T45G0011G03	1000		Copper	$158,787.00	$56,210.00	

	500 KVA	Low	$27,569.00			
		Medium	$44,299.00			
		High	$59,626.00			
	750 KVA	Low	$36,354.00			
		Medium	$44,299.00			
		High	$69,350.00			
	1000 KVA	Low	$50,794.00			
		Medium	$60,742.00			
		High	$82,958.00			

Estimated Pricing at
Low, Medium, & High Levels

	Size	Price	Install/Removal + Price	sioh	dc	Total Cost
	500 KVA	$27,569.00	$52,569.00	$3,154.14	$2,102.76	$57,825.90
Low	750 KVA	$36,354.00	$61,354.00	$3,681.24	$2,454.16	$67,489.40
	1000 KVA	$50,794.00	$75,794.00	$4,547.64	$3,031.76	$83,373.40
	500 KVA	$33,995.00	$58,995.00	$3,539.70	$2,359.80	$64,894.50
Medium	750 KVA	$44,299.00	$69,299.00	$4,157.94	$2,771.96	$76,228.90
	1000 KVA	$60,742.00	$85,742.00	$5,144.52	$3,429.68	$94,316.20
	500 KVA	$59,626.00	$84,626.00	$5,077.56	$3,385.04	$93,088.60
High	750 KVA	$69,350.00	$94,350.00	$5,661.00	$3,774.00	$103,785.00
	1000 KVA	$82,958.00	$107,958.00	$6,477.48	$4,318.32	$118,753.80

$25,000.00 install/removal

8760
take (kva*pf=kw) * 20% load * hrs in Year = yearly energy loads on 500kva xfmr
500Kva * .85pf = 425 KW

take yrly load* loss % = yearly energy loss

take yearly energy loss * $perwatt = loss$
$0.229 / kWh

		Low Level	Yearly Energy Loss	Med Level	Yearly Energy Loss	High Level	Yearly Energy Loss	Old/Current	Yearly Energy Loss
500 KVA =	425 KW	500 KVA		500 KVA		500 KVA		500 KVA	
YRLY LOAD									
20% load=	744600 kWh/YR	20% load=	19214.622 kWh/YR	20% load=	14188.11648 kWh/YR	20% load=	11910.096 kWh/YR	20% load=	16448.76556 kWh/YR
30% load=	1116900 kWh/YR	30% load=	23239.6668 kWh/YR	30% load=	16472.93472 kWh/YR	30% load=	13340.604 kWh/YR	30% load=	19744.31 kWh/YR
60% load=	2233800 kWh/YR	60% load=	42197.4456 kWh/YR	60% load=	31214.47296 kWh/YR	60% load=	24503.472 kWh/YR	60% load=	36919.75 kWh/YR
70% load=	2606100 kWh/YR	70% load=	51389.4012 kWh/YR	70% load=	38215.25472 kWh/YR	70% load=	30610.944 kWh/YR	70% load=	45186.87833 kWh/YR
750 KVA =	637.5 KW	750 KVA		750 KVA		750 KVA		750 KVA	
YRLY LOAD									
20% load=	1116900 kWh/YR	20% load=	26364.2712 kWh/YR	20% load=	18831.1092 kWh/YR	20% load=	16105.84692 kWh/YR	20% load=	22232.515 kWh/YR
30% load=	1675350 kWh/YR	30% load=	32012.6316 kWh/YR	30% load=	21683.7156 kWh/YR	30% load=	18309.74028 kWh/YR	30% load=	26777.6775 kWh/YR
60% load=	3350700 kWh/YR	60% load=	58405.2852 kWh/YR	60% load=	41559.4548 kWh/YR	60% load=	34128.741 kWh/YR	60% load=	50539.725 kWh/YR
70% load=	3909150 kWh/YR	70% load=	71292.9972 kWh/YR	70% load=	51255.3732 kWh/YR	70% load=	42544.035 kWh/YR	70% load=	62025.18 kWh/YR
1000 KVA =	850 KW	1000 KVA		1000 KVA		1000 KVA		1000 KVA	
YRLY LOAD									
20% load=	1489200 kWh/YR	20% load=	31875.45 kWh/YR	20% load=	21789.4488 kWh/YR	20% load=	19080.5064 kWh/YR	20% load=	26389.17556 kWh/YR
30% load=	2233800 kWh/YR	30% load=	38887.392 kWh/YR	30% load=	25302.2964 kWh/YR	30% load=	21835.176 kWh/YR	30% load=	31918.52 kWh/YR
60% load=	4467600 kWh/YR	60% load=	71352.6528 kWh/YR	60% load=	49177.9392 kWh/YR	60% load=	41467.7376 kWh/YR	60% load=	60933.1 kWh/YR
70% load=	5212200 kWh/YR	70% load=	87335.5356 kWh/YR	70% load=	60697.8648 kWh/YR	70% load=	52118.058 kWh/YR	70% load=	75026.72333 kWh/YR

Low Level	$ Loss	Med Level	$ Loss	High Level	$ Loss	Old/Curren	$ Loss
500 KVA		500 KVA		500 KVA		500 KVA	
20% load=	$4,400.15 /Year	20% load=	$3,249.08 /Year	20% load=	$2,727.41 /Year	20% load=	$3,766.77 /Year
30% load=	$5,321.88 /Year	30% load=	$3,772.30 /Year	30% load=	$3,055.00 /Year	30% load=	$4,521.45 /Year
60% load=	$9,663.22 /Year	60% load=	$7,148.11 /Year	60% load=	$5,611.30 /Year	60% load=	$8,454.62 /Year
70% load=	$11,768.17 /Year	70% load=	$8,751.29 /Year	70% load=	$7,009.91 /Year	70% load=	$10,347.80 /Year
750 KVA		750 KVA		750 KVA		750 KVA	
20% load=	$6,037.42 /Year	20% load=	$4,312.32 /Year	20% load=	$3,688.24 /Year	20% load=	$5,091.25 /Year
30% load=	$7,330.89 /Year	30% load=	$4,965.57 /Year	30% load=	$4,192.93 /Year	30% load=	$6,132.09 /Year
60% load=	$13,374.81 /Year	60% load=	$9,517.12 /Year	60% load=	$7,815.48 /Year	60% load=	$11,573.60 /Year
70% load=	$16,326.10 /Year	70% load=	$11,737.48 /Year	70% load=	$9,742.58 /Year	70% load=	$14,203.77 /Year
1000 KVA		1000 KVA		1000 KVA		1000 KVA	
20% load=	$7,299.48 /Year	20% load=	$4,989.78 /Year	20% load=	$4,369.44 /Year	20% load=	$6,043.12 /Year
30% load=	$8,905.21 /Year	30% load=	$5,794.23 /Year	30% load=	$5,000.26 /Year	30% load=	$7,309.34 /Year
60% load=	$16,339.76 /Year	60% load=	$11,261.75 /Year	60% load=	$9,496.11 /Year	60% load=	$13,953.68 /Year
70% load=	$19,999.84 /Year	70% load=	$13,899.81 /Year	70% load=	$11,935.04 /Year	70% load=	$17,181.12 /Year

Modern	Low Level									
XFMR	Load Efficiency at .085 PF			% Loss			Total Losses (w)			
Load %	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	
0.2	97.41947	97.63951	97.85956	2.580529	2.360486	2.140441	2193.45	3009.58	3638.75	
0.3	97.91927	98.0892	98.25914	2.080729	1.910803	1.740863	2652.85	3654.52	4439.2	
0.6	98.11096	98.25692	98.40289	1.889043	1.743077	1.597114	4817.25	6667.21	8145.28	
0.7	98.02811	98.17625	98.3244	1.971889	1.823747	1.675598	5866.37	8138.53	9969.81	
Modern	Medium Level									
XFMR	Load Efficiency at .085 PF			% Loss			Total Losses (w)			
Load %	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	
0.2	98.09453	98.31398	98.53684	1.905468	1.686016	1.463165	1619.648	2149.67	2487.38	
0.3	98.52512	98.70572	98.8673	1.47488	1.29428	1.132702	1880.472	2475.31	2888.39	
0.6	98.60263	98.75968	98.89923	1.397371	1.240322	1.100769	3563.296	4744.23	5613.92	
0.7	98.53362	98.68884	98.83547	1.466377	1.311164	1.164534	4362.472	5851.07	6928.98	
Modern	High Level									
XFMR	Load Efficiency at .085 PF			% Loss			Total Losses (w)			
Load %	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	
0.2	98.40047	98.55799	98.71874	1.599529	1.442013	1.281259	1359.6	1838.567	2178.14	
0.3	98.80557	98.90711	99.02251	1.194431	1.09289	0.97749	1522.9	2090.153	2492.6	
0.6	98.90306	98.98144	99.07181	1.096941	1.018556	0.928188	2797.2	3895.975	4733.76	
0.7	98.82541	98.91168	99.00008	1.174588	1.088319	0.999924	3494.4	4856.625	5949.55	
Older XFMR	Load Efficiency at .085 PF			% Loss			Total Losses (w)			
Load %	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	500 KVA	750 KVA	1000 KVA	
0.2	97.79093	98.00944	98.22796	2.209074	1.990556	1.772037				
0.3	98.23222	98.40167	98.57111	1.767778	1.598333	1.428889				
0.6	98.34722	98.49167	98.63611	1.652778	1.508333	1.363889				
0.7	98.26611	98.41333	98.56056	1.733889	1.586667	1.439444				
Savings										
20% Load						20% Load				
Replacement:		Low	Med	High		Replacement:		Low	Med	High
500 KVA		-2765.856	2260.649	4538.67		750 KVA		-4131.76	3401.406	6126.668
60% Load						60% Load				
Replacement:		Low	Med	High		Replacement:		Low	Med	High
500 KVA		-5277.696	5705.277	12416.28		750 KVA		-7865.56	8980.27	16410.98

500 KVA	PF .80	PF .85	PF .90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
0.1	95.94296	96.15815	96.37333	96.72407
0.15	97.11444	97.2687	97.42296	97.67667
0.2	97.66407	97.79093	97.91778	98.12185
0.25	97.96	98.07315	98.1863	98.36296
0.3	98.13148	98.23222	98.33296	98.50222
0.35	98.23074	98.32537	98.42	98.57667
0.4	98.28296	98.375	98.46704	98.61889
0.45	98.29778	98.39111	98.48444	98.6337
0.5	98.29519	98.38852	98.48185	98.63111
0.55	98.28259	98.37593	98.46926	98.62111
0.6	98.25259	98.34722	98.44185	98.5937
0.65	98.20778	98.30611	98.40444	98.5637
0.7	98.16778	98.26611	98.36444	98.5263
0.75	98.11296	98.2163	98.31963	98.48148
0.8	98.05815	98.16519	98.27222	98.44148
0.85	97.99333	98.10537	98.21741	98.38926
0.9	97.93111	98.04685	98.16259	98.34185
0.95	97.8663	97.98333	98.10037	98.28704
1	97.80148	97.92222	98.04296	98.23222

20% Load				
Replacement:		Low	Med	High
1000 KVA		-5486.27	4599.727	7308.669
60% Load				
Replacement:		Low	Med	High
1000 KVA		-10419.6	11755.16	19465.36

750 KVA	PF .80	PF .85	PF .90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
0.1	96.35222	96.54611	96.74	97.05556
0.15	97.40333	97.54278	97.68222	97.91
0.2	97.89556	98.00944	98.12333	98.30889
0.25	98.16	98.26111	98.36222	98.52222
0.3	98.31111	98.40167	98.49222	98.64667
0.35	98.39556	98.48278	98.57	98.71
0.4	98.44222	98.525	98.60778	98.74667
0.45	98.45333	98.53833	98.62333	98.75778
0.5	98.44889	98.53389	98.61889	98.75333
0.55	98.43444	98.51944	98.60444	98.74333
0.6	98.40444	98.49167	98.57889	98.71778
0.65	98.36333	98.45333	98.54333	98.68778
0.7	98.32333	98.41333	98.50333	98.65222
0.75	98.27222	98.36722	98.46222	98.61111
0.8	98.22111	98.31889	98.41667	98.57111
0.85	98.16	98.26278	98.36556	98.52444
0.9	98.10333	98.20889	98.31444	98.47889
0.95	98.04222	98.15	98.25778	98.42778
1	97.98111	98.09167	98.20222	98.37667

1000 KVA	PF .80	PF .85	PF .90	PF 1.0
Load %	Eff %	Eff %	Eff %	Eff %
0.1	96.76148	96.93407	97.10667	97.38704
0.15	97.69222	97.81685	97.94148	98.14333
0.2	98.12704	98.22796	98.32889	98.49593
0.25	98.36	98.44907	98.53815	98.68148
0.3	98.49074	98.57111	98.65148	98.79111
0.35	98.56037	98.64019	98.72	98.84333
0.4	98.60148	98.675	98.74852	98.87444
0.45	98.60889	98.68556	98.76222	98.88185
0.5	98.60259	98.67926	98.75593	98.87556
0.55	98.5863	98.66296	98.73963	98.86556
0.6	98.5563	98.63611	98.71593	98.84185
0.65	98.51889	98.60056	98.68222	98.81185
0.7	98.47889	98.56056	98.64222	98.77815
0.75	98.43148	98.51815	98.60481	98.74074
0.8	98.38407	98.47259	98.56111	98.70074
0.85	98.32667	98.42019	98.5137	98.65963
0.9	98.27556	98.37093	98.4663	98.61593
0.95	98.21815	98.31667	98.41519	98.56852
1	98.16074	98.26111	98.36148	98.52111

#	CAMP	CAPACITY KVA	Total Cost	Annual Savings 20% Load	Annual Savings 60% Load	TDOS 20% Load	TDOS 20% Load
1	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
2	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
3	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
4	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
5	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
6	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
7	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
8	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
9	FOSTER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
10	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
11	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
12	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
13	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
14	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
15	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
16	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
17	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
18	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
19	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
20	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
21	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
22	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
23	HANSEN	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
24	KINSER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
25	KINSER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
26	KINSER	500	$93,089.00	$1,039.00	$2,843.00	$20,395.00	$55,795.00
High-Level		Total:	$2,420,314.00	$27,014.00	$73,918.00	$530,270.00	$1,450,670.00

#	CAMP	CAPACITY KVA	Total Cost	Annual Savings 20% Load	Annual Savings 60% Load	TDOS 20% Load	TDOS 20% Load
1	FOSTER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
2	FOSTER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
3	FOSTER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
4	FOSTER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
5	FOSTER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
6	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
7	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
8	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
9	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
10	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
11	HANSEN	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
12	KINSER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
13	KINSER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
14	KINSER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
15	KINSER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
16	KINSER	750	$103,785.00	$1,403.00	$3,758.00	$27,531.00	$73,746.00
High-Level		Total:	$1,660,560.00	$22,448.00	$60,128.00	$440,496.00	$1,179,936.00

#	CAMP	CAPACITY KVA	Total Cost	Annual Savings 20% Load	Annual Savings 60% Load	TDOS 20% Load	TDOS 20% Load
1	FOSTER	1000	$118,754.00	$1,674.00	$4,458.00	$32,843.00	$87,471.00
2	FOSTER	1000	$118,754.00	$1,674.00	$4,458.00	$32,843.00	$87,471.00
3	HANSEN	1000	$118,754.00	$1,674.00	$4,458.00	$32,843.00	$87,471.00
4	HANSEN	1000	$118,754.00	$1,674.00	$4,458.00	$32,843.00	$87,471.00
High-Level		Total:	$475,016.00	$6,696.00	$17,832.00	$131,372.00	$349,884.00

		Total Cost	Savings 20% Load	Savings 60% Load	TDOS 20% Load	TDOS 60% Load
26 - 500 KVA		$2,420,314.00	$27,014.00	$73,918.00	$530,270.00	$1,450,670.00
16- 750 KVA		$1,660,560.00	$22,448.00	$60,128.00	$440,496.00	$1,179,936.00
4 - 1000 KVA		$475,016.00	$6,696.00	$17,832.00	$131,372.00	$349,884.00
	Total:	$4,555,890.00	$56,158.00	$151,878.00	$1,102,138.00	$2,980,490.00

NEMA PREMIUM® EFFICIENCY TRANSFORMER PROGRAM GUIDELINES

PROGRAM DESCRIPTION AND SPECIFICATION DOCUMENT

Below is the program description and product specification for the NEMA Premium® Efficiency Transformer program. A product must meet all of the identified criteria if it is to be qualified as a NEMA Premium Compliant Transformer by its manufacturer.

1) Qualifying Products: For the purposes of this Program, Qualifying Products are transformers meeting the following criteria:

Dry-type distribution transformers: for single phase, between 15 kVA and 333 kVA; for three-phase, between 15 kVA and 1000 kVA

2) Premium Efficiency Specifications for Qualifying Products: Qualifying Products which meet or exceed the nominal Premium Efficiency levels presented in 10 CFR § 431.196 and reproduced here. In case of discrepancy, the CFR values shall prevail

Table 1: Low-Voltage Dry-Type Distribution Transformers

Single-phase		Three-phase	
kVA	**Efficiency (%)**	**kVA**	**Efficiency (%)**
15	98.39%	15	97.90%
25	98.60%	30	98.25%
37.5	98.74%	45	98.39%
50	98.81%	75	98.60%
75	98.95%	112.5	98.74%
100	99.02%	150	98.81%
167	99.09%	225	98.95%
250	99.16%	300	99.02%
333	99.23%	500	99.09%
		750	99.16%
		1000	99.23%

3) Test Procedure: The manufacturer shall determine the energy efficiency in accordance with **10 C.F.R. Part 431 ("Test Procedures for Distribution Transformers)**.

4) Buyer Information: NEMA recommends that the manufacturer place the NEMA Premium® Mark on all Qualifying Product models, which meet or exceed the Premium Efficiency Specifications set forth in Tables 1 above, their packaging, and product-related materials such as brochures, manuals, catalogs, advertisements, and Web sites. In addition, the manufacturer is encouraged to disseminate educational materials to educate purchasers about energy efficiency and its benefits. The manufacturer may determine the best manner to disseminate such

educational material so that it complements the manufacturer's promotional and marketing strategy.

5) The NEMA Premium® Mark is the trademark of NEMA. As such, the name and NEMA Premium Mark may only be used in accordance with the following guidelines and Memorandum of Understanding and License signed by Partners and NEMA. NEMA oversees the proper use of the NEMA Premium® Mark. This includes monitoring the use of the mark in the marketplace and directly contacting those organizations that are using them improperly or without authorization. Consequences to Partners of misusing the NEMA Premium® Mark may include termination of the partner's participation in the NEMA Premium program.

6) Effective Date: The date that manufacturers may begin to qualify products as NEMA Premium Compliant Transformers is defined as the effective date of the specifications. The effective date is May 1, 2010.

7) Specification Revisions: The NEMA Transformer Section reserves the right to change the specifications should technological and/or market developments affect its usefulness to purchasers, customers, industry or the environment. Revisions are to be arrived at through industry discussions and consensus.

SEEDT

Intelligent Energy Europe

Strategies for development and diffusion of Energy Efficient Distribution Transformers

Selecting Energy Efficient Distribution Transformers
A Guide for Achieving Least-Cost Solutions

Prepared for Intelligent Energy Europe Programme

Strategies for Development and Diffusion of

Energy Efficient Distribution Transformers

Intelligent Energy Europe

Intelligent Energy Europe

About Intelligent Energy Europe Programme

There are many untapped opportunities to save energy and encourage the use of renewable energy sources in Europe, but market conditions do not always help.

The Intelligent Energy - Europe programme is the EU's tool for funding action to improve these conditions and move us towards a more energy intelligent Europe.

Selecting Energy Efficient Distribution Transformers
A Guide for Achieving Least-Cost Solutions

PROJECT Nº EIE/05/056/SI2.419632

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Strategies for Development and Diffusion of
Energy Efficient Distribution Transformers

by

Polish Copper Promotion Centre and European Copper Institute

in collaboration with

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ENDESA Distribución Electrica, ENDESA	Spain
Federazione delle Associazioni Scientifiche e Techniche, FAST	Italy
Łódzki Zakład Energetyczny S.A., ŁZE S.A.	Poland
Thelcon Ltd	Greece
Wuppertal Institut für Umwelt, Klima, Energie GmbH	Germany

with the support of the EUROPEAN COMMISSION

This SEEDT Guide is Something Good for You:

If …

…you would like to:

- ☞ purchase a distribution transformer at the least lifecycle costs
- ☞ achieve further energy and budget savings in your organisation
- ☞ contribute to increasing energy security and reducing greenhouse gas emissions …

… and you are:

- ☞ working in an electricity distribution company, industry, commercial or public organisation wanting to purchase a distribution transformer
- ☞ working as a facility manager, planner or equipment installer in charge of technical planning or preparing the purchase of a distribution transformer in a client's organisation …

… then we recommend you to read this brochure.

It presents recommendations and results of the European project SEEDT (Strategies for development and diffusion of energy-efficient distribution transformers), carried out with financial support from the EUROPEAN COMMISSION under the Intelligent Energy – Europe programme and national co-financiers. The aim of SEEDT is to promote the use of energy-efficient distribution transformers, which can be profitable for investors, and by contributing to European Community energy savings, may help to fulfil EU energy policy targets.

Disclaimer

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ILLUSTRATIONS

Photography used under the terms of the GNU Free Documentation license version 1.2:

- **Title page photo: Transformer building in Eizer (Overijse), Belgium - author Wouter Hagens.**
- **Page 27 top photo: Transformer in Wroclaw, Poland - author Kamil Kozłowski.**
- **Page 27 bottom photo: Three-Phase, Medium-Voltage Transformer - author Stahlkocher.**

1 INTRODUCTION

1.1 Profitable Solutions Contributing to European Targets

SEEDT – Strategies for development and diffusion of Energy-efficient Distribution Transformers - is one of the projects in the Intelligent Energy Europe programme.

The aim of this project is to promote the use of energy-efficient distribution transformers, which can be profitable for investors, and, by contributing to European Community energy savings, may help to fulfil EU energy policy targets. Strategies developed in SEEDT include proposals for changes to the regulatory scheme for electricity distribution companies, labelling, mandatory standards, further support mechanisms, and dissemination activities.

Energy efficiency has now become the top priority for European energy policy. The Action Plan on Energy Efficiency, released in 2006 by the European Commission, envisaged launching a debate on how the EU could achieve a reduction in its energy consumption by 20% (390 Mtoe) compared to the 'business as usual' projections for 2020 on a cost-effective basis and, by so doing, limit the growth in energy consumption to a level below 1500 Mtoe/year by 2020. In order to achieve this target, an annual improvement of 3.3% is needed, which is 1.5% more than in the baseline scenario.

Energy-efficient transformers can make a valuable contribution to European energy savings if they are effectively promoted and are given sufficient regulatory support. The calculations by the SEEDT project team show that energy savings of European distribution transformers can reach about 18.5 TWh of electricity per year if all transformers operating today are replaced by the most energy-efficient transformers available today (but excluding the superconductivity option). In other words, an energy-efficient transformer has 55.5% lower energy losses and thus substantially lower running costs than the average transformer installed today. If, for every future distribution transformer purchase, the most energy-efficient technical option is chosen, then, assuming the anticipated development of the electricity system and replacement rates, up to 11.6 TWh electricity per year can be saved over 15 years.

Additional incentives and further support are needed to realise the energy saving potentials and to reduce greenhouse gas emissions and to increase energy security respectively. This is in spite of the fact that, in many cases, energy-efficient transformers are economical. Energy-efficient transformers usually have lower lifetime costs, despite their higher capital cost, because of the lower cost of losses over time.

In Europe, unlike in many countries around the world, there is no general mandatory standard or even voluntary approach for energy efficiency of distribution transformers. The two main documents which describe losses in transformers are European Standard EN 50464-1 for oil cooled transformers, (which has superseded the harmonised document HD428), and harmonised document HD538 for dry type transformers (or their country equivalents, e.g., DIN, etc.).

1.2 European Distribution Transformer Characteristics

The population of distribution transformers in Europe is about 4.5 million units. The annual market for new investments and replacements is estimated at about 3% of existing stock. Important determinants of market development are the change in electricity consumption, the increase in decentralized generation, the development of electricity and material prices, and the pressure from re-regulation on the unbundled electricity distribution companies in the various countries.

The overall population of distribution transformers in the energy distribution sector in EU-27 is estimated at 3.7 million units. The average transformer power rating of these distribution transformers is between 116 and 369 kVA depending on the country. The population of privately owned (usually referred to as industrial) oil filled distribution transformers installed in the EU-27 is estimated at 800 000 units with an average transformer rating of about 400 kVA. The number of privately owned dry type transformers is estimated at less than 200 000 units but the average rating is just over 800 kVA, more than double that of the private oil-filled fleet.

