CHAPTER 7. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

TABLE OF CONTENTS

CHAPTER 7. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

7.1 INTRODUCTION

This chapter of the technical support document (TSD) presents DOE's method for deriving transformer prices. The objective of the equipment price determination is to estimate the price paid by the customer/purchaser for an installed transformer. Purchase price and installation cost are necessary inputs to the life-cycle cost (LCC) and payback period (PBP) analyses. Chapter 8 presents the LCC calculations; section 8.2.1 describes how the LCC uses purchase price and installation cost as inputs.

Purchase prices for distribution transformers are not generally known. Transformers are specialty items, often custom-built with unlisted prices. The engineering analysis (Chapter 5) provided the manufacturer selling prices for the units analyzed by the LCC. DOE derived a set of prices for each transformer design produced by the engineering analysis by applying markups to the manufacturer selling price in the form of markup equations. These markups represent all the costs associated with bringing a manufactured transformer into service as an installed piece of electrical equipment at a customer's site.

With respect to installation costs, DOE also developed cost equations for specific situations of particular concern to stakeholders. During the notice of proposed rulemaking (NOPR), stakeholder expressed a concern regarding the impacts of minimum efficiency standards on space-constrained vault transformer installations. Vault transformers are distribution transformers that are used in underground distribution networks were the transformers are installed inside a concrete vault that is open at the top, which can be very expensive to replace or expand. This chapter presents the equation describing vault transformer replacement expenses in section 7.3.5.

7.2 OVERVIEW OF MARKUP EQUATIONS

Depending on the purchasing environment, DOE used different markup equations to capture the various markups in the supply chain between the manufacturer and the customer. For example, electric utilities (except for the rural electric cooperatives) typically purchase liquid-immersed transformers through manufacturer representatives or distributors. The manufacturer selling price plus the small distributor markup is generally the utilities' price for transformers. Dry-type transformers go through several additional marketing and/or handling steps before they are installed by the end-use purchaser.

DOE adjusted the advance notice of proposed rulemaking (ANOPR) distributor markup assumptions based on stakeholder feedback. Liquid-type distribution transformers have a seven percent markup, accounting for distributor markup. The manufacturer selling prices for dry-type transformers include two price markups: a distributor markup of 15 percent and a contractor materials markup of 10 percent. DOE based these markups (expressed as average multipliers) on *RS Means Electrical Cost Data 2002.*[1] The distributor markup converts the manufacturer selling price to the distributor price, the price paid by the electrical contractor. This distributor markup covers the costs of the distribution business, including sales labor, warehousing, overhead, and profit. Then the contractor applies a markup to the distributor price to cover contractor overhead and profit.

For both liquid-immersed and dry-type transformers, DOE added shipping costs, sales tax, an installation labor and equipment markup, and weight-dependent installation costs. Distribution transformers can be very heavy (some weigh more than a ton) and costly to ship. It is common practice for transformers to be shipped directly to a construction site with no intermediate warehousing. DOE estimated shipping costs by collecting a small sample of quotations for transporting transformers. Based on an average shipping distance of 1,000 miles, DOE estimated shipping costs of $0.20/pound for large shipments. Using *RS Means Electrical Cost Data 2002,* DOE estimated an installation labor and equipment markup of 52 percent. By weighting the sales tax for each individual State by its population, DOE calculated a national average sales tax of 5.6 percent. Finally, DOE added installation costs. The installation cost is the cost of labor, equipment, and materials (other than the transformer itself) needed to install a distribution transformer. DOE developed several empirical equations for estimating installation costs as a function of transformer weight.

7.3 ESTIMATION OF INSTALLED PRICE

DOE estimated the installation costs and contractor markups on transformers by fitting a linear cost function to the *RS Means* electrical cost data. The *RS Means* data break down the total installed cost for transformers in terms of four cost components:

1. Materials: transformer purchase price, including mounting hardware.
2. Labor: labor cost required for installation, including unloading and uncrating, hauling within 200 feet of the loading dock, setting in place, connecting to the distribution network, and testing.
3. Equipment: equipment rentals necessary for completion of the installation.
4. Overhead and Profit: installation overhead and profit expenses for the contractor (for dry-type transformers only).

