A FEASIBILITY METHODOLOGY FOR MULTISTORY BUILDINGS WITH RESPECT TO FALLOUT RADIATION PROTECTION

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NOMENCLATURE

AP	ratio of total window area to total wall area.
ARATIO	cost per unit protected total area in building.
AREACL	required enclosed area - square feet.
AREAOP	required open area - square feet.
AREAPF	protected floor area of an individual floor - square feet.
AVGPF	average protection factor for all adequately protected areas.
BEO	barrier reduction factor for glass from <u>Chart 2</u>.
BEXE	wall barrier reduction factor from <u>Chart 2</u>.
BFXF	wall barrier reduction factor from <u>Chart 2</u>.
BIXI	interior partition reduction factor for the wall at the detector story from <u>Chart 1</u>.
BIXIPR	interior partition reduction factor for the roof on the next floor above the detector story from <u>Chart 1</u>.
BLDGLH	length of building - feet.
BLDGWD	width of building - feet.
BOXOPR	ceiling barrier reduction factor from <u>Chart 7</u>.
CAPARA	capacity as limited by area requirements - people
CAPVOL	capacity as limited by volume requirements - people
CG	ground contribution from detector story
CGA	ground contribution from story above detector
CGALL	total ground contribution from adjacent stories and the detector story
CGB	ground contribution from story below detector

CONTRF	roof contribution reduction factor for floor under the top floor and roof area within interior partition area from Chart 4.
CONTTL	roof contribution for the top story when the detector is is there.
COTOTL	roof contribution for the floor under the top story when detector is at that floor.
DLRFDN	total cost of site and foundation - dollars.
DLROOF	total cost of roof - dollars.
DLRPTN	total cost of partitions surrounding core of building protected area - dollars.
DLRWAL	total cost of exterior wall - dollars.
DOLLAR	summation of DLRFDN, DLROOF, DLRPTN, and DLRWAL.
EHALLL	width-to-length ratio of interior core area.
EWDLTH	width-to-length ratio of building.
E8	shape factor from Chart 8.
FLOORS	number of floors in the building being considered.
FLORNO	number of the floor being processed.
FLRMAS	mass of the individual floors.
GAA5	skyshine response on a window strip of detector plane from Chart 5.
GAPR5	skyshine response for floor above from Chart 5.
GA5	skyshine response for detector floor from Chart 5.
GDPR6	ground direct response for various heights due to story below from Chart 6.
GD6	ground direct response for various heights from Chart 6.
GSLPR5	wall scattered response for lower angle of wall base of the floor below from Chart 5.
GSL5	wall scattered response for lower angle of detector floor from Chart 5.
GSUA5	wall scattered response for upper angle along a windowstrip from Chart 5.

GSUPR5 — wall scattered response for upper angle of wall top of the floor above from Chart 5.

GSU5 — wall scattered response of detector floor for upper angle from Chart 5.

HALNTH — length of interior core protected area - feet.

HEIGHT — detector height from contaminated plane - feet.

$HTLNTH_1$ — ratio of distance from detector to roof through one floor to the length of building.

$HTLNTH_2$ — ratio of distance from detector to roof at top story to the length of building.

$HTLNTH_3$ — ratio of distance from detector to the ground at the ground floor to building length.

$HTLNTH_4$ — ratio of distance from detector to the ground at the second floor to building length.

$HTLNTH_5$ — ratio of window height above detector to building length.

$HTLNTH_6$ — ratio of distance from detector to roof at the top story limited to the partition walls to the building length.

$HTLNTH_7$ — ratio of distance from detector to roof at floor under the top story limited to the partition walls to building length.

PA — percentage of glass area within a building-encircling horizontal strip with a width equal to the average individual opening heights.

PERFAC — perimeter factor as derived in Chapter II.

PFAREA — floor area protected to minimum protection specifications - square feet.

PFCOST — cost per average protection factor.

PRFMIN — minimum specified protection factor.

PROTCN — people capacity times average protection factor.

PRTARA — surface area of partitions - square feet.

PRTOCS — unit cost of partitions - dollars/square foot.

PRTMAS — unit mass of partitions - pounds per square foot.

RATIO — cost per specified protection factor.