More than two-thirds of the installed transformers have a rated power below 400 kVA (practically up to 250 kVA with a few percent 315 kVA units). The newly purchased units have higher power ratings with less than 50% of them in the lower power category.

Table 1: EU27 distribution transformer populations and annual market (transformers installed in 2004)

		Fleet EU-27		Market EU-27	
		pcs	MVA	pcs	MVA
Distribution sector oil*	< 400 kVA	2 688 000	313 000	56 000	7 000
	≥ 400 kVA & ≤ 630 kVA	861 000	441 000	23 000	12 000
	> 630 kVA	127 000	157 000	6 000	8 000
	Subtotal	***3 676 000***	***911 000***	***85 000***	***27 000***
Industry oil	< 400 kVA	493 000	66 000	24 000	3 000
	≥ 400 kVA & ≤ 630 kVA	181 000	90 000	8 000	4 000
	> 630 kVA	127 000	173 000	6 000	8 000
	Total industry oil	***802 000***	***330 000***	***38 000***	***15 000***
Industry dry	< 400 kVA	39 000	13 000	3 000	1 000
	≥ 400 kVA & ≤ 630 kVA	69 000	41 000	5 000	3 000
	> 630 kVA	66 000	90 000	8 000	11 000
	Total industry dry	***174 000***	***144 000***	***16 000***	***14 000***
Total		**4 652 000**	**1 384 000**	**140 000**	**57 000**

** The population of dry-type transformers in the energy distribution sector is estimated at marginally low level (~ 1% of utility fleet).*

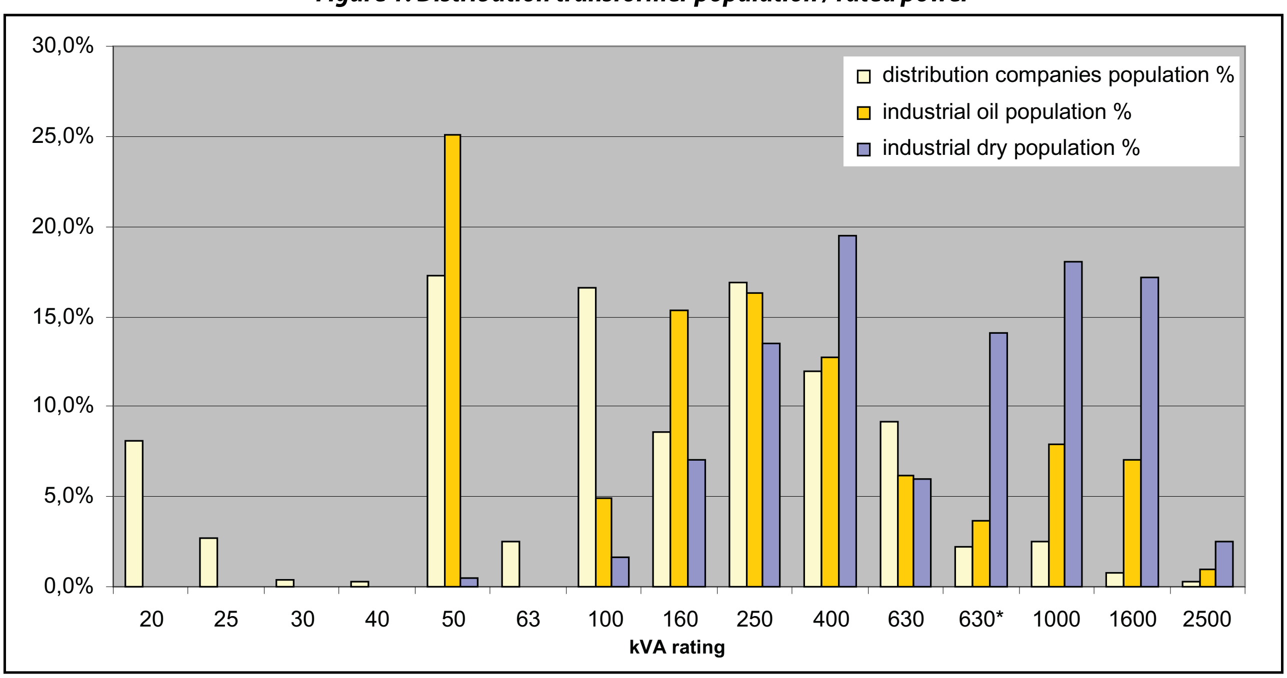
Distribution transformers operated and owned by electricity distribution companies are responsible for supplying 66% of electricity to final users at low voltage level and represent almost 80% of distribution transformers stock.

It is very clear from the table that smaller units dominate the distribution sector, while, in the industrial sector, especially for dry type transformers, larger units are more common.

From the 'market' columns it is evident that the growth of larger kVA ratings is strong – roughly estimated at 0.4% per annum.

Figure 1 presents the distribution of transformer power ratings across different transformer segments. Note that these are relative figures so, for absolute rating distribution compare, only bars of the same colour.

Figure 1. Distribution transformer population / rated power



** and upwards indicate 6% (compared to 4 or 4.5% for lower ratings) short circuit impedance*

2 Losses in transformers

2.1 Definition of transformer losses

Transformer losses can be divided into two main components: no-load losses and load losses. These types of losses are common to all types of transformers, regardless of transformer application or power rating. There are, however, two other types of losses; extra losses created by harmonics and losses which may apply particularly to larger transformers – cooling or auxiliary losses, caused by the use of cooling equipment like fans and pumps.

No-Load losses

These losses occur in the transformer core whenever the transformer is energised (even when the secondary circuit is open). They are also called iron losses or core losses and are constant.

They are composed of:

- Hysteresis losses, caused by the frictional movement of magnetic domains in the core laminations being magnetized and demagnetized by alternation of the magnetic field. These losses depend on the type of material used to build a core. Silicon steel has much lower hysteresis than normal steel but amorphous metal has much better performance than silicon steel. Nowadays hysteresis losses can be reduced by material processing such as cold rolling, laser treatment or grain orientation. Hysteresis losses are usually responsible for more than a half of total no-load losses (~50% to ~70%). This ratio was smaller in the past (due to the higher contribution of eddy current losses particularly in relatively thick and not laser treated sheets).
- Eddy current losses, caused by varying magnetic fields inducing eddy currents in the laminations and thus generating heat. These losses can be reduced by building the core from thin laminated sheets insulated from each other by a thin varnish layer to reduce eddy currents. Eddy current losses nowadays usually account for 30% to 50% of total no-load losses. When assessing efforts in improving distribution transformer efficiency, the biggest progress has been achieved in reduction of these losses.
- There are also marginal stray and dielectric losses which occur in the transformer core, accounting usually for no more than 1% of total no-load losses.

Load losses

These losses are commonly called copper losses or short circuit losses. Load losses vary according to the transformer loading. They are composed of:

- Ohmic heat loss, sometimes referred to as copper loss, since this resistive component of load loss dominates. This loss occurs in transformer windings and is caused by the resistance of the conductor. The magnitude of these losses increases with the square of the load current and is proportional to the resistance of the winding. It can be reduced by increasing the cross sectional area of conductor or by reducing the winding length. Using copper as the conductor maintains the balance between weight, size, cost and resistance; adding an additional amount to increase conductor diameter, consistent with other design constraints, reduces losses.
- Conductor eddy current losses. Eddy currents, due to magnetic fields caused by alternating current, also occur in the windings. Reducing the cross-section of the conductor reduces eddy currents, so stranded conductors are used to achieve the required low resistance while controlling eddy current loss. Effectively, this means that the 'winding' is made up of a number of parallel windings. Since each of these windings would experience a slightly different flux, the voltage developed by each would be slightly different and connecting the ends would result in circulating currents which would contribute to loss. This is avoided by the use of continuously transposed conductor (CTC), in which the strands are frequently transposed to average the flux differences and equalise the voltage.

Auxiliary losses

These losses are caused by using energy to run cooling fans or pumps which help to cool larger transformers.

Extra losses due to harmonics and reactive power

This category of losses includes those extra losses which are caused by reactive power and harmonics.

The reactive component of the load current generates a real loss even though it makes no contribution to useful load power. Losses are proportional to $1/(\cos \phi)^2$. Low power factor loads should be avoided to reduce losses related to reactive power.

Power losses due to eddy currents depend on the square of frequency so the presence of harmonic frequencies which are higher than normal 50 Hz frequency cause extra losses in the core and winding. Harmonics deserve separate attention and are discussed below.

2.1.1 Extra losses due to harmonics

Non-linear loads, such as power electronic devices, such as variable speed drives on motor systems, computers, UPS systems, TV sets and compact fluorescent lamps, cause harmonic currents on the network. Harmonic voltages are generated in the impedance of the network by the harmonic load currents. Harmonics increase both load and no-load losses due to increased skin effect, eddy current, stray and hysteresis losses.

The most important of these losses is that due to eddy current losses in the winding; it can be very large and consequently most calculation models ignore the other harmonic induced losses.

The precise impact of a harmonic current on load loss depends on the harmonic frequency and the way the transformer is designed.

In general, the eddy current loss increases by the square of the frequency and the square of the load current. So, if the load current contained 20% fifth harmonic, the eddy current loss due to the harmonic current component would be 5 x 5 x 0.2 x 0.2 multiplied by the eddy current loss at the fundamental frequency – meaning that the eddy current loss would have doubled.

In a transformer that is heavily loaded with harmonic currents, the excess loss can cause high temperature at some locations in the windings. This can seriously reduce the life span of the transformer and even cause immediate damage and sometimes fire.

- Reducing the maximum apparent power transferred by the transformer, often called de-rating. To estimate the required de-rating of the transformer, the load's de-rating factor may be calculated. This method, used commonly in Europe, is to estimate by how much a standard transformer should be de-rated so that the total loss on harmonic load does not exceed the fundamental design loss. This de-rating parameter is known as "factor K".

  The transformer de-rating factor is calculated according to the formula in HD 538.3.S1. The factor K is given by:

$$K = \left[1 + \frac{e}{1+e} \left(\frac{I_h}{I} \right)^2 \sum_{n=2}^{n=N} \left(n^q \left(\frac{I_n}{I_1} \right)^2 \right) \right]^{0.5} \quad [1]$$

  where:

  e - the eddy current loss at the fundamental frequency divided by the loss due to a DC current equal to the RMS value of the sinusoidal current, both at reference temperature.

  n - the harmonic order

Figure 2. Fire of a pole-mounted distribution transformer in the streets of Moscow

- I - the RMS value of the sinusoidal current including all harmonics given by:

$$I = \left(\sum_{n=1}^{n=N}(I_n)^2\right)^{0.5} = I_1\left[\sum_{n=1}^{n=N}\left(\frac{I_n}{I_1}\right)^2\right]^{0.5} \qquad [2]$$

- I_n - the magnitude of the n-th harmonic
- I_1 - the magnitude of the fundamental current
- q - exponential constant that is dependent on the type of winding and frequency. Typical values are 1.7 for transformers with round rectangular cross-section conductors in both windings and 1.5 for those with foil low voltage windings.

- Developing special transformer designs rated for non-sinusoidal load currents. This process requires analysis and minimising of the eddy loss in the windings, calculation of the hot spot temperature rise, individual insulation of laminations, and/or increasing the size of the core or windings. Each manufacturer will use any or all of these techniques according to labour rates, production volume and the capability of his plant and equipment. These products are sold as 'K rated' transformers. During the transformer selection process, the designer should estimate the K factor of the load and select a transformer with the same or higher K factor.

  K factor is defined as:

$$K = \sum_{n=1}^{n=n_{max}} I_n^2 n^2$$

There are some simple tools available which help to calculate the de-rating factor-K and K-factor. To use them it is necessary to know the harmonic spectrum of the load current. An example of a K-Factor & Factor K calculator can be found at:

http://www.leonardo-energy.org/drupal/node/456

As an example IEC 61378-1 deals with the specification, design and testing of power transformers and reactors, which are intended for integration within semiconductor converter plants; it is not designed for industrial or public distribution of AC power in general.

The scope of this standard is limited to applications of power converters, of any power rating, for local distribution, at moderate rated converter voltage, generally for industrial applications and typically with a highest voltage for equipment not exceeding 36 kV.

The converter transformers covered by this standard may be of the oil immersed or dry-type design. The oil-immersed transformers are required to comply with IEC 60076, and with IEC 60726 for dry-type transformers.

2.2 Losses in European Distribution Transformers

The study performed by the SEEDT team has estimated the distribution transformer losses in EU-27 countries and Norway.

The overall losses in EU-27 distribution transformers are estimated at about 33 TWh/year. However, this figure does not include reactive power and harmonic losses which, at a conservative estimate, add a further 5 TWh/year (or 15% of calculated total of no-load and load losses) for all electricity distribution companies and private distribution transformers. Therefore, total losses of distribution transformers in EU-27 might total about 38 TWh/year.

Table 2 below presents the EU-27 losses in distribution transformers divided into three sectors with the existing population (fleet) and newly installed units (market) listed separately. No-load losses (P_o) account for more than 70% of total losses (1 - ΣP_k / ΣP ratios).

Table 2: EU-27 distribution transformer losses

	Transformer Fleet EU-27		Transformer Market EU-27	
		GWh / year		GWh / year
electricity distribution companies oil	ΣP_o fleet	15 970	ΣP_o market	350
	ΣP_k fleet	6000	ΣP_k market	170
	ΣP_kfleet / ΣPtotal	27.3%	ΣP_kmarket / ΣPtotal	33.0%
industry oil	ΣP_o fleet	5540	ΣP_o market	260
	ΣP_k fleet	2170	ΣP_k market	100
	ΣP_kfleet / ΣPtotal	28.1%	ΣP_kmarket / ΣPtotal	26.5%
industry dry	ΣP_o fleet	2590	ΣP_o market	270
	ΣP_k fleet	1130	ΣP_k market	120
	ΣP_kfleet / ΣPtotal	30.4%	ΣP_kmarket / ΣPtotal	30.9%
Total	***Ptotal***	***33400***	***Ptotal***	***1270***
+ reactive power and harmonic losses		~5 000		~200
Total	**Ptotal**	**~38 400**	**Ptotal**	**~1 470**

Total losses in newly installed transformers are estimated at 1.24 TWh/year or 1.43 TWh/year including estimated reactive power and harmonic losses. Transformers purchased by electricity distribution companies account for more than 500 GWh/year of energy losses in the EU-25. Although transformers in electricity distribution companies have rather lower rated losses than those used by industry, their overall running efficiency is similar because the industrial population is made up of higher power transformers which are generally more efficient, run at higher loadings than transformers owned by electricity distribution companies.

Figure 3 presents the total, load and no-load losses of distribution transformers in electricity distribution companies in the EU-27 countries plus Norway (the labels apply to the total and load losses).

The ratio of no-load losses to load losses is close to 3, while the average operating efficiency for EU-27 countries is 93.38% (Figure 4).

This leads to the general conclusion that the reduction of no-load losses, especially for small, lightly loaded transformers, should be closely examined.

Figure 3. Breakdown of distribution sector distribution transformer losses, EU-27 and Norway

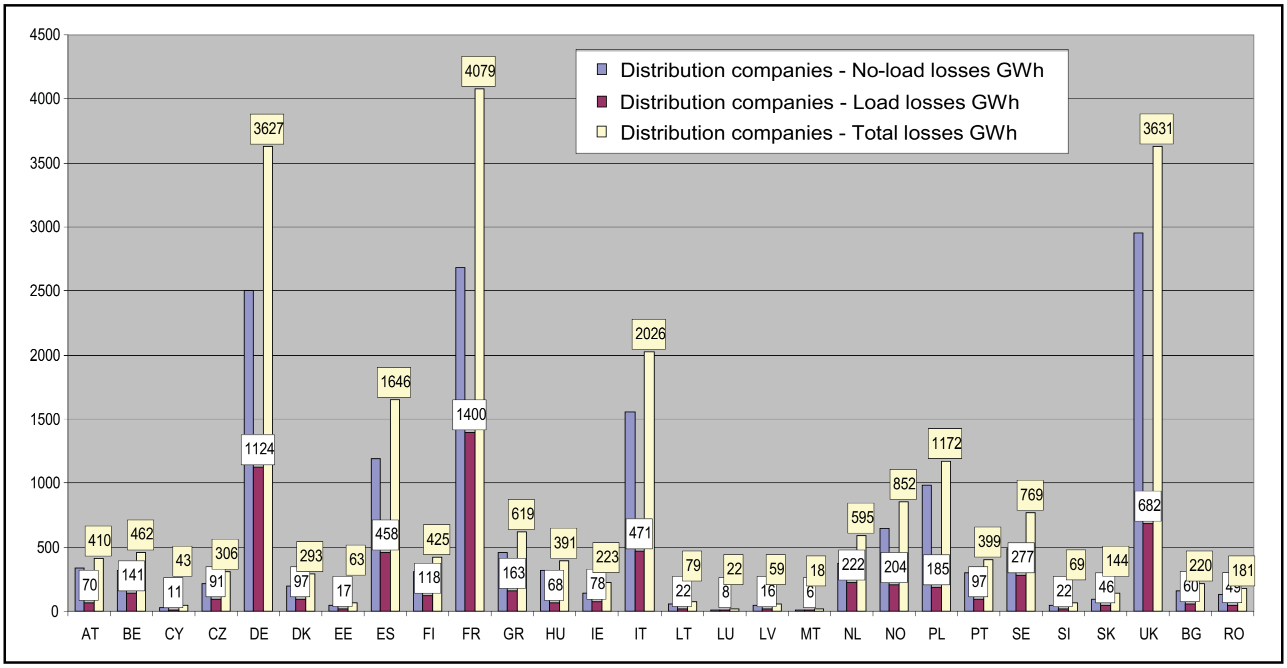
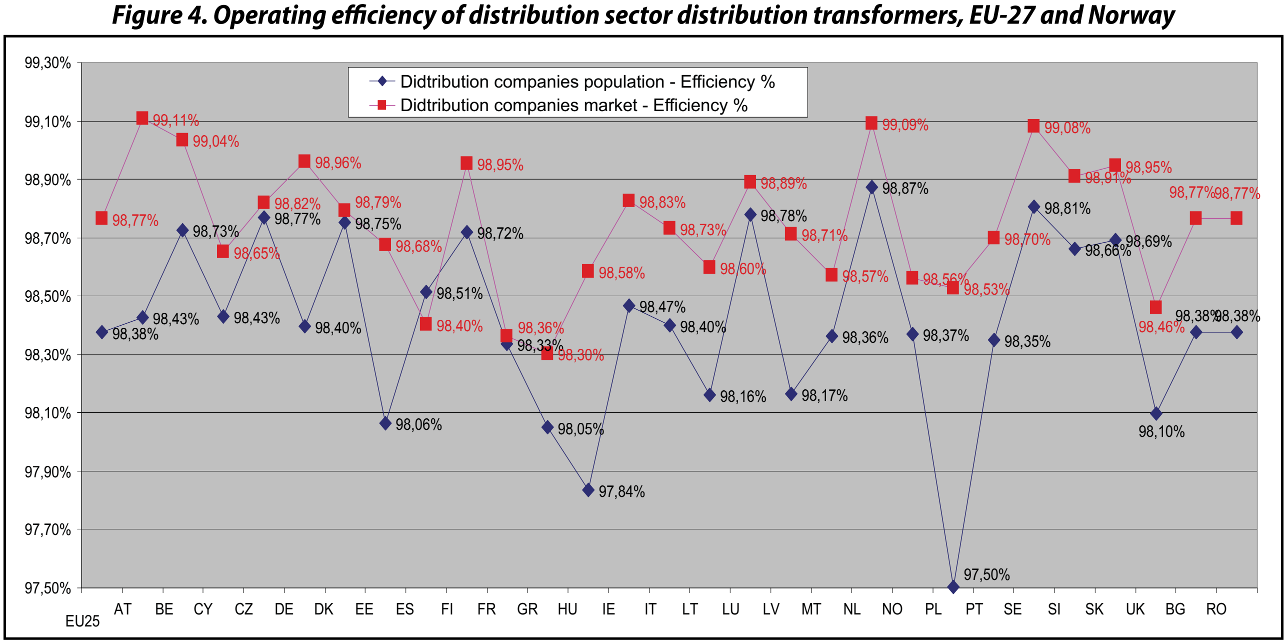


Figure 4. Operating efficiency of distribution sector distribution transformers, EU-27 and Norway



It is worth mentioning that this ratio of no-load to load losses is specific for distribution transformers, mainly because of the loading characteristics. In larger transformers like those used to step up voltage in power plants or in substation transformers no-load losses are smaller or much smaller than load losses. In typical generator step-up transformers the ratio of no-load to load losses can be as small as 0.2 to 0.3.

Other observations are that electricity distribution companies in different countries take different approaches to taking losses into account when buying a transformer. Some of them apply rational (life-cycle cost) considerations, but others just follow traditional purchasing habits. Transformer manufacturers therefore have to adapt their sales strategies according to these different approaches. The analysis of the existing market situation and purchasing procedures leads to the conclusion that much remains to be done to reduce the existing levels of both no-load and load losses. A comparison of the market situation in electricity distribution companies and industry/commerce does not lead to very clear trends. However two observations are worth mentioning:

- Distribution companies generally pay more attention to reduction of losses in transformers than industry. However, due to higher loading and larger units of industry and commerce population, the operating efficiencies remain at a similar level.
- In general, larger units are specified with lower rated losses. This trend is even more evident in case of load losses.

2.3 Transformer losses standards

Unlike many countries around the world, Europe has no mandatory standard on energy efficiency of distribution transformers. The two main documents which describe losses in transformers are: the European Standard EN 50464-1, which has superseded the harmonised document HD428 for oil cooled transformers, and the harmonised document HD538 for dry type transformers, which is still valid (or their various country equivalents, e.g., DIN, etc.). Data from these norms is given in the Annex.

Despite the fact that there are no mandatory standards in Europe, there are some procurement procedures (internal standards of electricity distribution companies) which are highly demanding in Benelux, Germany, Austria, Switzerland and Scandinavia. Most of the electricity distribution companies in these countries buy transformers at C [1] [C' minus 30%] (HD 428) or AoBk (new 50464) standards. ENDESA in Spain purchases HD 428 CC' for 400 kVA units. EdF has introduced a certain purchasing policy which specifies no load losses between Co and Eo and load losses between Dk and Bk. The mix of losses is focused on low no-load losses for small ratings and low load losses for higher ratings. Also tolerance of losses has changed recently. More often utilities reduce the tolerance of losses to, e.g., 0% instead of 15%.

Efficiency standards outside Europe may be expressed in terms of electrical efficiency, at a certain load level, or in terms of maximum values for no-load and load loss. Some examples follow below.

Australia "recalculated" the American 60 Hz efficiency NEMA TP-1 standard - which has never become mandatory in USA at federal level - to 50 Hz and also interpolated linearly the efficiencies for ratings which are different from those used in the USA.

New Zealand follows the Australian regulations for distribution transformers as a matter of policy.

In **China**, the standards are regularly upgraded since1999 with S7 and then S9 having been replaced by the current standard S11, which defines allowable levels for no-load and load losses slightly below Europe's AC' level. S11 will soon be replaced by S13 which is expected to specify lower loss levels.

The **Indian** Bureau of Energy Efficiency (BEE), classifies distribution transformers in the range from 25 up to 200 kVA into 5 categories from 1 Star (high loss) to 5 Stars (low loss). 5 Stars represents world-class performance. 3 Stars is being proposed as a minimum efficiency standard, and is being widely followed by utilities.

Japan has a different type of distribution system, with the last step of voltage transformation much closer to the consumer. The majority of units are pole mounted single phase transformers. The driver for setting up minimum efficiency standards was the Kyoto commitment. Transformers, together with 17 other categories of electrical equipment, should meet minimum efficiencies. In the case of transformers, the efficiency is defined at 40% load. Target average efficiency has been defined for the year 2006 (oil) or 2007 (dry type), based on the best products on the market in 2003.

1 *Designations are explained in Annex - European Distribution Transformer Loss standards*

The standard is designed differently from other standards, with efficiencies for different products being described by equations. This is currently the most demanding of all regulated standards.

Mexico sets the minimum efficiencies at slightly less stringent levels; 0.1% to 0.2% below NEMA TP-1 efficiency. As in Australia, the Mexican standard includes voluntary and mandatory elements.

