DOCUMENT RESUME

ED 026 806 EF 001 258

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Ultimate Cost of Building Walls.

Structural Clay Products Inst., Washington, D.C. Dept. of Engineering and Technology.
Report No-AIA-FILE-U6
Pub Date Sep 58
Note-41p.
Available from-Structural Clay Products Institute, 1520 18th St., N. W., Washington 6, D. C.
EDRS Price MF-$0.25 HC-$2.15
Descriptors-Air Conditioning, *Construction Costs, Heating, Lighting, Maintenance, Space Dividers, Structural Building Systems

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# ULTIMATE COST OF BUILDING WALLS

Published September, 1958

STRUCTURAL CLAY PRODUCTS INSTITUTE
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A.I.A. FILE NO. U6

# ULTIMATE COST OF BUILDING WALLS

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Library of Congress Catalog Card Number: 58-13845

## SYNOPSIS


The need for economic analysis of building walls is discussed, and the factors influencing the ultimate cost of exterior walls are studied. The present worth method is used to analyze three types of exterior, non-loadbearing panel or curtain walls. Anticipated costs are expressed in terms of their present value per square foot of wall area. The financial aspects of the value of money, depreciation, price increases and taxation are reviewed. Initial wall costs are estimated. Formulae are given for calculating the influence of depreciation, speed of erection, heating, air conditioning, illumination, real estate taxes, and useable floor space occupied by the wall. Fourteen examples are given to demonstrate calculation methods for anticipated costs. Typical cases are cited to show the effect of insurance rates and the cost of supporting walls. Maintenance and ultimate salvage value are considered. Twenty-four references helpful to the designer are cited. Charts and tables are provided to assist the designer in computing ultimate wall costs.

The authors conclude that aesthetics, engineering and economics are equally important to good architectural expression, but that the variation in the ultimate costs of typical walls may be five hundred per cent or more.



The authors wish to express their appreciation to those who have reviewed and given their valued criticism to the text of this report, particularly Messrs. Walter A. Taylor, Byron C. Bloomfield and Clinton H. Cowgill of the AIA Staff, Aladar Olgyay, A.I.A., Princeton University; Dr. Robinson Newcomb, Consulting Economist; Mr. Homer J. Smith, Staff Architect of the Building Research Advisory Board, and Mr. C. B. Monk of the Structural Clay Products Research Foundation.

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# ULTIMATE COST OF BUILDING WALLS

## I. ULTIMATE COST

Architecture has been aptly characterized as both an art and science. The natural presumption, perhaps, is to infer from these terms that the portion of the creative building process which involves aesthetics should be termed art, while the body of technical information which represents building technology lies in the field of science. However, from both the vantage points of the architect and engineer, this arbitrary judgment might justly be considered, as a Supreme Court Justice once said of another subject, a "pernicious over-simplification."

The fact is that there is much art in the complex process of arriving at the selection and use of building materials so as to combine sound economy with those other two criteria for good building, good engineering and aesthetics. Our building technology expands rapidly. It has never been a simple study, and even the most experienced architects and engineers have had over the span of many years to rely, occasionally, on "guestimates" rather than exact and authoritative information. The reason for this has not been a lack of interest in economy, but rather the lack of authoritative data on building costs and, inevitably, the counter-claims of producers of materials and equipment. Admittedly, it is difficult and often frustrating to arrive at the truth. Yet truth is what the professional man, architect and engineer, seeks in contemporary building.

It is the purpose of this report to serve the building professions in their search for truth in establishing sound principles of economy in the selection and use of building materials for exterior walls. The methods of economic analysis used herein are based on well-known financial principles and the best available technology. It is hoped that the reader will find in them information which will be of help to him in meeting the challenges of planning man's physical environment in today's complex society.

Building for profit presents special problems to the designer. The profitability of investment is a paramount consideration of the client. The economic consideration is of the utmost interest to the mortgage banker, understandably, because he is investing heavily in a market on which the return is slow and the risk is high.[1] As Theodore Crane, Professor Emeritus at Yale states in *"Architectural Construction"*, (John Wiley & Sons, 1956) the problem is to select a type of wall construction which fulfills the desired functions at the least ultimate cost.

In general, the nature of building materials is such that cheapness and true economy may be mutually exclusive. Real economy is obtained by seeking the lowest ultimate cost, including initial purchase price, plus operation and maintenance costs attributable to the wall. First cost and annual costs of building walls are sometimes inverse functions of each other. It is for this reason that a study of building economics is necessary. The lowest ultimate cost of a building is, of course, determined by selecting components having the lowest combination of initial cost, maintenance and operating costs. Thorough analysis is the only method by which economical selection may be made with any degree of accuracy.

As an aid to the design profession the application of economic analysis will be demonstrated herein by a consideration of exterior non-loadbearing or curtain walls. The following cost factors are involved:

1. Value of Money
2. Depreciation
3. Price Increases
4. Income Taxes
5. Initial Construction Cost
6. Cost of Supporting the Walls
7. Space Occupied by the Walls
8. Speed of Erection
9. Air Conditioning Costs
10. Heating Costs
11. Maintenance Expenditures
12. Illumination Costs
13. Salvage Value
14. Insurance Rates
15. Real Estate Taxes

[1] *"Stabilizing Construction"* by Colean and Newcomb, McGraw-Hill Book Co., 1952, page 35.

Each of these items affects the cost of ownership, some much more so than others, and it is important, therefore, to know which of these exert the greater influence. Time and talent may be spent trying to reduce the cost of supporting the wall by reducing its weight when the same amount of effort would be more productive, if more attention were given to air conditioning costs. Having in mind the relative order of magnitude of these cost factors will be of considerable assistance to the architect faced with the problem of creating a beautiful, safe and wise investment for his client.

As a demonstration of the economic analysis methods applicable to building walls, each of the 15 cost factors listed will be studied by the present worth method. Three exterior wall types will be scrutinized, and credits or charges made for each cost consideration. A summary of the results is given in Table I. Note that, all things considered, the glass wall cost is practically four times greater than masonry and metal skin is 71 per cent greater.

It should be emphasized that these figures are based on estimates. Many assumptions are built into the calculations, but a well-reasoned estimate is always better than a "hunch". If the assumptions used in this paper do not agree with the reader's experience, he is invited to apply that experience to the problem at hand. If that is accomplished, this paper will have served its purpose.

**TABLE I**

Present Value of Ultimate Costs
(Per sq. ft. of Wall Area)

FOR TAXABLE ORGANIZATION

| WALL | A | B | C |
|---|---|---|---|
| Material | Masonry Cavity Wall | Metal Panel Wall | Double Plate Glass Wall |
| 1. Total Initial Costs | $3.81 | $6.87 | $6.84 |
| 2. Less Recovered Costs | .70 | 1.42 | 3.00 |
| 3. Plus Maintenance & Operation Costs | 1.49 | 2.41 | 14.45 |
| 4. Total Present Value of Costs | $4.60 | $7.86 | $18.29 |
| 5. Relative Ultimate Cost | 100 | 171 | 398 |

## II. PRESENT VALUE

Each cost item and its frequency must be determined and expressed in comprehensible terms. Confusion is avoided when initial and operating costs are expressed in the same terms. This may be accomplished in one of two ways.

Initial cost may be amortized over a period of time and the annual amortization payment added to the average annual costs of maintenance and operation to produce the total annual cost. Because these annual payments are unequal, are off somewhere in the distant future and are a series of payments rather than a lump sum, they are vague and not so comprehensible as a demand for an immediate cash outlay.

Conversely, all future costs may be converted to a "present value" and this sum added to the initial erection cost. This provides a more accurate answer, because the annual costs need not be averaged. In comparing the relative economics of cost alternatives involving building segments, such as walls, it is best to express all future expenditures in terms of their present value. The owner then has an equivalent initial cost, which includes in one figure the first cost of construction and the present value of all future costs. A task group of the Federal Construction Council, an association of United States government construction agencies, has used and suggested the present value method of analyzing wall costs.[2]

The present worth of a future expenditure is the sum which may be secured today in exchange for the promise to make the specified future payment or series of payments. When the value of money (i.e., the interest rate) and the payment timing are known, the present value of future expenditures may be computed easily from interest tables.[3]

Everyone who has purchased government bonds has used the present worth concept. The present value of a $100.00 Series E Bond is $75.00; that is when the interest rate is 3 per cent, the present worth of receiving $100.00 nine years and nine months from now is $75.00. From the government's point of view, the present value of making a $100.00 expenditure 9.73 years hence is $75.00 when money is valued at 3 per cent.

It is not necessary to discuss in detail the mathematic relationship between time and interest on money exchange. However, a review of the arithmetic involved may be helpful. Suffice it to say that the "present value" of a future expenditure or series of expenditures may be determined by multiplying that future cost by a "present worth factor."

[2] Building Research Institute Technical Reprint No. 5, April 1956.

[3] The present value method of economic analysis is fully explained in the published literature, notable among which is "*Principles of Engineering Economy*," by Eugene L. Grant, published by the Ronald Press Company in New York. The Financial Publishing Company, 82 Brookline Avenue, Boston 15, Massachusetts, publishes detailed present worth tables in a book titled "*Financial Compound Interest and Annuity Tables*"

The particular factor to be used is a function of the interest rate and the timing of the payment. Table II gives present worth factors at 6 per cent interest for a uniform series of future annual payments, $F_u$, and for a single future payment, $F_s$. This table will be helpful in the examples which follow.

In the absence of tabular data, present worth factors may be determined from the following formulae:

(1) $F_s = \frac{1}{(1+i)^N}$

(2) $F_u = \frac{(1+i)^N - 1}{i\,(1+i)^N}$

$F_s$ is the present worth factor for a single future payment.

$F_u$ is the present worth factor for a uniform series of future annual payments.

i is the interest rate.[4]

N is the number of time periods.[4]

*First example:* A hypothetical case will illustrate the present value method involving a uniform annual series. Consider the relative value of two wall assemblies. Wall X has an initial purchase price of $1.00 per sq. ft. and must be painted every year at a cost of $.10 per sq. ft. Wall Y has an initial cost of $2.00 per sq. ft., but need not be painted. The anticipated useful life of both walls is twenty years, and money is valued at 6 per cent. Which is the more economical wall, considering the painting cost as the only annual payment?

From Table II the present worth factor for an annual series, $F_u$, to 20 years at 6 percent is 11.47. The present value of making 20 annual payments of $.10 each, therefore, is 11.47 × $.10 or $1.15. This amount added to the initial cost of $1.00 brings the total present value of wall X to $2.15 or $.15 more than wall Y. Therefore, the more economical alternative is wall Y.

*Second example:* The present worth factor for a non-annual series of equal payments, $F_{nu}$, may be found by adding the present worth factors for single payments, $F_s$. For example, if wall X is to be painted every fourth year, the present value factor is equal to the sum of the single payment factors found in Table II for the 4th, 8th, 12th, 16th and 20th years.

[4] Values of i and N are functions of the same period of time, i.e., if i is the interest rate per annum, N is expressed in years.

**TABLE II**

**Present Worth Factors, 6% Interest Rate**

| N Year | $F_s$ Single Payment | $F_u$ Uniform Annual Series |
|---|---|---|
| 1 | 0.9434 | 0.943 |
| 2 | 0.8900 | 1.833 |
| 3 | 0.8396 | 2.673 |
| 4 | 0.7921 | 3.465 |
| 5 | 0.7473 | 4.212 |
| 6 | 0.7050 | 4.917 |
| 7 | 0.6651 | 5.582 |
| 8 | 0.6274 | 6.210 |
| 9 | 0.5919 | 6.802 |
| 10 | 0.5584 | 7.360 |
| 11 | 0.5268 | 7.887 |
| 12 | 0.4970 | 8.384 |
| 13 | 0.4688 | 8.853 |
| 14 | 0.4423 | 9.295 |
| 15 | 0.4173 | 9.712 |
| 16 | 0.3936 | 10.106 |
| 17 | 0.3714 | 10.477 |
| 18 | 0.3503 | 10.828 |
| 19 | 0.3305 | 11.158 |
| 20 | 0.3118 | 11.470 |
| 21 | 0.2942 | 11.764 |
| 22 | 0.2775 | 12.042 |
| 23 | 0.2618 | 12.303 |
| 24 | 0.2470 | 12.550 |
| 25 | 0.2330 | 12.783 |
| 26 | 0.2198 | 13.003 |
| 27 | 0.2074 | 13.211 |
| 28 | 0.1956 | 13.406 |
| 29 | 0.1846 | 13.591 |
| 30 | 0.1741 | 13.765 |
| 31 | 0.1643 | 13.929 |
| 32 | 0.1550 | 14.084 |
| 33 | 0.1462 | 14.230 |
| 34 | 0.1379 | 14.368 |
| 35 | 0.1301 | 14.498 |
| 36 | 0.1227 | 14.620 |
| 37 | 0.1158 | 14.737 |
| 38 | 0.1092 | 14.846 |
| 39 | 0.1031 | 14.949 |
| 40 | 0.0972 | 15.046 |
| 41 | 0.0917 | 15.138 |
| 42 | 0.0865 | 15.225 |
| 43 | 0.0816 | 15.306 |
| 44 | 0.0770 | 15.383 |
| 45 | 0.0727 | 15.456 |
| 46 | 0.0685 | 15.524 |
| 47 | 0.0647 | 15.589 |
| 48 | 0.0610 | 15.650 |
| 49 | 0.0575 | 15.708 |
| 50 | 0.0543 | 15.762 |

| Year | $F_s$ |
|---|---|
| 4th | .7921 |
| 8th | .6274 |
| 12th | .4970 |
| 16th | .3936 |
| 20th | .3118 |
| $F_{nu}$ = | 2.6219 |

The present value of the cost of making a $.10 expenditure every fourth year for the next 20 years is equal to 2.6219 × $.10 or $.26. The present value of the cost of wall X is, therefore, only $1.00 plus $.26. In this case wall X is the more economic choice, all other things being equal.

## INTEREST AND TIME

As the interest rate is increased, the present value of a future expenditure is decreased. This may be understood by realizing that if the interest on a government savings bond of given face value is increased, the purchase price is reduced.

*Third example:* If the interest rate in the first example is increased to 8 per cent, the present worth factor of a uniform annual series, $F_u$, for 20 years is found from equation 2 to be 9.818. The present value of painting wall X every year in this case is only \$.98, bringing the total present value of wall X to \$1.98 vs. \$2.00 for wall Y. An investment in wall X would be slightly more economical under these conditions. If, however, the anticipated useful life is extended to 30 years, the present worth factor for a uniform annual series at 8 per cent interest is found from equation 2 to be 11.258. The total present value of wall X in this case is \$1.00 plus \$.10 × 11.258 or \$2.13, making wall Y a more economical choice.

It can be seen, then, that the interest rate and the anticipated useful life of the item must be carefully considered in any economic analysis. The interest rate to be used in a present worth study for a private investor is not the bare cost of borrowed money, but rather the rate of return required to justify the investment. A great change in the conclusion may result from a moderate change in the interest rate. Comparisons based on the cost of borrowed money have an undetected bias in favor of the alternative involving the lower annual cost.

However, for government investments on which there is no profit or by which the government does not compete with private industry, the proper interest rate to be used in a present worth study is the cost of borrowed money. For example, an economic study of a national defense project should employ the current interest rate being paid on government bonds. In a present worth analysis of a public power project, the interest rate should be comparable to that employed by the private industry with whom the government is competing.

The time of making future payments is also important. To illustrate: the present worth of making a \$5.00 expenditure every five years is not equivalent to making a \$1.00 payment every year. The annual payment is a less economic choice. For studies of building economics, the estimated average annual expenditure is more practical than monthly costs, which fluctuate. This simplifies an otherwise burdensome calculation.

The period of time over which costs should be considered in an economic study of building walls is the useful life of the building. An investor may wish to recover his capital in much less than that time, but an architect is designing a structure to reach its normal life expectancy. The purpose of analyzing the economics of building walls is to assist him in making a selection of materials which will attain that life at the lowest ultimate cost. A study of building economics based on a life expectancy shorter than can reasonably be expected may be biased in favor of materials having higher maintenance costs. For this reason the anticipated useful life of the item is important. Perhaps the most economical buildings in the world, and the most financially profitable, are those which face the Place Vendome in Paris. Built as residences over two and a half centuries ago, they now command high rents as offices.

The U. S. Treasury Department, Internal Revenue Service, has published "*Tables of Useful Life of Depreciable Property*" in Bulletin F, available from the U. S. Government Printing Office, Washington 25, D. C. The useful life of many types of building equipment and buildings as such are presented. "*Boeckh's Manual of Appraisals*", published by E. H. Boeckh and Associates, Washington, D. C., contains more detailed data on life expectancies of various building types utilizing several construction materials. The actual life may be considerably greater than the useful lives given in these references.

## PRICE CHANGE

In computing the present value of future expenditures, a decision must be made concerning price changes. The selection of one material may be indicated by an economic study in which no price change is anticipated, while an alternate material may prove more economical, if the maintenance and operation costs are expected to rise. Obviously, the anticipation of a price increase tends to make more attractive the alternative involving less maintenance and operation expense. Thus, economic studies which do not provide for an anticipated price increase may be biased in favor of materials requiring greater future expenditures, if prices are expected to increase during the life of the building.

The Engineering News-Record Building Construction Cost Index indicates that during the period 1913–1957 the weighted average annual rate of change in building cost was + .0377. The maintenance and operating costs attributable to walls are not all related to building costs. Suggested price change rates for individual items are given in Table VII.

Present value calculations involving a uniformly changing annual series may be solved by applying a correction factor determined approximately from the following integration:

$$(3) \qquad P_u = \frac{1}{F_u} \int_0^n \frac{(1+nf)\,dn}{(1+i)^n}$$

Where: $P_u$ is the present worth correction factor for a uniformly changing series of future annual expenditures.

$F_u$ is the present worth factor for uniform series of equal future annual expenditures for n years.

n is time in years.

i is the value of money.

f is the average annual rate of price change.

When the variables with respect to time are established, the above equation may be solved by Simpson's Rule for approximate integration. When the life of the building is 50 years, approximate values of $P_u$ for several positive values of f and i may be selected from Figure 1.

Thus, when the price change rate is + .0377 and the interest rate is 6 per cent, the present value of making a uniformly increasing series of future annual expenditures under these conditions is 59 per cent greater than if no price increase were anticipated (i.e., 1.59 times as much or $P_u = 1.59$).