RFCO	roof contribution reduction factor for top floor and total roof area from Chart 4.
RFCONT	roof contribution reduction factor for floor under the top floor and the total roof area from Chart 4.
RFMASS	unit mass of roof - pounds per square foot.
RFWCO	roof contribution reduction factor for top floor and roof area within interior partition area from Chart 4.
ROFCOS	unit cost of roof - dollars per square foot.
SITCOS	unit cost of site - dollars per square foot.
SITLTH	site length - feet.
SITWTH	site width - feet.
STORHT	height of individual story - feet.
SUMPF	sum of PF.
SW7	fraction of gamma radiation scattered from Chart 7.
TRYPF	highest value of PF to pass this point thus far in the course of program execution.
VACUUM	volume of the protected core space.
WA	upper solid angle fraction on detector story to window tops.
WALARA	total exterior wall area of building - square feet.
WALCOS	one of fifty wall cost values inserted into the main program as data - dollars per square foot.
WALMAS	unit wall mass - pounds per square foot.
WC	upper solid angle fraction on top detector story to exterior wall edges.
WL	lower solid angle fraction on detector story to the exterior walls.
WLPR	lower solid angle fraction on floor below the detector story to the exterior wall bottoms.
WNDWHT	height from sill to head of windows - feet.
WU	upper solid angle fraction on detector story to exterior walls.

WUPR upper solid angle fraction on floor above detector story to the exterior wall tops.

WIC upper solid angle fraction on top detector story as limited by interior partition wall tops.

XO combined wall and floor masses.

<u>Note</u>: As the computer recognizes no bracket signs, and as program readings were taken directly from computer cards, double parentheses are substituted for brackets and parentheses normally used. This applies to all chapters which follow.

CHAPTER I

INTRODUCTION

The purpose of this investigation is to introduce a method of optimizing radiation shielding protection factors in differently constructed types of multistory buildings with regard to the respective skin costs of proposed buildings.

A regional or urban area planner who must consider feasibility of fallout protection, will find this study to be a significant aid in determining the types of multistory construction to be used within his particular geographical area of influence.

A digital computer combines the variables of building heights, wall and floor areas, length-to-width floor ratios, and protection factors of buildings comprised of interior partitions and exterior walls with apertures.

The method is based on the assumption that the cost-to-protection factor ratio for a certain building type can be found from an accurate history of building costs of that particular region as supplied by local product manufacturers, architects, and city or regional planners. The proposed method shows how to provide the ratio of skin construction cost-to-protection factor of a building covered with a certain type of skin when a minimum protection factor is specified and when the building construction cost data of the skin is supplied to the computer program by estimaters on retainer or by manufacturers and

CHAPTER II

THE FEASIBILITY METHOD

The main computer program first fits the required areas within the given available rectangular dimensions of the site, forcing the building height to increase until the individual floor area of the building is able to be contained by the site. When a minimum building height has been achieved, the program begins its calculation of the protection factor at the top floor of the first trial building. The cycling operation continues downward to the bottom floor. If the minimum prescribed protection factor is not reached for any floor in the building, another floor is added to the building. This added floor will fill some of the area requirements formerly satisfied by the other floors. Hence the areas of the other floors will be reduced. This reduction in individual floor areas increases the amount of wall area required to enclose a given floor area by a quantity discussed in a later chapter. Also if the site restricts the building from forming a square one-level plan, the building width-to-length ratio will change whenever another floor is added to the multistory structure. A wall enclosing a rectangular floor plan will require more surface per square foot of floor area than will a wall which encloses a square plan of the same floor area.

Therefore a perimeter factor has been provided in the main program which converts required floor areas and site restrictions into required wall areas. Finally, the total cost of constructing these walls is computed as the wall area times the unit wall cost. The unit wall cost exists in the form of height-influenced data expressed in terms of percentage cost gain per square foot of wall surface.

The relationship between the wall areas of different floor heights will be expressed in terms of a perimeter factor. When the reference is is assumed to be a one-story square building, the perimeter factor, F, is a value equal to the square root of the number of floors in the building. In the case of the reference building, F is equal to one. The table of perimeter factors and the following explanation shows this to be a valid and useful term in the main program. (See Table 2.1).