DOE disaggregated its installation costs into these four cost components. *RS Means* lists the transformer price as a "material" cost. DOE performed a regression to disaggregate the overhead and profit associated with installation labor and equipment rental from the overhead and profit associated with the transformer (material) cost. The regression equation is:

$$O\&P = a \times Mat + b \times L\&E + c \qquad \textbf{Eq. 7.1}$$

where:

O&P	= the overhead and profit expense (2001$),
Mat	= the material cost (i.e., transformer and hardware) (2001$),
L&E	= the direct labor and equipment costs of installation (2001$), and
a, b, and c	= the computed linear regression coefficients.

DOE fitted the labor and equipment costs as a function of transformer weight. This relationship is justified because transformer weight (and its correlated size) is a significant factor in determining installation costs for labor and equipment. For pole-mounted transformers, DOE assumed pole costs did not vary with changes in efficiency but recognized that, in some cases, a more efficient, heavier transformer could require a stronger pole. Because the *RS Means* data do not specify transformer weight, DOE inferred the approximate weight of a transformer from its kVA (kilovolt-ampere) capacity, as described below.

For use in the LCC analysis, DOE adjusted these 2001$ to 2006$ using the gross domestic product (GDP) price deflator from the Energy Information Administration (EIA)'s *Annual Energy Outlook 2007* (AEO2007).

7.3.1 Estimation of Transformer Weights and Pole Costs

DOE derived the weight-versus-capacity relationship for typical transformers from the design data produced by the engineering analysis. It used the weight-versus-capacity relationship to estimate the transformer weight corresponding to the transformer costs reported in *RS Means*. DOE estimated a scaling relationship between transformer weight and direct installation labor and equipment costs by fitting the correlation between weight and installation costs to a power-law equation.

In evaluating design options and the impact of potential standard levels, DOE examined the potential for new standards for distribution transformers to lessen the utility or performance of these products. Stakeholders mentioned in their comments to DOE that heavy, more-efficient transformers could have lessened utility due to impacts on utility pole requirements for overhead transformers. For single-phase, pole-mounted, liquid-immersed transformers, DOE estimated the additional installation costs for those designs that would require an upgrade to the pole based on cost data provided by stakeholders.

For the NOPR analysis, DOE added a pole-replacement cost function to the installation cost equation for design line 2, which covers pole-mounted transformers. This analysis assumed that a pole change-out cost of $2,000 occurs for up to 25 percent of pole-mounted transformers when the weight of the transformer exceeds 1,000 pounds. DOE also included a transformer pole support cost of $0.12/lb to account for the cost of a sturdier pole. The pole cost equation is included in the LCC spreadsheet tool for DL2 so that stakeholders can conduct sensitivity analyses regarding pole replacement costs. Because not all transformer installations require a change-out of existing equipment even in the most extreme case, DOE assumed a maximum change-out fraction. DOE selected 25 percent as the maximum change-out fraction estimate based on stakeholder input.[2]

The method for deriving the weight-versus-capacity relationship uses a *typical* transformer weight from the engineering analysis. DOE defined the *typical* weight as the minimum weight plus 20 percent times the weight range, where the weight range is the difference between the minimum and maximum transformer weight for the selected designs.

From these data, DOE obtained the following power-law relationship for transformer weight as a function of capacity and basic impulse insulation level (BIL) rating:

$$Weight = 13.13 \times kVA^{0.765} \times BIL^{0.244} \qquad \textbf{Eq. 7.2}$$

where:

Weight	=	the weight of the transformer (lbs),
kVA	=	the capacity of the transformer (kVA), and
BIL	=	the BIL rating of the transformer (kV).