Certain future costs do not occur every year, but at some other regular interval. Painting, for example, is usually required every fourth year, but the cost of painting has an average annual rate of change. The cost of painting at any given future time is found by multiplying the present cost, C, by (1+nf), where f is the average annual rate of price change and n is the number of years to that future time. The present value of that changed future ex-

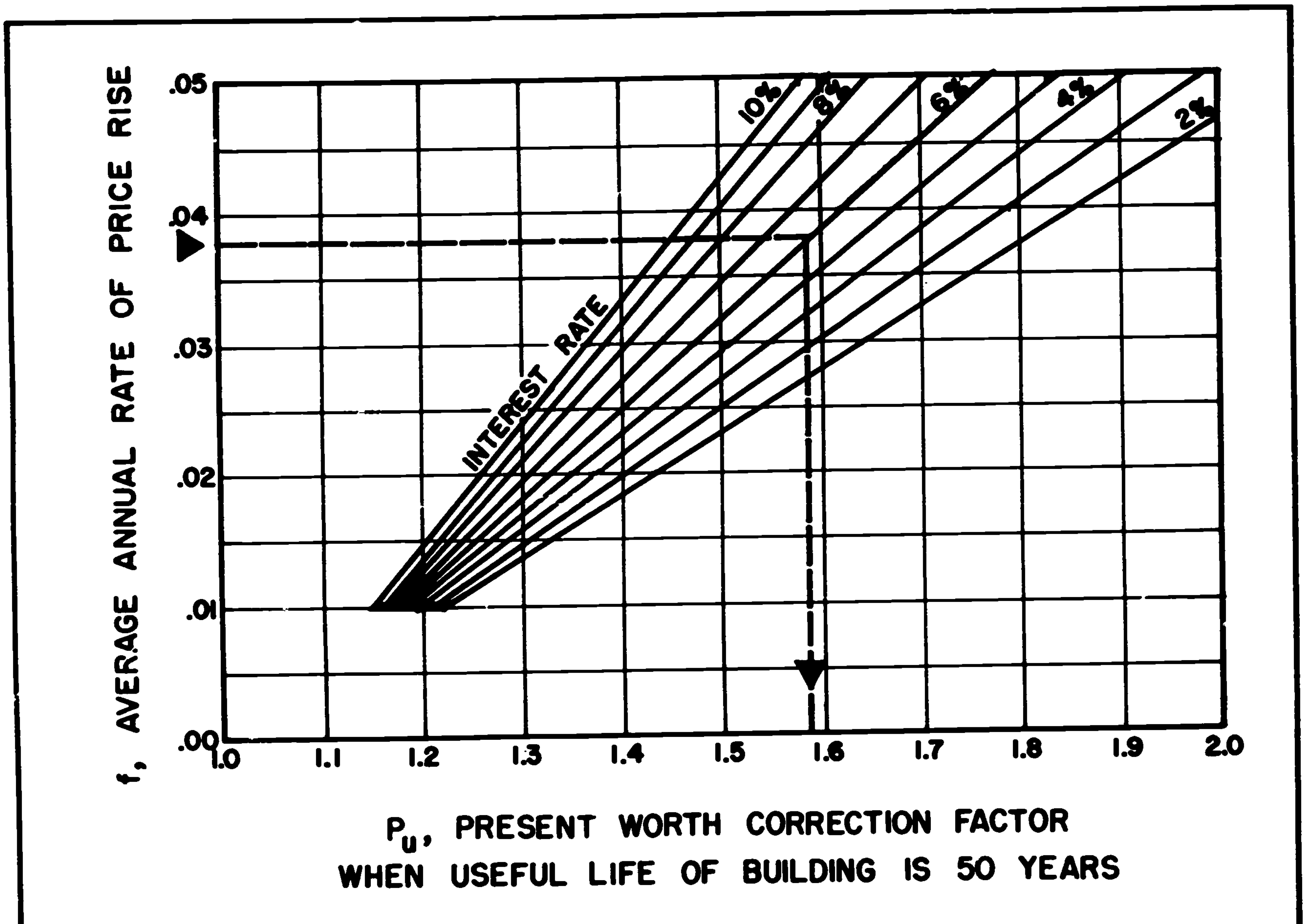



Figure 1

penditure is found by multiplying the product C $(1+nf)$ by $F_{\bullet}$ for that future time. Computing the total present value involving a non-annual series of payments, which are changing at some average annual rate, may be done in the following way:

*Fourth example:* The present value of the painting costs of wall X every four years for the next 20 years is computed as follows, when the present cost, C, is 10 cents per square foot and is expected to rise at the rate, f, of .0377:

| n Year | $F_{\bullet}$ at 6% From Table II | Future Cost of Painting Per Sq. Ft. $C(1 + fn)$ | Present Value of Future Cost, $F_{\bullet}C(1 + fn)$ |
|---|---|---|---|
| 4th | .7921 | \$.1151 | \$.091 |
| 8th | .6274 | .1302 | .082 |
| 12th | .4970 | .1452 | .072 |
| 16th | .3936 | .1603 | .063 |
| 20th | .3118 | .1754 | .055 |

Total present value of future painting costs \$.363

Thus, the present value of making a four-year series of uniformly increasing maintenance expenditures on the wall X for a period of 20 years is \$.36 instead of \$.26 as indicated in the second example, or some 38 per cent higher than if no price increase were anticipated.

### INCOME TAXES

Some business enterprises have considered the adoption of a construction policy which gives greater consideration to materials having lower first cost and higher operating costs, for the reason that operating expenditures may be charged off for income tax purposes. Since the government, in effect, pays a large portion of the operating and maintenance costs, the tendency is to let the government help pay the bill. In periods of high tax rates this course of action has possibilities, if not carried to an extreme. To be economically sound, however, the proposition must be carefully analyzed. It should not be overlooked that the government also eventually repays a part of initial cost by making depreciation tax deductible. It does not, however, pay interest which the initial cost could have accrued.

Under many circumstances it is proper to make economic studies omitting any calculation of disbursements for income taxes. Taxes are, of course, always omitted in studies for owners who do not pay taxes, e.g., schools, churches, non-profit institutions and public buildings. In the conclusion of this report cost data are summarized for both taxable and tax-exempt operations.

If income taxes are to be considered in a study of building wall economics, they may be reduced to an equivalent total rate on taxable income. This rate, henceforth referred to as T, is a composite figure including any local, state and national income taxes anticipated over the useful life of the structure. For example, if a corporation must give 57 per cent of its net taxable income to the government, T = .57. If the present tax rate is employed and the tax rate rises, the resultant study will be prejudiced against materials having higher maintenance costs. Although taxes may shift from one level of government to another, the authors see little hope for relief and do not believe peacetime taxes can get much higher.

## III. ECONOMIC ANALYSIS

### DESIGN AND COST ASSUMPTIONS

The problem studied here is the method of selecting the most economical exterior non-load-bearing or curtain wall for a building. The building described in Table III is used as an illustration. The three wall types defined in Table IV will be studied. The present worth calculations used are based on the cost and financial assumptions shown in Tables V, VI and VII. While the data presented in these tables are typical, they are used only to illustrate the calculation method. When possible, current local costs should be obtained for a particular project.

**TABLE III**

**Description of Building**

| | |
|---|---|
| 1. Type | Office |
| 2. NBFU classification | A |
| 3 Length | 200 ft. |
| 4. Width | 100 ft. |
| 5. Height | 120 ft. |
| 6. Number of floors, plus basement, F | 10 |
| 7. Story height, S | 12 ft. |
| 8. Gross floor area, plus basement | 200,000 sq. ft. |
| 9. Gross cubic content, plus basement | 2,400,000 cu. ft. |
| 10. Gross exterior wall area, above grade, $A_g$ | 72,000 sq. ft. |
| 11. Frame | Reinforced concrete |
| 12. Bay length | 20 ft. |

Since the usual purpose in an economic analysis of building walls is to compare two or more wall types, it is not essential to the conclusion that the basic cost data be absolutely accurate. So long as the percentage error is approximately the same for the data on each wall type, it will not seriously impair the accuracy of the relative ultimate cost of the walls.

## TABLE IV

### Wall Design Assumptions

| Wall Type | A | B | C |
|---|---|---|---|
| 1. Basic material | Masonry Cavity Wall | Metal Panel Wall | Double Plate Glass Wall |
| 2. Window area, percent | 0 | 0 | 100 |
| 3. Wall thickness, in., Y | 10 | 6 | 3 [5] |
| 4. Wall height, floor to floor, ft., S | 12 | 12 | 12 |
| 5. Wall weight, lbs. per sq. ft., P | 65 | 16 | 7 |
| 6. Fire resistance, hrs. | 4 | 1 | — |
| 7. U value, Btu/hr./sq. ft./°F | .12 | .12 | .55 |
| 8. Color | medium | medium | clear |
| 9. Interior artificial illumination, hrs. per year, L | 2000 | 2000 | 1000 |

[5] Includes venetian blinds.

## TABLE V

### Cost Assumptions

| Wall Type | A | B | C |
|---|---|---|---|
| 1. Initial cost | | | |
| a) of wall per sq. ft., $C_w$ | $2.30 | $6.00 | $6.40 [6] |
| b) of building per cu. ft., $C_c$ | 1.50 | 1.61 | 1.62 [6] |
| c) of building per sq. ft., $C_f$ | 18.00 | 19.35 | 19.50 [6] |
| d) of building, $C_b$ | $3.6 \times 10^6$ | $3.87 \times 10^6$ | $3.90 \times 10^6$ |
| e) of building contents | $2 \times 10^6$ | $2 \times 10^6$ | $2 \times 10^6$ |
| 2. Salvage value per sq. ft. of wall, $C_s$ | .16 | .80 | .57 |
| 3. Maintenance cost per sq. ft. of wall and frequency, $C_m$ | | | |
| a) cleaning exterior | .07 every 35 years | .02 every 8 years | .02 every 3 months |
| b) cleaning interior | — | — | .02 every 3 months |
| c) cleaning blinds | — | — | .02 every 3 months |
| d) pointing | .50 every 35 years | — | — |
| e) caulking | — | .06 every 8 years | .06 every 16 years |
| f) painting interior | .03 every 4 years | .03 every 4 years | — |
| 4. Fire insurance rate per $100.00 value: | | | |
| a) building, $I_r$ | .06 | .08 | .08 |
| b) contents, $I_e$ | .18 | .20 | .20 |

[6] Includes venetian blinds.

## TABLE VI

### Related Design & Cost Assumptions

| | |
|---|---|
| 1. Concrete costs: | |
| a) super structure | $80.00 per cu. yd. |
| b) foundations | $35.00 per cu. yd. |
| 2. Air conditioning: | |
| a) initial plant cost, $M_g$ | $.10 per Btu of hourly capacity |
| b) power costs, E | $.02 per kw-hr. |
| c) power input per ton, G | 2 kw |
| d) wall orientation | average of N, E, S, & W |
| e) design temperature on August 1st at 4 p.m. on 40°N. Lat. | |
| exterior, $t_d$ | 95°F |
| interior, $t_i$ | 74°F |
| daily range, $t_r$ | 20°F |
| f) summer degree-days, per year, K | 500 |

*continued*

## TABLE VI *continued*

### Related Design & Cost Assumptions

| | |
|---|---|
| 3. Heating: | |
| a) initial plant cost, $M_h$ | $.02 per Btu of hourly capacity |
| b) fuel cost, $C_h$ | $.10 per therm (100,000 Btu) |
| c) design temperature | |
| exterior, $t_o$ | 0°F |
| interior, $t_i$ | 70°F |
| d) heating degree days per year, $D_d$ | 5000 |
| 4. Illumination: | |
| a) power cost, E | $.02 per kw-hr. |
| b) lamp replacement cost | $.04 per watt |
| c) design level | 45 foot-candles |
| d) illumination, foot-candles per watt per sq. ft. of floor area, W | 15 foot-candles |
| e) normal lamp life, $L_l$ | 8000 hrs. |

## TABLE VII

### Financial Assumptions

| | |
|---|---|
| 1. Value of money, i | 6% per annum |
| 2. Anticipated useful life of building, $L_b$ | 50 years |
| 3. Depreciation rate on building, $D_b$ | 2% per year |
| 4. Anticipated useful life of mechanical equipment | 20 years |
| 5. Depreciation rate on mechanical equipment, $D_g$ and $D_h$ | 5% per year |
| 6. Anticipated average annual rate of price changes, f | |
| a) income taxes | none |
| b) real estate taxes | +.02 |
| c) insurance | +.01 |
| d) mechanical equipment | +.0377 |
| e) combined heating plant maintenance and fuel | +.0333 |
| f) combined air conditioning plant maintenance and electricity | +.02 |
| g) maintenance on walls | +.0377 |
| h) electricity | +.01 |
| 7. Total equivalent income tax rate, T | 57% of profit |
| 8. Real estate taxes | |
| a) ratio of assessed value to market value | .75 |
| b) tax rate | 4% |
| 9. Insurance rate | See Table V, item 4 |

## INITIAL COST

The cost of erecting a given wall type may be estimated from data presented in several excellent cost references now available. Local contractors are often helpful in this regard. However, there is no more accurate way to determine initial cost differances than by alternate bids. It should be mentioned that this method is expensive to the contractor and should be employed only when a reliable estimate cannot otherwise be obtained. The estimated initial costs of the three walls shown in Table V are taken from standard references and represent total cost to the owner, including all fees.

Mr. Arthur F. Comstock, a New York building construction cost estimator, presented in a 1957 copyrighted paper initial construction cost data on

## TABLE VIII

**Comparative Construction Costs Per Sq. Ft. of Exterior Wall of Modern New York Office Buildings. (Prices as of March, 1958)**

| No. | Street Location | No. of Stories | Facade Material | Mullion Material | Spandrel Material | Window Type | Percent Glass Area | Initial Wall Cost Per Sq. Ft. | Year Completed |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 380 Madison Ave. | 25 | Glazed Face Brick | | Glazed Face Brick | Steel, Continuous | 50 | $2.60 | 1955 |
| 2 | 711 Third Ave. | 19 | Glazed Face Brick | | Glazed Face Brick | Steel, Continuous | 50 | 2.60 | 1956 |
| 3 | 112 West 34th St. | 25 | Aluminum | Aluminum | Aluminum Cast | Aluminum Projected | 60 | 5.77 | 1955 |
| 4 | 300 Park Ave. (Colgate-Palmolive) | 25 | Glass | Aluminum | ½" Struct. Glass | Fixed Alum., Hopper Vent | 55 | 6.24 | 1955 |
| 5 | 400 Park Ave. | 21 | Aluminum | Aluminum | "Hutex" Glass | Aluminum Projected | 60 | 6.27 | 1957 |
| 6 | 575 Lexington Ave. | 34 | Gold Anodized Aluminum | Aluminum | Gold Anodized Aluminum | | 60 | 6.30 | 1958 |
| 7 | 100 Park Ave. | 36 | Face Brick | | Aluminum Cast | Aluminum Double Hung | 40 | 7.62 | 1951 |
| 8 | 261 Madison Ave. (Amer. Machine & Foundry) | 28 | Aluminum | Aluminum | Aluminum | Fixed Aluminum | 60 | 8.48 | 1953 |
| 9 | 99 Park Ave. (National Distillers) | 26 | Aluminum | Aluminum | Aluminum | Aluminum Double Hung | 35 | 9.04 | 1955 |
| 10 | 150 East 42nd St. (Socony-Mobil) | 45 | Stainless Steel | Stainless Steel | Stainless Steel | Stainless Steel Veritcal Pivot | 38 | 9.28 | 1956 |
| 11 | 390 Park Ave. (Lever House) | 21 | Heat Absorb. Glass | Stainless Steel | Glass | Stainless Steel Fixed | 53 | 11.66 | 1951 |
| 12 | First Ave. & 42nd St. (U. N. Secretariat) | 39 | Heat Absorb. Glass | Aluminum | Glass | Stainless Steel Fixed | 57 | 14.27 | 1950 |
| 13 | 375 Park Ave. (Seagram) | 38 | Heat Absorb Glass | Bronze | Bronze | Stainless Steel Fixed | 60 | 32.00 | 1958 |

the exterior walls of several New York City buildings. The data prepared by Mr. Comstock for all walls were based on cost prevailing in October 1955, when the Engineering News-Record Building Construction Cost Index for New York City was 548. The index for March 1958 was 593. Table VIII provides some of the cost data given by Mr. Comstock, but increased 8.2 per cent to provide comparable data for March 1958. The Comstock costs on walls 1 and 2 included $.33 per sq. ft. of wall area for structural framing, but nothing was included for this item in other wall costs. Accordingly, the figures for Walls 1 and 2 in Table VIII have been adjusted for this item to provide completely comparable data.

In the January, 1957 issue of *"Civil Engineering,"* Mr. H. C. Turner, Jr. of the Turner Construction Company, gives the following wall cost data:

| Facing Material | Cost per Square Foot of Wall Area |
|---|---|
| Brick | $ 4.00 to $ 5.00 |
| Porcelain enamel steel | 6.50 to 7.50 |
| Aluminum | 7.00 to 8.00 |
| Polished stainless steel | 10.00 to 11.00 |
| Glass | 10.00 to 11.00 |

The costs given above for metal walls include masonry backup and insulation. A 4-inch hollow masonry backup may be expected to cost about $.55 per sq. ft. Mr. Turner's article states that any reduction in the tonnage of structural steel required because of the lighter weight of metal walls would not materially affect the relative costs given above.

## COST OF SUPPORTING THE WALLS

In multi-story structures utilizing non-load-bearing panel or curtain walls, a portion of the cost of erecting the structural frame and foundations should be considered a part of initial wall cost for the purpose of an economic analysis. Heavier walls are more costly to support than lightweight walls, but this cost difference has frequently been exaggerated. In low buildings where load-bearing walls may be used, wall types which require a structural frame should be charged with the entire cost of that frame.

In a typical 10-story rigid frame office building, having 50 per cent glass area, the exterior walls account for about 25 per cent of the design load on the exterior columns, because the load on the frame comes largely from the floors and not from the walls. Reducing the weight of spandrel walls by 75 per cent reduces the load on the exterior foundations only about 5 per cent. The exterior columns in turn carry only a small portion of the total weight of the building. In this multi-story building, a 75 per cent reduction in the weight of the spandrel walls would reduce the total load on all foundations by about 2 per cent. Certainly no savings are achieved by reducing wall weight on low buildings, while some savings are possible by major reductions in wall weight on very tall structures.

In a comparison of structural framing and foundation costs due to wall weights, it is important not to overlook the significance of window area and to be reasonably accurate in estimating wall weights. To compare a 12-in. solid wall, for example, with a prefabricated panel wall having a 50 per cent window area is unrealistic. Twelve-inch walls weighing 120 lb. per sq. ft. are seldom used. A 10-in. cavity wall of conventional materials, weighing 65 lb. per sq. ft. and occupying the same proportion of the building's exterior surface, provides a more realistic basis for comparison.

In the usual case of a 20-story building the use of conventional masonry walls, rather than typical metal skin, may require the addition of 1 to 3 lb. of spandrel and column steel per sq. ft. of wall area. At $.15 per lb. the difference in structural steel cost would not exceed $.45 and would undoubtedly be closer to $.15 per sq. ft.

Information published by United States Steel indicates that on 20-story buildings a savings of about $.50 per sq. ft. of wall area may be achieved by reducing the weight of the wall from 120 to 42 lb. per sq. ft. If this estimate is accurate, it represents nearly the maximum which may be achieved. Walls weighing 120 lb. per sq. ft. are not generally used in current multi-story work, and few buildings are 20 stories high. Certainly no savings are achieved by wall weight reductions in very low buildings.

The approximate cost of supporting walls on a steel or concrete frame office building, having 20-foot bays and heights up to 25 stories, have been computed and are expressed graphically in Fig. 2. Equation 4 provides a mathematical expression for Fig. 2.

$$C_h = \frac{P\,(16.33+F)}{6670} \qquad (4)$$

Where: $C_h$ is the initial construction cost of the structural frame and foundations attributable to one square foot of wall area.

$P$ is the weight of the wall in pounds per per square foot.

$F$ is the number of floors.

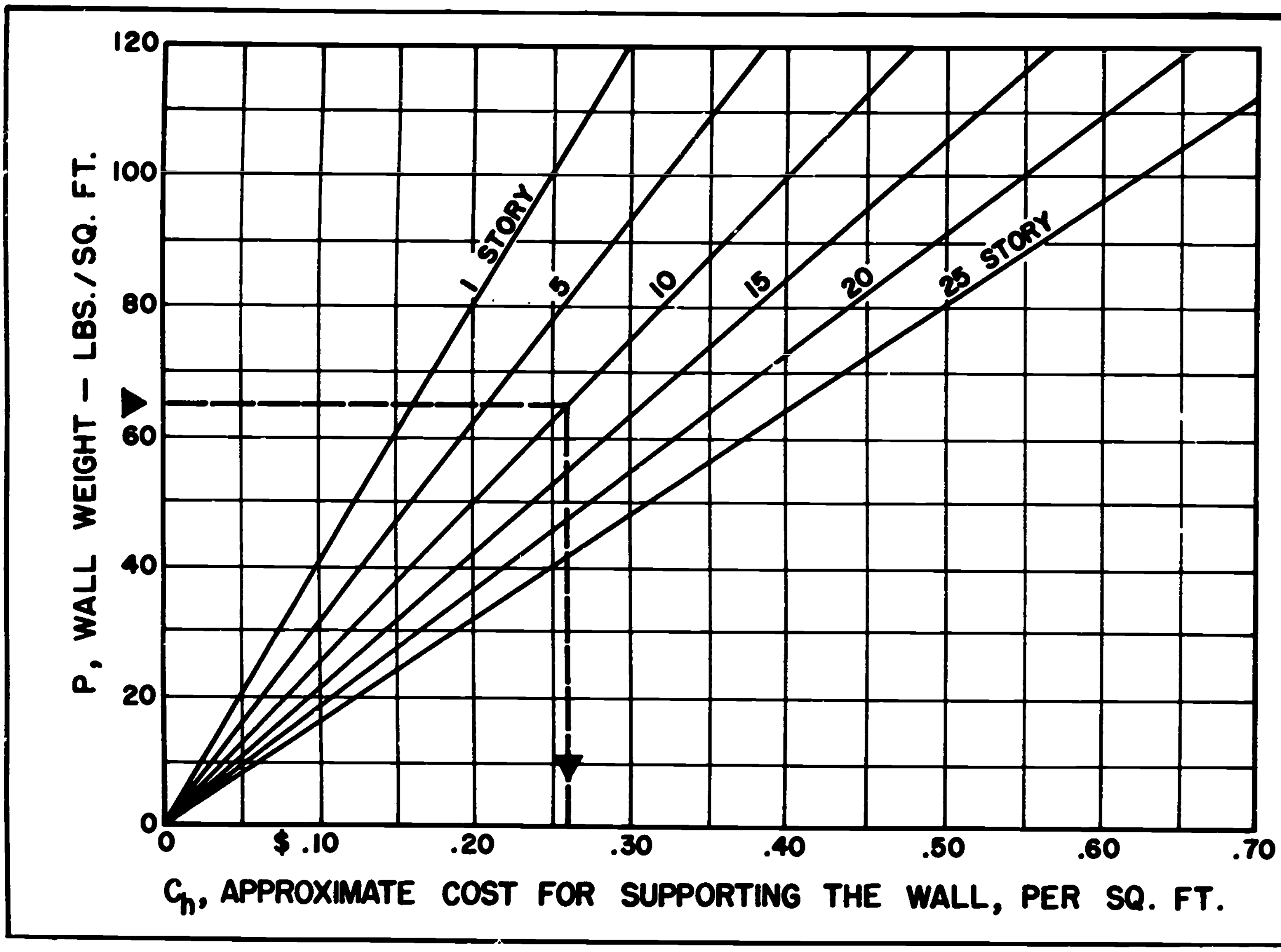



**Figure 2**

Thus, from equation 4, the cost of supporting wall A is \$.26 per sq. ft., \$.06 for wall B and \$.03 for wall C.