The table shows that for a constant given floor area, the unit length of a wall increases by a factor equal to the square root of the number of floors in the building. Assuming individual story wall height to be equal, then one is able to apply the same factor to wall area relationships when adding floors to a proposed building with constant area requirements.

Because most buildings are not square, but are rectangular in shape, it is desirable to include into the preceding perimeter factor due to the number of floors, the effects on perimeter due to different building width-to-length ratios. A square plan is used as a reference shape, the factor for which is equal to a value of one. The following figure will help to illustrate the derivation of the shape portion of the perimeter factor:

$$\text{perimeter} = 4S * \text{FACTOR} = 4\sqrt{A} * \text{FACTOR}$$

$$\text{FACTOR} = (2W + 2L) / 4\sqrt{A} = (W + L) / 2\sqrt{WL}$$

NUMBER OF FLOORS	AREA PER FLOOR	AREA	LENGTH OF SIDE	PERIMETER PER FLOOR	PERIMETER PER BLDG	UNIT BLDG PERIMETER	UNIT BLDG SIDE
1	A	S^2	S	4S	4S	4	1
2	A/2	$S^2/2$	$S/\sqrt{2}$	$4S/\sqrt{2}$	$8S/\sqrt{2}$	$8/\sqrt{2}$	$\sqrt{2}$
3	A/3	$S^2/3$	$S/\sqrt{3}$	$4S/\sqrt{3}$	$12S/\sqrt{3}$	$12/\sqrt{3}$	$\sqrt{3}$
4	A/4	$S^2/4$	$S/\sqrt{4}$	$4S/\sqrt{4}$	$16S/\sqrt{4}$	8	2
5	A/5	$S^2/5$	$S/\sqrt{5}$	$4S/\sqrt{5}$	$20S/\sqrt{5}$	$20/\sqrt{5}$	$\sqrt{5}$
N	A/N	S^2/N	$S/\sqrt{N}$	$4S/\sqrt{N}$	$4NS/\sqrt{N}$	$4N/\sqrt{N}$	$\sqrt{N}$

Table 2.1. Perimeter Factor due to Heights

Combining these factors by multiplication will yield the perimeter factor in terms of the number of floors in the building and in terms of the width-to-length ratio of the floor plan. This factor is thus equal to the following expression:

$$\text{PERIMETER FACTOR} = (\sqrt{N} * (W + L) / (2 \sqrt{WL}))$$

The final perimeter factor multiplied by individual story heights times the required floor area read into the main program in the form of data yields the total wall surface area of the building. The wall cost is then obtained by multiplying this total wall area by the unit wall cost, which is to be discussed in CHAPTER IV: (Figure 2.1. Plan Dimensions)

The following quantities are introduced to the main program as data constants. One figure equivalent to the site cost in dollars per square foot is inserted as input data of the main program. In this figure must be included the cost effects of taxes, insurances, foundations, and excavation. This foundation cost is not directly proportional to the basement floor area of the building although this assumption has been made for the sake of simplicity.

For certain use functions and from existing buildings, a general idea of a glass-to-wall area ratio and a glass percentage within a building-encircling strip can be assumed to be an accurate enough data input for most feasibility studies. Roof mass is assumed to be a constant for any building height or area that uses a conventional structural system and is expressed as a data input number. The roof cost although assumed to be a constant bit of program data input, is dependent upon the variables of building height, building area, and the equipment to be placed on the finished roof.

Wall mass is assumed constant although minor variations due to interior finishes and integral reinforcement can be considered in a later design phase. The mass of load-bearing interior partitions will be a much greater influence upon radiation shielding than will that mass of stud framing or some other light-weight material. Partitions are included because of their close relationship with load-bearing walls. Floor masses should generally remain constant regardless of building height or area whenever a type of floor construction is initially decided upon. If for a certain region of the country that an alternate type of floor construction is more economical outside the limits placed on the original floor construction, then the program may be adjusted to compensate for these limits or else the program can be run once for the floor mass of each construction type.

Window heights are needed to establish the solid angle fraction of non-wall scattered contribution. These heights are assumed to begin three feet from the floor and to extend upward. Every story height in the proposed building is assumed to be equal. Not only are constant story heights generally more economical due to mass quantity production, but computation requirements for estimating purposes are simplified.