In 1997, Oak Ridge National Laboratory performed extensive studies to determine whether energy conservation standards for distribution transformers would offer significant energy savings, be technically achievable and economically justified. The energy savings potential in the **USA** from switching to high efficient transformers was estimated to be 141 TWh cumulatively. One of the reasons for this high figure is the high number of distribution transformers in the utility networks in the US.

To reduce these losses, the National Electrical Manufacturers Association (NEMA) created the TP1 standard which defines a minimum efficiency for dry and oil-filled type transformers in the range from 10 to 2500 kVA. This became the basis for the rule making process on minimum standards. NEMA TP-1 has been used as a guideline by Canada, Australia, New Zealand and (partially) Mexico and was adopted by Massachusets, Minnesota, Wisconsin, New York, Vermont, California and Oregon. Subsequently, this standard was perceived as insufficiently demanding and, in 2006, the US Department of Energy (DoE) proposed a new standard. This proposal was a compromise between less stringent TP-1 and the level of losses which, on average, represent the minimum life cycle cost (MLLC), with the proposed loss levels set to represent one third of the improvement between TP-1 and MLCC.

Now, a new standard, closely based on the DoE proposal, has been introduced which will apply to all transformers manufactured for sale in the USA or imported into the USA on or after January 1, 2010. The requirement of the standard is very close to CC' -30% or AoBk.

In addition to this standard, transformers are also a part of the broader EnergyStar labelling programme. EnergyStar is a voluntary programme that encourages the participating utilities to calculate the total cost of ownership of their transformers and buy the type if it is cost-effective to do so. EnergyStar is based on TP1 but may be tightened in the future.

A third programme in the US, set up by the Consortium for Energy Efficiency (CEE), aims to increase the awareness of the potential of efficient transformers in industry. It consists of a campaign to measure the efficiency of industrial transformers and to stimulate companies to upgrade their transformer park to the best available in the market.

Canada follows TP-1 strictly but the mandatory levels apply only for dry type transformers. As far as oil transformers are concerned Canada has conducted an analysis of MEPS implementation potential and found that the great majority of Canadian oil distribution transformers already comply with NEMA TP-1 so the standard would have almost no influence on the market. The yearly MEPS standard impact would only be 0.98 GWh for liquid filled transformers compared to a saving potential at 132 GWh for dry-type transformers. Also Energy Star products are very actively promoted in Canada.

3 Cost of losses

3.1 Annual energy losses and cost of these losses

The annual energy losses of a transformer can be estimated from the following formula:

$$W_{Loss} = \left(P_0 + P_K * L^2\right) * 8760\,h \quad [3]$$

in which:

- W_{Loss} - is the annual energy loss in kWh
- P_o - is the no-load loss in kW. This factor is available from the transformer specifications or can be measured.
- P_k - is the short-circuit loss (or load loss) in kW. This factor is available from the transformer specifications or can be measured.
- L - is the average per-unit load on the transformer.
- 8760 - is the number of hours in a year

To calculate the cost of these losses, they need to be converted to the moment of purchase by assigning capital values, to be able to put them into the same perspective as the purchase price. This is called the Total Capitalised Cost of the losses, TCCloss. This can be calculated using the following formula:

$$TCC_{loss} = W_{loss} \times \frac{(1+i)^n - 1}{i \cdot (1+i)^n} \times C \times 8760 \quad [4]$$

where:

- C - is the estimated average cost per kWh in each year
- i - is the estimated interest rate
- n - is the expected life time of the transformer

3.2 Life cycle cost of transformers

To perform the economical analysis of transformer, it is necessary to calculate its life cycle cost, sometimes called total cost of ownership, over the life span of transformer or, in other words, the capitalised cost of the transformer. All these terms mean the same – in one formula, costs of purchasing, operating and maintaining the transformer need to be compared taking into account the time value of money.

The concept of the 'time value of money' is that a sum of money received today has a higher value – because it is available to be exploited – than a similar sum of money received at some future date.

In practice, some simplification can be made. While each transformer will have its own purchase price and loss factors, other costs, such as installation, maintenance and decommissioning will be similar for similar technologies and can be eliminated from the calculation. Only when different technologies are compared e.g. air cooled dry type transformers with oil cooled transformers will these elements need to be taken into account.

Taking only purchase price and the cost of losses into account the Total Cost of Ownership can be calculated by:

$$TCO = PP + A * P_0 + B * P_K \quad [5]$$

where:

- PP - is the purchase price of transformer,
- A - represents the assigned cost of no-load losses per watt,
- Po - is the rated no-load loss,
- B - is the assigned cost of load losses per watt,
- Pk - is the rated load loss.

This formula can also be found in HD428 and HD538.

P_o and P_k are transformer rated losses. A and B values depend on the expected loading of the transformer and energy prices.

The choice of the factors A and B is difficult since they depend on the expected loading of the transformer, which is often unknown, and energy prices, which are volatile, as well as interest rate and the anticipated economic lifetime. If the load grows over time, the growth rate must be known or estimated and the applicable energy price over the lifetime must be forecast. Typically, the value of A ranges from less than 1 to 8 EUR/Watt and B is between 0.2 and 5 EUR/Watt.

Below we propose a relatively simple method for determining the A and B factor for distribution transformers.

A and B factors are calculated as follows:
(no-load loss capitalisation)

$$A = \frac{(1+i)^n - 1}{i \cdot (1+i)^n} \times C_{kWh} \times 8760 \quad [6]$$

and (no-load loss capitalisation)

$$B = \frac{(1+i)^n - 1}{i \cdot (1+i)^n} \times C_{kWh} \times 8760 \times \left(\frac{I_l}{I_r}\right)^2 \quad [7]$$

where:

- i - interest rate [%/year]
- n - lifetime [years]
- C_{kWh} - kWh price [EUR/kWh]
- 8760 - number of hours in a year [h/year]
- I_l - loading current [A]
- I_r - rated current [A]

These formulae assume that energy prices and the loading are constant over the transformer life.

Usually, the loss evaluation figures A and B form part of the request for quotation are submitted to the transformer manufacturers, who can then start the complicated process of designing a transformer to give the required performance. The result of this open process should be the cheapest transformer, i.e. with the lowest total cost of ownership, optimised for a given application. The drawback of this process is, as mentioned, the difficulty in predicting the future load profile and electricity costs and tarrifs with any confidence. On the other hand, these optimisation efforts depend on material prices, particularly active materials, i.e. conductor and core material. Dynamic optimisation makes sense when there is the different price volatility of different materials like aluminium and copper or high and low loss magnetic steel..

For large transformers, above a few MVA, the cost of losses are so high that transformers are custom-built, tailored to the loss evaluation figures specified in the request for quotation for a specific project.

For distribution transformers, often bought in large batches, the process is undertaken once every few years. This yields an optimum transformer design, which is then retained for several years – less so nowadays because of the volatility of metal prices - until energy prices and load profiles have changed dramatically. In fact the loss levels established in HD428, HD538 and national standards reflect established practice of preferred designs with respect to loss evaluation values.

To make the capitalisation more attractive, so that the use of TCO is easier, we propose the use of a graph, shown in Figure 5, which allows determination of factor A.

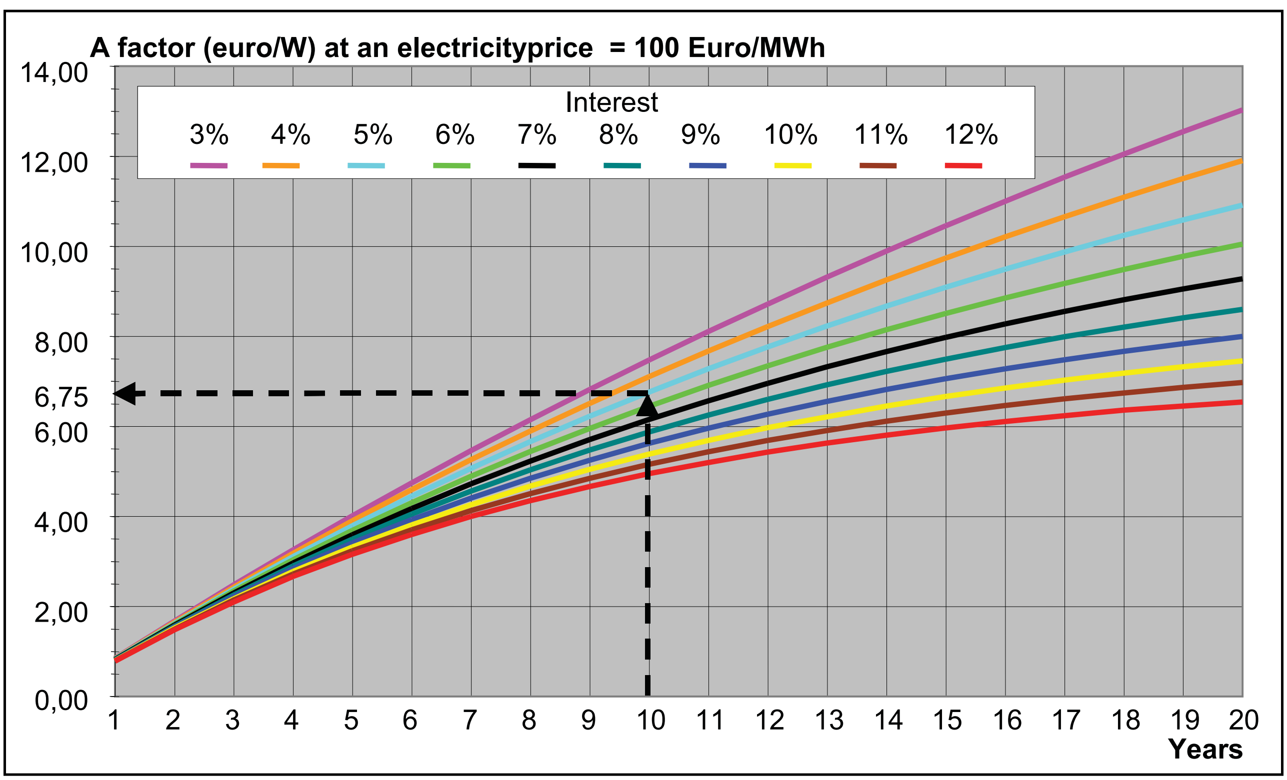
Factor A expresses the relation between the cost of no load losses and the following:

- Electricity price
- Discount rate or company interest rate or average cost of capital
- Capitalisation period or expected lifetime of the transformer

This example illustrates that for an electricity price of 100€/MWh, an interest rate of 5% and a 10 year capitalisation period, the cost of no load loss will be 6,75 € / Watt.

Factor A is directly proportional to electricity price so the A factor can simply be scaled to account for electricity price changes as long as the interest rate and capitalisation period remain unchanged.

Figure 5. Simplified chart for calculation of factor A



It is important to note that, for small interest rates, a doubling of the capitalisation period will result in almost doubling the cost of losses. On the other hand, applying too high a capital rate, by making, for example, too high a provision for risk, will produce a low value of loss.

Factor B, as explained previously, is simply the product of factor A and the square of the loading factor. (B = A * (Loading)2) The loading factor used here is the expected average load over the life span of the transformer, possibly taking harmonics into account.

Leonardo ENERGY offers a downloadable spreadsheet to be used as a calculator of TCO. The tool incorporates a more sophisticated modelling of loads and harmonics.

Furthermore, in the course of the SEEDT project, the tool SEEDT TLCalc has been developed. This transformer loss calculator is an interactive tool that allows comparison of two distribution transformers from both an economic and environmental point of view.

The Spreadsheet tools for life-cycle evaluation can be found at:

http://www.leonardo-energy.org/drupal/node/446

http://seedt.ntua.gr
(cf. main menu with the title "TLCalc")

Having determined the required values it is important to know how sensitive they are to changes in the assumptions on which they were based.

3.3 Price of a transformer

Today the production of transformers is characterised by a large variety of designs, manufactured in relatively short batches to meet the demands of a variety of customers with ever-changing expectations. Of course, fluctuations in commodity prices have a significant effect.

The designer has a certain choice of solutions which can be applied in order to build a transformer with expected rated losses. It is possible to use, for instance, different magnetic materials or change the proportions between the level of magnetic induction and current density. It is, however, important from the point of view of the manufacturer that the transformer with expected parameters will be designed in an optimum way.

It is also possible to vary the ratio of copper to steel quantities. According to an old rule of thumb within the transformer industry, the production cost optimum lies somewhere around a ratio of steel to copper usage of 2:1. However, it is a fairly flat optimum and, of course, varies with the price ratio of steel to copper. Independently of this, it should be taken into consideration that the operating properties of the transformer also vary when the shares are varied, especially with respect to losses: Holding the current densities in the windings and the magnetic flux density in the core constant, the loss per kilogram of copper or steel, respectively, will be more or less constant. Thereby a transformer designed according to this philosophy, but with more iron and less copper, tends to have higher iron losses, and one with more copper and less iron will have higher copper losses. But this does not mean that skimping on copper and steel pays off! Rather, enhancing the core cross-section while keeping the number of turns constant will reduce core losses, and enhancing the copper cross section while keeping the core cross section constant will reduce copper losses. In short: the bulkier transformer will always be more efficient, and metal prices will always be an obstacle against its implementation.

The progress in the scope of calculation techniques allows for optimisation to get a precise model of the transformer geometry, taking into account the actual core cross-section and the location of windings. It allows precise calculation of the transformer parameters. Manufacturers have many methods of design optimisation at their disposal which may be used in solving the issues in question.

At today's commodity prices (low loss magnetic steel 2 500 - 3 000 € / tonne, copper 6 000 - 7 000 € / tonne) the indicative transformer price for AC' class 100 kVA typical distribution transformer is around 3 000 €, 400 kVA is around 7 000 € and 1 000 kVA around 12 000 €. The price / rating characteristics can be roughly described as:

$$C_1 = C_0 * \left(\frac{S_{1n}}{S_{0n}} \right)^x \qquad [8]$$

where:

- C_1 - is cost of transformer "1"
- C_0 - is cost of transformer "0"
- S_{1n} - is rated power of transformer "1"
- S_{0n} - is rated power of transformer "0"
- x - exponent (cost factor)

The X factor is about 0.4 to 0.5. For more efficient units this factor has a tendency to increase up to 0.6 or even higher.

Dry type transformers representing rated losses specified by HD 538 standard are usually a few percent lighter than oil transformers (as they do not contain oil) but, because of the more costly manufacturing process, they are about 10% to 30% more expensive than CC' oil-filled machines. Because of some differences in design, particularly of magnetic circuit, no-load losses of dry transformers are substantially higher than in oil transformers.

Thanks to optimisation efforts and technology improvements, there is an area for transformer manufacturing cost reduction. Commodity prices have gone up for the last few years and have outweighed the cost-reducing effect of optimisation and technological improvements. The cost of active materials in typical transformers increased by more than 50% between the years 2003 and 2007. In these conditions transformer design optimisation can bring around 5% savings in manufacturing cost. This effect is better in less efficient machines.

Please note that, when the price of both active materials (magnetic steel and winding material) increases in similar proportion, the optimisation brings only marginal savings in manufacturing cost, when the same loss levels are specified. So manufacturers rather prefer to agree certain capitalisation based formula when optimisation of transformer may bring some savings in manufacturing cost.

Today, the cost active materials in an average distribution transformer represents about 50% of the transformer total price; taking all materials into account increases this to 70% of the total price.

Let's take the example of a typical medium size distribution transformer. Efficiency improvement today by reducing no-load losses adds to the cost by about 0.3% to 0.7% for **1% loss reduction** in the area of moderate losses (between A' and C' level) and from 0.7% (close to C') to 1.4% in area of very low losses (more than 20% below C'). For load losses, this proportion is higher, even at smaller load loss reduction and ranges from 0.6% to 1%. When we start to reduce load loss in the area of level C minus 15% (new Ak level) this cost may increase to 1.6%. Very roughly, if both losses are reduced at the same time, the cost should theoretically be higher (if no-load losses are reduced by adding more steel, the core becomes wider and requires longer conductor path resulting in increase of resistance and load loss, when load losses are reduced by increasing conductor cross-section the core becomes larger and requires more steel) but in fact this effect is almost negligible until a certain level of both losses. Beyond that, reducing both losses at the same time results in increasing suboptimum and going further towards both reduction extremes becomes extremely expensive and absolutely impractical.

It is, however, worthwhile mentioning that load loss reduction by increasing the amount of conductor material is not necessarily the most cost-effective measure. As already mentioned, to reduce load losses by design optimisation it is possible to reduce the amount of copper but change other transformer parameters e.g. adding more or higher grade magnetic steel.

As a very general comparison, ten years ago, amorphous transformers were more expensive than the European average transformers (with AC' losses) by a factor of 2 or more. Today, this proportion has reduced to a factor of 1.5 or less.

Note that values given above are indicative only!

3.4 Electricity price

The process of electricity market liberalisation led to an adjustment of electricity prices in Europe. Prices for end users consist of certain standardised components:

- energy and load price
- transmission price
- distribution price
- metering and billing price

Prices for industry and commerce are usually subject to bilateral contracts between supplier and end user. Large industry partly buys directly in the energy market. Electricity distribution companies usually tender for covering loss energy.

Prices may differ depending on the type and size of end user, the time when the electricity is consumed (e.g. night tariffs) and the voltage level at which electrical energy delivery and metering is made. VAT and other local or national taxes are added.

Electricity prices for industry in Europe vary between 60€/MWh to almost 120€ / MWh depending on country and industry size with the mean value of 90€/MWh for users consuming around 1GWh annually. Price evolution scenarios are not identical as EU energy policy may have different costs and different results but, in general, no dramatic increase is expected and after 2010/2015 prices should become rather stable.

Which price should be used when calculating TCO? For industrial and commercial users the contractual price, if possible with a price evolution scenario when changes are thought likely. For an electricity distribution company tendering for covering electricity losses, the price received under the tender should be used. For other electricity distribution companies, the question is more complex. First of all this should be long-term marginal cost not a price. It should not be an electricity cost having generation and transmission part included only. Marginal costs of distribution network should be included as well. If electricity prices reflect fair electrical energy supply business i.e. are based on cost calculation, the cost in question should be final end user price less profit of distribution company.

The real situation for electricity distribution companies is further complicated by regulation schemes, which do not allow for direct and full return on capital invested in - for example - more efficient transformers.

3.5 Time value of money – interest rate

Industrial investors have always in mind the rate of investment which should be applied when purchasing machines. This is either the weighted average cost of capital or the required rate of return on different investments. Investment in transformer is however essential to every business as it cannot be avoided. Applying too high rates with a lot of risk provisions is not advisable.

For electricity distribution companies, energy regulators usually recommend certain interest rates to value investments into electricity distribution assets. An indicative value is around 5% to 6 % real interest rate.

3.6 Lifetime

Lifetime is a crucial component of the TCO calculation. Transformers are durable and have long working lives. For financial purposes, the amortisation period for an investment in a transformer is often set at ten years. After that period, companies are no longer motivated to invest in new, more efficient, transformers since the 10 year-old one bears no cost and cannot be logically compared to the cost of a new investment. The average technical life of a transformer is 30 years or more; the SEEDT study has shown that more than 10% of the European transformer fleet is 40 years old or more. This 10% of the transformer fleet contributes more than 20% of the total no-load losses and more than 15% of load losses in European distribution companies.

Concluding, the minimum reasonable transformer lifetime in TCO calculations should be 20 years and arguments mentioned above indicate that applying 30 years lifetime in industry and commerce, and 40 years lifetime in electricity distribution companies can be justified as well

3.7 Loading profile and Load factor

Transformer loading conditions are probably most influential as far as optimum selection of distribution transformer losses is concerned. Very generally, for heavily loaded transformers, the focus should be on load losses while for those which are lightly loaded, it should be on no-load losses. What does heavily mean? Where is a difference?

Ideally, to calculate the load losses it would be necessary to integrate the squares of all momentary ratios of actual load to the rated load. This is practically impossible so the methodology to analyse load losses based on summation of energy consumed in transformers has been developed.

The formula to calculate load losses is presented below:

$$\sum P_k = \beta_S{}^2 \times \tau \times P_k \qquad [9]$$

where:

- ΣP_k - is sum of load losses in given period of time, usually one year
- β_S - is the peak load of a transformer in given period of time
- τ - is time duration of peak loss
- P_k - is rated load loss of a transformer

It should be noted that $(I_l/I_r)^2$ value from "B" factor calculation formula can be expressed by $\beta_S{}^2 \times \tau$

The sense of time duration of peak losses τ and its relation to time duration of peak load Ts is explained in Figure 6 below.

Ts represents the fraction of yearly time in which energy is transformed at peak load conditions equivalent to actual energy transformed. τs represents the fraction of yearly time of peak loss (which occurs at peak load) equivalent to actual load losses.

The equation describing this relation:

$$\tau_s = f(T_s) \quad [10]$$

is empirical and more than 20 different mathematical formulae exist to describe it.

Some of them propose the following formula:

$$\frac{\tau_s}{8760} = \left(\frac{T_s}{8760}\right)^X \quad [11]$$

with x varying around value of 1.7 to 1.8

Some other

$$\tau_s = A \cdot \left(\frac{T_s}{8760}\right) + B \cdot \left(\frac{T_s}{8760}\right)^2 \quad [12]$$

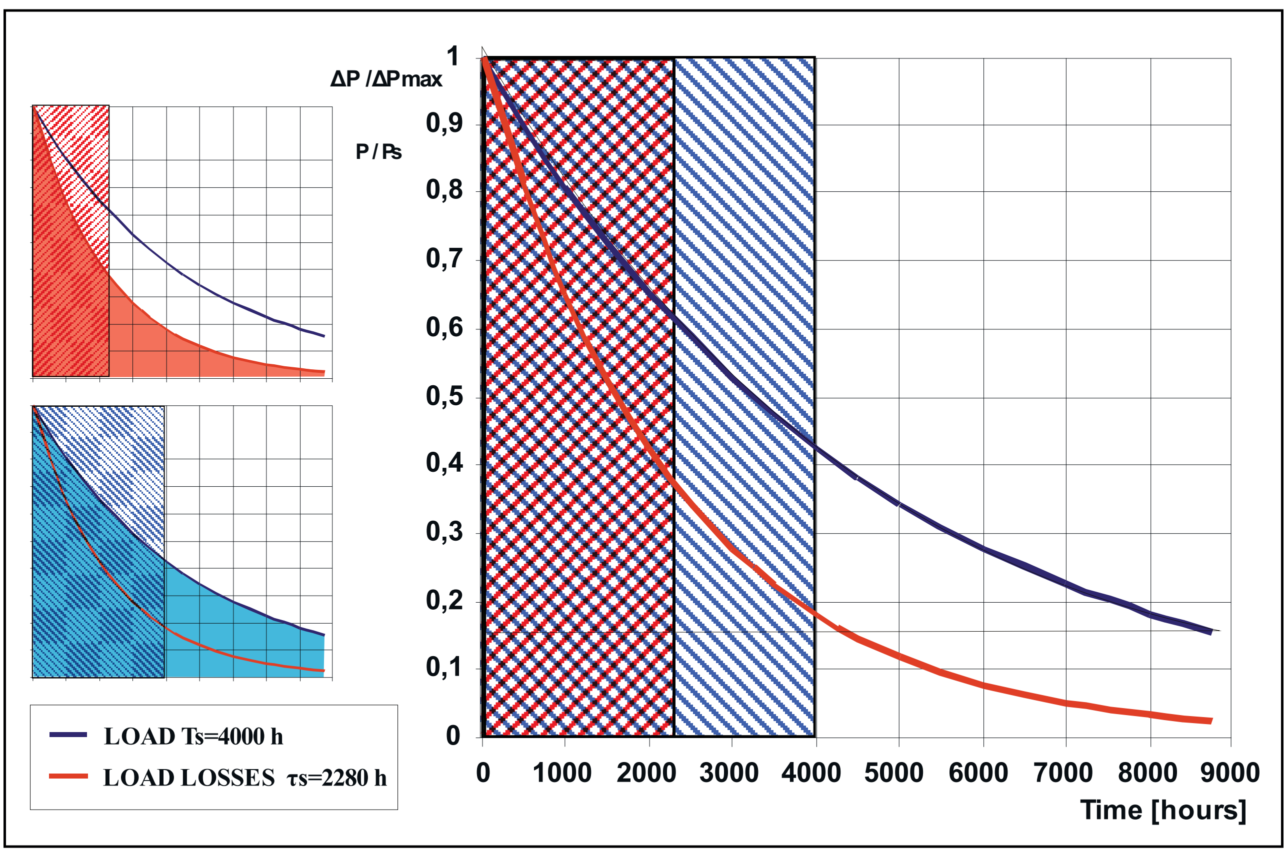
with A value between 0.15 to 0.5 and B value between 0.5 and 0.85 with additional feature of A+B = 1 (but there are exclusions from the last condition). The physical interpretation of all these formulae is hard and not always proven. SEEDT has analysed these formulas from the accuracy point of view. The x value which gives best results is 1.73 or A value of 0.3 and B value of 0.7.