The cost of supporting the wall is, of course, an initial construction cost and need not be converted to a present value. The cost of supporting the wall per square foot of wall area should be computed and added to the initial cost of erecting the wall.

#### WALL THICKNESS

When space is limited and the entire building site must be used, the thickness of walls is an important economic factor, because of rentable or usable floor space which the walls occupy. However, when lot area is not so limited, and the building walls are not erected on the building restriction line, the thickness of walls is not an economic factor. In this case, all of the floor area which can be economically used or rented has already been provided, and the walls are simply set outside that area.

When space is limited, the initial cost of providing the additional floor space attributable to each square foot of wall area may be computed from the following formula:

$$C_{fw} = \frac{C_f Y}{12\,S} \qquad (5)$$

Where: $C_{fw}$ is the initial cost per square foot of wall area for providing the additional floor space occupied by the wall.

$C_f$ is the cost of building per square foot of floor area.

$Y$ is the wall thickness in inches.

$S$ is the floor to floor wall height in feet.

Figure 3 provides a graphic solution to equation 5. $C_{fw}$ is, of course, an initial construction cost; the cost of providing the additional needed floor space to compensate for the area occupied by the wall thickness. If the space is needed, it should be provided.

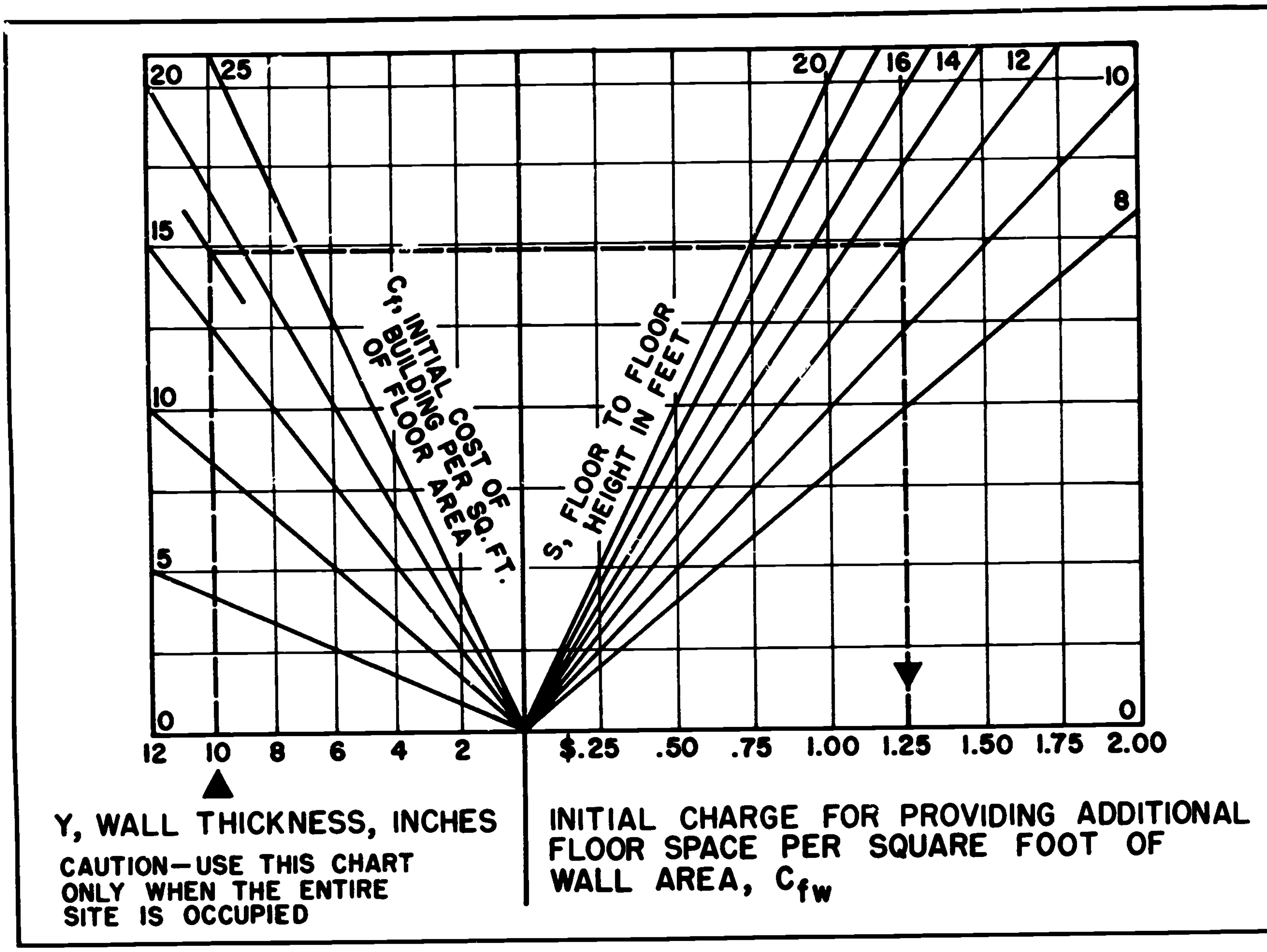



**Figure 3**

*Fifth example:* Building space is limited, and the entire site will be occupied. The completed building will cost $18.00 per sq. ft. of floor area to build ($C_f$=$18.00). Wall A has a thickness of 10 inches ($Y=10$), and the floor to floor height of the building wall is 12 feet ($S=12$).

The initial cost of providing the additional floor space occupied by the wall is, therefore, equal to $1.25 per sq. ft. of wall A from equation 5. If the alternate wall B is six inches thick, and the building cost is $19.35 per sq. ft., the additional cost for wall B is $.81, and for wall C this amounts to $.41, when the building costs $19.50 per sq. ft. These charges should be made only when space is limited. Since it is an initial cost, it need not be converted to present value.

**DEPRECIATION**

Although the rate of depreciation of the exterior walls affects the selection between cost alternatives, there seems to be little agreement on the calculation method which might be employed. Different approaches are indicated for the purposes of accounting, insurance and taxation. Regardless of method, the variables encountered are numerous. The anticipated life, the maintenance required to sustain a given condition of repair, obsolescence, and many variations of these affect the depreciation rate.

For the purpose of analyzing the economics of building walls, depreciation may be considered on a straight line basis over the life of the building. Depreciation rates are provided in references previously cited. In certain cases very rapid depreciation is permitted by the tax laws. Because depreciation is deductible for tax purposes, a part of the initial construction cost is eventually recovered. There is, of course, no depreciation tax credit on buildings owned by tax exempt organizations. The present value of the amount thus recovered may be computed from the following formula:

(6) $V_{pd} = F_u T C_t D_b$

Where: $V_{pd}$ is the present value of the initial cost recovered by depreciation tax credit per square foot of wall area.

$F_u$ is the present worth factor for a uniform annual series for the tax life of the building from equation 2.[7]

T is the total equivalent income tax rate.

$C_t$ is the total initial cost attributable to the wall per square foot, including wall construction, cost of supporting the wall, and a charge for floor space occupancy, if any.

$D_b$ is the annual depreciation rate.[7]

Under the financial conditions given in Table VII, equation 6 may be written as:

(6A) $V_{pd} = .18\ C_t$

Under the financial conditions given in Table VII, Figure 4 provides a graphic determination for the total initial wall cost less depreciation tax credit: $(C_d = C_t - V_{pd})$

*Sixth example:* The initial cost of wall A, including its pro rata portion of structural frame and foundation costs, is \$2.56 per sq. ft. This amount added to the initial cost of providing additional floor space due to wall thickness, $C_{fw}$, brings the total initial cost attributable to wall A to \$3.81 per sq. ft. of wall area. Similarly, the total initial cost of wall B is \$6.87 and wall C is \$6.84. Money is valued at 6 per cent, and the tax life of the building is 50 years ($F_u = 15.762$). On a straight line basis the depreciation rate is 2 per cent ($D_b = .02$). The tax rate is 57 per cent ($T = .57$). The present value of the total initial cost recovered by depreciation per square foot of wall A from equation 6A is, therefore:

$$V_{pd} = .18 \times \$3.81$$
$$V_{pd} = \$.69$$

Similarly, the amount recovered on walls B and C is \$1.23 per sq. ft.

[7] $F_u$ and $D_b$ are functions of the same period of time. If the depreciation rate is based on a tax life of five years, $F_u$ is 4.212 from Table II or equation 2 and $D_b$ is .20.

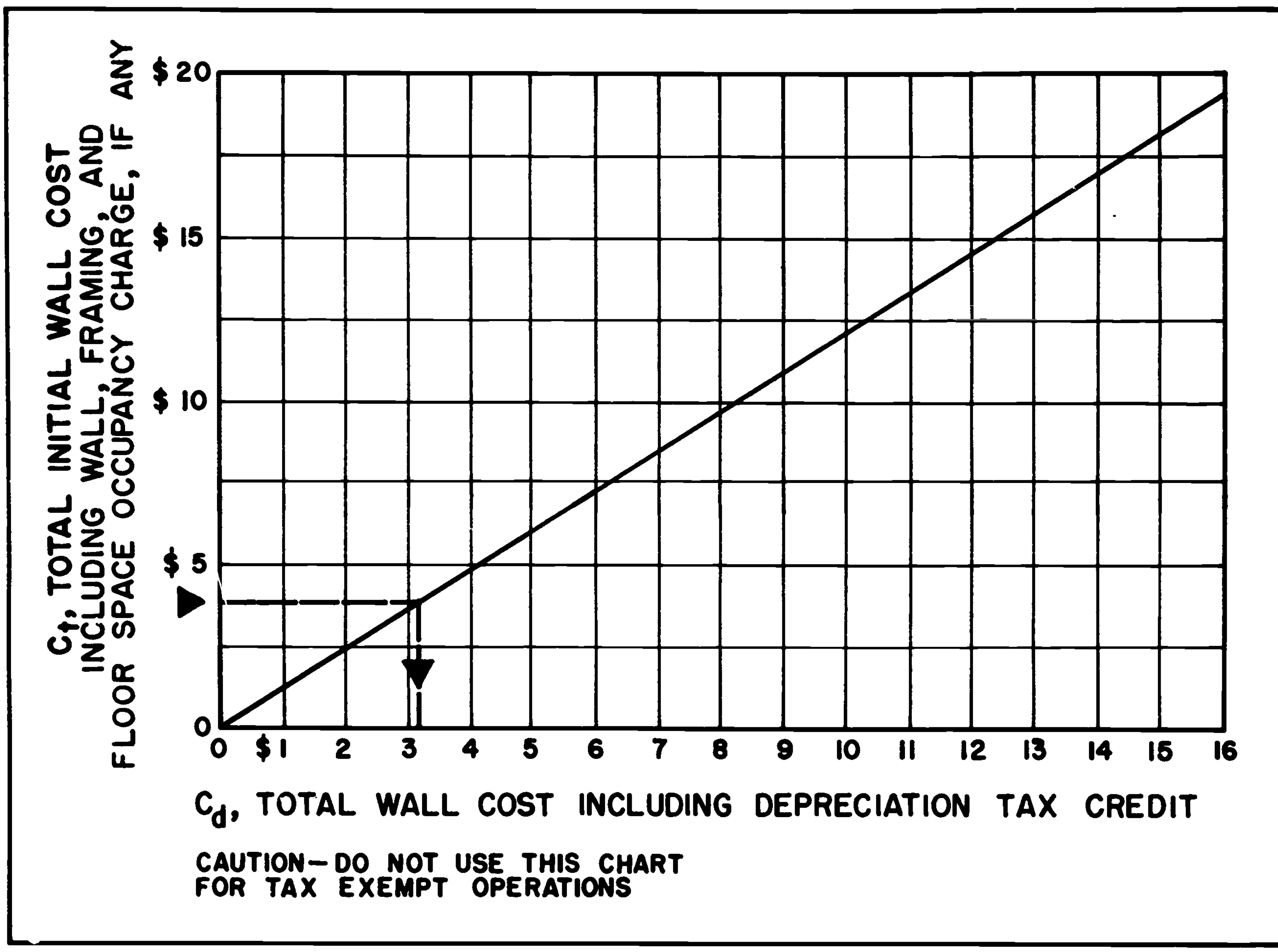



Figure 4

## MAINTENANCE COSTS

The U. N. Secretariat spends $40,000.00 each year to wash its windows every six weeks. This fact points out the necessity of considering anticipated maintenance when cost is important.

Maintenance costs of walls include costs of cleaning, painting, caulking and pointing. Estimates for these costs and the frequency with which they are required may be obtained from local contractors or estimating reference books. Some useful data are given in the "*Maintenance Engineers Handbook*", published by McGraw-Hill. The data found in Table IX may be helpful. The frequencies shown in this table are subject to considerable variation, depending on the color of some materials and the exposure to which they are subjected. Variations in maintenance frequency of plus or minus 50 per cent from these values can be expected.

**TABLE IX**

Maintenance Cost and Frequency

| | Cost per Sq. Ft. of Wall Area in Dollars | Frequency of Maintenance in Years |
|---|---|---|
| **Exterior painting of old surfaces, 2 coats** | | |
| Concrete masonry, cement | .10 | 4 |
| Wood frame. oil | .08 | 4 |
| Concrete, cement | .10 | 4 |
| Asbestos shingles, oil | .21 | 4 |
| Wood shingles, stained | .16 | 4 |
| Smoth metal, oil | .07 | 4 |
| **Interior painting of old surfaces, 1 coat** | | |
| Plaster, sprayed paint | .03 | 4 |
| Concrete masonry, cement | .05 | 4 |
| **Cleaning** | | |
| Windows, washing, each side | .02 | ¼ |
| Brick work, acid cleaning | .07 | 35 |
| Terra cotta, washing interior | .02 | 4 |
| Terra cotta, washing exterior | .03 | 35 |
| Glazed facing tile, washing interior | .02 | 4 |
| Metal skin, washing exterior | .02 | 8 |
| Masonry, sand blasting | .20 | 35 |
| Venetian blinds | .02 | ¼ |
| **Pointing** | | |
| Cutting out old mortar joints and tuck-pointing brick work | .50 | 35 |
| **Caulking** | | |
| ⅔ linear foot per sq. ft. | | |
| Glass | .06 | 16 |
| Metal panel | .06 | 8 |

The present worth factors for making a non-annual series of uniformly increasing expenditures every fourth, eighth and sixteenth year for the next 50 years are computed as follows when prices are expected to rise at the annual rate of .0377 ($f = +.0377$) and i is 6 per cent per year:

| n Year | $F_s$ | $(1 + nf)$ | $F'_{nu} = F_s(1 + nf)$ |
|---|---|---|---|
| 4th | .7921 | 1.151 | .912 |
| 8th | .6274 | 1.302 | .817 |
| 12th | .4970 | 1.452 | .722 |
| 16th | .3936 | 1.603 | .631 |
| 20th | .3118 | 1.754 | .547 |
| 24th | .2470 | 1.905 | .471 |
| 28th | .1956 | 2.055 | .402 |
| 32nd | .1550 | 2.21 | .343 |
| 36th | .1227 | 2.36 | .290 |
| 40th | .0972 | 2.51 | .244 |
| 44th | .0770 | 2.66 | .205 |
| 48th | .0610 | 2.81 | .171 |

$F'_{nu4} = 5.755$

| n Year | $F_s$ | $(1 + nf)$ | $F'_{nu} = F_s(1 + nf)$ |
|---|---|---|---|
| 8th | .6274 | 1.302 | .817 |
| 16th | .3936 | 1.603 | .631 |
| 24th | .2470 | 1.905 | .471 |
| 32nd | .1550 | 2.21 | .343 |
| 40th | .0972 | 2.51 | .244 |
| 48th | .0610 | 2.81 | .171 |

$F'_{nu8} = 2.677$

| n Year | $F_s$ | $(1 + nf)$ | $F_{nu} = F_s(1 + nf)$ |
|---|---|---|---|
| 16th | .3936 | 1.603 | .631 |
| 32nd | .1550 | 2.21 | .343 |
| 48th | .0610 | 2.81 | .171 |

$F'_{nu16} = 1.145$

Under the financial conditions given in Table VII, Figure 5 provides a graphic solution to the present value of maintenance costs.

*Seventh example:* It is anticipated that the useful life of a proposed building is 50 years. Money is valued at 6 per cent. The tax rate is 57 per cent ($T = .57$) and is not expected to change.

It is believed that, under the severe local climatic conditions at the end of 35 years, wall A will require cleaning and tuck-pointing; the present cost of which is $.57 per sq. ft. of wall area. Interior painting will be required every fourth year; the present cost of which is $.03 per sq. ft.

It is further assumed that wall B will require exterior cleaning and caulking every eight years; the present cost of which is $.08 per sq. ft., and interior painting every four years; the present cost of which is $.03 per sq. ft.

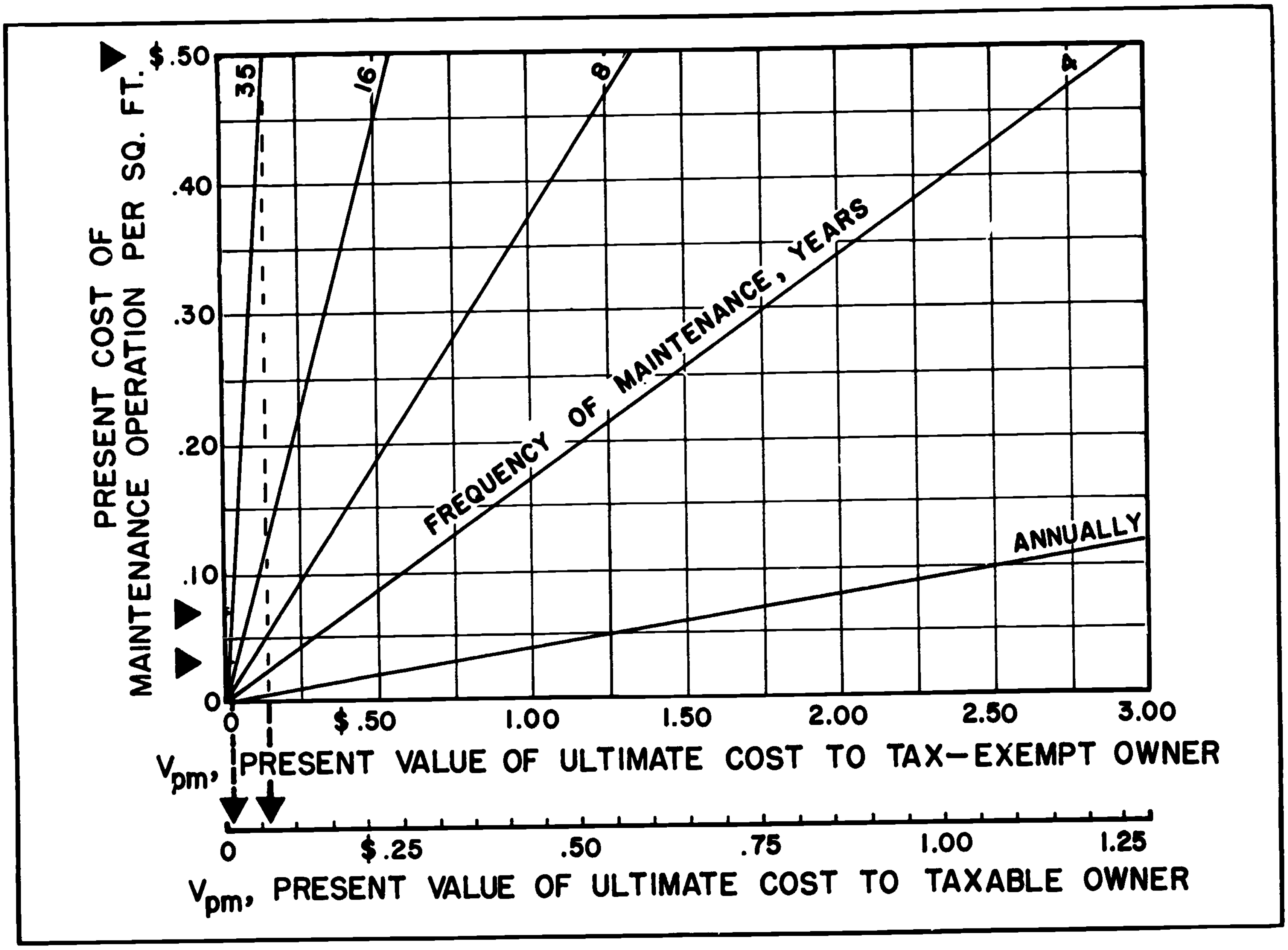



**Figure 5**

Wall C will require interior and exterior cleaning every three months at a present cost of $.04 per sq. ft., plus venetian blind cleaning every three months at the present cost of $.02 per sq. ft., and exterior caulking every 16 years at a present cost of $.06 per sq. ft.

