CHAPTER 7: MARKUPS FOR EQUIPMENT PRICE DETERMINATION

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7.1 INTRODUCTION

To carry out the LCC calculations described in Chapter 8, the Department needed to determine the cost to the consumer of distribution transformers. However, the customer price of such units is not generally known because distribution transformers are specialty items often custom built with unlisted prices. What is known from the results of the engineering analysis (Chapter 5) is the manufacturing price for selected distribution transformer designs. The transformer design software used in the engineering analysis produced specific designs and manufacturing costs associated with transformers designed to meet different values for load and no-load losses. By applying "markup" equations to these manufacturing prices, the Department can estimate the customers' price of equipment. This chapter describes how the Department derived these markup equations for transformers.

7.2 OVERVIEW OF MARKUP EQUATIONS

Manufacturer selling price plus markups, shipping costs, sales tax, and installation costs are all associated with bringing a manufactured transformer into service as an installed piece of electrical equipment. Since electric utilities typically purchase liquid-immersed transformers directly from manufacturers, the manufacturer selling price is the utilities' price for these transformers. Dry-type transformers go through several additional marketing and/or handling steps before the final transformer cost is determined. The Department subjected the manufacturer selling prices of dry-type transformers to two price markups: a distributor markup of 35 percent and a contractor materials markup of 10 percent. The Department estimated these markups (expressed as average multipliers) using *RS Means Electrical Cost Data 2002.*[1] The distributor applies a markup on the manufacturer selling price to arrive at a distributor price, which is the price paid by the electrical contractor. This distributor markup is intended to cover the costs of the distribution business, including sales labor, warehousing, overhead, and profit for the distributor. The contractor then applies a markup on the distributor price to cover contractor overhead and profit.

For both liquid-immersed and dry-type transformers, the Department added shipping costs, sales tax, installation labor and equipment markup and weight dependent installation costs. Distribution transformers can be very heavy (over a ton each) and costly to ship. It is common for the transformers to be shipped directly to a construction site with no intermediate warehousing. The Department estimated shipping costs by collecting a small sample of shipper quotations for transporting distribution transformers. Using an estimated average shipping distance of 1,000 miles, the Department estimated a marginal shipping cost for transformers in large shipments of $0.20/pound. The Department estimated an installation labor and equipment markup of 52 percent using *RS Means Electrical Cost Data 2002.*[1] The Department calculated a national average sales tax of 5.6 percent by weighting the sales tax for each individual state by

its population. Finally, the Department 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. The Department based the installation cost on transformer weight, using several empirical equations developed for this analysis.

7.3 ESTIMATION OF INSTALLED PRICE

To estimate installation costs and contractor markups on transformers, DOE fitted *RS Means* electrical cost data to a linear cost function. The *RS Means* data provide a breakdown of the total installed cost of transformers in terms of four cost components:

1. Materials: the transformer purchase price, including mounting hardware.

2. *Labor*: the labor 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).

The Department disaggregated the installation costs into these four cost components. *RS Means* lists the transformer price as a "material" cost. The Department performed a regression of the overhead and profit costs 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:

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

where:

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

The Department fitted the labor and equipment costs as a function of the transformer weight. This relationship is justified because the weight (and the correlated size) of the transformer is a significant factor in the labor and equipment required for transformer installation. The Department assumed no change in pole cost with changes in efficiency but recognized that in some cases a more-efficient, and therefore heavier, pole mounted transformer

could require a stronger pole. Because the *RS Means* data do not specify the weight of the transformer, the Department inferred the approximate weight of the transformer from its kVA capacity, as described below.

7.3.1 Estimation of Transformer Weights

The Department 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*. Then the Department empirically extracted the 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.

The method for deriving the weight-versus-capacity relationship is to record the minimum and maximum transformer weights for the selection of designs in the engineering analysis, and then select the "typical" transformer weight as the minimum weight plus 20 percent times the weight range.

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

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

where:

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

Although *RS Means* does not provide transformer weights, it does provide the capacity and primary voltage of the transformer. The Department used the primary voltage of the transformer to estimate the BIL rating and then the BIL and capacity to estimate the weight. The Department then compared the weight to the direct installation costs from labor and equipment to obtain a power law relationship between transformer weight and direct installation costs.

The first regression is the installation direct labor and equipment costs as a function of transformer weight. The Department analyzed data for all 115 kVA distribution transformer kVA ratings across 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:

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

where:

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

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

7.3.2 Overhead and Profit for Installation Expenses

Next, the Department performed a regression to explain contractor overhead and profit expenses of the purchase in terms of a markup on materials (i.e., the transformer), and labor and equipment (i.e., direct installation). Initially, the Department performed a linear regression with a constant term. Finding that the constant term was not significantly different from zero, DOE ran the regression again, assuming a constant of zero, and obtained the equation:

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

The Department used the above equation 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 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 that yields the cost of the installed transformer to the customer as a function of the manufacturer selling price and the weight of the transformer:

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

where:

Installed_Price	=	the final installed price of the transformer in dollars,
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 in dollars (2001$),
Weight	=	the transformer weight in pounds,
M_{Ship}	=	the shipping cost in dollars per pound, estimated as 0.20,

M_{Mat}	=	the factor that accounts for the contractor markup on the purchase of the transformer from the distributor, estimated as 1.10,
M_{Dist}	=	the average distributor markup factor, estimated as 1.35, and
ManPrice	=	the manufacturer's selling price.

The Department 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 7 (three-phase, 75 kVA) transformer with the minimum manufacturer price, weighs 544 pounds and has a manufacturer price of $962.62. For this transformer, the Department estimated the installed cost to be $2855.38, where $1222.48 is the installation cost, and $1632.90 is the transformer retail price including shipping, taxes, and all markups.

7.3.4 Liquid-Immersed Transformer Installed Price Equation

For liquid-immersed transformers, the Department removed the contractor and distributor markups from the cost equation to obtain:

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

As with the dry-type transformers, the Department 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 766 pounds and has a manufacturer price of $1178.98. For this transformer, the Department estimated the installed cost to be $2834.73, where $1430.60 is the installation cost, and $1404.43 is the transformer price for the utility, including shipping and taxes. The Department used the same value for the markup factors in equations 7.5 and 7.6.

REFERENCES

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