Average loading values from SEEDT study for distribution companies are presented below:

Average load	18,86%
βs	0,53
Ts	0,36
τ	0,2

The average loading of distribution transformers in electricity distribution companies in the EU-27 is 18,9% and peak load is 0,53 (53%). The time of peak load is 0.36 and time of peak loss is 0.2. The definitions of loading parameters like time of peak load and peak loss are given under point 3.7. For comparison, industry transformers in EU-27 are loaded at 37.7% on average. Transformers in electricity distribution companies have such low loadings for many reasons, such as the anticipated high variability of load and the need to reserve capacity to provide resilience against failure of other equipment. Another reason could also be that users try to limit the loading on transformers that are in a poor technical condition (e.g. moist insulation and risk of bubbling effect). A further reason might be that distribution transformers are protected against short circuit, but not against overload or excessive temperature.

Figure 6. Explanation of relation between time of peak losses τ and time of peak load T



Industrial transformers are loaded higher than transformers owned by distribution companies. Average load is 37.7%, peak load above 0.7, while time of peak load and peak loss are about 0.3 and 0.15, which suggests that industry as a whole time capacity and subsequent load are fairly intermittent.

It is quite visible that τ value is around 50 to 60% of T value. Theoretically τ is 50% of T in situations where the T curve (blue) in Figure 6 is a straight line between peak load and zero (load is continuously and uniformly distributed between peak load and zero). On the contrary, when the T curve is a straight horizontal line (equal load all the year), both values T and τ will be equal.

Understanding the influence of loading conditions is necessary to calculate the "B" factor. In practical situations additional effort should also be made to anticipate loading changes over time.

3.8 Other aspects; technical (cos phi, harmonics), operational and environmental (climate change mitigation, ecodesign)

Apart from the parameters discussed in sections 3.3 to 3.7, which are inputs into the TCO calculation, other parameters, such as power factor (or reactive power), harmonics and even voltage level, have an influence on the energy efficiency of transformers and thus on the TCO results.

The influence of power factor and harmonics has already been explained in section 2.1. Voltage level also influences losses; simply reducing the voltage results in a reduction in flux density by almost the same proportion and core losses will be lower. Approaches to the design of transformers for different voltage ratios, but with the same losses, will be different. Higher ratios will naturally have higher losses.

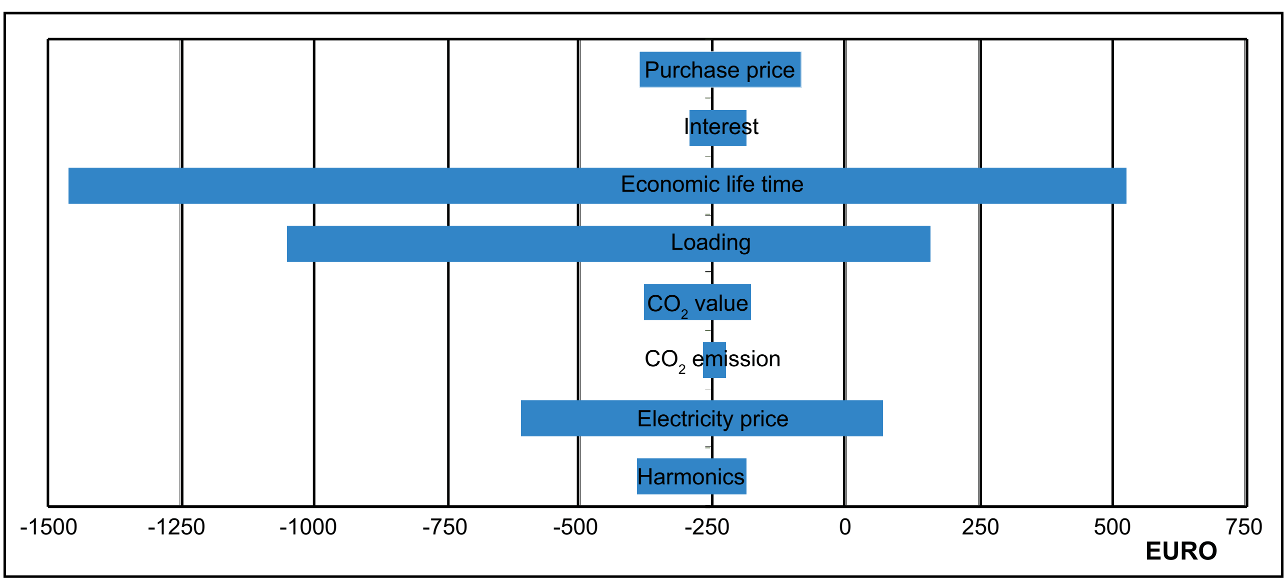
The mode of operation of a transformer may also have an influence on losses. Load imbalance induces a circulating current in a delta winding, so balancing loads results in lower losses. The balanced components of triple n harmonics also circulate in the delta winding of a transformer.

The environmental performance of transformers may have an additional bearing on the selection of a more efficient unit. Usually, the cost of CO_2 emission certificates are included in the calculation of the electricity price for electricity losses. Furthermore, purchasing an energy-efficient distribution transformer demonstrates the company's willingness to contribute to societal goals of reducing greenhouse gas emissions and increasing energy security in Europe. The ecodesign picture of typical distribution transformer depends in 90% or more on energy losies which result from transformer operation.

3.9 Sensitivity analysis

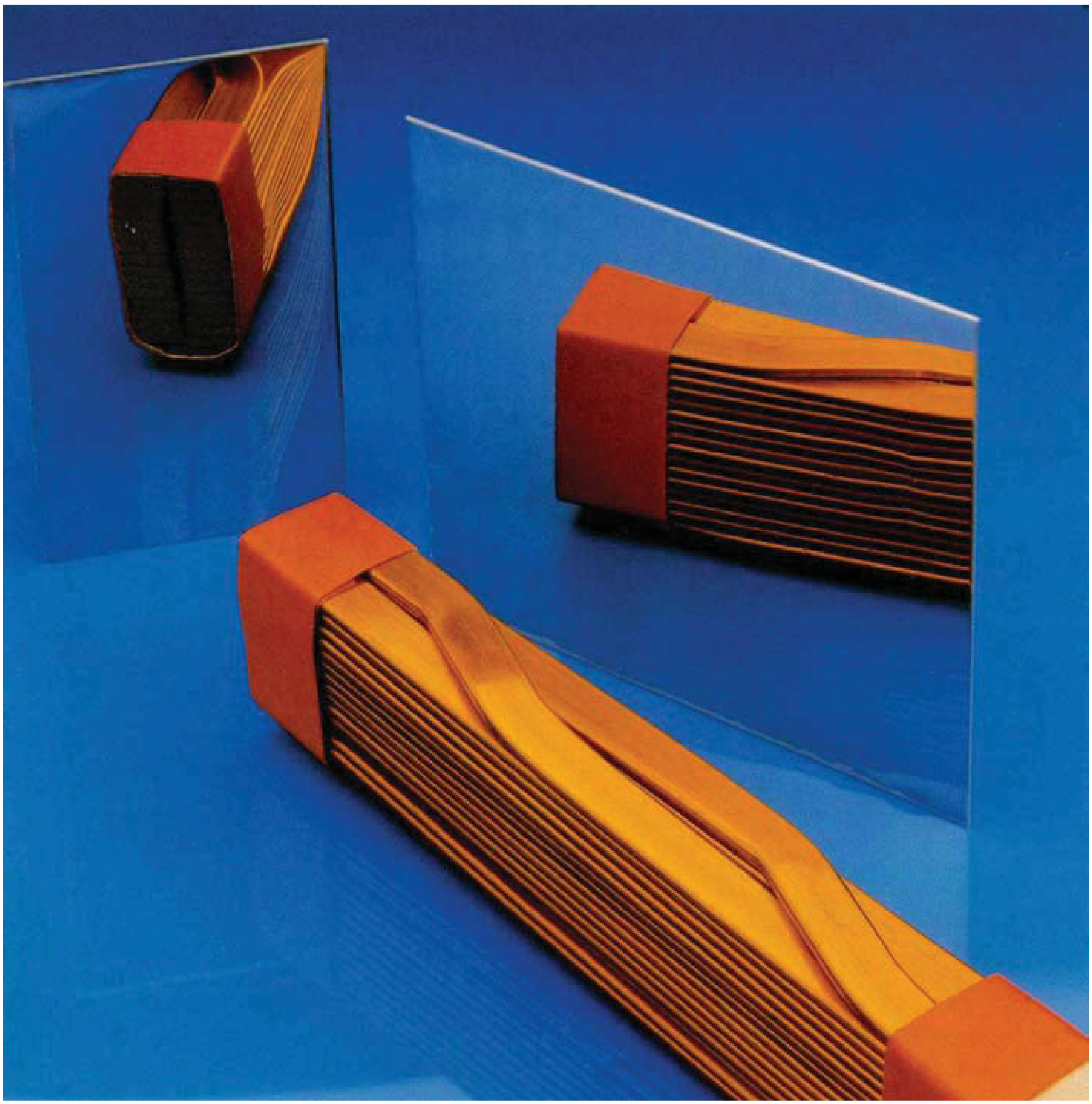
In 2002, KEMA performed a sensitivity analysis to demonstrate the extent to which changes in input data affect the result given by the capitalisation formula. This analysis was published in 'Energy Saving in Industrial Distribution Transformers'. [1]

Figure 7. Sensitivity analysis – capitalised cost [1]



A negative value means it is useful to choose the transformer with the low losses. When the result is positive, the transformer with the losses according to HD 538 (not very efficient) should be used. It is clear that most attention should be given to the economic lifetime, loading pattern and electricity price. Disregarding these values will certainly have a great influence on deciding which transformer should be used and could give a poorly optimised transformer. The influence of the purchase price of the transformer is relatively small and the remaining parameters even smaller.

Figure 8. Continuously transposed conductors (courtesy DKI)



4 Energy-efficient transformers

4.1 Traditional technologies

According to the SEEDT study the load losses have been reduced by about 30 to 50% during last 40 years. Copper conductors have replaced aluminium conductors due to their lower resistance and better tensile strength. Conductor design has also been upgraded by the introduction of continuously transposed conductors (a single conductor sub divided into several flat sub-conductors which are regularly transposed), reducing eddy current losses and allowing better packing density of the winding.

Also winding design and insulation improvements, making it thinner, allowing operation at higher temperature, adding some dielectric strength, also helped to reduce load losses by improving heat evacuation and increasing the conductor area.

As far as no-load losses are concerned, their reduction over the last 40 years can be called revolutionary having been reduced by factor 3 to 4. The replacement of hot rolled steel by cold rolled steel, about 40 years ago, has been followed by many material improvements leading to the development of low loss silicon steel.

The introduction of laser cutting for laminations has reduced burrs, improving insulation between laminations and reducing no-load losses. Laminations are also thinner down to 0.1 mm (usually between 0.2 and 0.3 mm) reducing no load-losses further.

4.2 Superconducting transformers

In a superconducting transformer the windings, made of a high temperature superconducting material (HTS), are cooled with liquid nitrogen at about 77K so that the resistance is almost negligible. Load losses, even after adding losses from nitrogen processing, can be reduced by 50%.

The use of HTS transformers on a larger scale is economically justified and will become more attractive as cooling systems improve and the cost of liquid nitrogen production falls. Another important factor is progress in the processing of long lengths of HTS conductors.

These transformers have smaller weight and volume and are more resistant to overload but cost about 150% to 200% of the price of conventional transformers.

So, in applications where weight is crucial (railway vehicles), transformers are much more "squeezed" (by forced cooling) to cut the weight. So efficiencies are much lower, and saving weight saves energy twice.

In our opinion, HTS transformers are suitable only in applications where the load losses make up a high proportion of the total losses, but are not yet ready for general use.

4.3 Amorphous transformers

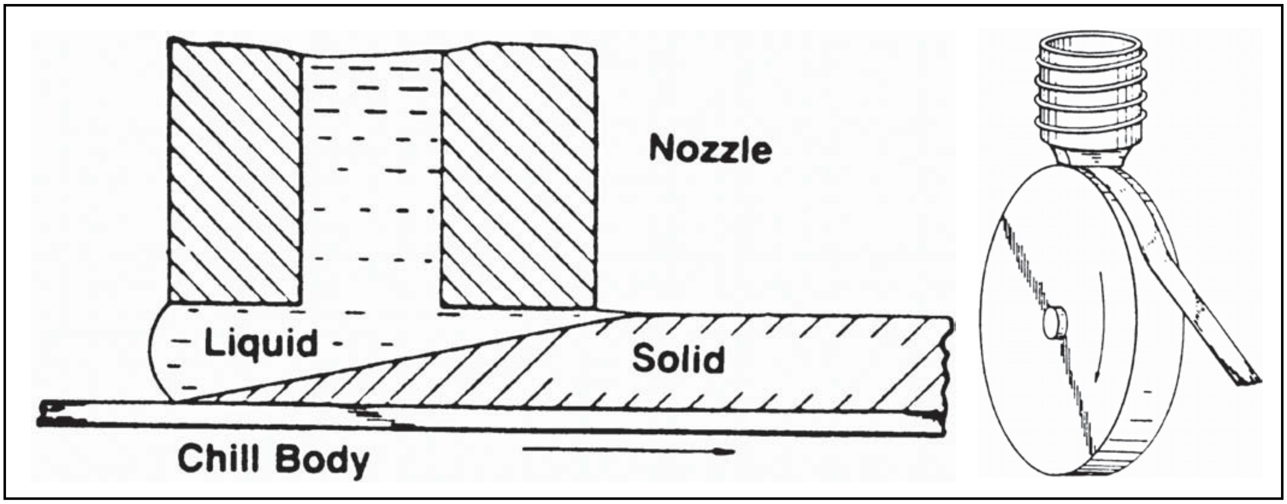
Amorphous alloys differ from conventional crystalline alloys in their magnetic and mechanical properties (such as hardness and strength).

Allied-Signal (US) spent more than 25 years and considerable R&D effort to achieve the commercial production of METGLAS® amorphous alloys. The Hitachi/Metglas group manufactures amorphous metals and is the biggest promoter of amorphous technology in distribution transformers. The worldwide market share of amorphous core transformers is quite significant with about 3 million single phase units and a few hundred thousand three phase units. It represents about 5% market share worldwide but this is not reflected in the European market. According to the SEEDT findings, the European market for amorphous transformers is just beginning. For example, ENDESA, the Spanish utility, has started to purchase amorphous transformers from outside Europe and is promoting this technology to local manufacturers.

To achieve an amorphous structure in a solid metal, the molten metal must be solidified very rapidly so that crystallisation cannot take place. The required rate for molten-metal cooling is about one million degrees Celsius per second. Figure 9 illustrates a method of manufacture of amorphous metal.

Amorphous metal core transformers improve electrical power distribution efficiency by reducing transformer core losses. The loss reduction ranges from 65 to 90% compared with typical silicon steel-based transformers used in Europe under sinusoidal load conditions. Amorphous technology is especially appropriate for transformers operating with low loading because the effect of harmonics on no-load

Figure 9. Casting amorphous metal – Courtesy Metglas, Inc



losses is reduced.

Lately, Metglas introduced a new amorphous material, HB1, (improved from the earlier SA1 material) which compensates for the deficiency of reduced saturation induction. The new material reaches saturation at induction levels close to those typical of traditional magnetic steel. This allows more compact cores and smaller and lighter transformers than older amorphous designs. It is also characterised by lower noise level, which was a perceived deficiency of the earlier amorphous metal.

The increase in the use of power electronics has resulted in a considerable amount of higher harmonic distortion in electricity systems. High frequency harmonics lead to increased transformer core losses, especially in distribution transformers that use conventional steel core materials. Amorphous metal core distribution transformers are uniquely suited to providing low loss performance under low loading and at higher frequencies. This is due to improved processing techniques that allow thinner and more consistent strip to be manufactured, as well as to the amorphous nature of the material that gives a higher electrical resistivity and low energy magnetic flux reversal.

From manufacturing cost perspective, amorphous transformers have only slightly higher or almost the same prices as highly efficient traditional

Figure 10. Amorphous transformer from the inside

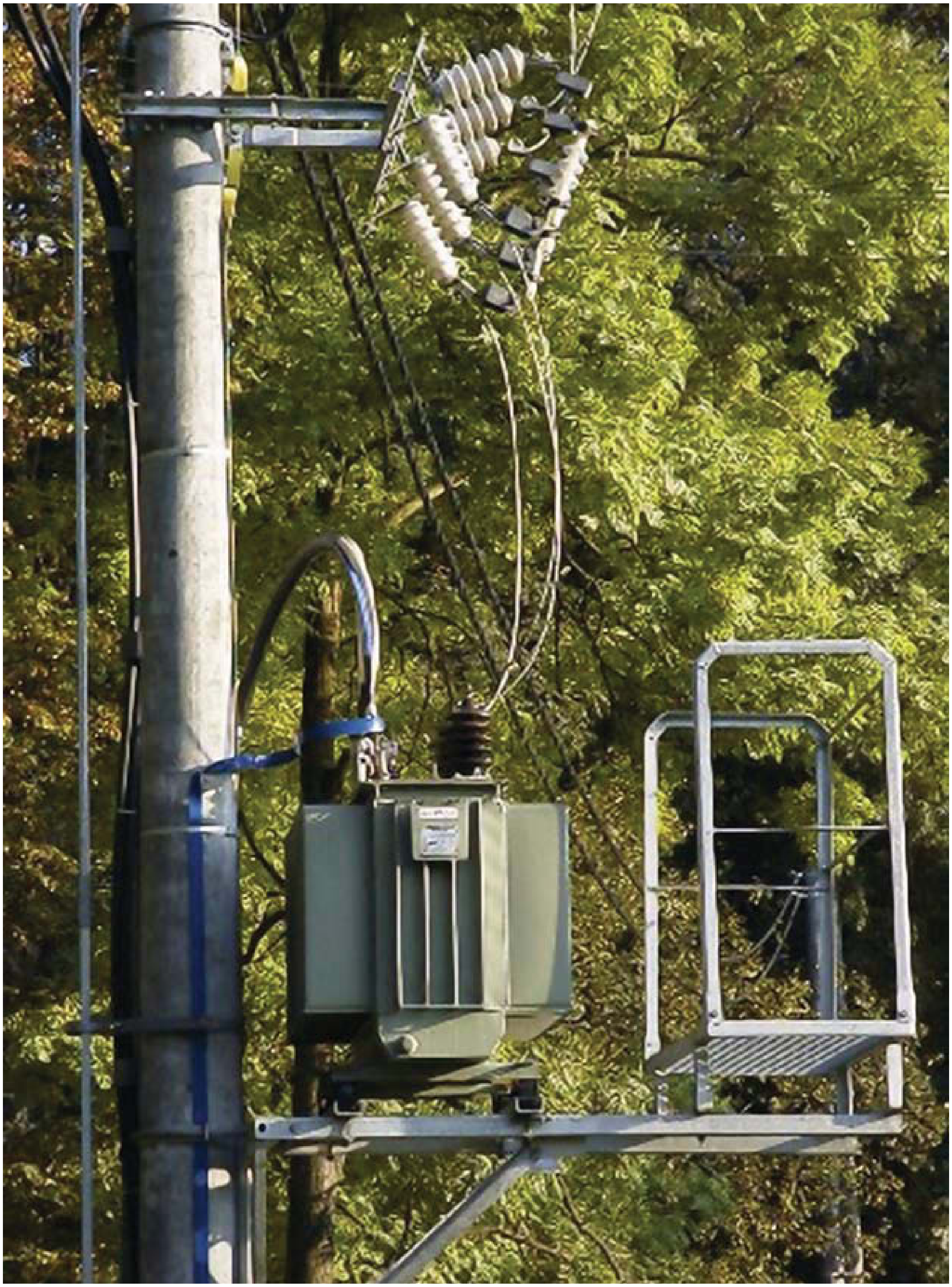
transformers.

Figure 10 shows a 1.6 MVA transformer, with an amorphous iron core, which was produced in 1998 for use in an engine plant in Waterford, Ireland. The load loss for this transformer is 18.2 kW, and the no-load loss as low as 384 W (80% lower than the typical losses of this size traditional transformer)

5 Policy support proposed by SEEDT

The main types of market actors having a direct influence on the decision to purchase a distribution transformer are electricity distribution companies and end users in industry and commerce, as well

Figure 11. Energy-efficient transformers can help our environment.



as the engineering firms, energy service companies and consultants who advise to them in the planning and tendering phases of procurement. These market actors face different barriers and obstacles with regard to the development, planning, sales and purchase of energy-efficient distribution transformers. They currently do not receive any support to realise energy-efficient targets.

Therefore, in order to adequately address and overcome these barriers and obstacles and to realise the existing energy efficiency potentials in this field, different policies and measures are needed. These policies and measures should be bundled in an appropriate policy-mix. The SEEDT project proposes:

- Changes in the regulatory schemes are needed to remove disincentives and provide incentives to increase the use of energy-efficiency of distribution transformers by electricity distribution companies. The income of, and investment by, electricity distribution companies is mainly controlled by regulation due to the fact that distribution grids are in most cases natural monopolies. Therefore, the regulation scheme will have a large impact on the investment decisions of electricity distribution companies, including whether or not to buy energy-efficient distribution transformers. In most European Member States, the regulatory mechanisms currently in place do not give any incentives and may even provide a disincentive to the purchase of energy-efficient distribution transformers by electricity distribution companies. Until changes are made to these regulatory regimes, additional fiscal or financial incentives will be needed to offset the current disincentives.
- A bundle of "soft" measures such as:
  - the requirement for clearly visible nameplate information,
  - a labelling scheme,
  - the inclusion in energy advice and audit programmes and
  - the provision of a toolkit for buyers.
- Would particularly address those market actors who lack information and knowledge or who tend to follow traditional purchasing routines that do not lead to least-cost solutions. This particularly affects small and medium industry and commerce, but also some smaller electricity distribution companies, engineering firms, energy service companies, energy consultants and planners.
- A European mandatory standard would effectively contribute to realising the saving potentials by addressing the same market actors as the bundle of "soft" measures. A mandatory standard makes it necessary that the regulation of electricity distribution acknowledges the higher investment costs needed for the more efficient distribution transformers and would help Europe to catch up with the developments in the US and in Asia.
- All market actors can implement demonstration or pilot projects together with manufacturers (and their suppliers), but larger companies, particularly, would benefit from increased availability of R&D support.

In total, very roughly estimated, up to about 10 TWh electricity savings could be realised, per year, by 2025, if the policies and measures proposed by the SEEDT project were broadly implemented, and if general development of the electricity system followed European trend scenarios. These potentials can be realised with technology already available today.

The calculations clearly show that changes in the regulatory schemes are most important to realise the existing saving potentials and to enable investments in transformers with the lowest lifecycle costs. As long as disincentives remain and positive incentives are missing, additional financial or fiscal incentives for electricity distribution companies should be introduced. The largest absolute electricity saving potentials in electricity distribution companies seem to be in France and UK, followed by Spain, Italy and Germany. Therefore, changes in the regulatory schemes are most urgent and should be implemented particularly in these countries.

Compared to saving potentials in other areas, the electricity saving potentials of distribution transformers seem to be small. Nevertheless, every contribution to climate change mitigation and energy security is necessary, particularly if it is economical. Since, in many cases, energy-efficient transformers are economical, it is recommended that the policies and measures proposed by the SEEDT project are implemented. In particular, if avoided external costs were included, or if electricity prices increase compared to the assumptions taken in the SEEDT project, the economic results would be even more favourable for energy-efficient distribution transformers.

6 Conclusions

Distribution transformers today can be more efficient than ever, and at the same time economical. Market reality shows that amorphous technology can be even more efficient and not excessively costly.

Electricity distribution companies and commercial and industrial users should use the methods discussed in Chapter 4 to make transformer purchasing decisions. Total cost of ownership and life cycle cost are important concepts, embodied in the capitalisation formula, that allow losses over the whole of the expected transformer life cycle to be taken into account.

The main barrier to the reduction of transformer losses in electricity distribution companies is regulation. It changes frequently - compared to the lifetime of infrastructure investments - and the changes do not really address transformer losses. The removal of real disincentives in existing regulation is necessary to make a first critical step in transformer efficiency improvement. Additional incentives to encourage investment in energy-efficient transformers should then follow to accelerate market transformation.