The present value of making an expenditure for cleaning and pointing wall A of $.57 at the end of 35 years less taxes plus price increases is $F_8\,C(1 - T)(1 + nf)$ or $.1301 \times \$.57\,(1 - .57)\,(1 + 35 \times .0377)$ or $.074, when prices are expected to rise at the annual rate of .0377.

The present value of the anticipated four-year series of painting costs less taxes on wall A is $F'_{nu4}\,C(1 - T)$ or $5.755 \times \$.03(1 - .57)$ or $.074. The present value of the total anticipated maintenance cost for cleaning, pointing and painting wall A is, therefore, $.074 plus $.074 or $.15.

The present value of the anticipated four-year series of painting costs on wall B is the same as for wall A, $.074. The present value of the eight-year series of caulking and cleaning costs on wall B is $F'_{nu8}\,C(1 - T)$ or $2.677 \times \$.08(1 - .57)$ or $.092. The present value of the total anticipated maintenance cost to be added to the initial cost of wall B is, therefore, $.092 plus $.074 or $.17.

The annual washing and cleaning charges on wall C are $.02 × 3 (two sides and the blinds) × 4 times per year or $.24 per sq. ft. per year. Other required maintenance is $.06 per sq. ft. for caulking every 16th year. The present value of making an expenditure, the current cost of which is $.24, every year for the next 50 years, after taxes, is $F_uP_u\,C(1 - T)$ or $15.762 \times 1.59 \times \$.24(1 - .57)$ or $2.59. The present value of the caulking charge every 16 years is $F'_{nu16}\,C(1 - T)$ or $1.145 \times \$.06\,(1 - .57)$ or $.03. The total present value of the maintenance costs on wall C is, therefore, $2.59 plus $.03 or $2.62.

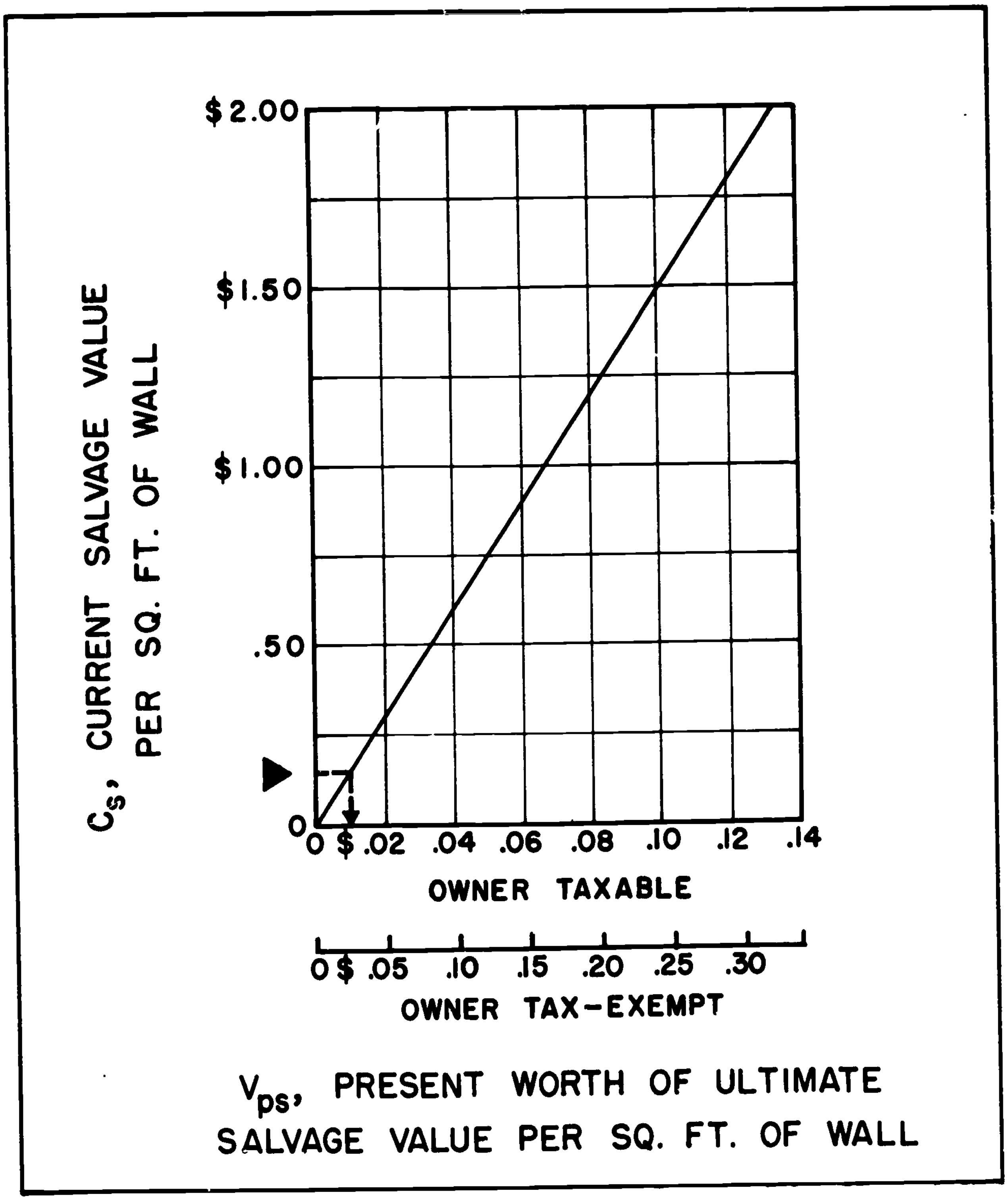



**Figure 6**

## SALVAGE VALUE

Since some building materials have a salvage value, this may be considered in an economic study. Under the financial conditions given in Table VII, the present value of the salvage credit may be determined graphically from Figure 6.

*Eighth example:* The present scrap value of wall B is $.80 per sq. ft. ($.05 per lb. including demolition). At the end of the 50-year life of the building, the present value of the anticipated salvage income less taxes is equal to $F_sC_s(1 + nf)(1 - T)$. Under the financial assumptions presented in Table VII, this formula may be expressed as $.0674\ C_s$, or $.0543 \times \$.80\ (1 + 50 \times .0377)(1 - .57)$ or $.054. This recovered cost should be deducted from the present value of other costs. Salvage value may be computed for other materials in a similar way. Walls A and C have salvage credits of .01 and .04, respectively.

## ILLUMINATION

Many observers indicate that in most building types the lights are fully utilized during the entire working day regardless of the window area provided. Usually, no reduction in illumination costs may be attributed to the window area. However, because windows may sometimes permit the use of natural illumination to supplement artificial illumination, through a reduction in power costs.[8] A reduction in annual hours of illumination would also increase the life of lamps and produce a corresponding reduction in lamp replacement costs. The following formula may be used to compute the present value of the savings thus achieved:

$$(7) \qquad V_{pi} = \frac{IQ\ (1-T)}{W}\left[\frac{E(L_x - L_y)F_uP_u}{1000} + C_1(F'_{nux} - F'_{nuy})\right]$$

Where:
- $V_{pi}$ is the present value of the savings in power and lamp costs attributable to each square foot of window area.
- $I$ is the illumination design level at the working plane in foot-candles.
- $Q$ is the average ratio of floor area in rooms with windows to window area.
- $W$ is the illumination provided in foot-candles per square foot per watt of electricity.
- $T$ is the total equivalent income tax rate.
- $E$ is the electric power costs per kw-hr.
- $L_x$ is the annual number of hours of artificial illumination in a windowless structure.
- $L_y$ is the annual number of hours of artificial illumination, when supplementary natural illumination is used.
- $F_u$ is the present worth factor for a uniform annual series to the life of the building.
- $P_u$ is the approximate present worth correction factor for a uniformly increasing series of future annual expenditures from equation 3.
- $C_1$ is the lamp replacement costs per watt.
- $F'_{nux}$ is the present worth factor for a non-annual series of uniformly increasing cost to replace lamps in a windowless structure.
- $F'_{nuy}$ is the present worth factor for a non-annual series of uniformly increasing cost to replace lamps where supplementary natural illumination is used.

[8] Illumination References:

| | | | |
|---|---|---|---|
| *Architectural Forum* | October | 1953 | Pages 157 & 187 |
| *Architectural Record* | February | 1954 | Page 205 |
| *Architectural Record* | March | 1954 | Page 207 |
| *IES Lighting Handbook* | | 1957 | Pages 10–23 |

puted is the normal lamp life in hours divided by the annual hours of an artificial illumination in a windowless structure to the nearest whole year, i.e., $L_1/L_x$. The time interval for which $F'_{nuy}$ is to be computed is the normal lamp life in hours divided by the annual hours of artificial illumination when supplemented by natural illumination to the nearest whole year, i.e., $L_1/L_y$.

Under the financial assumptions given in Table VII formula 7 may be reduced to:

$$(7A) \qquad V_{pi} = \frac{.43QI}{W}\left[.0185\ E\ (L_x - L_y) + C_1(F'_{nux} - F'_{nuy})\right]$$

It might be expected that a reduction in power consumption for illumination would reduce air conditioning costs. However, there is no reduction in initial cost of air conditioning, because the plant is designed for peak loads. A reduction in operating costs of the air conditioning plant is dubious, because as solar heat gain diminishes, artificial illumination increases.

*Ninth example:* Three watts of fluorescent lighting per square foot of floor area are used to provide 45 foot-candles of illumination at desk level ($I=45$ and $W=15$). A windowless office is occupied 2,000 hours per year ($L_x=2{,}000$). If windows are provided, the lights will be burned 1,000 hours per year ($L_y=1{,}000$). A 50 per cent reduction is probably greater than would be achieved under average conditions.[9] It is assumed here to give windows the benefit of a considerable doubt. The average ratio of floor area in rooms with windows to exterior window area is 2.5 ($Q=2.5$). Presently, illumination power cost is $.02 per kw-hr. ($E=.02$) and is expected to rise at the annual rate of .01. ($P_u=1.175$ from equation 3). Lamp replacement costs are $.04 per watt ($C_1=.04$). The normal lamp life is 8,000 hours ($L_1=8{,}000$). Money is valued at 6 per cent. The life of the building is 50 years ($F_u=15.762$). The tax rate is 57 per cent ($T=.57$) and is not expected to change.

Compute the present value of the savings in costs attributable to each square foot of window area from equation 7A.

Since $L_1/L_x$ is equal to 8,000/2,000 or 4, $F'_{nux}$ is computed for a non-annual four-year series as illustrated in the maintenance section of this report. $F'_{nu4}=5.755$, when lamp replacement costs increase at a .0377 rate annually. Since $L_1/L_y=8{,}000/1{,}000$

[9] "*Modern Masonry*", Building Research Institute, Sept. 1956, page 101.

or 8, $F'_{nuy}$ is computed for a non-annual eight-year series as illustrated in the maintenance section of this report. $F'_{nus}=2.677$ when lamp replacement costs increase at an annual rate of .0377. From equation 7A:

$$V_{pi}=\frac{.43\times2.5\times45}{15}\Big[.0185\times.02\ (2{,}000-1{,}000)$$
$$+.04\ (5.755-2.677)\Big]$$

$V_{pi}=\$1.59$

This amount is credited to Wall C.

## SPEED OF ERECTION

The speed with which the exterior enclosing walls are erected can, but rarely does, affect the completion date of a building. Some rather startling stunts have created the false impression that the use of prefabricated curtain walls insures earlier occupancy, and therefore, greater rental income. In 1954 the prefabricated exterior walls of a multi-story office building in New York were installed in one eight-hour day, but a crew of 20 men spent five months preparing for the event, and for at least one week preceding the event all other construction trades were laid off. There is no evidence to indicate that the building was occupied sooner or that any savings were achieved.

Prefabrication does not necessarily insure earlier occupancy. Nearly one-third of the contractors responding to a 1955 survey by the Building Research Advisory Board of the National Academy of Sciences indicated that the erection time for conventional walls was equal to or less than that required for prefabricated panel walls. An average time saving of 31 per cent was reported for conventional walls. Even when walls go up faster, the building is not necessarily occupied sooner, due to the concurrent work of other trades.[10]

It is conceivable, however, that under some circumstances earlier occupancy may be achieved by some wall types. When and if this is accomplished, the principal economies which may result will accrue to the contractor, who may pass the savings on to the owner. The significant economy will be in the form of reduced initial cost.

The useful life of a building is not prolonged by the amount of time saved in its erection. The estimated economic life of a building is predicated among other things on its durability under a planned maintenance schedule and the predicted obsolescence of the facilities which it provides. It is fallacious, therefore, to assume that quicker erection will ultimately produce more rental income, but it may provide a slightly quicker return on the investment. The following formula gives the present value of the savings per square foot of wall area which may be achieved by earlier occupancy:

$$(8)\qquad V_{po}=\frac{C_b}{A_g}\left[1-\frac{1}{(1+i)^W}\right]$$

Where: $V_{po}$ is the present value of the savings per square foot of wall area made by a faster return on the investment due to earlier occupancy.

$C_b$ is the investment or total initial cost of the building.

$A_g$ is the gross exterior wall area in square feet.

i is the anticipated rate of return on the investment.

W is the number of time periods saved by earlier occupancy.

When the interest rate is 6 per cent per annum and when W is expressed in weeks, formula 8 becomes:

$$(8A)\qquad V_{po}=\frac{C_b}{A_g}\left[1-\frac{1}{(1.00115)^W}\right]$$

Figure 7 provides a graphic solution to equation 8A.

*Tenth example:* Assume a 10-story office building, the initial cost of which is \$3,870,000.00 ($C_b=3.87\times10^6$). The gross exterior wall area is 72,000 square feet ($A_g=72{,}000$). The anticipated rate of return on the investment is 6 per cent per year or .00115 per week. The type of exterior wall assembly used permits occupancy 16 days sooner than if an alternate wall were employed. $W=\frac{16}{7}$ or 2.3 weeks.

From equation 8A the present value of the savings made per square foot of wall area by a faster return on the investment due to a 16 days' earlier occupancy is computed as follows:

$$V_{po}=\frac{3.87\times10^6}{72{,}000}\left[1-\frac{1}{(1.00115)^{2.3}}\right]$$

$V_{po}=\$.14$

The preceding calculation illustrates the procedure to be used when it can be demonstrated conclusively that the use of a particular wall will insure earlier occupancy. The data in this regard are far from conclusive; the claims of some manufacturers not

[10] Building Research Institute:
"*Metal Curtain Walls*", Dec. 1955, page 26.
"*Modern Masonry*", Sept. 1956, page 101

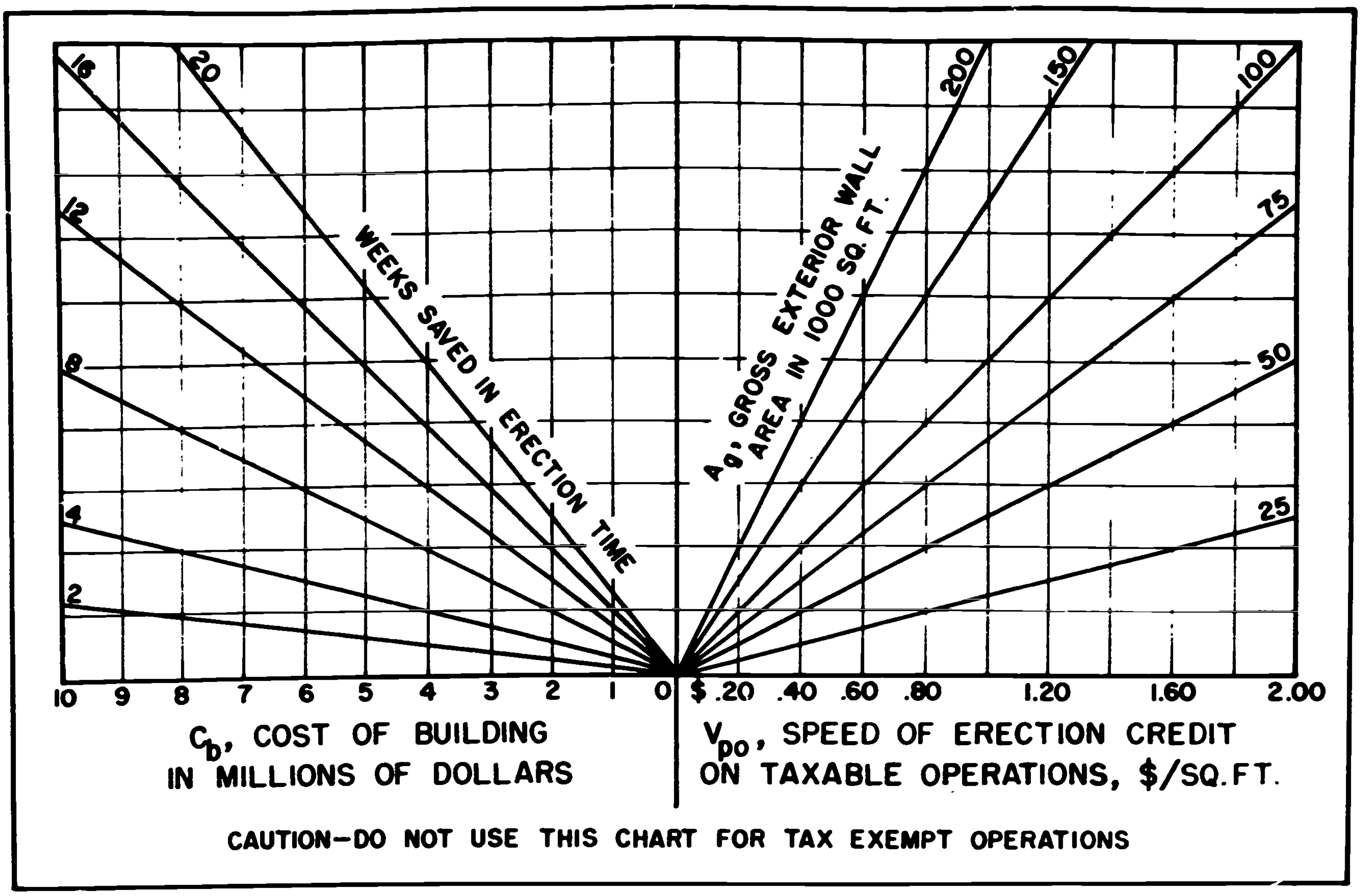



**Figure 7**

withstanding. It is suggested that this credit be given a particular wall only when a reputable general contractor will guarantee completion at a specified earlier date.

If the building is to be erected for a nonprofit organization, the problem of computing the credit to be given a particular wall type for earlier occupancy is considerably more difficult, because the return on the investment is not always related to the investment. What is the return expected from an investment in national defense against atheistic communism? How much is it worth to get children into a better school faster? The only solution here is the faster the better, but the value received is truly immeasurable. Whether or not the use of a particular wall material can accomplish this is open to conjecture. However, when a new building affords greater efficiency of operation and, therefore, lower operating cost for a nonprofit organization, and when this savings can be ascertained, the savings achieved by earlier occupancy per square foot of wall area can be computed.