Unit wall costs for a construction type from one story to a predetermined number of stories are introduced to the main program in as many data bits as there are number of stories in a possible building of this construction type. The appropriate unit wall cost will be used while the computer is calculating for the corresponding building having that number of floors. CHAPTER IV of this thesis will tell how the relationships deriving actual wall cost data have been found in an example for the Oklahoma City area.

Unit partition costs must be included because of the many instances of integral structure with exterior load-bearing walls. Other types of construction do not necessarily require interior partitions for structural support as do many load-bearing types, but their cost and protection factor should, nevertheless, be included for comparison purposes.

In computing the total wall cost, the unit wall cost, described above, is multiplied by the total wall area. Total wall area is equal to the perimeter factor multiplied by the length of wall for a one-level square building having the required floor area times individual story height.

Total partition cost is the product of the unit partition cost, described above, and the surface area of partitions in the building. Foundation and site costs are merely figured as the unit site cost times the basement floor area of the building. Total roof cost is the product of unit roof cost and roof area of the building.

Adding total wall, partition, foundation, and roof costs and then dividing this sum by the average protection factor yielded by this building will provide the cost of each unit of protection factor for that particular building which is derived from the previously-mentioned limiting conditions.

The total floor area providing the given required protection factor is the sum of the individual floor areas within the interior partitions of each protected floor. This the "core concept"[1] of radiation shielding and is utilized because the geometry variable of direct unobstructed radiation does not exist inside of the core that is surrounded by interior partitions as shown in figure 2.2:

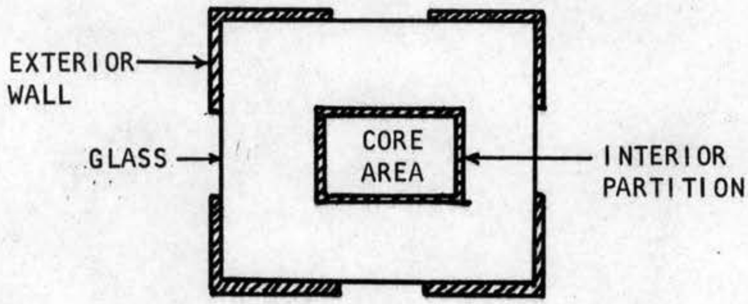

Figure 2.2. Assumed Floor Plan

The cost per square foot of shielded area represents the total skin cost of the building divided by that protected floor area within the interior partitions. The cost per unit minimum protection factor is the index showing the skin cost to provide this minimum required protection factor.

Next is the number of people which can be accommodated in this building from OCD volume and floor area restrictions per person assuming that equipment and supplies are stored outside the interior partitions. The capacity based on no ventilation ($\frac{1}{2}$ cfm or less of fresh air per person) and 500 cubic feet of space per person is expressed by the by the following formula:

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[1] National School Fallout Shelter Competition (1963), p. 11.

Capacity = Volume/500

The capacity based upon adequate ventilation (3 cfm or more of fresh air per person) is limited by requirements of 10 square feet of floor area per person, and 65 cubic feet of space per person. These formulas are shown below:

Capacity due to area = Floor Area/10

Capacity due to volume of air = Volume/65

The final ratio of cost to protection is computed as the total skin cost divided by the product of the number of people accommodated by the shelter core and the average protection factor given by the structure's adequately-shielded areas. This term is used for comparing the different construction types. A high degree of protection is useless if there is inadequate space to care for a large number of people and in the opposite view, a low protection factor space which can accommodate many people is also just as worthless. But combining the two factors of people accommodated and protection factor will give a useful relationship to the skin cost of that building.

CHAPTER III

PROTECTION FACTOR PROGRAMMING

Charts in Shelter Design and Analysis[1] were approximated by dividing them into areas small enough to allow the chart curves to approximate straight lines. The end points of each curve within a chart division are fed into the program as data. Then by feeding the known chart value into the equation of this particular curve segment, the desired corresponding data is read from the chart.