Transformer manufacturers offer many choices. Users can usually find sufficient information about transformer operating conditions and economic parameters to make rational decisions. Adequate policies and measures could support end users in this process.

Making appropriate investment in an energy-efficient transformer means reducing energy losses and reducing the environmental burden, together with reducing life cycle costs and thus increasing profitability.

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Annex

European Distribution Transformer Loss standards:

Table A.1 HD428/HD538

RATED POWER	Load Losses for Distribution Transformers				No-Load Losses for Distribution Transformers			
	OIL-FILLED (HD428) UP TO 24kV			DRY TYPE (HD538)	OIL-FILLED (HD428) UP TO 24kV			DRY TYPE (HD538)
	LIST A	LIST B	LIST C	12kV PRIMARY	LIST A'	LIST B'	LIST C'	12kV PRIMARY
kVA	W	W	W	W	W	W	W	W
50	1100	1350	875	N/A	190	145	125	N/A
100	1750	2150	1475	2000	320	260	210	440
160	2350	3100	2000	2700	460	375	300	610
250	3250	4200	2750	3500	650	530	425	820
400	4600	6000	3850	4900	930	750	610	1150
630 /4%	6500	8400	5400	7300	1300	1030	860	1500
630 /6%	6750	8700	5600	7600	1200	940	800	1370
1000	10500	13000	9500	10000	1700	1400	1100	2000
1600	17000	20000	14000	14000	2600	2200	1700	2800
2500	26500	32000	22000	21000	3800	3200	2500	4300

Table A.2 EN 50464-1
No load losses P (W) and sound power level (Lw) for U≤24 kV

Rated power	E0		D0		C0		B0		A0		Short circuit impedance
kVA	P0	LwA	P0	LwA	P0	LwA	P0	LwA	P0	LwA	%
	W	dB(A)	W	dB(A)	W	dB(A)	W	dB(A)	W	dB(A)	
50	190	55	145	50	125	47	110	42	90	39	4
100	320	59	260	54	210	49	180	44	145	41	
160	460	62	375	57	300	52	260	47	210	44	
250	650	65	530	60	425	55	360	50	300	47	
315	770	67	630	61	520	57	440	52	360	49	
400	930	68	750	63	610	58	520	53	430	50	
500	1 100	69	880	64	720	59	610	54	510	51	
630	1 300	70	1 030	65	860	60	730	55	600	52	
630	1 200	70	940	65	800	60	680	55	560	52	6
800	1 400	71	1 150	66	930	61	800	56	650	53	
1 000	1 700	73	1 400	68	1 100	63	940	58	770	55	
1 250	2 100	74	1 750	69	1 350	64	1150	59	950	56	
1 600	2 600	76	2 200	71	1 700	66	1450	61	1 200	58	
2 000	3 100	78	2 700	73	2 100	68	1800	63	1 450	60	
2 500	3 500	81	3 200	76	2 500	71	2150	66	1 750	63	

Table A.3 EN 50464-1
Load losses Pk (W) at 75 °C for Um ≤ 24 kV

Rated power	Dk	Ck	Bk	Ak	Short circuit impedance
KVA	W	W	W	W	%
50	1 350	1 100	875	750	4
100	2 150	1 750	1 475	1250	
160	3 100	2 350	2 000	1 700	
250	4 200	3 250	2 750	2 350	
315	5 000	3 900	3 250	2800	
400	6 000	4 600	3 850	3 250	
500	7 200	5 500	4 600	3 900	
630	8 400	6 500	5400	4600	
630	8 700	6 750	5 600	4 800	6
800	10 500	8 400	7 000	6 000	
1 000	13 000	10 500	9000	7 600	
1 250	16 000	13 500	11 000	9 500	
1 600	20 000	17 000	14 000	12 000	
2 000	26 000	21 000	18 000	15 000	
2 500	32 000	26 500	22 000	18 500	

Table A.4 EN 50464-1
Load losses Pk36 (W) at 75 °C for Um = 36 kV

Rated power	Ck36	Bk36	Ak36	Short-circuit impedance
KVA	W	W	W	%
50	1 450	1 250	1 050	4 or 4,5
100	2 350	1 950	1 650	
160	3 350	2 550	2 150	
250	4 250	3 500	3 000	
400	6 200	4 900	4 150	
630	8 800	6 500	5500	
800	10 500	8 400	7 000	6
1 000	13 000	10 500	8 900	
1 250	16 000	13 500	11500	
1 600	19 200	17 000	14 500	
2 000	24 000	21000	18 000	
2 500	29 400	26 500	22 500	

Table A.5 EN 50464-1
No load losses P036 (W) and sound power level (Lw (A)) for Um = 36 kV

Rated power	C036		B036		A036		Short-circuit impedance
kVA	P0	LwA	P0	LwA	P0	LwA	%
	W	dB(A)	W	dB(A)	W	dB(A)	
50	230	52	190	52	160	50	4 or 4,5
100	380	56	320	56	270	54	
160	520	59	460	59	390	57	
250	780	62	650	62	550	60	
400	1 120	65	930	65	790	63	
630	1 450	67	1 300	67	1 100	65	
800	1 700	68	1 500	68	1 300	66	6
1 000	2000	68	1 700	68	1 450	67	
1 250	2 400	70	2 100	70	1 750	68	
1 600	2 800	71	2 600	71	2 200	69	
2 000	3 400	73	3 150	73	2 700	71	
2 500	4 100	76	3 800	76	3 200	73	

SEEDT

Intelligent Energy Europe

Strategies for development and diffusion of Energy Efficient Distribution Transformers

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- Wuppertal Institut für Umwelt Klima, Energie GmbH im Wissenschaftszentrum Nordrhein-Westfalen
- THELCON Constructions Ldt

Leonardo ENERGY

www.leonardo-energy.org

Intelligent Energy Europe

Pad-Mounted Transformers

Contents

Pad-Mounted Transformers

Specifications

See Eaton's *Product Specification Guide*, available on CD or on the Web.

	1995	2010
CSI Format	**Section 16321**	**Section 26 12 19**

Typical Pad-Mounted Transformer

Three-Phase Pad-Mounted Transformers

Typical Pad-Mounted Transformer

Introduction

Eaton's three-phase pad-mounted transformer is offered in a variety of designs and configurations. The following pages describe the standard designs and the common options that are available.

Some special designs and options may require additional engineering, factory coordination, unusual application requirements or special manufacturing needs.

Higher impedances limit secondary fault currents such that coordination with secondary low voltage molded-case circuit breakers is usually possible. (Low impedances are also available if required for paralleling, and so on.)

Standard color is pad-mounted green [Munsell® Green (#7GY3.29/1.5)]. ANSI #24, 61 and 70 are available as options.

Application

Liquid-filled, three-phase, commercial pad-mounted distribution transformers are designed for servicing such underground distribution loads as shopping centers, schools, institutions and industrial plants. They are available in both livefront and deadfront construction, for radial or loop-feed applications, with or without taps.

Industry Standards

Pad-mounted transformers meet industry standards: IEEE® C57.12.00, IEEE C57.12.34, IEEE C57.12.28, IEEE C57.12.29, IEEE C57.12.70, IEEE C57.12.80, IEEE C57.12.90, IEEE C57.91 and NEMA®.

Ratings

- 75–5000 kVA
- High voltages (primary):

4160 Grd. Y/2400 through 34,500 Grd. Y/19,920	2400Δ through 34,500Δ

- HV Taps: 2–2-1/2% above and below normal, or 4–2-1/2% below normal
- Standard BIL levels:

kV Class	BIL (kV)
1.2	30
2.5	45
5.0	60
8.7	75
15.0	95
25.0 Grd. Y Only	125
25.0	150
34.5 Grd. Y Only	150
34.5	150

- Low voltages (secondary). All voltages through 5 kV class
- UL labeling available
- Factory Mutual labeling available

Design Impedances

Impedances are supplied to meet IEEE C57.12.00 standards. Customer-specified impedances are available. (Subject to IEEE/ANSI ±7.5% impedance tolerance.)

- Typical design impedances:

kVA	%Z
75	4.00
112-1/2	4.00
150	4.00
225	4.00
300	5.00
500	5.00
750	5.75
1000	5.75
1500	5.75
2000	5.75
2500	5.75
3000	5.75
3750	5.75
5000	5.75

Note: Subject to NEMA/IEEE ±7.5% impedance tolerance.

Note: Non-standard design impedance may be obtained by contacting Eaton.

Application Limitations

The transformers described herein are designed for the application conditions normally encountered on electric power distribution systems. As such, they are suitable for use under the "usual service conditions" described in IEEE Standard C57.12.00 general requirements for liquid-immersed distribution, power and regulating transformers.

Consult Eaton for unusual service conditions such as:

- Abnormal environmental conditions
- Unusual transient voltages present on the source voltage
- Frequent or planned through-fault duty
- Planned overloading unless in strict accordance with the IEEE loading guide (C57.91)
- Motors whose horsepower rating is greater than half the transformer kVA rating
- Unusual frequency of impact loading may occur when supplying welding apparatus, electric arc furnaces or motors with cyclical loads
- Loads involving abnormal harmonic or DC current that may result where appreciable load currents are controlled by solid-state or similar devices

These lists do not purport to cover all unusual conditions and applicable limitations. Other "unusual service conditions" are described in IEEE Standard C57.12.00.

Table 17.0-1. Temperature Guarantees

Description	Ambient ①	Rise ②③
Standard	30°C	65°C
Optional	30°C	55°C

① 30°C average ambient temperature of cooling air not to exceed 40°C maximum over any 24-hour period.

② Degree rise is the average winding temperature rise by resistance.

③ A dual temperature rating of 55°/65°C adds 12% additional continuous capacity to the base kVA rating of the transformer.

Note: Altitudes not to exceed 3300 ft (1006m).

Fluids—Liquid Dielectric

The choice of fluid, mineral oil or less flammable natural esther fluid (BIOTEMP®, Envirotemp FR3®) is made based upon site conditions and proximity to facility walls, windows and flammable structures, and environmentally sensitive areas.

Note: For additional information about transformer applications and types of insulating fluids, see **Tab 14**.

Standard Features

① Four lifting hooks

② Bolted-on terminal compartment with removable front sill

③ Hinged, lift-off cabinet doors

④ Interlocked hex-head or penta-head bolt padlock handle operates a cam assembly that is part of the three-point door latching mechanism

Hex-head or penta-head bolts must be removed from the flange formed on the steel high/low barrier before the HV door can be opened—not shown

Removable neutral ground strap—not shown

⑤ Tank ground pads (1 in HV, 1 in LV)

⑥ Steel high/low voltage compartment barrier

⑦ Nameplate

⑧ Fill plug and self-actuating pressure relief device

⑨ Externally operated no load tap changer

⑩ Drain valve and sampling device

Options

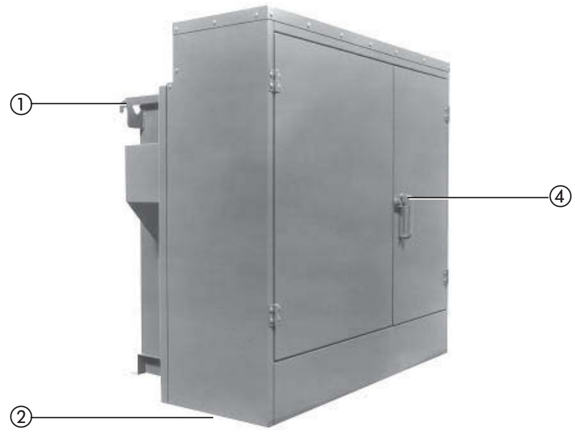
Primary Termination

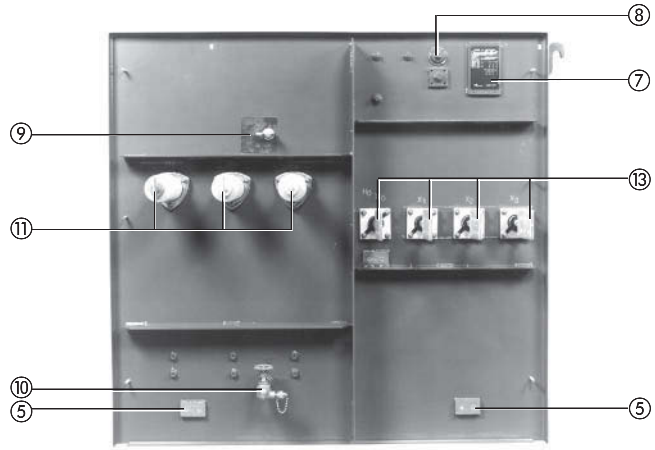
⑪ For livefront construction, externally clamped high voltage porcelain bushings double eye-bolt or spade for cable (75–225 kVA) or a single eyebolt or spade for cable (300–1500 kVA). Spade bushings are also offered

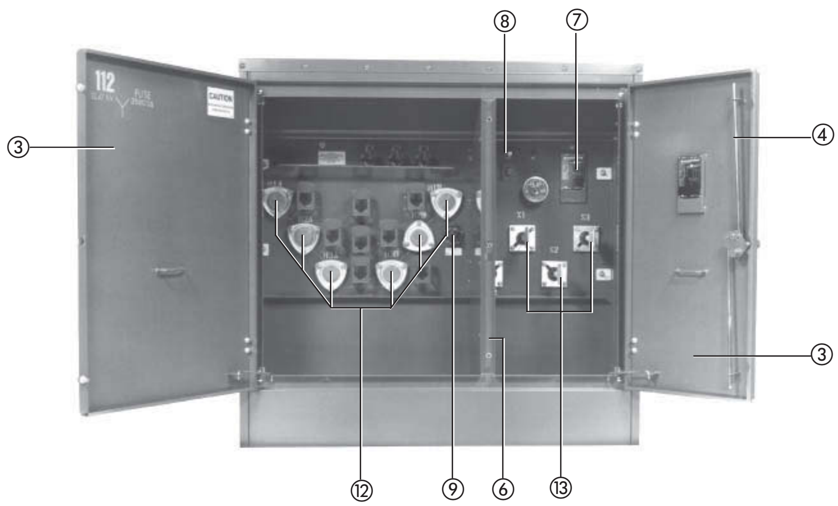
⑫ For deadfront construction, externally clamped high voltage epoxy bushing wells for 200A loadbreak, or 600A non-loadbreak inserts

Secondary Termination

⑬ NEMA spade terminals







Primary and Secondary Compartment Features

Transformer Cooling Classes

Table 17.0-2. Fluids Advantages and Disadvantages

Advantages	Disadvantages
Mineral Oil	
■ Low transformer cost ■ Good dielectric performance ■ Low maintenance cost ■ Good heat dissipation ■ Good cold climate performance ■ Preventative maintenance—DGA historical data available	■ Higher installation cost ■ Vaults required for indoor installations per code low fire point—160°C ■ <30% biodegradability
Silicone Fluid	
■ Low heat release ■ Reduced smoke ■ Low flame ■ Self extinguishing ■ Good dielectric performance ■ Low toxicity ■ Moderate viscosity ■ High stability	■ Non-biodegradable ■ Not suitable for use with internal Bay-O-Net fuses ■ Transformer cost ■ Disposal cost ■ Viton gaskets required ■ Retrofil applications ■ High transformer cost ■ High moisture absorption
Environmentally Friendly Fluids	
■ High fire point—360°C ■ High flash point—343°C ■ Compatible with mineral oil ■ Excellent retrofil fluid (compatible with oil up to a 10% mixture) ■ Excellent dielectric performance ■ 97% biodegradable ■ Renewable resource ■ Greater tolerance to moisture	■ Transformer cost (lower than silicone fluid) ■ Pour point (–15° to –25°C) transformer energized with full load with top oil temperature at –50°C with no problems—no crystals formed at –68°C

Table 17.0-3. Fluid Properties Comparison

Property	Mineral Oil	Silicone Fluid	Environmentally Friendly Fluids
Specific gravity	0.91	0.96	0.91
Flash point °C	145	300	343
Fire point °C	160	330	360
Viscosity (cSt.) 100°C	3	16	10
40°C	12	38	45
0°C	76	90	300
Pour point °C	–40	–55	–15 to 25
Dielectric strength, kV	30	4.3	49
Dissipation factor (%) 25°C	0.05	0.01	0.025–0.05
Permittivity	2.2	2.7	3.1
Resistivity	10^{13}	10^{14}	10^{13}
Oxidation inhibitor	Optional	No	Required
Biodegradability	<30%	0%	97%

NEC Requirement Guidelines for the Installation of Listed Less-Flammable Liquid-Filled Transformers

NEC (NFPA) Recognition

These guidelines focus on the requirements of Article 450.23 of the National Electrical Code® (NEC®) for the installation of less-flammable liquid-insulated transformers. Less-flammable liquids are used in transformers where an extra margin of fire safety is important. Typical applications include installations indoors, on rooftops, near buildings, bush and forest fire prone areas and in pedestrian traffic areas.

Less-flammable liquids, also known as high fire point liquids, are transformer dielectric coolants that have a minimum fire point of 300°C. Commonly used fire-resistant fluids include dimethysiloxane and ester-based fluids. Two Nationally Recognized Testing Laboratories (NRTL); Underwriters Laboratories (UL) and FM Approvals (FM) currently list less-flammable liquids. They also list less-flammable liquid-filled transformers.

Less-flammable liquid-filled transformers were formally recognized by the NEC for indoor installation in 1978. In 1990, the NEC integrated specific less-flammable transformer requirements for outdoor installations for Article 450.23, in effect recognizing less-flammable transformers as inherently safer than conventional oil-filled transformers. Less-flammable transformers, long recognized as an additional safeguard for indoor installations, are becoming increasingly recognized for outdoor applications as well.

General NEC Requirements

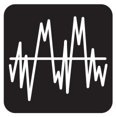
The requirements and options for the different types of outdoor installations are outlined in **Table 17.0-4**. These guidelines also summarize the UL Classification and FM Approvals installation requirements for less-flammable fluids referred to as "listing" requirements in NEC 450.23.

In cases where the transformer installation presents a fire hazard, one or more of the following safeguards will be applied according to the degree of hazard involved:

1. Space requirements.
2. Fire-resistant barriers.
3. Automatic fire suppression systems.
4. Enclosures that confine the oil of a ruptured transformer tank.

NEC Article 450.28, Modification of Transformers, requires that when modifications are made to transformers in existing installations that change the transformer type, the transformers must be marked to show the type of insulating liquid installed and the installations must comply with current requirements of the NEC. Examples of changes include replacing a complete transformer (retrofitting) or replacement of the liquid only (retrofilling). Askarel (PCB) and conventional mineral oil-filled transformers are frequently retrofitted or retrofilled using less-flammable liquids. NEC 110.34 sets minimum clear work space dimensions around transformers.

Seismic Qualification



Refer to **Tab 1** for information on seismic qualification for this and other Eaton products.

Table 17.0-4. NEC Article 450.23 Requirements

Installation Type	NEC Requirements
Outdoor Installations	
Non-combustible building ① and no combustible materials stored in area.	Either of the following listing requirements ②: ■ Underwriters Laboratories ■ FM approvals
Combustible building ① or combustible materials stored in area.	In accordance with NEC Article 450.27, oil-insulated transformers installed outdoors, i.e., space separation, fire barriers or water spray systems.

① Refer to NFPA 220-1999 for definition of non-combustible Type I and II building construction.

② Fine Print Note, Article 450.23, (B) (1) states: "Installations adjacent to combustible material, fire escapes, or door and window openings may require additional safeguards such as those listed in Article 450.27."

Primary Overcurrent Protection Options

Primary protective devices are applied to distribution transformers in order to:

1. Prevent injury to personnel.
2. Prevent or minimize damage to equipment.
3. Improve the continuity of service by selectively controlling outages.

Factors that affect the protection scheme are:

1. Industry standard.
2. Customer's specification.
3. Customer's system configuration (available fault current, system voltage, system connection, and so on.)
4. Availability of equipment.

The first consideration in determining the ampere rating of a fuse is to verify that the fuse in question is capable of withstanding typical inrush currents without element damage. When a transformer is energized, it is exposed to very large currents for very short periods of time. These currents are known as magnetizing inrush (or fuse withstand) and cold load pickup, and are a result of the transformer's magnetic circuit, the electrical system configuration and the connected load.

The second consideration for selecting the fuse ampere rating is the maximum load current the fuse is expected to carry without damage. Transformer fusing tables available from the manufacturer normally list the range of overload provided. If the longtime minimum melt current for a particular fuse size is known, it can be compared to the transformer rated current to determine the exact amount of overload permitted. An ambient of 25°–40°C is generally assumed for application tables. Care should be taken when fuses are applied in higher ambient conditions, which will reduce the amount of overload permitted. An example of a high ambient condition used frequently in distribution transformers is that of current limiting fuses in dry-well canisters. To accommodate the overload and derating factors referred to, the following ratios are used on general-purpose CL fuses.

Nameplate current rating of fuse/nameplate current rating of transformer = 1.25 for enclosures surrounded by air (EFD, clip mount, arc-strangler) or = 1.35 for enclosures surrounded by oil (canisters).

Derating factors are not applied to expulsion or backup CL fuses because high temperature has minimal effect on their operation.

Finally, it is necessary to verify that the fuse current rating under consideration will, in fact, operate prior to the transformer sustaining any permanent thermal damage (conductor or insulation burning or melting). This is done by comparing the total clearing characteristics of the fuse in question with the IEEE (I^2t) damage line.

It is important that the total clearing characteristics of the device under consideration lie to the left of the damage line for all expected values of fault current. Note that most fuse characteristics will cross the damage line at some point. It is important to make this occur at the lowest possible value of the current.

The interrupting rating of a device is a measure of the maximum symmetrical fault current at which the device can successfully clear a fault condition without excessive damage to itself, the equipment it is protecting or the surrounding environment.

It is extremely critical that the interrupting rating of a device be greater than the maximum available symmetrical fault current. For devices applied to the transformer primary, the maximum fault current must be supplied by the utility because this value is dependent on the electrical system configuration.

Protective Fuse Link

- Internal, oil-immersed, expulsion type
- Sized to operate only in the event of a winding failure, isolating the transformer from the primary system
- Interrupting rating is 3500A at 8.3 kV

Protective Fuse Link

Bay-O-Net-Type Fuse

- Oil immersed, expulsion type
- Drawout for fuse replacement
- Hookstick operable, loadbreak design
- Available with either overload-sensing or fault sensing
- 3500 AIC at 8.3 kV, 1800 AIC at 15.5 kV

Bay-O-Net fuse assemblies are used to protect transformers and distribution systems. They are designed for use in pad-mounted or sub-surface distribution transformers filled with transformer oil or approved equivalent. The assemblies combine the ease of hotstick operation with the safety of deadfront construction.

Removal of the fuse holder from the assembly indicates that the apparatus is electrically disconnected. It also allows convenient fuse element inspection and replacement. When typical safety practices are followed, the assemblies can be load-break operated for working on the transformer secondary; changing distribution voltage with dual voltage switches or tap changers; or disconnecting the apparatus from the line.

The optional Flapper™ Bay-O-Net Assembly (available as sidewall-mounted only) includes a flapper valve inside the housing, which closes when the fuse holder is removed, thus minimizing oil spillage.

Table 17.0-5. Bay-O-Net Fuse Electrical Ratings

kV Rating	Specification
Electrical Ratings	
150	BIL and full wave crest
50	60 Hz, AC, 1-minute withstand
Maximum Single-Phase Interrupting Ratings ①	
8.3	3000A rms asymmetrical—cover mount
	3500A rms symmetrical—sidewall mount
15.5	2500A rms asymmetrical—cover mount
	2500A rms symmetrical—sidewall mount ②
23.0	1000A rms asymmetrical—cover mount
	1000A rms symmetrical—sidewall mount
Load Break Ratings (Phase-to-Phase at 80% PF)	
10.0	160A
15.5	150A
26.7	80A
34.5	50A

① With RTE Bay-O-Net fuse links only.
② Except high ampere overload links, which are rated at 2000A symmetrical.

Bay-O-Net-Type Fuse Assembly

Current Limiting Fuses

- Air immersed in drywell canister
- Drawout for fuse replacement
- Hookstick operable
- Limits both the current magnitude and energy associated with low impedance faults
- Effective in minimizing the probability of tank rupture due to internal, high energy, low impedance faults
- Available fuse interrupting ratings of 25,000–50,000A rms (symmetrical)
- Maximum fuse ampere rating at 15 kV (2–50A fuses)

Partial Range Current Limiting Fuses

- Oil immersed, internally block mounted
- Applied in series with an expulsion type fuse (Bay-O-Net type—see above)
- Protection against tank rupture

The current-limiting backup fuse is used in series with low-current primary protection devices such as a Bay-O-Net fuse.