No early occupancy credit for nonprofit operations has been given to any of the three wall types considered in this study. However, a $.14 credit has been given to wall types B and C when built for profit corporations, just to give these walls the benefit of a considerable doubt.

### HEAT GAIN

The cost of removing heat from air conditioned buildings is frequently a very important economic factor. The amount of heat penetrating the occupied space through a building wall can be removed only at considerable expense. Several references on mechanical equipment costs, which may be helpful to the designer, are cited in footnote 11. The quantity of heat gain through 1 sq. ft. of wall area may be computed from data presented in the American Society of Heating and Air Conditioning Engineers *Guide*.

[11] *Architectural Record*, October 1953, page 202
*House & Home*, April 1954, page 125
*House & Home*, March 1955, page 152
*Architectural Record*, July 1956, page 215
*House & Home*, November 1956, page 160
"*Windows & Glass*," Building Research Institute, March 1957, page 29.
*Architectural Forum*, October 1957, page 154
"*School Building Costs*," Owens-Corning Fiberglas Corporation, September 1957, page 10.
*Progressive Architecture*, March 1958, page 162
*Construction Specifier*, Summer 1958, page 9.

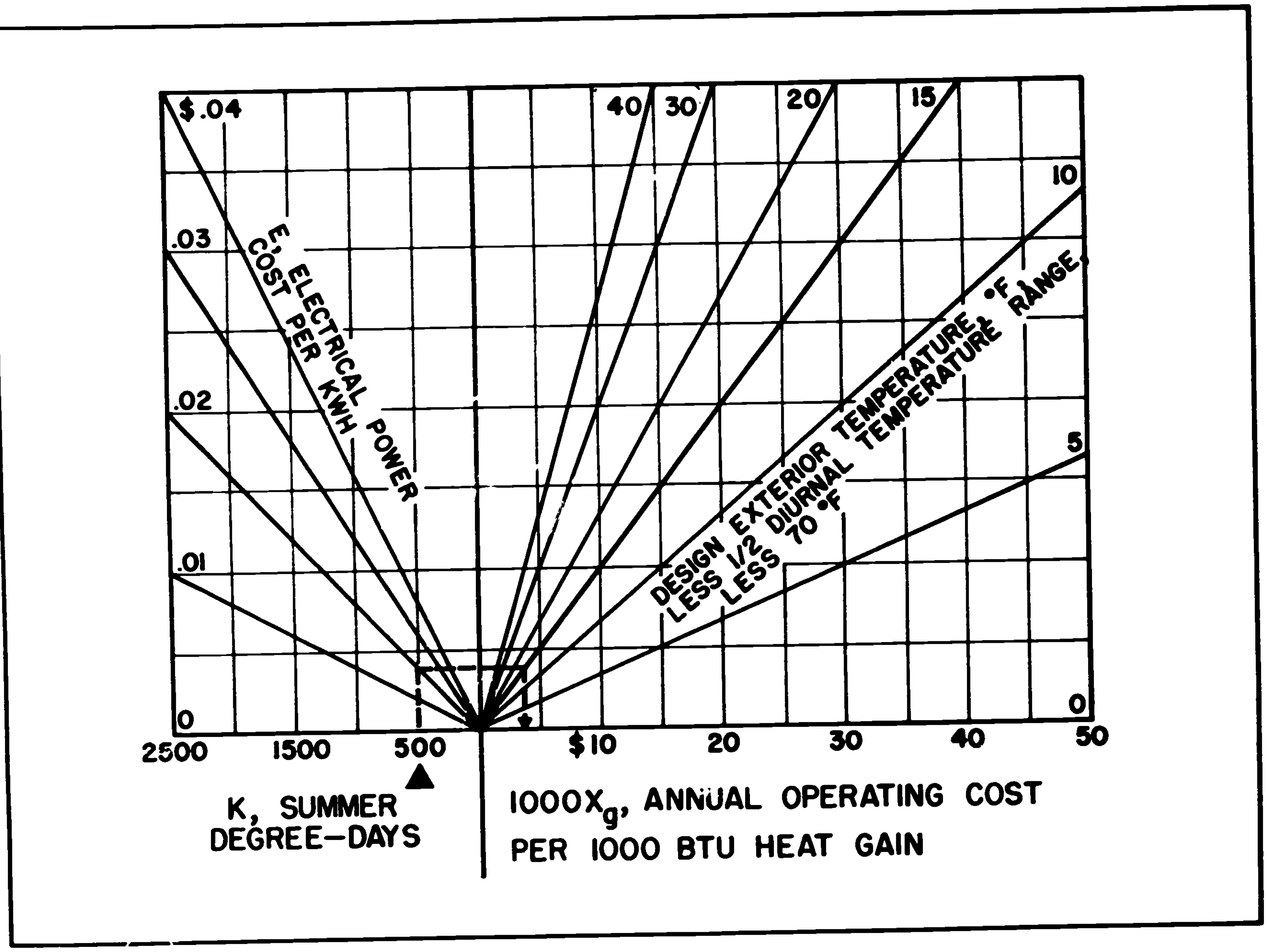



**Figure 8**

The initial cost of central summer air conditioning currently ranges from \$600 to \$1,800 per ton or from \$.05 to \$.15 per Btu of hourly plant capacity.

Annual power cost for cooling per Btu of heat gain used herein was determined as follows[12]:

$$(9) \qquad C_g = \frac{KEG}{(t_d - .5t_r - 70)\ 500}$$

Where: $C_g$ is the annual electric power cost per Btu of hourly plant capacity.

- K is the number of summer degree-days.
- E is the electric power costs per kw-hr.
- G is the power input in kw per ton.
- $t_d$ is the design exterior temperature.
- $t_r$ is the diurnal temperature range.

Total annual cooling costs per Btu of hourly plant capacity, $X_g$, were determined by increasing electrical cost 50 per cent for operating personnel and maintenance. This percent increase will vary considerably with the type and size of the installation. It would, of course, be much less for a residential plant. However, it should be noted later in studying the eleventh example, that a 50 per cent increase in $C_g$ produces only a 10 per cent increase in the present value of the total air conditioning cost attributable to 1 sq. ft. of wall area. Admittedly, equation 9 is an approximation of fact. However, it is considered sufficiently accurate for the purpose. When $X_g = 1.5\ C_g$ Figure 8 provides a graphic solution for $X_g$.

For a true economic comparison of wall types, the initial and present value of future operating costs of a summer air conditioning plant necessary to meet the heat gain through the wall must be added to the initial wall cost. The following formula may be used:

[12] *"Operating Costs of Residential Cooling Equipment."* ASHAE Transactions, Vol. 60, 1954.
*Heating and Ventilating,* July 1954.

$$V_{pg} = H_g M_g[1 + F'_{nu}(1-T) - D_g T F'_u + I_r F_u(1-T) + V_t R_t F_u(1-T)] + X_g H_g P_u F_u(1-T) \tag{10}$$

Where: $V_{pg}$ is the present value of the initial cost and operating cost of the air conditioning plant attributed to 1 sq. ft. of wall area.

- $H_g$ is the heat gain through the wall in Btus per hour per square foot.
- $M_g$ is the initial cost of the air conditioning plant per Btu of hourly capacity.
- $F'_{nu}$ is the present worth factor for a non-annual series of expenditures to rebuild the air conditioning plant when rebuilding cost is expected to change.
- $T$ is the total equivalent income tax rate.
- $D_g$ is the depreciation rate on the air conditioning plant.
- $F'_u$ is the present worth factor for a uniform annual series of depreciation tax credits on the air conditioning plant, when rebuilding costs are expected to change.
- $I_r$ is the insurance rate on the building with the wall type under consideration.
- $F_u$ is the present worth factor for a uniform annual series to the life of the building from equation 2.
- $V_t$ is the ratio of tax assessed value to market value of the air conditioning plant.
- $R_t$ is the real estate tax rate.
- $X_g$ is the total annual cooling costs per Btu of hourly plant capacity.
- $P_u$ is the approximate present value correction factor for a uniformly changing series of future annual expenditures from equation 3.

The useful life of mechanical equipment is considerably less than the useful life of a building. Bulletin "F" of the Bureau of Internal Revenue gives the useful life of boilers, furnaces and air conditioning systems over 20 tons at 20 years. Since walls contribute to the cost of this equipment, they must be charged not only with its initial cost but also the present value of rebuilding it. $F'_{nu}$ in Formulae 10 and 12 is, therefore, computed as follows, when the cost of rebuilding is expected to rise at the annual rate of .0377:

| Cost Item | n Year | $F_s$ | $(1+nf)$ | $F_s(1+nf)=K_n$ | |
|---|---|---|---|---|---|
| First rebuilding | 20th | .3118 | $1+20\times.0377$ | .547 | $=K_{20}$ |
| Second rebuilding | 40th | .0972 | $1+40\times.0377$ | .244 | $=K_{40}$ |
| $F'_{nu}=K_{20}+K_{40}$ | | | | .791 | $=F'_{nu}$ |

Because the rebuilding costs are higher each time, due to price increases, the depreciation after each rebuilding is also higher. Since the walls contribute to the rebuilding cost, they should also share in the depreciation credit. $F'_u$ in equation 10 is computed as follows:

$$F'_u = F_{u20}(1+K_{20}) + F_{u10}K_{40}$$

$$F'_u = 11.47(1+.547) + 7.36\times.244$$

$$F'_u = 19.54$$

If the useful life of the building is more than 50 years, the present worth factors in the above formula should be appropriately modified.

The amount of insurance carried on the plant at any time is the replacement cost less depreciation. Insurance rates are expected to rise annually at a .01 rate, replacement costs are expected to go up at a .0377 annual rate and depreciation goes down at a .05 annual rate. The net rate of change is considered negligible. $P_u$ for insurance, therefore, is one and does not appear in equation 10.

The trend in power costs is up by an average annual rate of .01. Plant maintenance and other operating costs may be expected to rise at an annual rate of about .04. The combined rate of annual price increase is, therefore, .02. Therefore, $P_u$ for operating costs is 1.32 from Figure 1 or equation 3.

The amount of real estate taxes paid on the assessed value of the plant at any time is the replacement cost less depreciation. Real estate taxes are expected to rise at an annual rate of .02; replacement costs are expected to rise at a .0377 annual rate and depreciation goes down at a .05 annual rate. The net rate of change is considered negligible. $P_u$ for real estate taxes, therefore, is one and does not appear in equation 10.

Under the financial conditions given in Table VII, equation 10 may be written as:

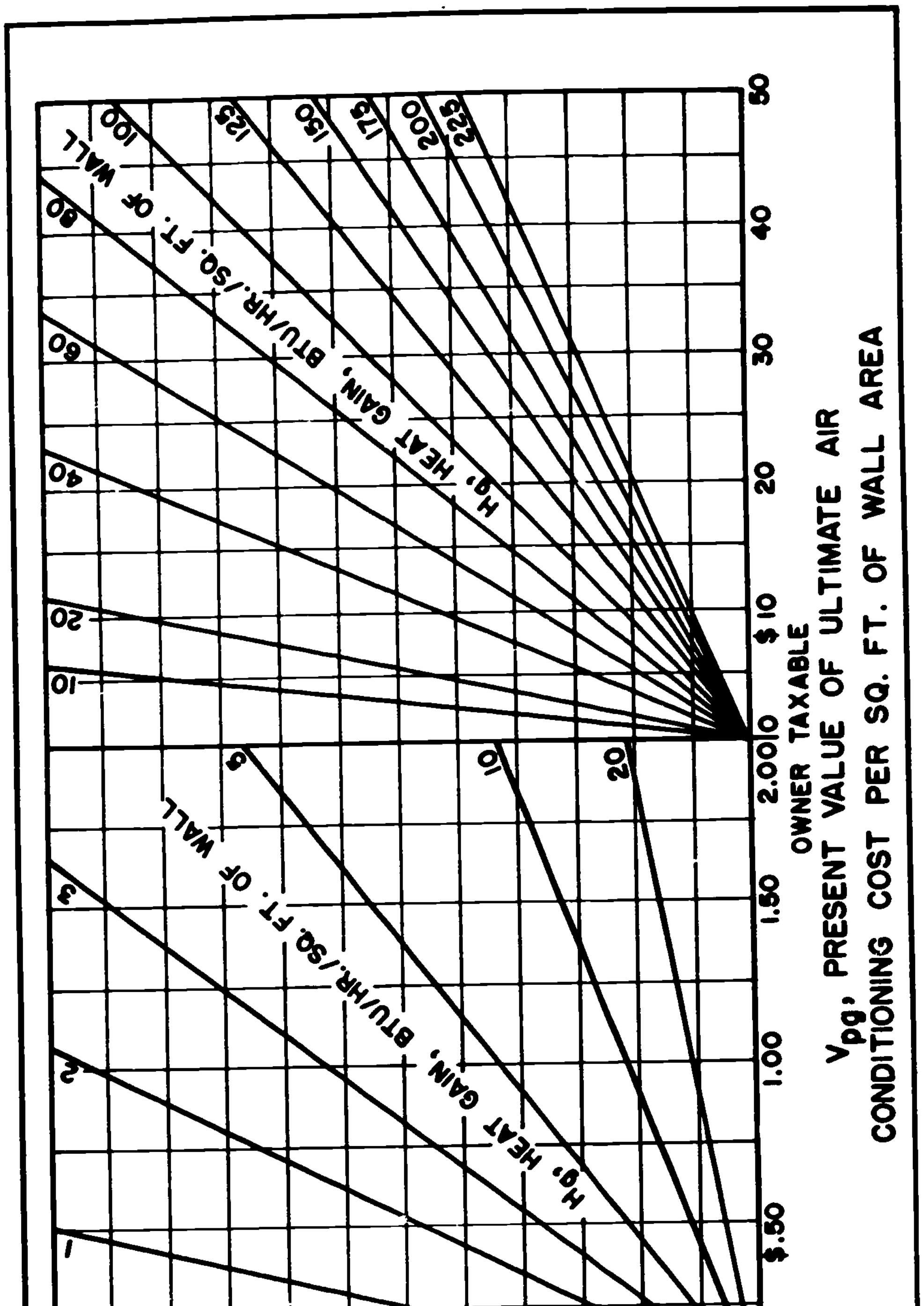
$$V_{pg} = H_g(M_g + 9.0X_g) \tag{10A}$$

Figure 9 provides a graphic solution to equation 10A. For a tax exempt owner (i.e., when $T=0$ and $R_t=0$) $V_{pg}$ may be computed from equation 10B:

$$V_{pg} = 1.8H_g(M_g + 11.6X_g) \tag{10B}$$

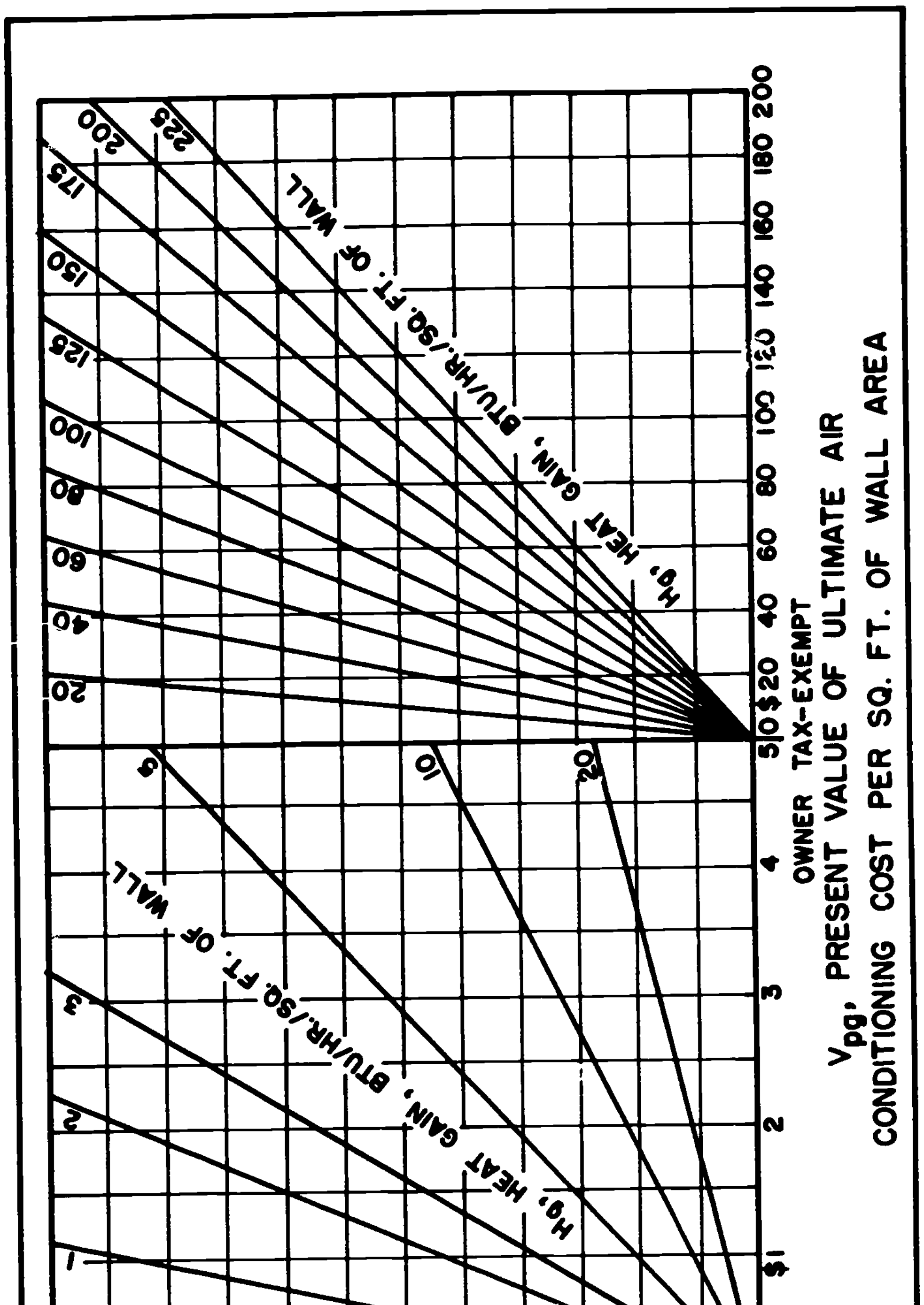
Figure 10 provides a graphic solution to equation 10B.

*Eleventh example:* Under the design conditions given in Tables IV and VI, the heat gain through wall A is computed from the ASHAE *Guide* at 1.23 Btu per hour per sq. ft. ($H_g=1.23$). The initial cost of air conditioning is \$.10 per Btu of hourly plant capacity ($M_g=.10$). This includes a charge for building space occupancy by the cooling equip-



$H_g$, HEAT GAIN, BTU/HR./SQ. FT. OF WALL
10
20
40
60
80
100
125
150
175
200
225
$H_g$, HEAT GAIN, BTU/HR./SQ. FT. OF WALL
1
2
3
5
10
20
$M_g$, INITIAL COST OF AIR CONDITIONING PLANT PER TON OF CAPACITY
$1800
$1200
$600
$0
$ 50
40
30
20
10
0
0
$.50
1.00
1.50
2.00
0
$ 10
20
30
40
50
FROM FIGURE 8, $X_g$, ANNUAL OPERATING COST PER 1000 BTU OF HEAT GAIN
OWNER TAXABLE
$V_{pg}$, PRESENT VALUE OF ULTIMATE AIR CONDITIONING COST PER SQ. FT. OF WALL AREA


Figure 9



OWNER TAX-EXEMPT
Vpg, PRESENT VALUE OF ULTIMATE AIR CONDITIONING COST PER SQ. FT. OF WALL AREA
FROM FIGURE 8, Xg, ANNUAL OPERATING COST PER 1000 BTU OF HEAT GAIN
Mg, INITIAL COST OF AIR CONDITIONING PLANT PER TON OF CAPACITY
$1800
$1200
$600
$0
Hg, HEAT GAIN, BTU/HR./SQ. FT. OF WALL
Hg, HEAT GAIN, BTU/HR./SQ. FT. OF WALL


Figure 10

ment computed at \$1.50 per cu. ft. and 100 cu. ft. per ton. The income tax rate is 57 per cent ($T=.57$) and is not expected to change. Money is valued at 6 per cent. The useful life of the building is 50 years, and the useful life of the air conditioning plant is 20 years. ($F'_{nu}=.791$, $F'_{u}=19.54$ from preceding discussion and $F_u=15.762$.) The ratio of assessed value to market value of the air conditioning plant is .75($V_t=.75$), and the real estate tax rate is 4 per cent ($R_t=.04$). The insurance rate is \$.06 per \$100.00 of value ($I_r=.0006$ from Table V). The number of summer degree-days from Table VI is 500 ($k=500$). Electric power costs are \$.02 per kw-hr. ($E=.02$). The cost of operating the plant is expected to rise at a rate of .02($P_u=1.32$ from figure 1). The power input per ton is 2 kw. ($G=2$). The exterior design temperature is 95°F ($t_d=95$). The diurnal temperature range is 20°F($t_r=20$). What is the present value of the air conditioning costs attributed to 1 sq. ft. of wall A? From equations 9 and 10A:

$$(9)\qquad X_g=\frac{1.5\times500\times.02\times2}{(95-.5\times20-70)\ 500}$$

$$X_g=.004$$

$$(10A)\qquad V_{pg}=1.23\ (.10+9.0\times.004)$$

$$V_{pg}=\$.17$$

If the heat gain through the alternate wall B is 2.55 Btu per hr. per sq. ft., the present value of the air conditioning operating and initial costs attributable to each square foot of wall area would be \$.34. Since the sole air temperature differentials used in this calculation for prefabricated panel walls are not presented in the ASHAE *Guide*, the heat gain for wall B must be based on an estimated total equivalent temperature differential. The value of 2.55 Btu per hr. per sq. ft. is a low figure, especially since it is based on a published "U" value of .12, which does not take into account through wall metal connections. These thermal bridges may increase heat transmission as much as 218 per cent.[13]

It should be noted that the exterior wall color, weight and transparency, among other factors, have a considerable effect on heat gain and, therefore, on initial and operating cost of air conditioning. For example, under the same design conditions, $H_g$ for wall C is 58.8 Btu per hr. per sq. ft., and the present value of air conditioning operating and initial cost attributable to each square foot is \$8.00.