Although *RS Means* does not provide transformer weights, it does provide transformer capacity and primary voltage. DOE estimated weight from capacity and BIL, which it estimated using primary voltage. DOE then compared the weight to the direct installation costs from the labor and equipment to obtain a power-law relationship.

The first regression performed was the installation direct labor and equipment costs as a function of transformer weight. Data analyzed included all 115 distribution transformer kVA ratings spanning the three *RS Means* electrical equipment categories: "dry type transformer" (16270-200), "oil-filled transformer" (16270-600), and "transformer, liquid-filled" (16270-610). The resulting correlation equation is:

$$L\&E = 42.08 \times Weight^{0.46} \qquad \textbf{Eq. 7.3}$$

where:

L&E	=	the installation, direct labor, and equipment costs (2001$), and
Weight	=	the transformer weight (lbs).

The regression, performed as a power-law trend line fit in Excel, resulted in an R-square of 0.95, indicating a good fit to the data.

7.3.2 Overhead and Profit for Installation Expenses

The next regression targeted contractor overhead and purchase profit expenses in terms of a markup on materials (i.e., the transformer), and labor and equipment (i.e., direct installation). Initially, DOE performed a linear regression with a constant term. When it found that the constant term was not significantly different from zero, it ran the regression again. The resulting equation is:

$$O\&P = 0.10 \times Mat + 0.52 \times L\&E \quad \textbf{Eq. 7.4}$$

DOE used equation 7.4 to allocate overhead and profit expenses to a markup on the distributor price and a separate markup on the direct labor and equipment costs for the installation.

7.3.3 Dry-Type Transformer Installed Price Equation

For dry-type transformers, the result of these analytical steps is a total installed cost equation as a function of the manufacturer selling price and transformer weight:

$$Installed\_Price = M_{tax} \times (M_{L\&E} \times L\&E + M_{Mat} \times (M_{Ship} \times Weight + M_{Dist} \times ManPrice)) \quad \textbf{Eq. 7.5}$$

where:

$Installed\_Price$	=	the final installed price of the transformer (2006$),
M_{tax}	=	the factor that accounts for sales tax, estimated as 1.054,
$M_{L\&E}$	=	the factor that accounts for the markup on direct installation labor and equipment costs, estimated as 1.52,
$L\&E$	=	the installation, direct labor, and equipment costs (2001$), adjusted to 2006$ using the GDP price deflator from *AEO2007*,
M_{Mat}	=	the factor that accounts for the contractor markup on the purchase of the transformer from the distributor, estimated as 1.10,
M_{Ship}	=	the shipping cost, estimated as $0.20/lb,
$Weight$	=	the transformer weight (lbs),
M_{Dist}	=	the average distributor markup factor, estimated as 1.15, and
$ManPrice$	=	the manufacturer's selling price (2006$).

DOE applied the installed cost equation by using the manufacturer price and weight from the engineering analysis. For example, the engineering analysis estimated that the design line 9 (three-phase, 300 kVA) transformer with the minimum manufacturer price weighs 1733 pounds and has a manufacturer price of $5341.80. For this transformer, DOE estimated the installed cost to be \$9631.39, where \$2082.73 is the installation cost, and \$7548.66 is the transformer retail price, including shipping costs, sales tax, and markups.

7.3.4 Liquid-Immersed Transformer Installed Price Equation

For liquid-immersed transformers, DOE removed the contractor markup from the cost equation to obtain :

$$Installed\_Price = M_{tax} \times (M_{L\&E} \times L\&E \times (M_{Ship} \times Weight + M_{Dist} \times ManPrice)) \quad \textbf{Eq. 7.6}$$

where:

Installed_Price	=	the final installed price of the transformer (2006\$),
M_{tax}	=	the factor that accounts for sales tax, estimated as 1.054,
$M_{L\&E}$	=	the factor that accounts for the markup on direct installation labor and equipment costs, estimated as 1.52,
L&E	=	the installation, direct labor, and equipment costs (2001\$), adjusted to 2006\$ using the GDP price deflator from *AEO2007*,
M_{Ship}	=	the shipping cost, estimated as \$0.20/lb,
Weight	=	the transformer weight (lbs.),
M_{Dist}	=	the average distributor markup factor, estimated as 1.07, and
ManPrice	=	the manufacturer's selling price (2006\$).