The fuse's highly efficient current-limiting section minimizes the effects of high fault current stresses on equipment and the distribution system. Its minimum interrupting rating is coordinated with that of a low current interrupter to avoid undesirable low current operation; yet its maximum interrupting rating will clear the highest fault currents likely to occur. Higher continuous current ratings can be achieved by connecting two fuses in parallel.

The current-limiting fuse is used in transformers to protect and isolate faulted equipment. When connected in series with a low current primary protection device, the fuse becomes an element of a two-part protection system that gives a full range of fault protection.

Drawout Current Limiting Fuse Canister

Drawout Current Limiting Fuse Loadbreak Assembly

Table 17.0-6. Current-Limiting Backup Fuse Electrical Ratings and Characteristics

Fuse Type	Maximum Interrupting Current
Backup (partial range) "C" rated	50,000A rms symmetrical ①

① See **Table 17.0-8** for fuses with ratings other than 50,000 amperes rms symmetrical.

This two-part system provides low current protection with the replaceable expulsion fuse and it adds the energy-limiting protection of a current-limiting fuse. Together, they coordinate easily with upstream and downstream devices.

Table 17.0-7. Two- and Four-Position, Load Break, Sectionalizing Switch

Ratings	200 Ampere	300 Ampere	600 Ampere
Voltage kV phase—phase maximum	35	25	15
Voltage kV phase—ground maximum	21.1	15.2	8.3
Impulse withstand kV	150	125	95
60 Hz 1-minute withstand kV	50	40	34
Continuous current	200	300	600
Loadbreak	200	300	600
Momentary, 10 Hz	10,000	10,000	15,000
2-second	10,000	10,000	10,000
3-shot make and latch ampere	6000	10,000	10,000

Table 17.0-8. Current-Limiting Backup Fuse Interrupting Ratings

Continuous Ampere Current Rating	Minimum Interrupting (Amperes)	Minimum Melt I^2t (A^2x s)	Maximum Clear I^2t (A^2x s)
8.3 kV ②			
30	100	1200	5800
40	125	1800	8200
50	165	4100	16,500
65	300	6200	26,700
80	200	9600	42,900
100	350	17,100	62,000
125	375	30,500	97,800
150	450	43,900	148,000
165	500	68,600	245,000
250 ③	800	122,000	369,000
300 ③	1000	175,600	566,000
330 ③	1200	274,400	875,700
15.5 kV ④			
30	100	1200	7600
40	150	1800	11,000
50	200	4100	23,000
65	350	6200	33,000
80	250	9600	52,900
100	350	17,100	93,800
125	400	30,500	125,700
150	450	43,900	162,300
165	—	—	—
250 ③	800	122,000	408,000
300 ③	1000	175,600	660,700
330 ③	—	—	—
23 kV ⑤			
30	125	1200	10,500
40	200	1800	15,100
50	325	4100	34,300
65	400	6200	38,400
80	300	9600	68,300
100	400	17,100	121,000
125	500	30,500	149,700
150	600	43,900	196,700
165	700	68,600	307,300
250 ④	900	122,000	391,100
300 ④	1200	175,600	563,000
330 ④	1400	274,400	882,000

② The 8.3 kV, 30–100A ratings have been tested and approved for application at 9.9 kV. The maximum interrupting capacity for the 65–100A ratings at 9.9 kV is 18 kA.
③ Parallel fuses.
④ The 15.5 kV, 30–125A and 250A ratings have been tested and approved for application at 17.2 kV. The maximum interrupting rating for the 15.5 kV fuse, 30–125A at 17.2 kV is 43 kA. For the 15 kV, 250A fuse at 17.2 kV, the maximum interrupting rating is 12 kA.
⑤ The maximum interrupting rating for the 23 kV fuse, 80–165A, 300 and 330A, is 30 kA. For the 23 kV, 250A fuse, the maximum interrupting rating is 12 kA.

Primary Switching Options

Eaton's oil-immersed switches are available for radial or loop-feed system switching in three current ratings. The three-phase gang-operated switch has a spring-loaded mechanism for loadbreak and latch operation. The switch is mounted near the core and coil assembly, for low cable capacitance; and with simultaneous three-phase switching, the possibility of ferroresonance is reduced. Available in ratings through 600A at 15 kV, 300A at 25 kV, and 200A at 35 kV.

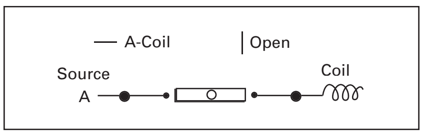


Figure 17.0-1. Two-Position Switch

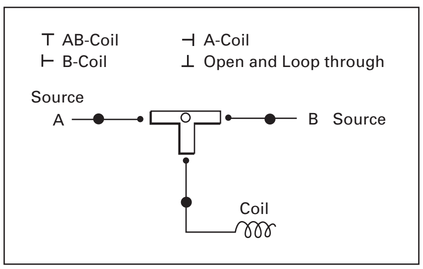
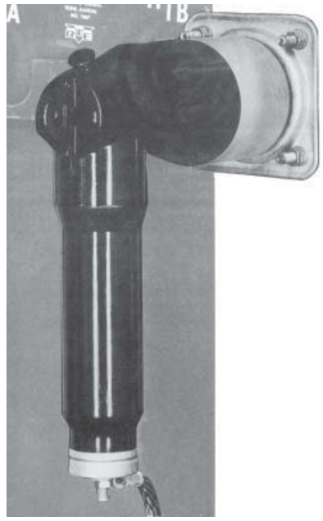


Figure 17.0-2. Four-Position Switch (Loop Feed) "T Blade"



Deadfront Elbow Arrester

Surge Arresters

Eaton distribution class surge arresters are supplied on transformers when specified. Transformers with livefront configuration have mounting nuts welded on the tank wall for arrester mounting.

Metal Oxide Varistor (MOV) Deadfront Arrester

Surge protection is available without losing deadfront construction in the cabinet. The Eaton type MOV arrester is completely deadfront. It is compact, and is usable wherever a loadbreak elbow can be used.

The highly nonlinear characteristics of the varistor elements provide more precise and predictable operating characteristics. The MOV arrester is capable of withstanding temporary overvoltages, so that ratings can be reduced, providing improved margins of protection.

Because it is fully shielded and deadfront, it is mountable at any angle and submersible. Its durable rubber construction means there are no fragile porcelain skirts to chip or crack. The MOV arrester is available in ratings from 3 kV to 27 kV.

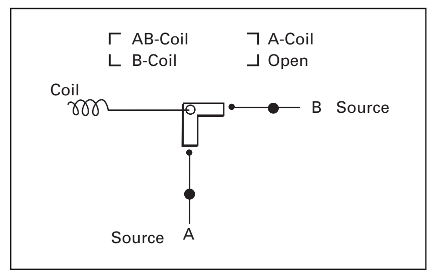


Figure 17.0-3. Four-Position Switch (Loop-Feed) "V Blade"

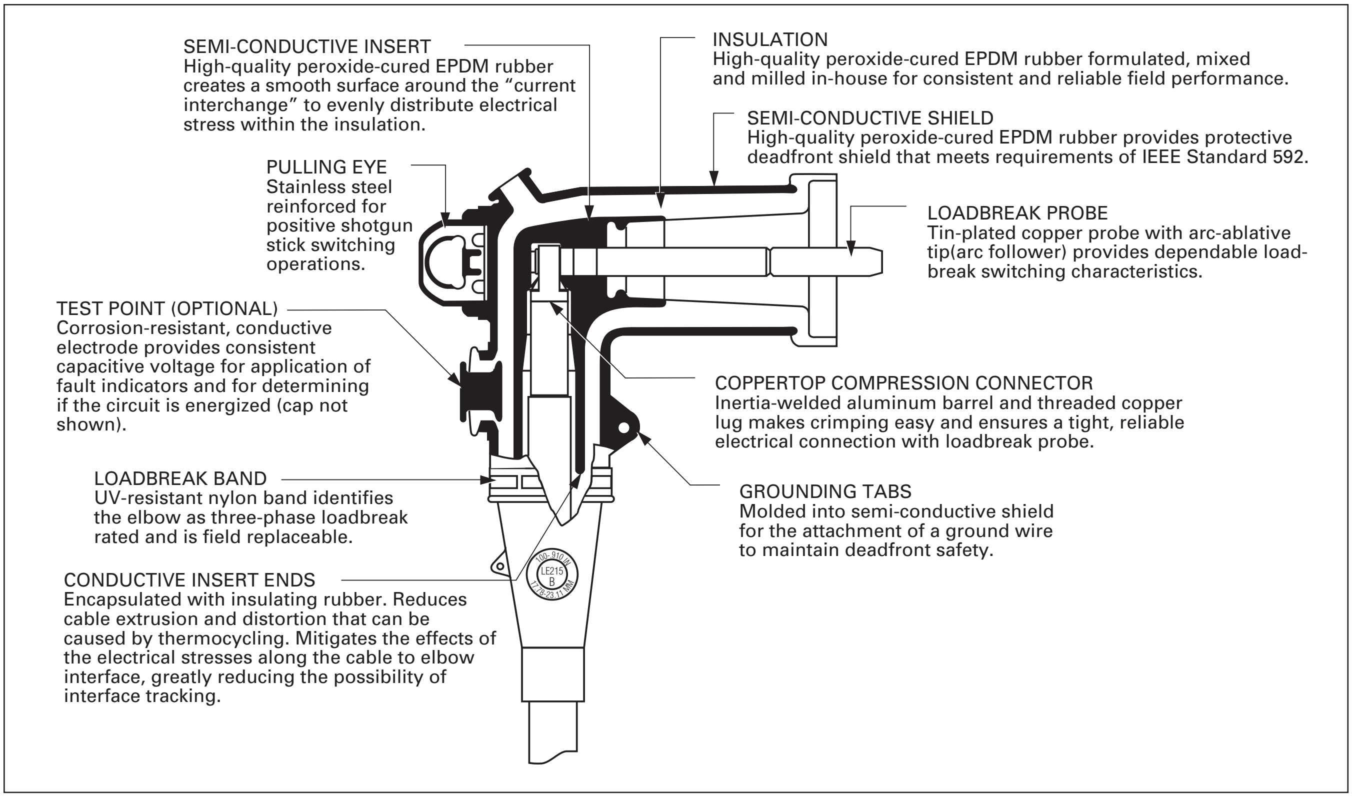


Figure 17.0-4. 200A, 15 kV Class Loadbreak Elbow Connector

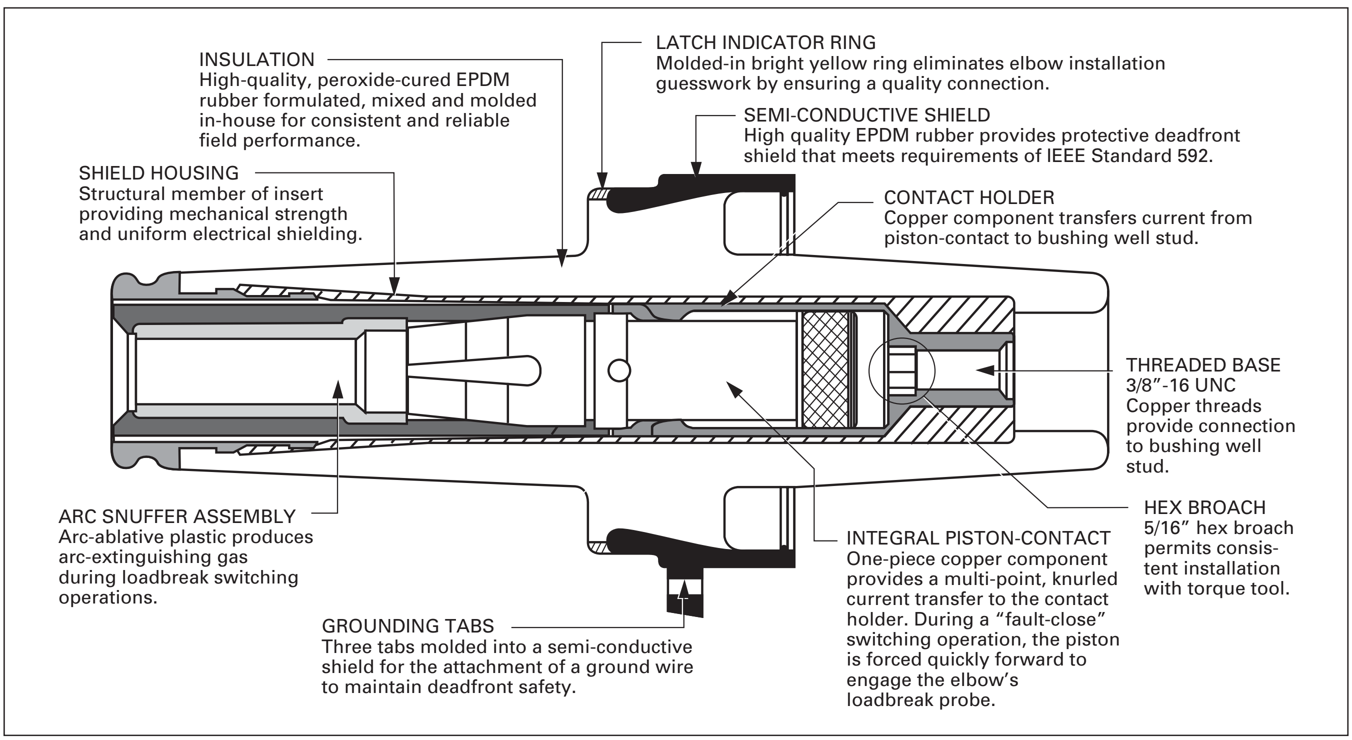


Figure 17.0-5. Bushing Well Insert Cutaway Illustrates Uncomplicated Nature of Current Path

General Description

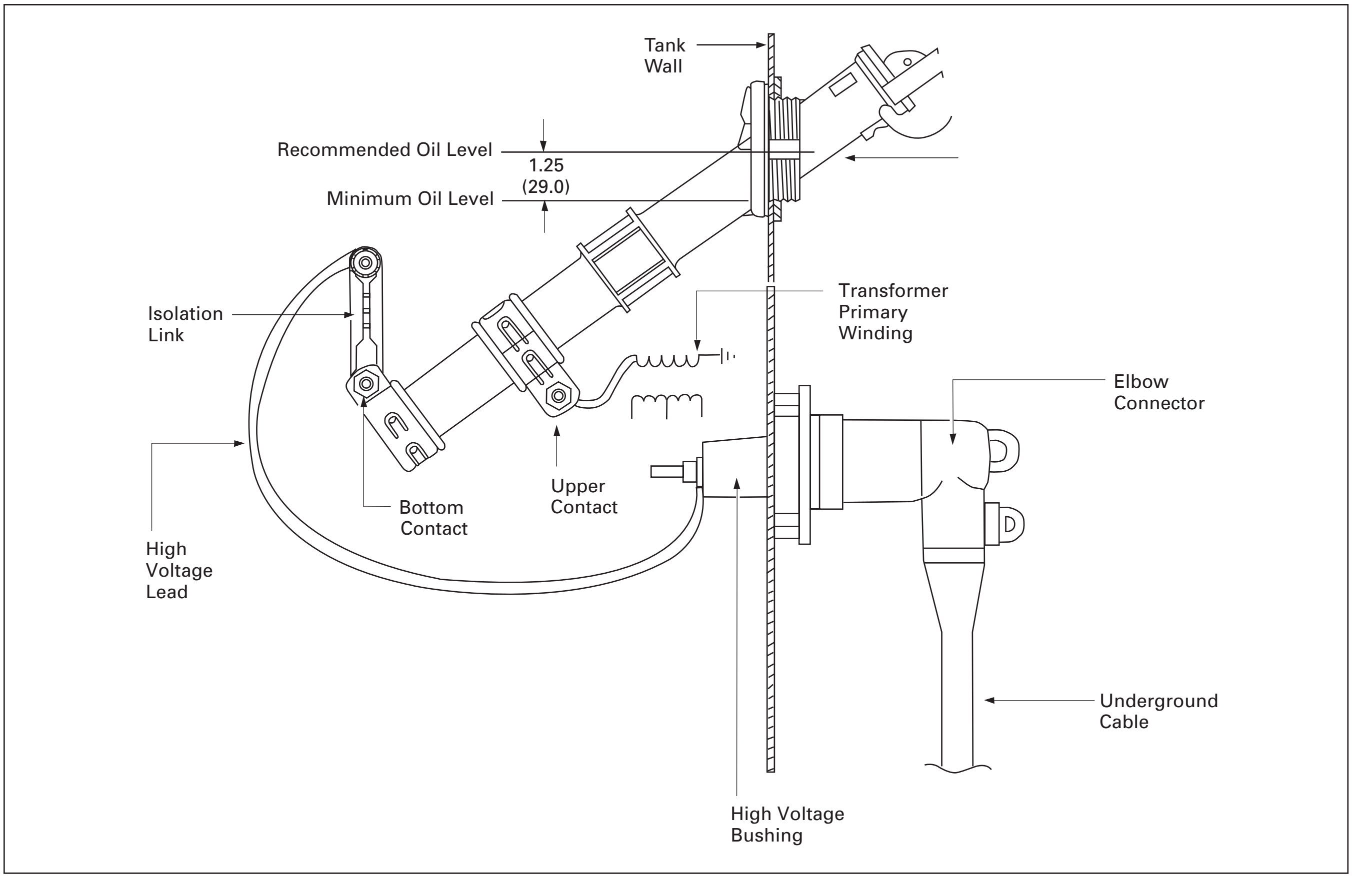


Figure 17.0-6. Bay-O-Net Assembly with Isolation Link

Note: Isolation link is not required if the Bay-O-Net fuse is used in series with a backup energy limiting fuse.

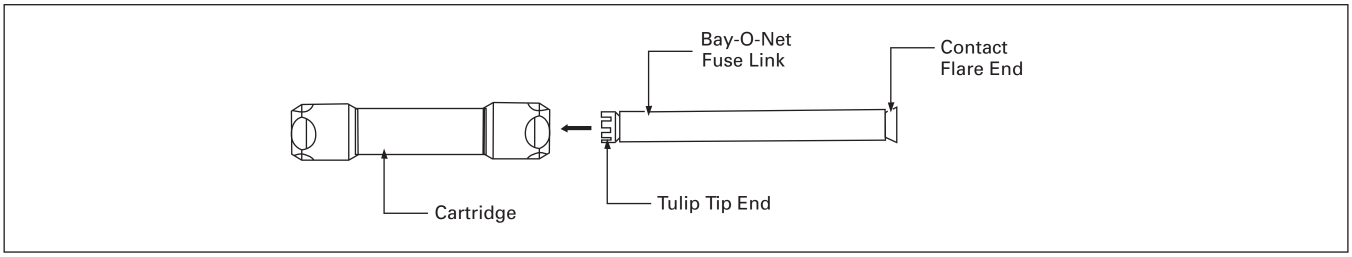


Figure 17.0-7. Insertion of Bay-O-Net Into Cartridge

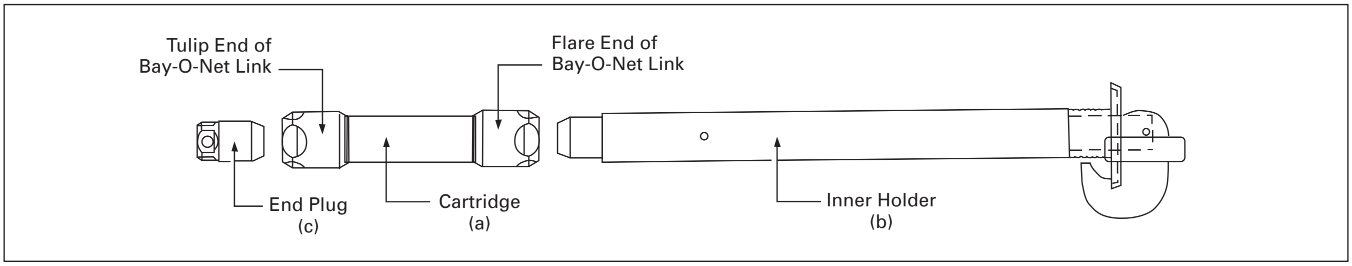


Figure 17.0-8. Assembly of Cartridge with Fuse Onto Inner Holder

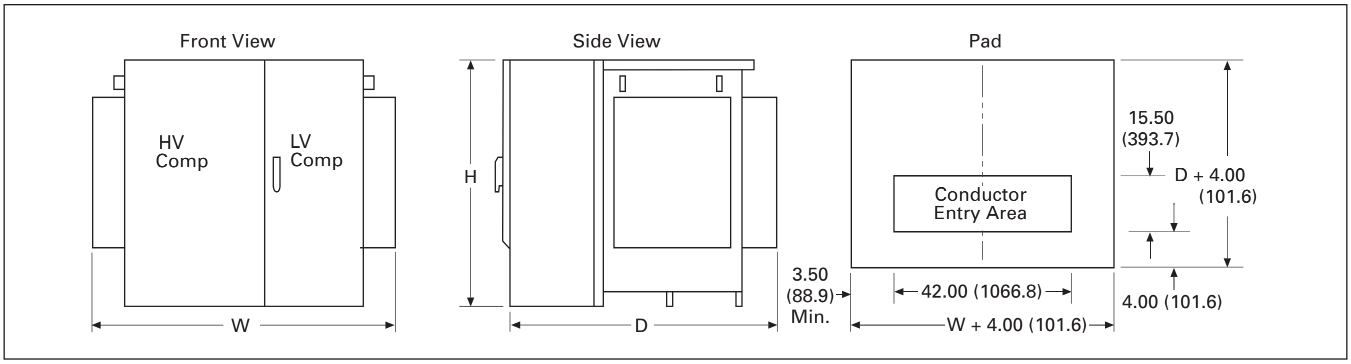


Figure 17.0-9. Pad-Mounted Transformer (75–2500 kVA)—Dimensions in Inches (mm)

Table 17.0-9. Standard Unit, Oil-Immersed 65°C Rise, 75–2500 kVA—Dimensions in Inches (mm)

kVA	Transformer Dimensions			Approximate Weight Lbs (kg)	Gallons (Liters) of Oil (Approximate)
	Width (W)	Depth (D)	Height (H)		
HV: 5–15 kV Radial Feed, Livefront					
75	56.00 (1422.4)	50.00 (1270.0)	56.00 (1422.4)	2280 (1034.2)	115 (435.3)
112	56.00 (1422.4)	50.00 (1270.0)	56.00 (1422.4)	2400 (1088.6)	115 (435.3)
150	56.00 (1422.4)	50.00 (1270.0)	56.00 (1422.4)	2700 (1224.7)	125 (473.2)
225	56.00 (1422.4)	54.00 (1371.6)	58.00 (1473.2)	3350 (1519.5)	150 (567.8)
300	60.00 (1524.0)	58.00 (1473.2)	58.00 (1473.2)	3650 (1655.6)	165 (624.6)
500	66.00 (1676.4)	62.00 (1574.8)	60.00 (1524.0)	5200 (2358.7)	200 (757.1)
750	81.00 (2057.4)	64.00 (1625.6)	68.00 (1727.2)	7200 (3265.9)	360 (1362.7)
1000	84.00 (2133.6)	66.00 (1676.4)	68.00 (1727.2)	9000 (4082.3)	400 (1514.2)
1500	86.00 (2184.4)	72.00 (1828.8)	68.00 (1727.2)	10,250 (4649.3)	440 (1665.6)
2000	92.00 (2336.8)	80.00 (2032.0)	72.00 (1828.8)	13,400 (6078.1)	550 (2082.0)
2500	98.00 (2489.2)	82.00 (2082.8)	72.00 (1828.8)	15,000 (6803.9)	570 (2157.7)
3000	102.00 (2590.8)	83.00 (2108.2)	77.00 (1955.8)	16,500 (7484.3)	625 (2365.9)
HV: 5–15 kV Radial Feed, Deadfront					
75	62.00 (1574.8)	50.00 (1270.0)	56.00 (1422.4)	2350 (1065.9)	115 (435.3)
112	62.00 (1574.8)	50.00 (1270.0)	56.00 (1422.4)	2450 (1111.3)	115 (435.3)
150	62.00 (1574.8)	50.00 (1270.0)	56.00 (1422.4)	2700 (1224.7)	125 (473.2)
225	62.00 (1574.8)	54.00 (1371.6)	58.00 (1473.2)	3400 (1542.2)	150 (567.8)
300	62.00 (1574.8)	58.00 (1473.2)	58.00 (1473.2)	3700 (1678.3)	165 (624.6)
500	66.00 (1676.4)	62.00 (1574.8)	60.00 (1524.0)	5400 (2449.4)	200 (757.1)
750	81.00 (2057.4)	64.00 (1625.6)	68.00 (1727.2)	7200 (3265.9)	360 (1362.7)
1000	84.00 (2133.6)	66.00 (1676.4)	68.00 (1727.2)	9000 (4082.3)	400 (1514.2)
1500	86.00 (2184.4)	72.00 (1828.8)	68.00 (1727.2)	10,250 (4649.3)	440 (1665.6)
2000	92.00 (2336.8)	80.00 (2032.0)	72.00 (1828.8)	13,400 (6078.1)	550 (2082.0)
2500	98.00 (2489.2)	82.00 (2082.8)	72.00 (1828.8)	15,000 (6803.9)	570 (2157.7)
3000	102.00 (2590.8)	83.00 (2108.2)	77.00 (1955.8)	16,500 (7484.3)	625 (2365.9)
HV: 5–15 kV Loop Feed, Livefront					
75	65.00 (1651.0)	50.00 (1270.0)	56.00 (1422.4)	2400 (1088.6)	115 (435.3)
112	65.00 (1651.0)	50.00 (1270.0)	56.00 (1422.4)	2500 (1134.0)	115 (435.3)
150	65.00 (1651.0)	50.00 (1270.0)	56.00 (1422.4)	2800 (1270.1)	125 (473.2)
225	65.00 (1651.0)	54.00 (1371.6)	58.00 (1473.2)	3500 (1587.6)	150 (567.8)
300	66.00 (1676.4)	58.00 (1473.2)	58.00 (1473.2)	3800 (1723.7)	165 (624.6)
500	68.00 (1727.2)	62.00 (1574.8)	60.00 (1524.0)	5600 (2540.1)	200 (757.1)
750	82.00 (2082.8)	64.00 (1625.6)	68.00 (1727.2)	7200 (3265.9)	360 (1362.7)
1000	86.00 (2184.4)	66.00 (1676.4)	68.00 (1727.2)	9000 (4082.3)	400 (1514.2)
1500	88.00 (2235.2)	72.00 (1828.8)	68.00 (1727.2)	10,250 (4649.3)	440 (1665.6)
2000	92.00 (2336.8)	80.00 (2032.0)	72.00 (1828.8)	13,400 (6078.1)	550 (2082.0)
2500	98.00 (2489.2)	82.00 (2082.8)	72.00 (1828.8)	15,000 (6803.9)	570 (2157.7)
3000	102.00 (2590.8)	83.00 (2108.2)	77.00 (1955.8)	16,500 (7484.3)	625 (2365.9)

Dimensional Variations

Height Variations

1. Add 3.00 inches (76.2 mm) to the height when using bayonet fusing on all kVA ratings.
2. Add 7.00 inches (177.8 mm) to the height when using dry well canister fusing on 75–500 kVA ratings.
3. Add 8.00 inches (203.2 mm) to the height when using dry well canister fusing on 750 kVA rating only.