[13] *"Metal Curtain Walls,"* Building Research Institute, December, 1955, page 67.

In these examples the value of $H_g$ (heat gain in Btu per hour per square foot of wall area) is based on an average of north, east, south and west orientations at 4:00 p.m. on August 1st at 40° north latitude, as indicated in Table VI. The figure assumes an equal distribution of wall area on all sides of the building and is not, therefore, applicable to any specific wall orientation. If a west wall only had been considered under these design conditions, the heat gain for wall C would be 171 Btu per hr. per sq. ft. The present value of the initial and operating cost of the air conditioning plant would be \$23.30 per sq. ft. of wall C. An exterior shading device would reduce this figure substantially and more than pay for itself.[14]

## HEAT LOSS

The quantity of heat lost through 1 sq. ft. of wall area may also be computed from data presented in the ASHAE *Guide*. The initial cost of the heating plant, including occupied building space, is approximately \$.02 per Btu of hourly plant capacity. Annual operating costs per square foot of wall area, $X_h$, may be computed from the following formula:

$$(11)\qquad X_h=\frac{D_dC_h}{(t_i-t_o)4167}$$

Where: $X_h$ is the annual operating costs per Btu of hourly capacity.

$D_d$ is the heating degree-days per year.

$C_h$ is the operating cost of the heating plant per therm (100,000 Btu) of hourly capacity.

$t_i$ is the inside design temperature.

$t_o$ is the outside design temperature

Figure 11 provides a graphic solution to equation 11.

The initial cost and present value of operating costs of the heating plant necessitated by each square foot of wall area may be computed from the following formula, which includes real estate taxes, insurance and rebuilding costs less depreciation on the plant:

[14] *Solar Control and Shading Devices*, Olgyay and Olgyay, Princeton University Press, 1957, page 73.
*"Clay Masonry Shading Devices"*, *Technical Notes*, Vol. 8, No. 3, March, 1957, Structural Clay Products Institute.

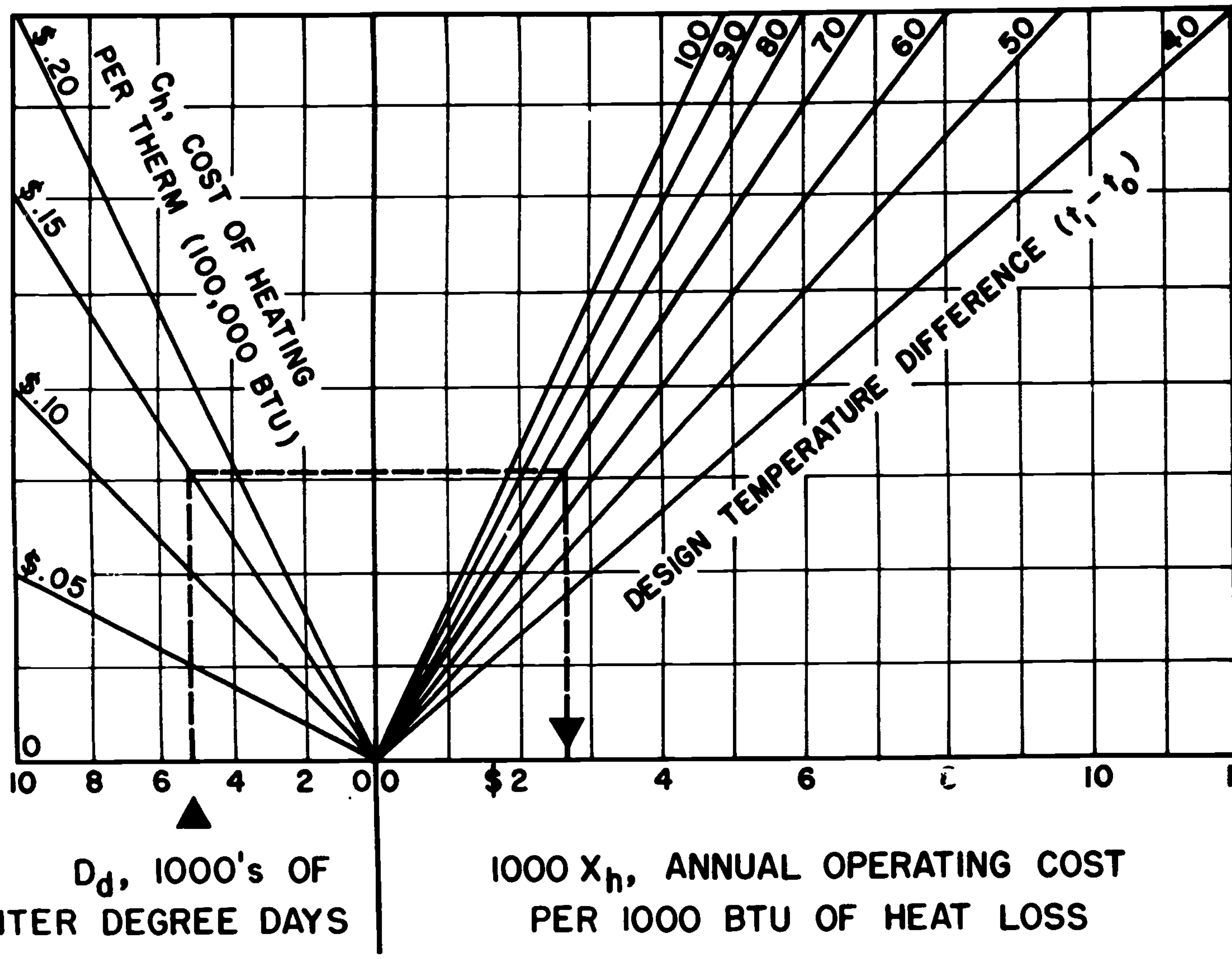



**Figure 11**

$$(12)\quad V_{ph} = M_h U(t_i - t_o)[1 + F'_{nu}(1-T) - TD_h F'_u + V_t R_t F_u(1-T) + I_r F_u(1-T)] + U(t_i - t_o) X_h (1-T) P_u F_u$$

Where: $V_{ph}$ is the present value of the annual heating cost and the initial cost of the heating plant attributed to each square foot of wall area.

$M_h$ is the initial cost of the heating plant per Btu of hourly capacity.

$U$ is the heat loss through 1 sq. ft. of wall area in Btu per hr. per degree Fahrenheit differential across the wall.

$t_i$ is the inside design temperature, °F.

$t_o$ is the outside design temperature, °F.

$F'_{nu}$ is the present worth factor for a non-annual series of expenditures to rebuild the heating plant, when rebuilding cost is expected to change, obtained as for formula 10.

$T$ is the total equivalent income tax rate.

$D_h$ is the depreciation rate on the heating plant.

$F'_u$ is the present worth factor for a uniform annual series of tax credits on the heating plant, when rebuilding costs are expected to change, computed as for formula 10.

$V_t$ is the ratio of tax assessed value to market value of the heating plant.

$R_t$ is the real estate tax rate.

$F_u$ is the present value factor for a uniform annual series for the life of the building from equation 2.

$I_r$ is the insurance rate on the building with the wall under consideration.

$X_h$ is the total annual heating costs per Btu of hourly plant capacity.

$P_u$ is the approximate present worth correction factor for a uniformly changing series of future annual expenditures from equation 3.

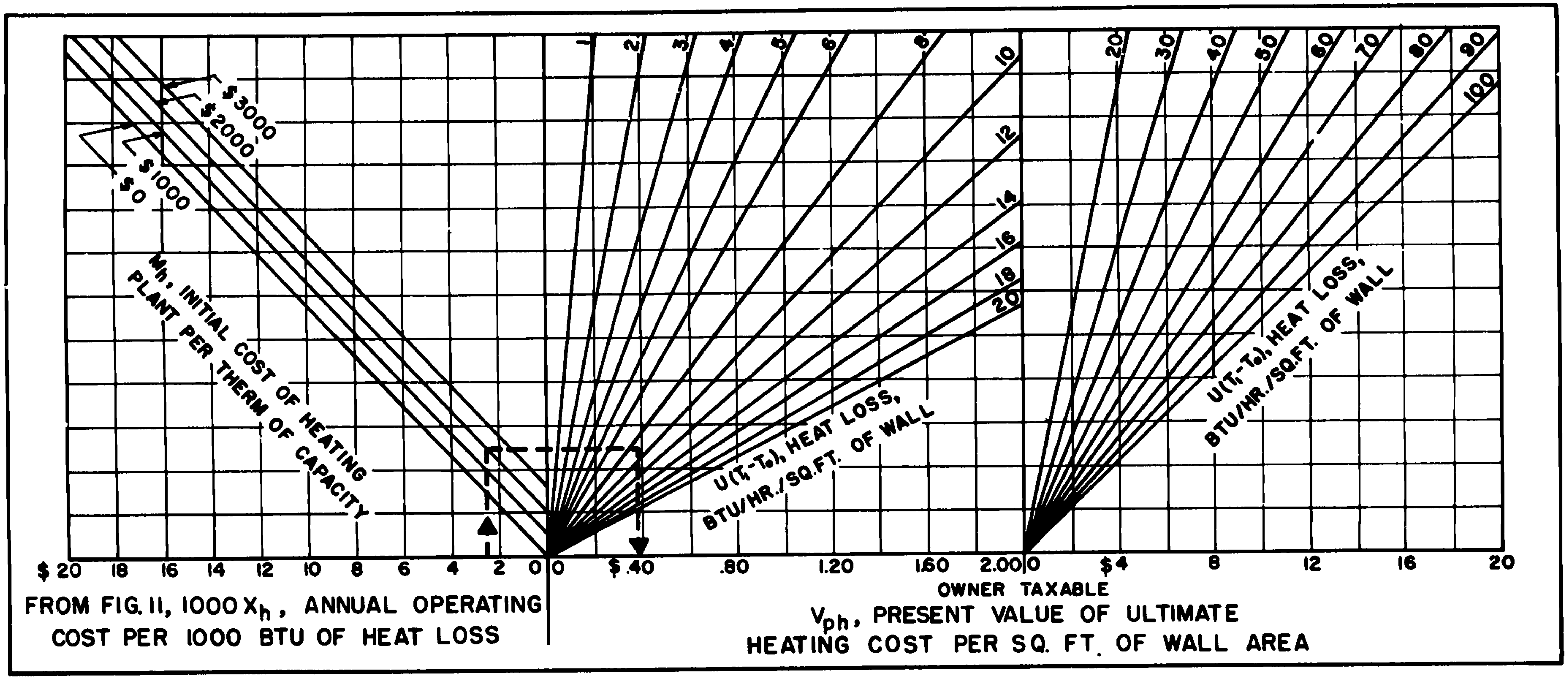

$3000
$2000
$1000
$0
$M_h$, INITIAL COST OF HEATING PLANT PER THERM OF CAPACITY
1 2 3 4 5 6 8 10 12 14 16 18 20
$U(T_i - T_o)$, HEAT LOSS, BTU/HR./SQ.FT. OF WALL
20 30 40 50 60 70 80 90 100
$U(T_i - T_o)$, HEAT LOSS, BTU/HR./SQ.FT. OF WALL
$ 20 18 16 14 12 10 8 6 4 2 0
FROM FIG. 11, 1000 $X_h$, ANNUAL OPERATING COST PER 1000 BTU OF HEAT LOSS
0 $.40 .80 1.20 1.60 2.00
0 $4 8 12 16 20
OWNER TAXABLE
$V_{ph}$, PRESENT VALUE OF ULTIMATE HEATING COST PER SQ. FT. OF WALL AREA

**Figure 12**

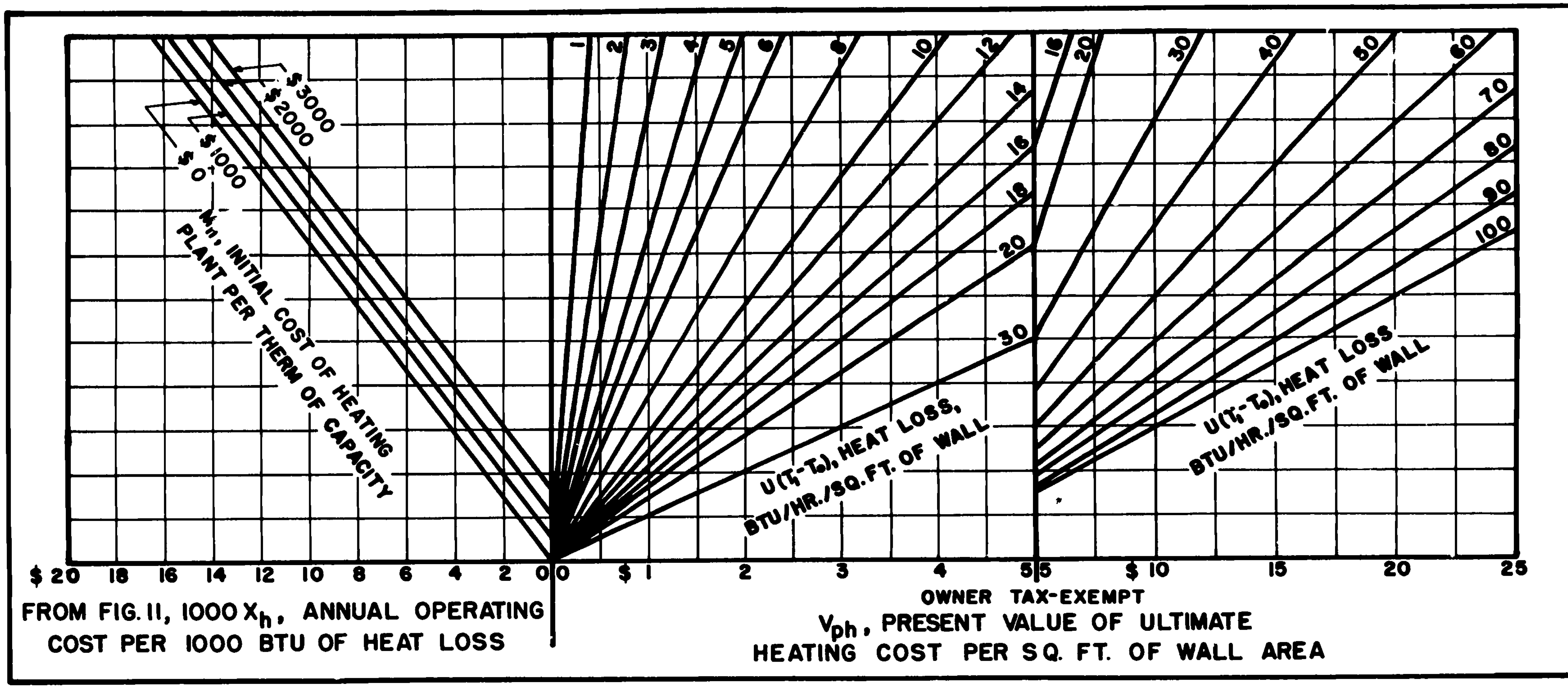

$ 20 18 16 14 12 10 8 6 4 2 0 0 $ 1 2 3 4 5 5 $ 10 15 20 25
$ 3000
$ 2000
$ 1000
$ 0
$M_h$, INITIAL COST OF HEATING PLANT PER THERM OF CAPACITY
1 2 3 4 5 6 8 10 12 14 16 18 20 30
16 20 30 40 50 60 70 80 90 100
U($T_i$-$T_o$), HEAT LOSS, BTU/HR./SQ.FT. OF WALL
U($T_i$-$T_o$), HEAT LOSS BTU/HR./SQ.FT. OF WALL
FROM FIG. 11, 1000 $X_h$, ANNUAL OPERATING COST PER 1000 BTU OF HEAT LOSS
OWNER TAX-EXEMPT
$V_{ph}$, PRESENT VALUE OF ULTIMATE HEATING COST PER SQ. FT. OF WALL AREA

Figure 13

Under the financial assumptions given in Table VII equation 12 may be expressed as follows:

(12A) $V_{ph}=U(t_i-t_o)(M_h+10.4X_h)$

Figure 12 provides a graphic solution to equation 12A. For a tax exempt owner (i.e., when T=O and $R_t$=O) $V_{ph}$ may be computed from equation 12B:

(12B) $V_{ph}=1.8\ U(t_i-t_o)(M_h+13.4\ X_h)$

Figure 13 provides a graphic solution to equation 12B.

*Twelfth example:* From Table IV the "U" value of wall A is .12. The initial cost of the heating plant is $.02 per Btu of capacity ($M_h$=.02) from Table VI. From Table VI the inside design temperature is 70°F ($t_i$=70), and the outside design temperature is 0°F ($t_o$=0). The annual winter degree-days are 5,000. ($D_d$=5,000). The plant operating cost for fuel, considering various fuels and plant efficiencies, is $.10 per therm (100,000 Btu) of hourly capacity plus 50 per cent for operating personnel and maintenance costs ($C_h$=.15). This per cent increase will vary with the type and size of the installation. It would, of course, be much less for a residential plant. However, it should be noted that a 50 per cent increase in fuel costs in this case produces only a 23 per cent increase in $V_{ph}$.

The cost of operating the heating plant is expected to rise at an annual rate of .033. ($P_u$= 1.53 from figure 1). The useful life of the building is 50 years, and money is valued at 6 per cent ($F_u$=15.762, $F'_{nu}$=.791 and $F'_u$=19.54 computed as for formula 10). The income tax rate is 57 per cent and not expected to change (T=.57). The ratio of assessed value to market value of the heating plant is .75 ($V_t$=.75), and the real estate tax rate is .04 ($R_t$=.04). The insurance rate is $.06 per $100.00 of value ($I_r$=.0006 from Table V). From the discussion regarding equation 10, insurance and real estate tax costs on the plant are not expected to change. What is the total present value of the operating and initial cost of the heating plant attributable to each square foot of wall A? From equations 11 and 12A:

(11) $X_h=\frac{5,000\times.15}{(70-0)\ 4167}$

$X_h=\$.00257$

(12A) $V_{ph}=.12(70-0)(.02+10.4\times.00257)$

$V_{ph}=\$.39$

It should be noted that in present design practice heat loss is assumed to be a direct function of the coefficient of heat transmission or "U" value. The value of $V_{ph}$ is, therefore, also a direct function of "U". Wall A has a "U" value of .12. If the cavity wall were not insulated, the coefficient of heat transmission would be .30, and $V_{ph}$ would equal $.39 × .30/.12 or $.97. Since the "U" value of walls A and B are equal, the present value of heating costs is the same for both walls. For wall C the "U" value is .55, and the present value of the heating cost is $1.78.