As with the dry-type transformers, DOE applied the installed cost equation by using the manufacturer price and weight from the engineering analysis. For example, the engineering analysis estimated that the design line 1 (single-phase, 50 kVA) transformer with the minimum manufacturer price weighs 719 pounds and has a manufacturer price of \$937.32. For this transformer, DOE estimated the installed cost to be \$2607.64, where \$1389.70 is the installation cost, and \$1217.94 is the transformer price for the utility, including shipping cost, sales tax, and markups.

7.3.5 Liquid-Immersed Transformer Space-Constraint Cost Equation

DOE also developed cost equations to estimate the economic impacts of minimum efficiency standards on space-constrained vault transformer installations. Vault transformers are distribution transformers that are used in underground distribution networks were the transformers are installed inside a concrete vault that is open at the top. If a replacement transformer is too large to fit within existing concrete vault space-constraints then a vault may need to be modified or moved incurring an extra installation cost.

For space-constrained transformers, DOE assume a vault replacement or modification cost equation that included both fixed and variable cost components as follows :

$$Vault\_Change\_Cost = VCC\_Fixed + VCC\_Variable \times Volume \qquad \textbf{Eq. 7.7}$$

where:

Vault_Change_Cost	=	the cost of changing or expanding a transformer vault (2006$),
VCC_Fixed	=	the fixed component of the transformer vault change cost (2006$),
VCC_Variable	=	the variable component of the transformer vault change cost relative to increase in transformer volume (2006$ per cubic foot),
Volume	=	the transformer volume (cubic feet).

DOE used this cost equation for vault replacement and modification costs in its subgroup analysis for space-constrained transformers in Chapter 11 of this TSD. To obtain estimates of the fixed and variable cost components of the transformer vault cost function, DOE examined transformer vault costs as a function of transformer size as provided by *RS Means (2003)*. First, using standard drawings for utility vaults, DOE determined a transformer to vault volume ratio of 0.27 : 1. Then using cost data from *RS Means*, DOE estimated vault replacement costs including replacement of the vault, removal and reset of the manhole cover and demolition of the existing vault. As reported in the notice of data availability published on February 9, 2007, DOE estimated the fixed cost as $1740 per transformer and the variable cost as $26 per transformer cubic foot. 72 FR 6189

In response to the NODA, several stakeholders commented on DOE's cost equation parameter estimates. The Canadian Electricity Association, estimated that rebuilding or expanding a vault may cost more than $15,000 Canadian dollars per installation. (CEA, No. 171 at p. 2) Dominion power company estimated that to remove sidewalk and street coverings, excavate around the vault, form up and pour walls, and break out the old wall for a transformer vault will cost $50,000 to $60,000 while new tops and grates for the expanded vault will cost $10,000 to $15,000. (Dominion, No. 172 at p. 2) And Georgia Power estimated the cost of vault replacement ranges from $26,000 for just the lid to $100,000 for a single 500 kVA vault to $1 million for a five-unit 2000 kVA vaults. (Southern Company, No. 178 at p. 8) Georgia power's estimate corresponds to a fixed cost component of approximately $30,000 and a variable cost component of $688 per cubic foot of transformer. DOE examined the full range of vault cost equation parameters in its subgroup analysis of vault transformers.

REFERENCES

1. RS Means Company Inc. *Electrical Cost Data: 26th Annual Edition*. 2003. ed. J.H. Chiang. Kingston, MA.

2. Rosenstock, S. *ANOPR for Distribution Transformers, Docket # EE-RM/STD-00-550, RIN #1904-AB08, comment No. 63.* November 8, 2004. Edison Electric Institute.