Depth Variations

4. Canister fuses require deeper tanks on some transformer sizes.
   a. Add 4.00 inches (101.6 mm) to the depth of kVA ratings 75, 150 and 225.
   b. Add 2.00 inches (50.8 mm) to the depth of kVA rating 500.
5. Less flammable natural esther fluid requires deeper tanks on some transformer ratings.
   a. Add 2.00 inches (50.8 mm) to the depth of kVA ratings 75–1500. Add 8.00 inches (203.2 mm) to the depth of kVA ratings 2000 and 2500.

Dimensions are approximate—not for construction.

Table 17.0-9. Standard Unit, Oil-Immersed 65°C Rise, 75–2500 kVA—Dimensions in Inches (mm) (Continued)

kVA	Transformer Dimensions			Approximate Weight Lbs (kg)	Gallons (Liters) of Oil (Approximate)
	Width (W)	Depth (D)	Height (H)		
HV: 25 kV Radial Feed Deadfront					
75–150	68.00 (1727.2)	52.00 (1320.8)	55.00 (1397.0)	3500 (1587.6)	135 (511.0)
225–300	72.00 (1828.8)	54.00 (1371.6)	55.00 (1397.0)	4500 (2041.2)	185 (700.3)
500	72.00 (1828.8)	56.00 (1422.4)	55.00 (1397.0)	6000 (2721.6)	190 (719.2)
750	76.00 (1930.4)	69.00 (1752.6)	60.00 (1524.0)	7200 (3265.9)	360 (1362.7)
1000	80.00 (2032.0)	66.00 (1676.4)	70.00 (1778.0)	9000 (4082.3)	400 (1514.2)
1500	89.00 (2260.6)	72.00 (1828.8)	72.00 (1828.8)	10,250 (4649.3)	440 (1665.6)
2000	92.00 (2336.8)	74.00 (1879.6)	75.00 (1905.0)	13,400 (6078.1)	550 (2082.0)
2500	98.00 (2489.2)	82.00 (2082.8)	77.00 (1955.8)	15,000 (6803.9)	570 (2157.7)
3000	102.00 (2590.8)	83.00 (2108.2)	78.00 (1981.2)	16,500 (7484.3)	625 (2365.9)
HV: 25 kV Loop Feed Deadfront					
75–150	68.00 (1727.2)	52.00 (1320.8)	55.00 (1397.0)	3500 (1587.6)	135 (511.0)
225–300	72.00 (1828.8)	54.00 (1371.6)	55.00 (1397.0)	4500 (2041.2)	185 (700.3)
500	72.00 (1828.8)	56.00 (1422.4)	55.00 (1397.0)	6000 (2721.6)	190 (719.2)
750	76.00 (1930.4)	69.00 (1752.6)	60.00 (1524.0)	7200 (3265.9)	360 (1362.7)
1000	80.00 (2032.0)	66.00 (1676.4)	70.00 (1778.0)	9000 (4082.3)	400 (1514.2)
1500	89.00 (2260.6)	72.00 (1828.8)	72.00 (1828.8)	10,250 (4649.3)	440 (1665.6)
2000	92.00 (2336.8)	74.00 (1879.6)	75.00 (1905.0)	13400 (6078.1)	550 (2082.0)
2500	98.00 (2489.2)	82.00 (2082.8)	77.00 (1955.8)	15,000 (6803.9)	570 (2157.7)
3000	102.00 (2590.8)	83.00 (2108.2)	78.00 (1981.2)	16,500 (7484.3)	625 (2365.9)

Technical Data

Table 17.0-10. Liquid Filled<34.5 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	60–150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
75	175	960	1135	413
112.5	250	1250	1500	562
150	300	1630	1930	696
225	330	2500	2830	942
300	520	2600	3120	1164
500	730	4900	5630	1889
750	1100	6200	7300	2567
1000	1500	6700	8200	3221
1500	1900	10,000	11,900	4375
2000	2600	12,000	14,600	5429
2500	2800	15,000	17,800	6408
3000	3800	16,000	19,800	—

Note: Losses offered are typical only, not guaranteed.

Table 17.0-11. Liquid Filled<34.5 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp. (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	60–150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp per DOE (Watts)
75	190	950	1140	413
112.5	260	1300	1560	562
150	320	1600	1920	696
225	400	2300	2700	942
300	500	3000	3500	1164
500	700	5000	5700	1889
750	1000	6500	7500	2567
1000	1300	8500	9800	3221
1500	1900	10,500	12,400	4375
2000	2100	14,500	16,600	5429
2500	2700	15,500	18,200	6408
3000	4000	18,000	22,000	—

Note: Losses offered are typical only, not guaranteed.

Table 17.0-12. Environmentally Friendly Fluid<34.5 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	60–150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
75	175	960	1135	413
112.5	250	1250	1500	562
150	300	1630	1930	696
225	330	2500	2830	942
300	520	2600	3120	1164
500	730	4900	5630	1889
750	1100	6200	7300	2567
1000	1500	6700	8200	3221
1500	1900	10,000	11,900	4375
2000	2600	12,000	14,600	5429
2500	2800	15,000	17,800	6408
3000	3800	16,000	19,800	—

Note: Losses offered are typical only, not guaranteed.

Table 17.0-13. Environmentally Friendly Fluid<34.5 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp. (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	60–150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp per DOE (Watts)
75	190	950	1140	413
112.5	260	1300	1560	562
150	320	1600	1920	696
225	400	2300	2700	942
300	500	3000	3500	1164
500	700	5000	5700	1889
750	1000	6500	7500	2567
1000	1300	8500	9800	3221
1500	1900	10,500	12,400	4375
2000	2100	14,500	16,600	5429
2500	2700	15,500	18,200	6408
3000	4000	18,000	22,000	—

Note: Losses offered are typical only, not guaranteed.

Layout Dimensions

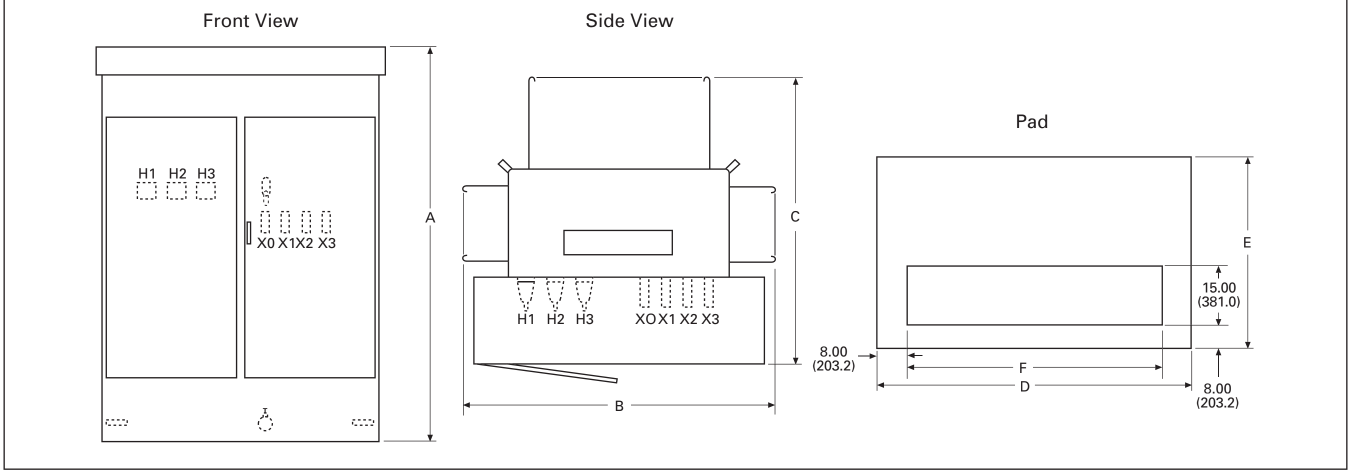


Figure 17.0-10. Pad-Mounted Transformer (3000–5000 kVA)—Dimensions in Inches (mm)

Table 17.0-14. Standard Unit, Oil-Immersed Rated 65°C Rise, 3000–5000 kVA—Dimensions in Inches (mm)

kVA	Transformer			Pad			Approximate Weight Lbs (kg)	Gallons (Liters) of Oil
	A	B	C ①	D	E ②	F		
15 kV Class, Delta Connected HV-HV 95 kV BIL, LV 30 kV BIL ③								
3000	76.00 (1930.4)	119.00 (3022.6)	100.00 (2540.0)	74.00 (1879.6)	72.00 (1828.8)	58.00 (1473.2)	12,900 (5851)	385 (1457)
3750	80.00 (2032.0)	82.00 (2082.8)	111.00 (2819.4)	79.00 (2006.6)	83.00 (2108.2)	63.00 (1600.2)	20,000 (9072)	540 (2044)
5000	78.00 (1981.2)	137.00 (3479.8)	108.00 (2743.2)	76.00 (1930.4)	80.00 (2032.0)	60.00 (1524.0)	21,500 (9752)	565 (2139)
15 kV Class, Wye Connected HV-HV 95 kV BIL, LV 30 kV BIL ③								
3000	74.00 (1879.6)	117.00 (2971.8)	102.00 (2590.8)	78.00 (1981.2)	74.00 (1879.6)	62.00 (1574.8)	15,000 (6804)	390 (1476)
3750	97.00 (2463.8)	81.00 (2057.4)	101.00 (2565.4)	81.00 (2057.4)	77.00 (1955.8)	65.00 (1651.0)	21,800 (9888)	550 (2082)
5000	91.00 (2311.4)	119.00 (3022.6)	108.00 (2743.2)	84.00 (2133.6)	80.00 (2032.0)	68.00 (1727.2)	22,000 (9979)	585 (2214)
25 kV Class, Delta Connected HV-HV 150 kV BIL, LV 30 kV BIL ③								
3000	83.00 (2108.2)	84.00 (2133.6)	101.00 (2565.4)	86.00 (2184.4)	74.00 (1879.6)	70.00 (1778.0)	15,400 (6985)	515 (1949)
3750	96.00 (2438.4)	84.00 (2133.6)	98.00 (2489.2)	86.00 (2184.4)	78.00 (1981.2)	70.00 (1778.0)	20,100 (9117)	650 (2461)
5000	101.00 (2565.4)	101.00 (2565.4)	107.00 (2717.8)	84.00 (2133.6)	79.00 (2006.6)	68.00 (1727.2)	22,900 (10,387)	670 (2536)
25 kV Class, Wye Connected HV-HV 125 kV BIL, LV 30 kV BIL ③								
3000	84.00 (2133.6)	80.00 (2032.0)	102.00 (2590.8)	80.00 (2032.0)	74.00 (1879.6)	64.00 (1625.6)	16,300 (7394)	450 (1703)
3750	93.00 (2362.2)	85.00 (2159.0)	99.00 (2514.6)	84.00 (2133.6)	78.00 (1981.2)	68.00 (1727.2)	21,200 (9616)	575 (2177)
5000	90.00 (2286.0	110.00 (2794.0)	108.00 (2743.2)	84.00 (2133.6)	80.00 (2032.0)	68.00 (1727.2)	23,100 (10,478)	605 (2290)
35 kV Class, Delta Connected HV-HV 200 kV BIL, LV 30 kV BIL								
3000	86.00 (2184.4)	86.00 (2184.4)	101.00 (2565.4)	78.00 (1981.2)	73.00 (1854.2)	62.00 (1574.8)	15,700 (7121)	420 (1590)
3750	86.00 (2184.4)	82.00 (2082.8)	102.00 (2590.8)	82.00 (2082.8)	76.00 (1930.4)	66.00 (1676.4)	19,800 (8981)	525 (1987)
5000	102.00 (2590.8)	122.00 (3098.8)	106.00 (2692.4)	83.00 (2108.2)	78.00 (1981.2)	67.00 (1701.8)	22,600 (10,251)	580 (2196)
35 kV Class, Wye Connected HV-HV 125 kV BIL, LV 30 kV BIL								
3000	82.00 (2082.8)	86.00 (2184.4)	101.00 (2565.4)	78.00 (1981.2)	73.00 (1854.2)	62.00 (1574.8)	15,700 (7121)	420 (1590)
3750	91.00 (2311.4)	82.00 (2082.8)	102.00 (2590.8)	82.00 (2082.8)	76.00 (1930.4)	66.00 (1676.4)	19,800 (8981)	525 (1987)
5000	92.00 (2336.8)	122.00 (3098.8)	106.00 (2692.4)	83.00 (2108.2)	78.00 (1981.2)	67.00 (1701.8)	22,600 (10,251)	580 (2196)
35 kV Class, Delta Connected HV-HV 150 kV BIL, LV 30 kV BIL								
3000	84.00 (2133.6)	84.00 (2133.6)	100.00 (2540.0)	86.00 (2184.4)	74.00 (1879.6)	70.00 (1778.0)	15,400 (6985)	530 (2006)
3750	84.00 (2133.6)	84.00 (2133.6)	101.00 (2565.4)	86.00 (2184.4)	77.00 (1955.8)	70.00 (1778.0)	19,300 (8754)	630 (2385)
5000	92.00 (2336.8)	122.00 (3098.8)	106.00 (2692.4)	81.00 (2057.4)	78.00 (1981.2)	65.00 (1651.0)	20,500 (9299)	600 (2271)
35 kV Class, Wye Connected HV-HV 150 kV BIL, LV 30 kV BIL								
3000	80.00 (2032.0)	84.00 (2133.6)	104.00 (2641.6)	86.00 (2184.4)	76.00 (1930.4)	70.00 (1778.0)	17,100 (7756)	500 (1893)
3750	86.00 (2184.4)	87.00 (2209.8)	107.00 (2717.8)	86.00 (2184.4)	79.00 (2006.6)	70.00 (1778.0)	20,600 (9344)	560 (2120)
5000	95.00 (2413.0)	105.00 (2667.0)	107.00 (2717.8)	85.00 (2159.0)	79.00 (2006.6)	69.00 (1752.6)	23,800 (10,795)	625 (2366)
35 kV Class, Wye Connected HV-HV 200 kV BIL, LV 30 kV BIL								
3000	88.00 (2235.2)	104.00 (2641.6)	99.00 (2514.6)	107.00 (2717.8)	83.00 (2108.2)	91.00 (2311.4)	19,800 (8981)	720 (2725)
3750	90.00 (2286.0)	104.00 (2641.6)	104.00 (2641.6)	107.00 (2717.8)	90.00 (2286.0)	91.00 (2311.4)	24,400 (11,068)	840 (3180)
5000	101.00 (2565.4)	102.00 (2590.8)	106.00 (2692.4)	107.00 (2717.8)	90.00 (2286.0)	89.00 (2260.6)	28,600 (12,973)	920 (3483)

① Standard compartment depth is 22.00 inches (558.8 mm) except 200 kV BIL has a depth of 30.00 inches (762.0 mm). Depth may be altered by the addition of switching and fusing.
② Extends under base of transformer only. Does not include rear coolers.
③ Standard low voltages are 480Y and 480 delta (through 3750 kVA only). Low voltage above 3750 kVA must be 2400V or above.

Dimensions are approximate—not for construction.

Liquid Filled Technical Data

Table 17.0-15. Liquid Filled 15 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	95 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5517	22,491	28,008	11,140
3750	6521	26,340	32,861	13,110
5000	8193	32,255	40,448	16,260

Table 17.0-16. Liquid Filled 5 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	60 kV HV BIL Total Losses at 50% load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5461	22,269	27,730	11,030
3750	6455	26,076	32,531	12,230
5000	8111	31,932	40,043	16,090

Table 17.0-17. Liquid Filled 25 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5570	22,046	27,616	11,080
3750	6584	25,815	32,399	13,040
5000	8273	31,612	39,885	16,180

Table 17.0-18. Liquid Filled 35 kV Primary 55°C Temp. Rise

kVA	No Load at 75°C Ref. Temp. (Watts)	Load Loss at 100% Load and 75°C Ref. Temp. (Watts)	Total Losses at 100% LOAD and 85°C (Watts)	200 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5848	21,825	27,673	11,300
3750	6913	25,556	32,469	13,300
5000	8686	31,295	39,981	16,510

Table 17.0-19. Liquid Filled 15 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	95 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5985	24,402	30,387	12,090
3750	7075	28,578	35,653	14,220
5000	8889	34,996	43,885	17,640

Table 17.0-20. Liquid Filled 5 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp. (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	95 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	5925	24,161	30,086	11,970
3750	7003	28,292	35,295	14,080
5000	8800	34,646	43,446	17,460

Table 17.0-21. Liquid Filled 25 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp. (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	150 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	6043	23,919	29,962	12,020
3750	7143	28,009	35,152	14,150
5000	8976	34,299	43,275	17,550

Table 17.0-22. Liquid Filled 35 kV Primary 65°C Temp. Rise

kVA	No Load at 85°C Ref. Temp. (Watts)	Load Loss at 100% Load and 85°C Ref. Temp. (Watts)	Total Losses at 100% Load and 85°C (Watts)	200 kV HV BIL Total Losses at 50% Load and 55°C LL Ref. Temp. and 20°C NL Ref. Temp. per DOE (Watts)
3000	6345	23,680	30,025	12,270
3750	7500	27,728	35,228	14,430
5000	9424	33,955	43,379	17,910

Note: Losses offered are typical only, not guaranteed. Losses based on aluminum windings. Losses based on LV rating 0.48 kV.

Distribution Transformer National Efficiency Standards

ABB

An overview

On October 12, 2007, the United States Department of Energy (DOE) issued its final ruling on distribution transformer efficiency for liquid and dry distribution transformers. The ruling impacts the following:

- Single phase – 10 to 833 kVA
- Three phase – 15 to 2500 kVA

Distribution transformers that are manufactured in or imported into the U.S. and its territories on or after January 1, 2010, will be required to comply with these new DOE standards.

Benefits of the National Efficiency Standard

Saves 2.74 quads (10^{15} BTU's) of energy over 29 years

- Energy of 27 million US households in a single year
- Eliminating need for 6 new 400 MW power plants

Reduce greenhouse gas emission of ~238 million tons of CO_2

- Equivalent to removing 80% of all light vehicles for one year
- Others emission reductions not included in final justification
  - – Greater than 46 thousand tons (kt) of nitrous oxide (NO_2)
  - – Greater than 4 tons of mercury (Hg)

Payback ranges from 1 to 15 years based on design line

- Net present value of $1.39 billion using a 7% discount rate
- Net present value of $7.8 billion using a 3% discount rate
- Cumulative from 2010 to 2073 in 2006

Definition of transformer efficiency

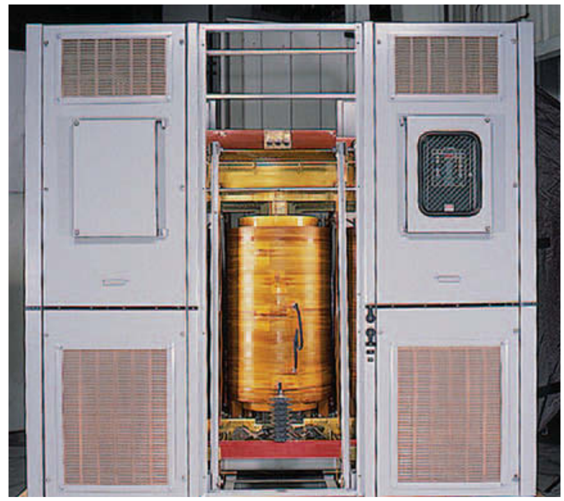
% Efficiency = 100 x output watts / input watts

Output being less than input due to losses in form of heat

$$\%\text{Efficiency} = \frac{L \cdot kVA \cdot COS\,\theta \cdot 10^5}{L \cdot kVA \cdot COS\,\theta \cdot 10^3 + \underbrace{Fe}_{\text{No-load losses (A)}} + L^2 \cdot \underbrace{(LL)}_{\text{Load losses (B)}}}$$

Fe = No-load losses (A)

LL = Load losses (B)



Definition of transformer losses

Total transformer losses are a combination of no-load losses and load losses.

No-load losses, or core losses, are a function of hysteresis loss from the steel, chemistry, coating and processing, and eddy loss from steel thickness.

Load losses, or conductor losses, are caused by I^2R loss from the copper or aluminum material plus current density and length, and eddy loss from the design geometry and proximity to steel parts.

Development of new national standards

When the DOE first began this process, they established six levels of efficiency.

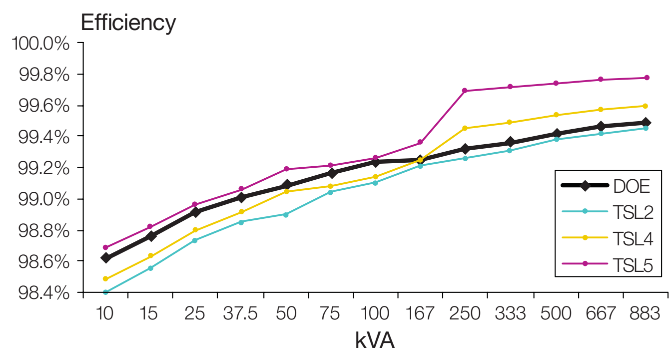
- TSL1 = NEMA TP1
- TSL2 = 1/3 difference between TSL1 and TSL4
- TSL3 = 2/3 difference between TSL1 and TSL4
- TSL4 = minimum LCC (Life Cycle Cost)
- TSL5 = maximum efficiency with no change in the LCC
- TSL6 = theoretical maximum possible efficiency

(TSL = Trial Standard Level)

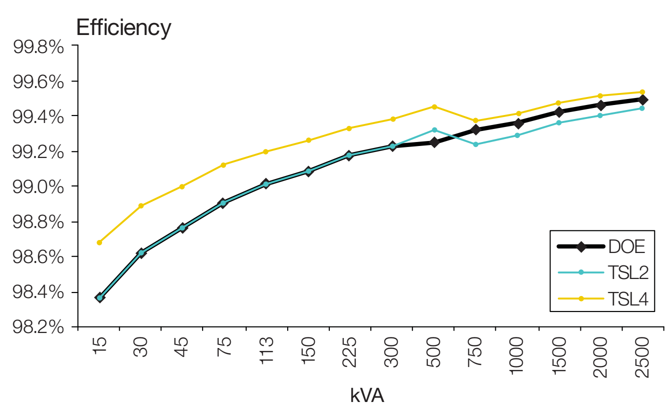
At the conclusion the following standards were adapted.