The published "U" values of building materials are usually computed or obtained under "steady state" laboratory test conditions which rarely correspond to "in service" conditions. A small difference in the "U" values of two materials is, therefore, negligible and should not seriously affect the decision indicated by an economic analysis based on "U" value. Frequently, published "U" values are those computed through an insulated section and do not take into consideration thermal bridges built into the wall. Since through-the-wall metal connections may have a considerable effect on "U" value, ranging up to a 218 per cent increase, the designer should carefully scrutinize manufacturers' published data.[15]

The important thing to be discovered here is the order of magnitude of heating costs per square foot of wall area. Under these design conditions the range is from $.39 for insulated walls through $.97 for uninsulated walls and $1.78 for double glazed windows to $3.68 for single plate glass. Data presented in the ASHAE *Guide* indicate that double plate glass occupying 80 per cent of the area of an aluminum sash has an overall "U" value some 30 per cent higher than for the glass alone, bringing the cost to $2.32 per sq. ft. For 80 per cent single sheet glass in an aluminum frame the overall "U" value is 10 per cent higher, bringing the cost to $4.05 per sq. ft.

## INSURANCE

The premiums for fire insurance on a building and its contents represent a considerable annual payment for building owners and occupants. The insurance rate on a given building and its contents is a function of many variables, ranging from building materials used to the cleanliness of housekeeping. It behooves the designer to consult the local insurance rating bureau for advice on improvements which will lower insurance cost. Frequently, minor changes in design or the addition of inexpensive equipment will save building owners and occupants a considerable amount of money.

[15] *Ibid.*, footnote 13.

The case of a recently completed hotel in Dallas, Texas, is typical. The owner discovered that the fire insurance premium on his metal panel building and its contents was $5,800.00 per year more than if his architect had used masonry walls. In this building there are 63,000 sq. ft. of metal panels. The increased insurance charge per square foot per year is nearly $.10. Few designers would specify an exterior wall material which had to be painted every year at a cost of $.10 per sq. ft, but the "invisible" cost of insurance was either ignored or considered unobjectionable.

Insurance rates are established on four principal considerations; the structure, occupancy, degree of exposure, and the protection provided. A grading system of charges and credits to a base rate is used. Credits are given for items which reduce risk of loss and debits are charged for items which increase the possibility of loss. Regarding wall construction, all other things being equal, the rate may vary considerably with the selection of materials.

In 1958 a survey was made of the 39 insurance rating bureaus in the United States. Replies were received from bureaus writing insurance schedules in 33 states.

In 94 per cent of the states for which replies were received, fire insurance rates on buildings and their contents are more for buildings having incombustible metal panels not backed up with masonry than for the buildings having masonry walls. This is true in the following states:

| | |
|---|---|
| Arkansas | Missouri |
| California | Nebraska |
| Colorado | Nevada |
| Florida | North Dakota |
| Georgia | New Mexico |
| Illinois | New York |
| Indiana | Ohio |
| Iowa | Oklahoma |
| Kansas | South Dakota |
| Kentucky | Tennessee |
| Louisiana | Texas |
| Massachusetts | Utah |
| Maryland | West Virginia |
| Michigan | Wisconsin |
| Minnesota | Wyoming |
| Mississippi | |

In 87 per cent of these states fire insurance rates on buildings and their contents are affected by the amount of window area.

In 77 per cent of these states the fire insurance rates on buildings and their contents have been modified within the last five years by a revaluation of charges for exterior wall types.

The "*Uniform Grading Schedule*" of the Middle Department Association of Fire Underwriters in Philadelphia, Pennsylvania, has one of the more modern grading schedules in the United States. Table X describes several wall types and gives the grading point charges made for each in this schedule, when the building in which they are used is erected in accordance with the National Board of Fire Underwriters requirements for Class A fire resistive construction. The introduction to the schedule states that these point gradings produce a charge in proper proportion to the total grading of a risk. Since the insurance rates under this schedule are a function of the grading points, the fire insurance premiums on a building with metal or all glass walls would be considerably higher than for the same structure with conventional walls. The premiums paid for fire insurance on the contents of the building would also be comparably higher.

The present value of the fire insurance costs on a building chargeable to any wall may be computed from equation 13.

$$V_{pf}=\frac{(C_b I_r - C'_b I'_r)P_u F_u(1-T)E}{A_g} \tag{13}$$

Where: $V_{pf}$ is the present value of the fire insurance costs attributable to 1 sq. ft. of wall area.

$C_b$ is the value of the building with the wall under consideration.

$I_r$ is the insurance rate on the building with the wall under consideration.

$C'_b$ is the value of the building with a type of wall construction carrying the lowest rate of any wall.

$I'_r$ is the insurance rate on the building with a type of wall construction carrying the lowest rate of any wall.

$P_u$ is the approximate present worth correction factor for a uniformly changing series of future annual expenditures from equation 3.

$F_u$ is the present worth factor for a uniform annual series for the life of the building.

T is the total equivalent income tax rate.

E is the ratio of the initial replacement cost to initial building cost.

$A_g$ is the gross exterior wall area in square feet.

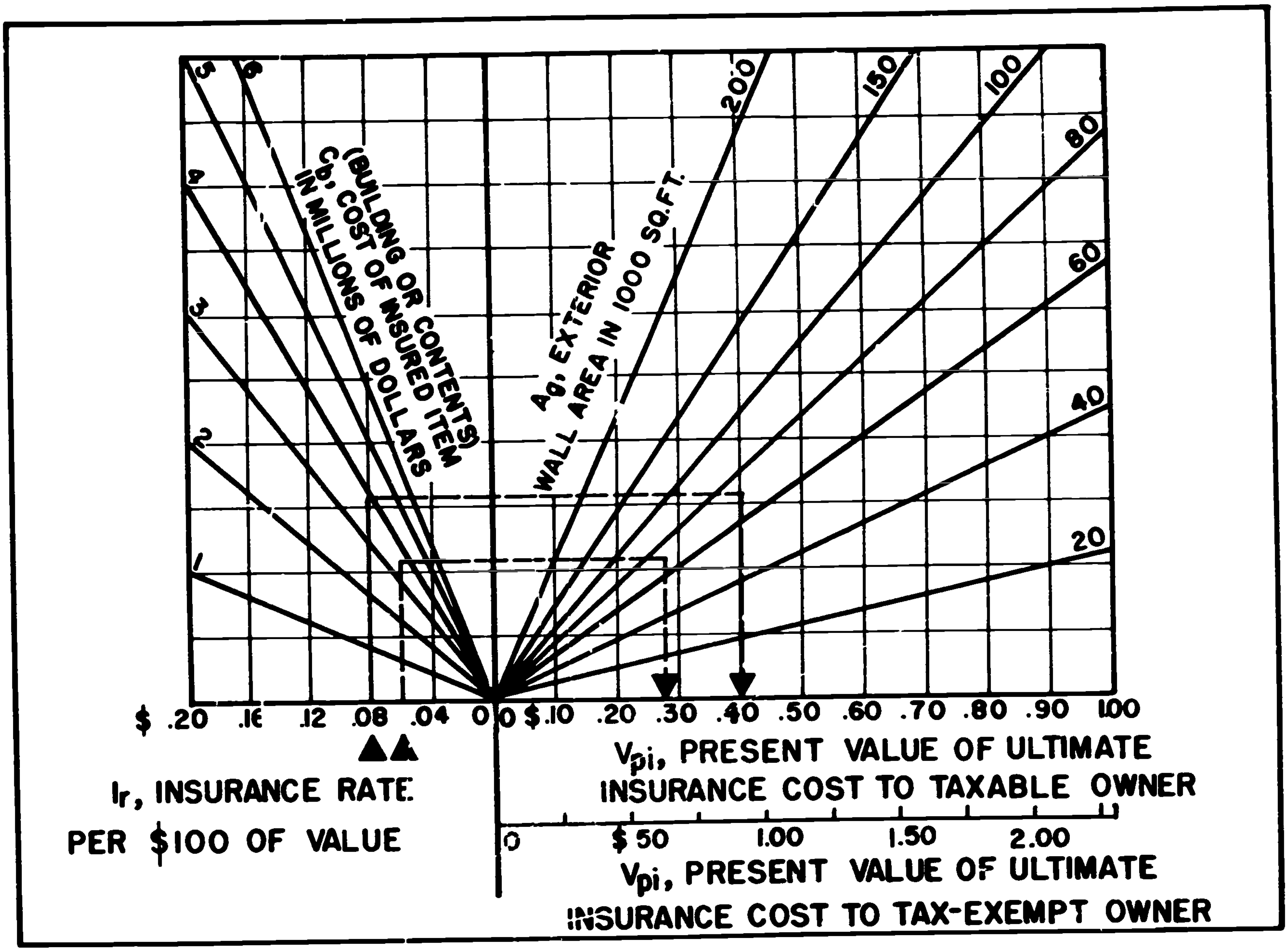



**Figure 14**

Under the financial assumptions given in Table VII equation 13 may be written:

$$(13A)\quad V_{pi} = \frac{9.8E(C_b I_r - C'_b I'_r)}{A_g}$$

Figure 14 provides a graphic solution to equation 13A.

*Thirteenth example:* A typical National Board of Fire Underwriters Class A office building in the Philadelphia area will be used to demonstrate the effect of exterior wall materials on insurance premiums. The gross exterior wall area is 72,000 sq. ft. ($A_g = 72{,}000$) of which 40 per cent is window area. The fire insurance rate on this building with wall A (grading points of 100, wall No. 9 in Table X) is $.06 per $100.00 of insurance. Wall A produces the lowest rate of any wall type ($C'_b = 3.6 \times 10^6$ and $I'_r = .0006$ from Table V). The fire insurance rate on the building with walls B or C (grading points of 350, walls No. 13 and 18 in Table X) is $.08 per $100.00 of insurance ($C_b = 3.87 \times 10^6$ and $I_r = .0008$ from Table V). Money is valued at 6 per cent and the useful life of the building is 50 years ($F_u = 15.762$ from Table II).

Since a percentage of the cost of the building is spent for items not usually destroyed by fire (e.g., foundation, excavations and underground piping), the initial replacement cost is less than the initial cost. The percentage of the initial cost to be insured varies from 97 per cent to 86 per cent, depending on the building type and height; 94 per cent is applicable to 10-story office buildings ($E = .94$).

The amount of insurance carried on the building at any time is the replacement cost less depreciation. Insurance rates are expected to go up annually at a .01 rate, replacement costs are expected to go up at a .0377 annual rate, and depreciation goes down at a .02 annual rate. The net average annual rate of change in the insurance cost, therefore, is + .0277 ($P_u = 1.45$ from equation 3 or figure 1).

**TABLE X**

**Insurance Grading Points**

| | | |
|---|---|---|
| | **Bearing Walls** | |
| 1 | 12-in. brick | 100 |
| 2 | less than 12-in. brick | 150 |
| 3 | 8-in. reinforced concrete | 100 |
| 4 | less than 8 inches reinforced concrete | 150 |
| 5 | any thickness structural clay tile or concrete block one story in height | 150 |
| 6 | same as wall No. 5, more than one story in height | 300 |
| | **Non Bearing Walls** | |
| 7 | 12-in. curtain walls any unit masonry | 100 |
| 8 | less than 12-in. curtain walls structural clay tile or concrete block | 150 |
| 9 | 8-in. panel walls any unit masonry | 100 |
| 10 | less than 8-in. any unit masonry wall | 175 |
| 11 | 6-in. reinforced concrete curtain wall | 100 |
| 12 | less than 6-in. reinforced concrete | 175 |
| 13 | metal or other non-masonry walls when incombustible throughout and mounted on incombustible supports | 350 |
| 14 | same as wall No. 13 except with combustible coatings on inner face | 400 |
| 15 | same as wall No. 13 except with combustible internal materials | 900 |
| | **Windows** | |
| 16 | less than 75% of total wall area | same as wall |
| 17 | 75% to 100% of total wall area | 150 |
| 18 | continous glass construction | 350 |
| 19 | glass block | 175 |

From equation 13A the present value of the fire insurance costs on the building chargeable to 1 sq. ft. of wall area is computed as follows:

$$\text{(13A)}\quad V_{pf}\,(\text{building}) = \frac{9.8\times.94\,[(3.87\times10^6\times.0008)-(3.6\times10^6\times.0006)]}{72{,}000}$$

$$V_{pf}\,(\text{building}) = \$.12$$

The present value of the fire insurance costs for the contents of the building may also be computed from equation 13. Insurance rates may be expected to rise at an annual rate of .01, and the replacement cost of office furniture, fixtures and equipment may be expected to rise at an annual rate of .04. Depreciation, however, on the contents is 5 per cent per year. The net rate of change in the insurance cost for the contents is, therefore, zero, and $P_u=1$. Since the loss on such equipment is apt to be total, $E=1$. Equation 13 for contents, therefore, becomes:

$$\text{(13B)}\quad V_{pf}(\text{contents}) = \frac{C_e(I_e-I'_e)(1-T)F_u}{A_g}$$

Owners of rented office buildings, of course, do not pay fire insurance on the contents, but someone does. In many building types the owner pays this cost. Suppose the value of the contents of the building in question is $2,000,000. The insurance rate per $100.00 value is $.18, when wall A is used and $.20 when wall B or C is used (see Table V).

**TABLE XI**

**LOCAL TAX RATES AND ASSESSMENT RATIO**

| City | Rate per $100.00 valuation | Ratio of assessed value to market value (per cent) |
|---|---|---|
| Albuquerque, N. M. | $6.2117 | 16 |
| Atlanta, Georgia | 2.075 | 70 |
| Baltimore, Maryland | 3.1225 | 75 |
| Bismarck, North Dakota | 7.412 | 25 |
| Boise, Idaho | 12.00 | 20 |
| Boston, Massachusetts | 8.60 | 100 |
| Buffalo, New York | 4.20 | 60 |
| Charleston, West Va. | 2.9096 | 60 |
| Chicago, Illinois | 3.974 | 100 |
| Cleveland, Ohio | 3.47 | 50 |
| Columbia, South Carolina | 4.50 | 7.5 |
| Concord, New Hampshire | 5.64 | 59 |
| Dallas, Texas | 3.88 | 39 |
| Denver, Colorado | 5.371 | 40 |
| Greensboro, N. C. | 1.15 | 70 |
| Houston, Texas | 3.43 | 38.5 |
| Indianapolis, Ind. | 6.72 | 33.3 |
| Jackson, Mississippi | 4.15 | 67 |
| Las Vegas, Nevada | 4.68 | 33 |
| Los Angeles, Calif. | 10.25 | 35 |
| Louisville, Kentucky | 4.05 | 40 |
| Nashville, Tennessee | 2.50 | 50 |
| New Orleans, La. | 2.9775 | 26.25 |
| New York, N. Y. | 4.21 | 100 |
| Oklahoma City, Okla. | 7.31 | 25 |
| Omaha, Nebraska | 6.193 | 35 |
| Philadelphia, Pa. | 3.46 | 100 |
| Portland, Maine | 6.45 | .. |
| Portland, Oregon | 7.05 | 48 |
| Richmond, Virginia | 1.88 | 90 |
| Salt Lake City, Utah | 7.22 | 20 |
| Seattle, Washington | 5.80 | 35.6 |
| Sioux Falls, S. D. | 5.60 | 60 |
| St. Paul, Minnesota | 15.383 | 17.32 |
| San Francisco, Calif. | 7.37 | 50 |
| Tucson, Arizona | 13.456 | 24 |
| Washington, D. C. | 2.30 | 75 |
| Wichita, Kansas | 8.92 | 21 |
| Wilmington, Delaware | 2.48 | 70 |

The present value of the fire insurance costs for the contents per square foot of wall area is computed as follows:

$$\text{(13B)}\,V_{pf}(\text{contents}) = \frac{2\times10^6(.002-.0018).43\times15.762}{72{,}000}$$

$$V_{pf}\,(\text{contents}) = \$.04$$

If the owner is tax exempt, the answers obtained from equations 13A and 13B would be increased. Since tax exempt owners are apt to carry insurance on the contents of their buildings, this item amounts to $.09 for walls A and B.

## REAL ESTATE TAXES

Nearly 90 per cent of all tax revenue for local governments is derived from general property taxation.[16] A tax rate is applied to an assessed value of the property to determine the tax due. The ratio

[16] *Assessed Values and Sales Prices of Transferred Real Property*, 1957 Census of Governments, Advance Release No. 7, Bureau of the Census, May 5, 1958.

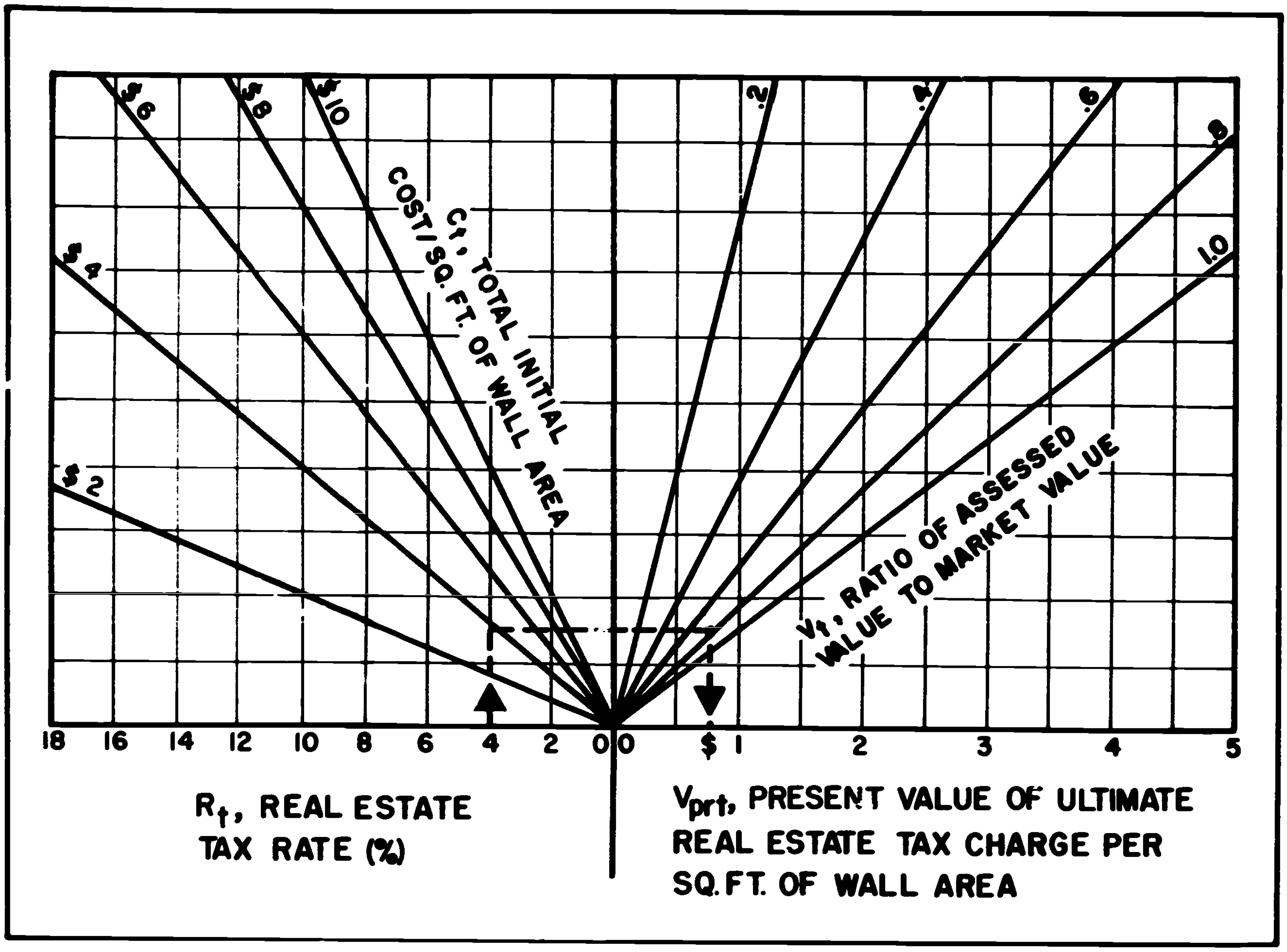



**Figure 15**

of assessed value to market value varies greatly with the community. In some areas the ratio is 100 per cent, while in others the ratio is as low as 7.5 per cent. Local tax rates also vary considerably. Since these figures are available from the local tax office, they should not be estimated.

In mid-1958, a survey was made of tax collectors in 52 cities in the United States. Table XI provides the local tax rate and ratio of tax assessed value to market value for many of these cities.

The present value of all future real estate taxes chargeable to 1 sq. ft. of wall area may be computed from the following equation, which is based on the reproduction cost method of valuation:

(14) $V_{prt} = C_t R_t V_t F_u (1-T)$

Where: $V_{prt}$ is the present value of all future expenditures for real estate taxes chargeable to 1 sq. ft. of wall area.

$C_t$ is the total initial cost of the wall per square foot.

$R_t$ is the local real estate tax rate per year.

$V_t$ is the local ratio of assessed valuation to market value.

$F_u$ is the present worth factor for a uniform annual series for the life of the building.

Under the financial conditions given in Table VII figure 15 provides a graphic solution for $V_{prt}$.

Real estate taxes may be expected to decrease as the value of the building depreciates. Real estate tax rates, however, may be expected to rise. It is common practice in economic studies to assume that these changes will cancel each other and that the real estate tax will continue at its initial level.

*Fourteenth example:* The total initial cost of wall A, including the cost of supporting the wall and the charge for floor space occupancy, is $3.81 ($C_t$=3.81). The local real estate tax rate is 4 per cent per year ($R_t$=.04), and the ratio of assessed

**TABLE XII**

Calculation of Ultimate Wall Cost

Project No.________ Cost Analysis By:________

Project Location:________ Owner Taxable ✓ , tax-exempt________

Owner:________ Date:________

Wall Type Studied: MASONRY CAVITY WALL

1. Initial wall cost per sq. ft., $C_w$ ........ $ 2.30

2. Cost of supporting wall, $C_b$;
   a. Wall wt., lb/sq. ft., P; ........ 65 lbs.
   b. No. of stories in building, F; ........ 10

   (Enter Fig. 2 with "wt.", proceed horizontally to "story" curve, drop down to read cost, $C_b$). ........ $ .26

3. Floor space occupancy charge, $C_{fw}$:
   a. Wall thickness, in., Y; ........ 10 in.
   b. Initial cost of buidling \$/sq. ft of floor area, $C_f$; ........ $ 18.00
   c. Fl. to fl. height, ft., S; ........ 12 ft.

   (Enter Fig. 3 with "thickness", proceed vertically to "bldg. cost" curve, proceed horizontally to "fl. height" curve, drop down to read cost, $C_{fw}$. *Note:* If the entire building site is not occupied, enter zero here.) ........ $ 1.25

4. Total initial wall cost, $C_t$:

   (Enter sum of items 1, 2 and 3 here) ........ $ 3.81

5. Total initial wall cost less depreciation tax credit, $C_d$:

   (Enter Fig. 4 with amount shown in item 4 above, proceed horizontally to curve, and drop down to read $C_d$. *Note:* If owner is tax exempt, enter zero here.) ........ $ 3.12

6. Salvage credit, $V_{ps}$:
   a. Present salvage value, $C_s$; ........ $ .16

   (Enter Fig. 6 with present salvage value, proceed horizontally to curve, drop down to read $V_{ps}$.) ........ $ .01

7. Speed of erection credit, $V_{po}$:
   a. Cost of building in millions of dollars, $C_b$; ........ $ 3.6
   b. Construction time saved by use of this wall type in weeks ........ 0 weeks
   c. Gross exterior wall area sq. ft. $A_g$; ........ 72M sq. ft.

   (Enter Fig. 7 with "building cost", proceed vertically to "time saved" curve, proceed horizontally to "wall area" curve, drop down to read $V_{po}$. *Note:* If owner is tax-exempt, enter zero here.) ........ $ 0

8. Total credits:

   (Enter sum of items 6 and 7 here.) ........ $ .01

9. Total initial cost less credits:
   a. For taxable owner, subtract item 8 above from item 5 above and enter difference here
   b. For tax-exempt owner, subtract item 8 above from item 4 above and enter difference here
   ........ $ 3.11

10. Heat gain charge, $V_{pg}$:
    a. Summer degree-days, k; ........ 500 degree-days
    b. Electric power costs per kw-hr, E; ........ $ .02
    c. Design exterior temp. °F, $t_d$; ........ 95 °F
    d. Diurnal temp. range, °F, $t_r$; ........ 20 °F
    e. ½ item 10d, °F; ........ 10 °F
    f. Item 10c less item 10e less 70°F; ........ 15 °F

    (Enter Fig. 8 with "degree-days", proceed vertically to "power cost" curve, proceed horizontally to "temperature" curve, item 10f above, drop down to read annual operating cost, 1000 $X_g$).

    g. Annual operating cost (from Fig. 8), 1000 $X_g$ ........ $ 4.00
    h. Initial Cost of air conditioning plant per ton of refrigeration, $M_g$; ........ $ 1,200
    i. Heat gain through wall, Btu/hr/sq. ft. from ASHAE Guide, $H_g$; ........ 1.23 Btu

    (For taxable operation enter Fig. 9 with "1000$X_g$" from Fig. 8, item $10_g$ above, proceed vertically to "plant cost" curve, proceed horizontally to "heat gain" curve, and drop down to read $V_{pg}$. If owner is tax-exempt use Fig. 10) ........ $ .17

## 11. Heat loss charge, $V_{ph}$:

a. Winter degree-days, $D_d$; .......... 5000 degree-days
b. Plant operating costs per therm (100,000 Btu), $C_h$; .......... $ .15
c. Interior design temp; °F, $t_i$; .......... 70 °F
d. Exterior design temp; °F, $t_o$; .......... 0 °F
e. Temp. diff; $(t_i - t_o)$; .......... 70 °F

(Enter Fig. 11 with "degree days", proceed vertically to "cost" curve, proceed horizontally to "temperature difference" curve, drop dawn to read annual operating costs, 1000 $X_h$.)

f. Annual operating costs (from Fig. 11) 1000 $X_h$; .......... $ 2.57
g. Initial cost of heating plant per therm of capacity, $M_h$; .......... $ 2,000
h. U value of wall, Btu hr. sq. ft/°F; .......... 0.12
i. Heat loss per sq. ft. of wall area per hr., $U(t_i - t_o)$, Btus; .......... 8.4 Btu

(For taxable operations enter Fig. 12 with "annual operating cost" from Fig. 11; item 11f above, proceed vertically to "plant cost" curve, proceed horizontally to "heat loss" curve, drop down to read $V_{ph}$. If owner is tax exempt, use Fig. 13) .......... $ .39

## 12. Maintenance charge, $V_{pm}$:

| No. | Item | Present Cost Per sq. ft. | Frequency in Years | $V'_{pm}$ |
|---|---|---|---|---|
| a | Cleaning | $.50 | 35 | .065 |
| b | Caulking | | | |
| c | Pointing | $.07 | 35 | .009 |
| d | Painting | $.03 | 4 | .074 |
| e | Total, $V_{pm}$ | | | .148 |

(Enter Fig. 5 with present cost of maintenance operation, proceed horizontally to "frequency,' curve, drop down to read $V'_{pm}$. Record in above table and enter sum here.) .......... $ .15

## 13. Insurance charge, $V_{pi}$:

a. Fire insurance rate on building (or contents) per $100.00 of value with wall type under consideration, $I_r$; .......... $ .06
b. Costs of building (or contents) with wall type under consideration in millions of dollars, $C_b$; $ 3.6
c. Gross exterior wall area, sq. ft. $A_g$; .......... 72M sq. ft.
d. (Enter Fig. 14 with "rate", item 13a above, proceed vertically to "building cost" curve, proceed horizontally to wall area curve, drop down to read $V'_{pi}$. Note: If building owner pays insurance premium on the building contents, use Fig. 14 also) .......... $ .27
e. Fire insurance rate on building with wall type producing lowest insurance rate, $I'_r$; .......... $ .06
f. Cost of building with wall type producing lowest possible insurance rate, $C'_b$ .......... $ 3.6
g. Enter Fig. 13 and proceed as before. Enter $V''_{pi}$ here; .......... $ .27
h. Item 13d less item 13g equals $V_{pi}$; .......... $ 0

## 14. Real Estate Tax charge, $V_{prt}$:

a. Real estate tax rate, $R_t$; .......... 4 %
b. Total initial cost of wall per sq. ft., Item 4 above, $C_t$; .......... $ 3.81
c. Ratio of assessed value to market value, $V_t$; .......... .75

(Enter Fig. 15 with "rate", proceed vertically to "cost" curve, proceed horizontally to "ratio" curve, drop down to read $V_{prt}$. Note: If the owner is tax-exempt, enter zero here.) .......... $ .78

## 15. Total charges:

a. Item 10 above .......... $ .17
b. Item 11 above .......... $ .39
c. Item 12 above .......... $ .15
d. Item 13 above .......... $ 0
e. Item 14 above .......... $ .78
f. Total .......... $ 1.49

## 16. Total ultimate cost:

a. Item 9 above .......... $ 3.11
b. Plus item 15 above .......... $ 1.49
c. Total ultimate cost per sq. ft. of wall area, $V_{pu}$ .......... $ 4.60

(For glass walls, compute the illumination credit, if any, and deduct from item 16c above to obtain the total ultimate cost per sq. ft. of window area.)

value to market value is .75 ($V_t$=.75). The income tax rate is 57 per cent (T=.57). The life of the building is 50 years and money is valued at 6 per cent ($F_u$=15.762.)

From equation 14 the present value of all future expenditures for real estate taxes chargeable to 1 sq. ft. of wall area is computed as follows:

$$(14) \qquad V_{prt} = 3.81 \times .04 \times .75 \times 15.762(1 - .57)$$
$$V_{prt} = .78$$

Similarly, for walls B and C, $V_{prt}$ is $1.39.

## IV. RECAPITULATION OF DATA

To facilitate the calculations necessary to the computation of ultimate wall cost, Table XII has been provided for the convenience of the analyst. Each step in the operation is described and space provided for entering the data. Reprints of this table are available for calculating the ultimate cost of specific walls.

## V. COST COMPARISON

When one considers the number of variables upon which these calculations depend, it would be coincidence if the total present value of all costs and credits incurred by wall A were exactly $4.60 per sq. ft. as indicated in Table XIII, which summarizes all of the costs previously computed for the three wall types. The best that can be obtained by such an analysis is an intelligent estimate of the relative ultimate cost of the wall types considered. While the total costs may not be absolute values, the relative costs of the walls provide a very accurate basis for comparison. The purpose of an economic analysis is to permit the designer to base his judgment on something better than "hunch."

In this analysis each wall type was assumed to occupy the entire facade. For all practical purposes when wall C is combined in any proportion with walls A or B, the average total cost of the assembly may be computed by interpolation between the two wall costs on a straight line basis. Although this is not a precise calculation, it offers a very reasonable solution. For example, if the glass area is 30 per cent, a composite wall of masonry and glass would cost $8.71 per gross sq. ft. That is, (.7 × 4.60) + (.3 × 18.29) or $8.71. Similarly, a metal and glass wall with 60 per cent window area would have an average cost of $14.12 per sq. ft.

Table XIV may be used to facilitate the calculation of composite wall costs for walls with any per cent window opening.

**TABLE XIII**

**Present Value of Ultimate Costs (Per Sq. Ft. of Wall Area)**

**FOR TAXABLE OPERATIONS**

| Cost Item | Masonry Cavity Wall | Metal Panel Wall | Double Plate Glass Wall |
|---|---|---|---|
| 1. Initial wall cost, $C_w$ | $2.30 | $6.00 | $6.40 [17] |
| 2. Support of the wall charge, $C_h$ | .26 | .06 | .03 |
| 3. Charge for floor space occupancy[18], $C_{fw}$ | 1.25 | .81 | .41 |
| 4. Total initial wall cost, $C_t$ | 3.81 | 6.87 | 6.84 |
| 5. Less depreciation credit, $V_{pd}$ | .69 | 1.23 | 1.23 |
| 6. Less salvage credit, $V_{ps}$ | .01 | .05 | .04 |
| 7. Less illumination credit, $V_{pi}$ | none | none | 1.59 |
| 8. Less early occupancy credit, $V_{po}$ | none | .14 | .14 |
| 9. Total initial cost less recovered costs | 3.11 | 5.45 | 3.84 |
| 10. Heat gain charge, $V_{pg}$ | .17 | .34 | 8.00 |
| 11. Heat loss charge, $V_{ph}$ | .39 | .39 | 2.32 |
| 12. Maintenance charge, $V_{pm}$ | .15 | .17 | 2.62 |
| 13. Insurance charge[19], $V_{pf}$ | none | .12 | .12 |
| 14. Real estate tax charge, $V_{prf}$ | .78 | 1.39 | 1.39 |
| 15. Present value of ultimate cost | 4.60 | 7.86 | 18.29 |
| 16. Relative ultimate cost | 100% | 171% | 398% |

[17] Includes venetian blinds
[18] Entire site occupied
[19] For building only, not including contents

The cost given in Table XIII may be applied to an office building having 72,000 sq. ft. of gross wall area, 40 per cent of which is glass. Is it really worth $140,000.00 to use a metal rather than a masonry wall? Is a glass wall worth $690,000.00 more than a masonry wall with 30 per cent windows?

All of the preceding calculations have assumed that the owner pays income taxes at a 57 per cent rate. However, about one-half of the non-residential, non-farm building dollar volume in 1957 was spent by owners who do not pay taxes, e.g., schools, churches, public buildings, defense construction, associations, etc. The cost of building walls to these owners is considerably higher, because the government does not help pay the bills. Table XV shows the costs and credits for each item, when the owner does not pay taxes. Note that an all glass wall is 146 per cent (2.46 times) more expensive than a masonry wall with 30 per cent windows.

The authors do not propose, at this juncture, to enter into a discussion of the relative public relations or publicity values of various types of building materials, although it seems to be a temptation afflicting many today to "read" public relations benefits into whatever type of construction they happen to favor. It is our view that advice of this type should come, not from designers and cost experts, but from competent public relations counsel. We succumb to

## TABLE XIV

Comparison of Ultimate Wall Costs

1. Ultimate cost of composite basic walls:
   a. Ultimate cost of basic wall, psf .......... $4.60
   b. Ultimate cost of window, psf .......... $18.29
   c. Per cent window openings .......... 30 %
   d. Ultimate cost of composite basic wall, psf .......... $8.71

   (In figure 16 plot item 1(a) above on right scale and item 1(b) above on left scale. Connect these two points by straight line. From the point of intersection of this line and the vertical line representing 1(c) above proceed horizontally to read the ultimate cost of the composite wall. Record answer in line 1(d) above. If two composite walls are to be compared repeat this process and record the data below)

2. Ultimate cost of composite alternate wall:
   a. Ultimate cost of alternate wall, psf .......... $7.86
   b. Ultimate cost of window, psf .......... $18.29
   c. Per cent window openings .......... 60 %
   d. Ultimate cost of composite alternate wall, psf .......... $14.12

3. Difference in ultimate cost of composite walls, psf (Item 2(d) less item 1(d)) .......... $5.41

## TABLE XV

Present Value of Ultimate Costs
(Per Sq. Ft. of Wall Area)

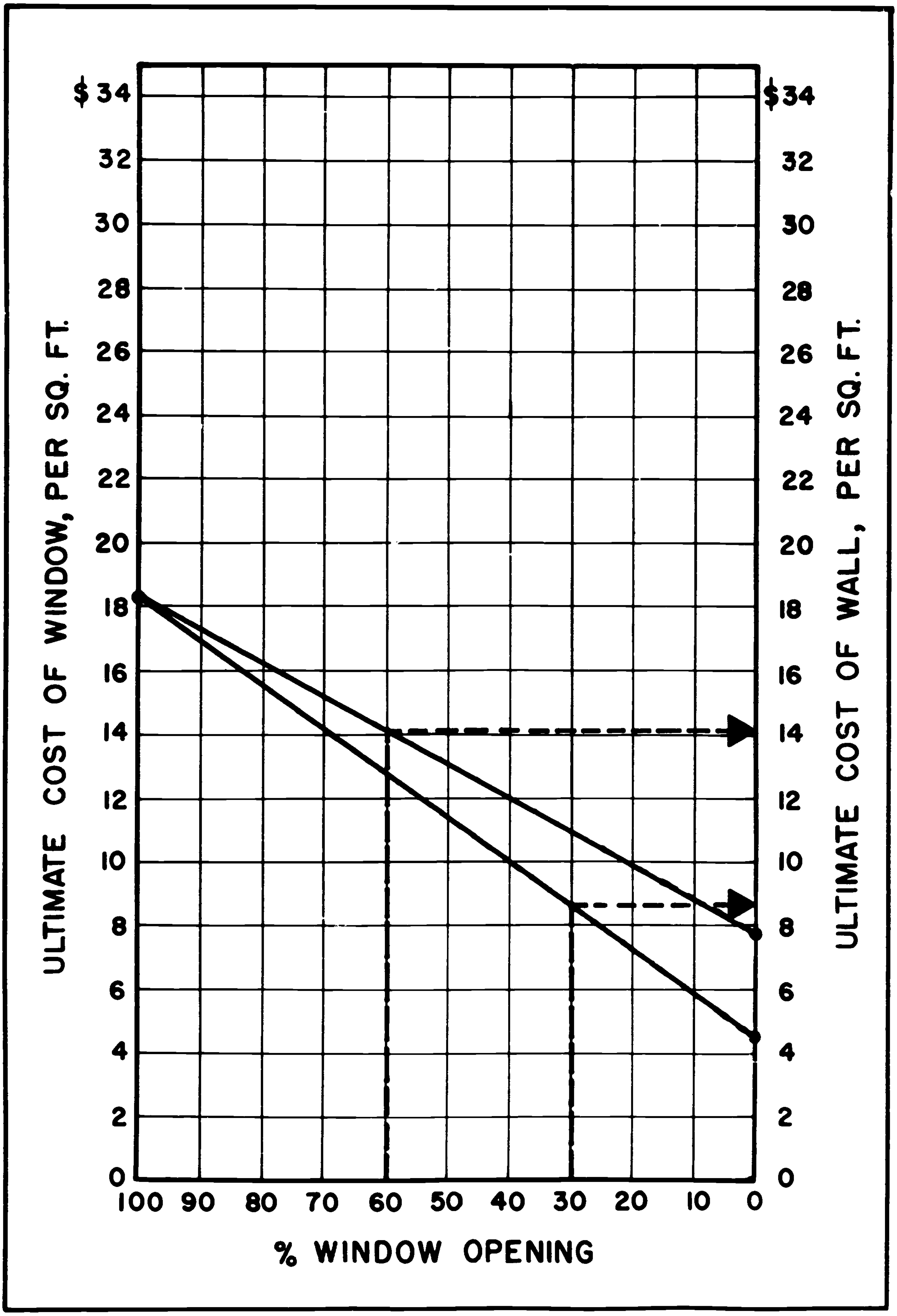
FOR TAX EXEMPT OPERATIONS

| Cost Item | Masonry Cavity Wall | Metal Panel Wall | Double Plate Glass Wall |
|---|---|---|---|
| 1. Initial wall cost | $2.30 | $6.00 | $6.40[20] |
| 2. Support of the wall charge | .26 | .06 | .03 |
| 3. Charge for floor space occupancy[21] | 1.25 | .81 | .41 |
| 4. Total initial wall cost | 3.81 | 6.87 | 6.84 |
| 5. Less depreciation credit | none | none | none |
| 6. Less salvage credit | .02 | .13 | .09 |
| 7. Less illumination credit | none | none | 3.70 |
| 8. Less early occupancy credit | — | — | — |
| 9. Total initial cost less recovered costs | 3.79 | 6.74 | 3.05 |
| 10. Heat gain charge | .32 | .67 | 15.60 |
| 11. Heat loss charge | .82 | .82 | 4.89 |
| 12. Maintenance charge | .33 | .39 | 6.09 |
| 13. Insurance charge[22] | none | .39 | .39 |
| 14. Present value of total cost | $5.26 | $9.01 | $30.02 |
| 15. Relative ultimate cost | 100% | 172% | 572% |

[20] Includes venetian blinds
[21] Entire site occupied
[22] For building and contents

the temptation only enough to venture the thought that it is not the material, but its use, which will provide an effect leading to good public relations; and that the most expensive material will not necessarily create that effect.

Three elements are necessary for the proper performance of building walls: aesthetics, engineering and economics. Walls should be economical, but they should also contribute to the beauty and safety of man's environment. No attempt has been made here to consider the very important aspects of architectural and engineering design which are not directly related to economics. The economics of safety factors in structural design has not been considered, since under the law of building codes little latitude is left to the designer in this regard. Sound resistance, suitable strength, impermeability, vapor resistance, acoustics, color, texture and form are all important factors. To place too much emphasis on any one facet of the problem is to invite failure. A balanced approach will ultimately provide the best solution. To sacrifice aesthetics for economics is poor architectural practice, but the converse is also true.




8M 958
5M 1258

Figure 16

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