National standard – liquid-filled

Product class 1 table EA.3	**Liquid**-immersed medium voltage **single** phase transformer TSL						
KVA	1	2	3	4	5	6	**Standard**
5							
10	98.40%	98.40%	98.44%	98.48%	98.69%	99.32%	98.62%
15	98.60%	98.56%	98.59%	98.63%	98.82%	99.39%	98.76%
25	98.70%	98.73%	98.76%	98.79%	98.96%	99.46%	98.91%
37.5	98.80%	98.85%	98.88%	98.91%	99.06%	99.51%	99.01%
50	98.90%	98.90%	98.90%	99.04%	99.19%	99.59%	99.08%
75	99.00%	99.04%	99.06%	99.08%	99.21%	99.59%	99.17%
100	99.00%	99.10%	99.12%	99.14%	99.26%	99.62%	99.23%
167	99.10%	99.21%	99.23%	99.25%	99.35%	99.66%	99.25%
250	99.20%	99.26%	99.36%	99.45%	99.69%	99.70%	99.32%
333	99.20%	99.31%	99.40%	99.49%	99.71%	99.72%	99.36%
500	99.30%	99.38%	99.46%	99.54%	99.74%	99.75%	99.42%
667	99.40%	99.42%	99.50%	99.57%	99.76%	99.77%	99.46%
833	99.40%	99.45%	99.52%	99.60%	99.77%	99.78%	99.49%



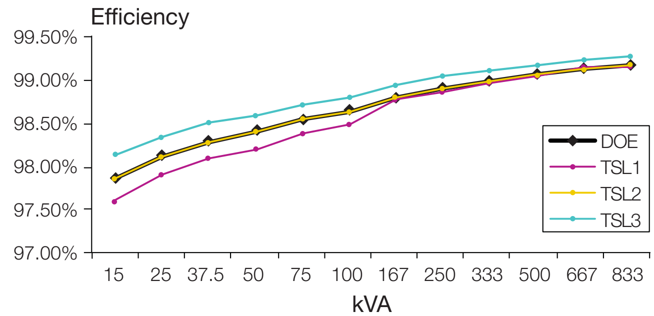
Product class 2 table EA.4	**Liquid**-immersed medium voltage **three** phase transformer TSL						
KVA	1	2	3	4	5	6	**Standard**
15	98.10%	98.36%	98.68%	98.68%	99.25%	99.31%	98.36%
30	98.40%	98.62%	98.89%	98.89%	99.37%	99.42%	98.62%
45	98.60%	98.76%	99.00%	99.00%	99.43%	99.47%	98.76%
75	98.70%	98.91%	99.12%	99.12%	99.50%	99.54%	98.91%
112.5	98.80%	99.01%	99.20%	99.20%	99.55%	99.58%	99.01%
150	98.90%	99.08%	99.26%	99.26%	99.58%	99.61%	99.08%
225	99.00%	99.17%	99.33%	99.33%	99.62%	99.65%	99.17%
300	99.00%	99.23%	99.38%	99.38%	99.65%	99.67%	99.23%
500	99.10%	99.32%	99.45%	99.45%	99.69%	99.71%	99.25%
750	99.20%	99.24%	99.31%	99.37%	99.66%	99.66%	99.32%
1000	99.20%	99.29%	99.36%	99.41%	99.68%	99.68%	99.36%
1500	99.30%	99.36%	99.42%	99.47%	99.71%	99.71%	99.42%
2000	99.40%	99.40%	99.46%	99.51%	99.73%	99.73%	99.46%
2500	99.40%	99.44%	99.49%	99.53%	99.74%	99.74%	99.49%



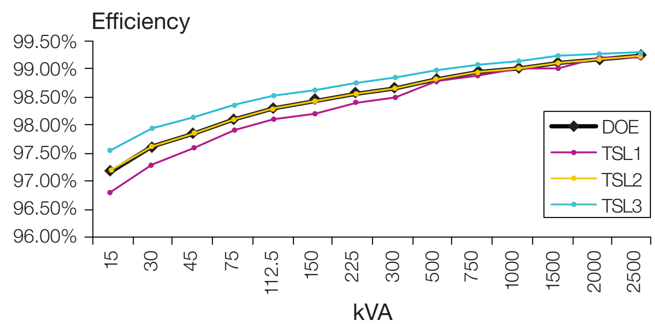
Shaded columns indicate Trial Standard Levels that make up the standard.

National standard – dry-type

Product class 7 table EA.7		Dry-type medium voltage **single** phase transformer **(46-96 kV BIL)** TSL								
	KVA	0-Avg	0-Min	1	2	3	4	5	6	**Standard**
	15	97.46%	96.87%	97.60%	97.86%	98.14%	98.41%	98.54%	98.54%	97.86%
	25	97.77%	97.24%	97.90%	98.12%	98.36%	98.60%	98.71%	98.71%	98.12%
	37.5	97.98%	97.51%	98.10%	98.30%	98.52%	98.73%	98.84%	98.84%	98.30%
	50	98.12%	97.68%	98.20%	98.42%	98.62%	98.82%	98.92%	98.92%	98.42%
	75	98.30%	97.90%	98.40%	98.57%	98.75%	98.94%	99.02%	99.02%	98.57%
DL11	100	98.42%	98.05%	98.05%	98.67%	98.84%	99.01%	99.09%	99.09%	98.67%
	167	98.61%	98.28%	98.80%	98.83%	98.98%	99.13%	99.20%	99.20%	98.83%
	250	99.02%	98.58%	98.90%	98.95%	99.08%	99.23%	99.42%	99.42%	98.95%
	333	99.09%	98.68%	99.00%	99.03%	99.15%	99.28%	99.46%	99.46%	99.03%
DL12	500	99.18%	98.81%	99.10%	99.12%	99.23%	99.35%	99.51%	99.51%	99.12%
	667	99.24%	98.89%	99.20%	99.18%	99.28%	99.40%	99.54%	99.54%	99.18%
	833	99.28%	98.95%	99.20%	99.23%	99.43%	99.57%	99.57%	99.57%	99.23%



Product class 8 table EA.8		Dry-type medium voltage **three** phase transformer **(46-96 kV BIL)** TSL								
	KVA	0-AVg	0-Min	1	2	3	4	5	6	**Standard**
	15	96.66%	95.88%	96.80%	97.19%	97.55%	97.91%	98.08%	98.08%	97.18%
	30	97.19%	96.53%	97.30%	97.63%	97.94%	98.24%	98.38%	98.38%	97.63%
	45	97.46%	96.87%	97.60%	97.86%	98.14%	98.41%	98.54%	98.54%	97.86%
	75	97.77%	97.24%	97.90%	98.12%	98.36%	98.60%	98.71%	98.71%	98.12%
	112.5	97.98%	97.51%	98.10%	98.30%	98.52%	98.73%	98.84%	98.84%	98.30%
	150	98.12%	97.68%	98.20%	98.42%	98.62%	98.82%	98.92%	98.92%	98.42%
	225	98.30%	98.90%	98.40%	98.57%	98.75%	98.94%	99.02%	99.02%	98.57%
DL11	300	98.42%	98.05%	98.50%	98.67%	99.84%	99.01%	99.09%	99.09%	98.67%
	500	98.61%	98.28%	98.80%	98.83%	98.98%	99.13%	99.20%	99.20%	98.83%
	750	99.02%	98.58%	98.90%	98.95%	99.08%	99.23%	99.42%	99.42%	98.95%
	1000	99.09%	98.68%	99.00%	99.03%	99.15%	99.28%	99.46%	99.46%	99.03%
DL12	1500	99.18%	98.81%	99.00%	99.12%	99.23%	99.35%	99.51%	99.51%	99.12%
	2000	99.24%	98.89%	99.20%	99.18%	99.28%	99.40%	99.54%	99.54%	99.18%
	2500	99.28%	98.95%	99.20%	99.23%	99.32%	99.43%	99.57%	99.57%	99.23%



Shaded columns indicate Trial Standard Levels that make up the standard.

Impact of the new efficiency standards

The new efficiency standards will increase the conductor cross section thus increasing copper and aluminum consumption. In addition, weights and dimensions will increase in most cases.

Due to these increases, transportation costs will rise as there will be fewer units per truckload. And since the wider and deeper tanks will not be offset by a reduction in tank height, the average oil volume per unit will increase as well. In some cases, higher efficiency will lead to lower losses, less heating and a reduction or elimination of radiators.

Overall, transformers will get bigger and heavier due to an increase in the total amount of material used. Also, there will be more need for higher grade and higher cost electrical steel. We project a 16 percent increase in tonnage of electrical steel, 16 percent increase in copper and 19 percent increase in aluminum.

ABB is ideally positioned to help you through this process

At ABB, we have taken these additional material requirements into consideration with our suppliers to make sure we have the necessary materials to meet the DOE standards.

Currently, in our present design base, the following ABB transformers meet or exceed the standards:
- 50% of liquid single phase
- 40% of liquid three phase
- 25% of dry-type

ABB will assure compliance

According to the regulations, the manufacturer (ABB) will determine the efficiency of a basic model whether by testing or by an Alternative Efficiency Determination Method (AEDM).

The basic model is defined as the transformer design with the same energy consumption along with electrical features including kVA, BIL, voltage and taps. The load is calculated at 50 percent, the power factor is equal to 1 (one). The no-load loss is calculated at 20°C and load losses are calculated at 55°C for liquid-filled units and 75°C for dry-type transformers. Auxiliary devices, such as circuit breakers, fuses and switches, are excluded from the calculation of efficiency.

The ABB response to the efficiency standards

All of us at ABB support this move to higher efficiency standards, since this has been part of our strategy as a sustainable corporation from the beginning. We understand the impact on you, in terms of cost, and we are committed to using our design technology and material supply management expertise to minimize any negative factors for our customers.

We are confident that we will be able to meet the needs of our customers in 2010 and for many years thereafter. In short, ABB will be able to provide you with standards-compliant distribution transformers when and where you need them.

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Distribution Transformers
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171 Industry Drive
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Phone +1 276 688 3325
Fax +1 276 688 4588

1LUJ460200-LTE

Richards Communications 216 514 7800

Appendix D

LCC Analysis Reports

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:18:50 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_500_Low.xml		

1. Investment

Construction Cost	$52,569
SIOH	$3,154
Design Cost	$2,103
Total Cost	$57,826
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$57,826

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-9.4 MBtu	-$633	19.623	-$12,429
Energy Subtotal		-9.4 MBtu	-$633		-$12,429
Water Subtotal		0.0 Mgal	$0		$0
Total			-$633		-$12,429

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$633	
5. Simple Payback Period (in years)	-91.30	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$12,429	
7. Savings to Investment Ratio (SIR)	-0.21	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	□	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:18:50 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_500_Low.xml		

1. Investment

Construction Cost	$52,569
SIOH	$3,154
Design Cost	$2,103
Total Cost	$57,826
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$57,826

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-9.4 MBtu	-$633	19.623	-$12,429
Energy Subtotal		-9.4 MBtu	-$633		-$12,429
Water Subtotal		0.0 Mgal	$0		$0
Total			-$633		-$12,429

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings -$633

5. Simple Payback Period (in years) -91.30 (total investment/first-year savings)

6. Total Discounted Operational Savings -$12,429

7. Savings to Investment Ratio (SIR) -0.21 (total discounted operational savings/total investment)

8. Adjusted Internal Rate of Return (AIRR) □ (1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:20:00 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_500_Med.xml		

1. Investment

Construction Cost	$58,995
SIOH	$3,540
Design Cost	$2,360
Total Cost	$64,894
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$64,894

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	7.7 MBtu	$518	19.623	$10,159
Energy Subtotal		7.7 MBtu	$518		$10,159
Water Subtotal		0.0 Mgal	$0		$0
Total			$518		$10,159

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$518	
5. Simple Payback Period (in years)	125.35	(total investment/first-year savings)
6. Total Discounted Operational Savings	$10,159	
7. Savings to Investment Ratio (SIR)	0.16	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-3.17%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:07:32 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_500_High.xml		

1. Investment

Construction Cost	$84,626
SIOH	$5,078
Design Cost	$3,385
Total Cost	$93,089
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$93,089

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	15.5 MBtu	$1,039	19.623	$20,395
Energy Subtotal		15.5 MBtu	$1,039		$20,395
Water Subtotal		0.0 Mgal	$0		$0
Total			$1,039		$20,395

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$1,039	
5. Simple Payback Period (in years)	89.56	(total investment/first-year savings)
6. Total Discounted Operational Savings	$20,395	
7. Savings to Investment Ratio (SIR)	0.22	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-2.08%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:23:51 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_750_Low.xml		

1. Investment

Construction Cost	$61,354
SIOH	$3,681
Design Cost	$2,454
Total Cost	$67,489
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$67,489

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-14.1 MBtu	-$946	19.623	-$18,567
Energy Subtotal		-14.1 MBtu	-$946		-$18,567
Water Subtotal		0.0 Mgal	$0		$0
Total			-$946		-$18,567

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$946	
5. Simple Payback Period (in years)	-71.33	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$18,567	
7. Savings to Investment Ratio (SIR)	-0.28	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	□	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:25:03 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_750_Med.xml		

1. Investment

Construction Cost	$69,299
SIOH	$4,158
Design Cost	$2,772
Total Cost	$76,229
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$76,229

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	11.6 MBtu	$779	19.623	$15,285
Energy Subtotal		11.6 MBtu	$779		$15,285
Water Subtotal		0.0 Mgal	$0		$0
Total			$779		$15,285

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$779	
5. Simple Payback Period (in years)	97.86	(total investment/first-year savings)
6. Total Discounted Operational Savings	$15,285	
7. Savings to Investment Ratio (SIR)	0.20	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-2.37%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:21:01 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_750_High.xml		

1. Investment

Construction Cost	$94,350
SIOH	$5,661
Design Cost	$3,774
Total Cost	$103,785
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$103,785

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	20.9 MBtu	$1,403	19.623	$27,531
Energy Subtotal		20.9 MBtu	$1,403		$27,531
Water Subtotal		0.0 Mgal	$0		$0
Total			$1,403		$27,531

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$1,403	
5. Simple Payback Period (in years)	73.97	(total investment/first-year savings)
6. Total Discounted Operational Savings	$27,531	
7. Savings to Investment Ratio (SIR)	0.27	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-1.46%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:05:33 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_1000_Low.xml		

1. Investment

Construction Cost	$75,794
SIOH	$4,548
Design Cost	$3,032
Total Cost	$83,373
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$83,373

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-18.7 MBtu	-$1,256	19.623	-$24,654
Energy Subtotal		-18.7 MBtu	-$1,256		-$24,654
Water Subtotal		0.0 Mgal	$0		$0
Total			-$1,256		-$24,654

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$1,256	
5. Simple Payback Period (in years)	-66.36	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$24,654	
7. Savings to Investment Ratio (SIR)	-0.30	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)		(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:06:27 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_1000_Med.xml		

1. Investment

Construction Cost	$85,742
SIOH	$5,145
Design Cost	$3,430
Total Cost	$94,316
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$94,316

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	15.7 MBtu	$1,053	19.623	$20,670
Energy Subtotal		15.7 MBtu	$1,053		$20,670
Water Subtotal		0.0 Mgal	$0		$0
Total			$1,053		$20,670

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$1,053	
5. Simple Payback Period (in years)	89.54	(total investment/first-year savings)
6. Total Discounted Operational Savings	$20,670	
7. Savings to Investment Ratio (SIR)	0.22	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-2.08%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 08:59:24 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_20_1000_High.xml		

1. Investment

Construction Cost	$107,958
SIOH	$6,477
Design Cost	$4,318
Total Cost	$118,754
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$118,754

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	24.9 MBtu	$1,674	19.623	$32,843
Energy Subtotal		24.9 MBtu	$1,674		$32,843
Water Subtotal		0.0 Mgal	$0		$0
Total			$1,674		$32,843

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$1,674	
5. Simple Payback Period (in years)	70.95	(total investment/first-year savings)
6. Total Discounted Operational Savings	$32,843	
7. Savings to Investment Ratio (SIR)	0.28	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-1.32%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:50:43 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_500_Low.xml		

1. Investment

Construction Cost	$52,569
SIOH	$3,154
Design Cost	$2,103
Total Cost	$57,826
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$57,826

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-18.0 MBtu	-$1,209	19.623	-$23,716
Energy Subtotal		-18.0 MBtu	-$1,209		-$23,716
Water Subtotal		0.0 Mgal	$0		$0
Total			-$1,209		-$23,716

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$1,209	
5. Simple Payback Period (in years)	-47.85	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$23,716	
7. Savings to Investment Ratio (SIR)	-0.41	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	□	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:51:45 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_500_Med.xml		

1. Investment

Construction Cost	$58,995
SIOH	$3,540
Design Cost	$2,360
Total Cost	$64,894
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$64,894

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	19.5 MBtu	$1,307	19.623	$25,638
Energy Subtotal		19.5 MBtu	$1,307		$25,638
Water Subtotal		0.0 Mgal	$0		$0
Total			$1,307		$25,638

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$1,307	
5. Simple Payback Period (in years)	49.67	(total investment/first-year savings)
6. Total Discounted Operational Savings	$25,638	
7. Savings to Investment Ratio (SIR)	0.40	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	-0.14%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:49:48 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_500_High.xml		

1. Investment

Construction Cost	$84,626
SIOH	$5,078
Design Cost	$3,385
Total Cost	$93,089
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$93,089

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	42.4 MBtu	$2,843	19.623	$55,795
Energy Subtotal		42.4 MBtu	$2,843		$55,795
Water Subtotal		0.0 Mgal	$0		$0
Total			$2,843		$55,795

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$2,843	
5. Simple Payback Period (in years)	32.74	(total investment/first-year savings)
6. Total Discounted Operational Savings	$55,795	
7. Savings to Investment Ratio (SIR)	0.60	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	1.26%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:57:15 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_750_Low.xml		

1. Investment

Construction Cost	$61,354
SIOH	$3,681
Design Cost	$2,454
Total Cost	$67,489
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$67,489

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-26.8 MBtu	-$1,801	19.623	-$35,345
Energy Subtotal		-26.8 MBtu	-$1,801		-$35,345
Water Subtotal		0.0 Mgal	$0		$0
Total			-$1,801		-$35,345

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$1,801	
5. Simple Payback Period (in years)	-37.47	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$35,345	
7. Savings to Investment Ratio (SIR)	-0.52	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	□	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:58:08 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_750_Med.xml		

1. Investment

Construction Cost	$69,299
SIOH	$4,158
Design Cost	$2,772
Total Cost	$76,229
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$76,229

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	30.6 MBtu	$2,056	19.623	$40,354
Energy Subtotal		30.6 MBtu	$2,056		$40,354
Water Subtotal		0.0 Mgal	$0		$0
Total			$2,056		$40,354

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$2,056	
5. Simple Payback Period (in years)	37.07	(total investment/first-year savings)
6. Total Discounted Operational Savings	$40,354	
7. Savings to Investment Ratio (SIR)	0.53	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	0.84%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:56:36 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_750_High.xml		

1. Investment

Construction Cost	$94,350
SIOH	$5,661
Design Cost	$3,774
Total Cost	$103,785
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$103,785

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	56.0 MBtu	$3,758	19.623	$73,746
Energy Subtotal		56.0 MBtu	$3,758		$73,746
Water Subtotal		0.0 Mgal	$0		$0
Total			$3,758		$73,746

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$3,758	
5. Simple Payback Period (in years)	27.62	(total investment/first-year savings)
6. Total Discounted Operational Savings	$73,746	
7. Savings to Investment Ratio (SIR)	0.71	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	1.83%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:26:49 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_1000_Low.xml		

1. Investment

Construction Cost	$75,794
SIOH	$4,548
Design Cost	$3,032
Total Cost	$83,373
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$83,373

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	-35.6 MBtu	-$2,386	19.623	-$46,822
Energy Subtotal		-35.6 MBtu	-$2,386		-$46,822
Water Subtotal		0.0 Mgal	$0		$0
Total			-$2,386		-$46,822

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	-$2,386	
5. Simple Payback Period (in years)	-34.94	(total investment/first-year savings)
6. Total Discounted Operational Savings	-$46,822	
7. Savings to Investment Ratio (SIR)	-0.56	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)		(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:27:30 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_1000_Med.xml		

1. Investment

Construction Cost	$85,742
SIOH	$5,145
Design Cost	$3,430
Total Cost	$94,316
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$94,316

2. Energy and Water Savings (+) or Cost (-)
Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	40.1 MBtu	$2,692	19.623	$52,824
Energy Subtotal		40.1 MBtu	$2,692		$52,824
Water Subtotal		0.0 Mgal	$0		$0
Total			$2,692		$52,824

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$2,692	
5. Simple Payback Period (in years)	35.04	(total investment/first-year savings)
6. Total Discounted Operational Savings	$52,824	
7. Savings to Investment Ratio (SIR)	0.56	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	1.03%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-11: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A
The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2011.

Location:	U.S. Average	Discount Rate:	3%
Project Title:	Japan Transformer	Analyst:	INL
Base Date:	January 1, 2013	Preparation Date:	Wed May 16 09:25:55 MDT 2012
BOD:	January 1, 2013	Economic Life:	30 years 0 months
File Name:	C:\Documents and Settings\bushjw\Desktop\Work At Home\Japan Study\Report\LCC Files\LCC_60_1000_High.xml		

1. Investment

Construction Cost	$107,958
SIOH	$6,477
Design Cost	$4,318
Total Cost	$118,754
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$118,754

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$67.11329	66.4 MBtu	$4,458	19.623	$87,471
Energy Subtotal		66.4 MBtu	$4,458		$87,471
Water Subtotal		0.0 Mgal	$0		$0
Total			$4,458		$87,471

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$0			$0

4. First year savings	$4,458	
5. Simple Payback Period (in years)	26.64	(total investment/first-year savings)
6. Total Discounted Operational Savings	$87,471	
7. Savings to Investment Ratio (SIR)	0.74	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	1.96%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

"Robertson CIV Lubka" <lubka.robertson@usmc.mil>

03/19/2012 07:17 PM

To "Jason W Bush" <Jason.Bush@inl.gov>

cc "Karen R HNC Moore" <Karen.R.Moore@usace.army.mil>, "Kurt S Myers" <Kurt.Myers@inl.gov>, "Robert J Turk" <Robert.Turk@inl.gov>, "Robertson CIV Lubka"

bcc

Subject RE: Transformer Efficiency Assessment PWS -- Onelines

History: This message has been replied to.

Hi Jason,

We are currently using an average rate of $0.229 / kWh for the installation costs. The rate fluctuates from ~Y16 to ~Y18 / kWh, it can go higher or lower, and the dollar costs depends completely on the Y to $ conversion.

$0.229 is acceptable for the purposed of this study.

Thank you, Lubka

-----Original Message-----
From: Jason W Bush [mailto:Jason.Bush@inl.gov]
Sent: Friday, March 16, 2012 8:59
To: Robertson CIV Lubka
Cc: Karen R HNC Moore; Kurt S Myers; Robert J Turk
Subject: RE: Transformer Efficiency Assessment PWS -- Onelines

Hi Lubka,

I have found off base energy cost in Okinawa (From Okinawa Electric Power Company) to be pretty high:

26.77 yen/ kWh or ~$0.3287/ kWh

I believe this is most likely a higher rate than the base pays... is it possible to get a closer figure for what the base's cost per kwh is?

Thanks for your help,

"Robertson CIV Lubka" <lubka.robertson@usmc.mil>

01/22/2012 07:55 PM To
"Jason W Bush" <Jason.Bush@inl.gov>
cc
"Karen R HNC Moore" <Karen.R.Moore@usace.army.mil>, "Kurt S Myers" <Kurt.Myers@inl.gov>, "Robert J Turk" <Robert.Turk@inl.gov> Subject
RE: Transformer Efficiency Assessment PWS -- Onelines