Each chart is written in the form of a subprogram which can be called either once or several times as needed by the main program while it tests taller and taller buildings for the required minimum protection factor. The main program, as previously discussed, approximates skin areas and their construction costs for each building that successfully provides the minimum protection factor requirements. It it the purpose of this chapter to illustrate the assumptions and procedures used to program each of the first eight charts in Shelter Design and Analysis for the 7040 IBM digital computer, and to illustrate where the results taken from these subprograms are inserted into the roof and ground contribution equations.

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[1] OCD, p. 4-26 to 4-32

CHARTS FOR THE DETAILED PROCEDURE

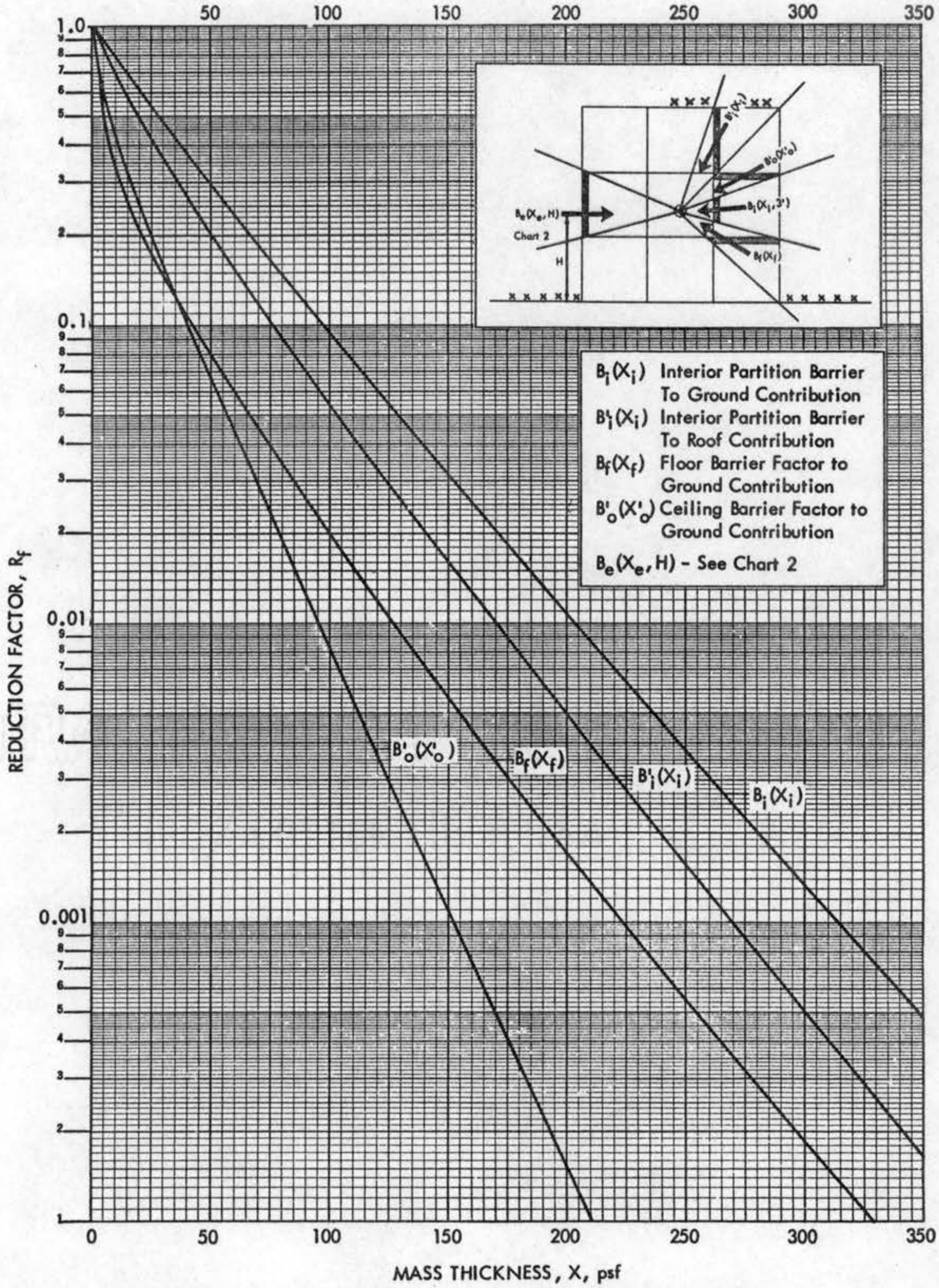


Chart 1. BARRIER SHIELDING EFFECTS, PLANE ISOTROPIC SOURCES,

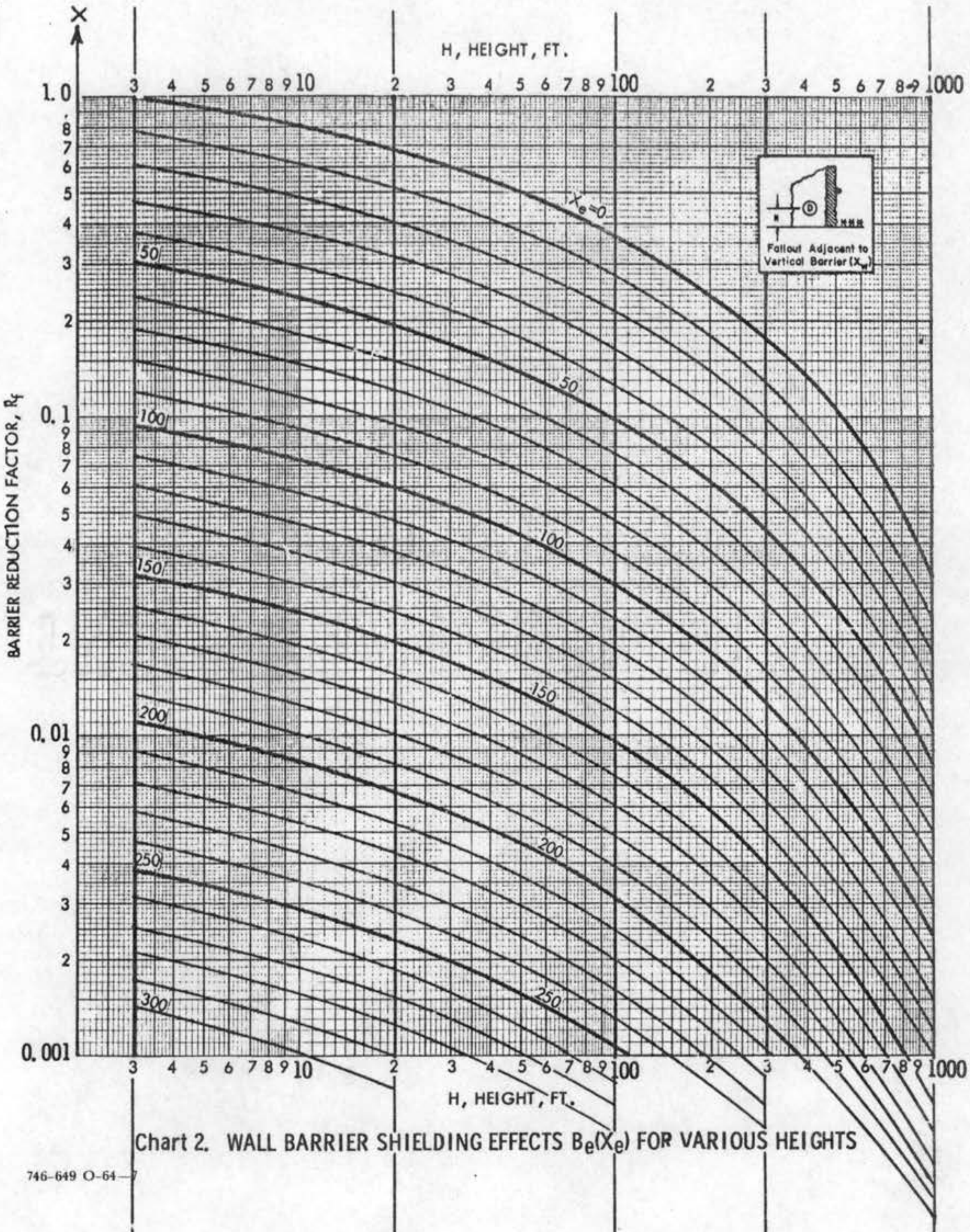


Chart 2. WALL BARRIER SHIELDING EFFECTS $B_e(X_e)$ FOR VARIOUS HEIGHTS

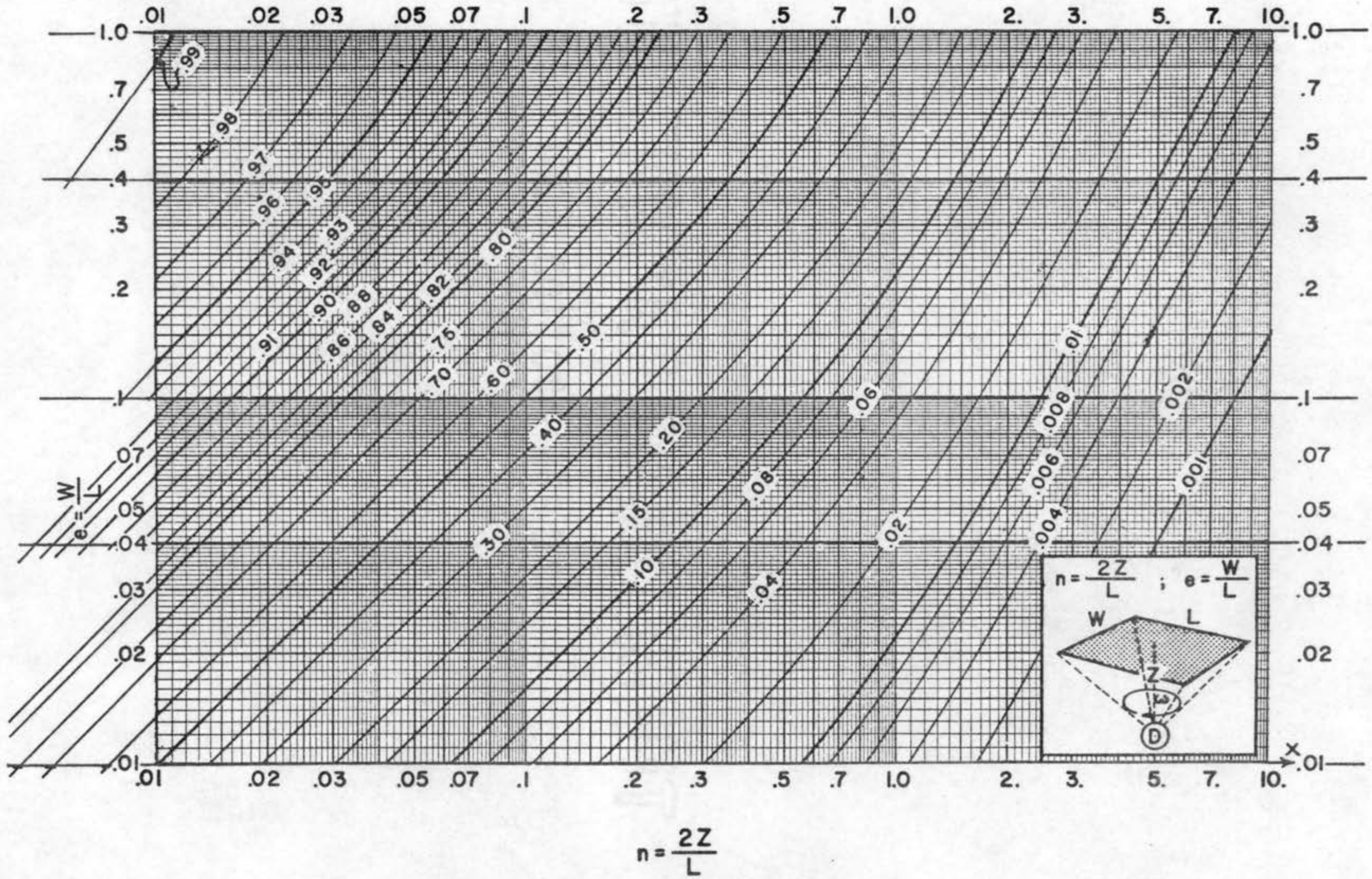
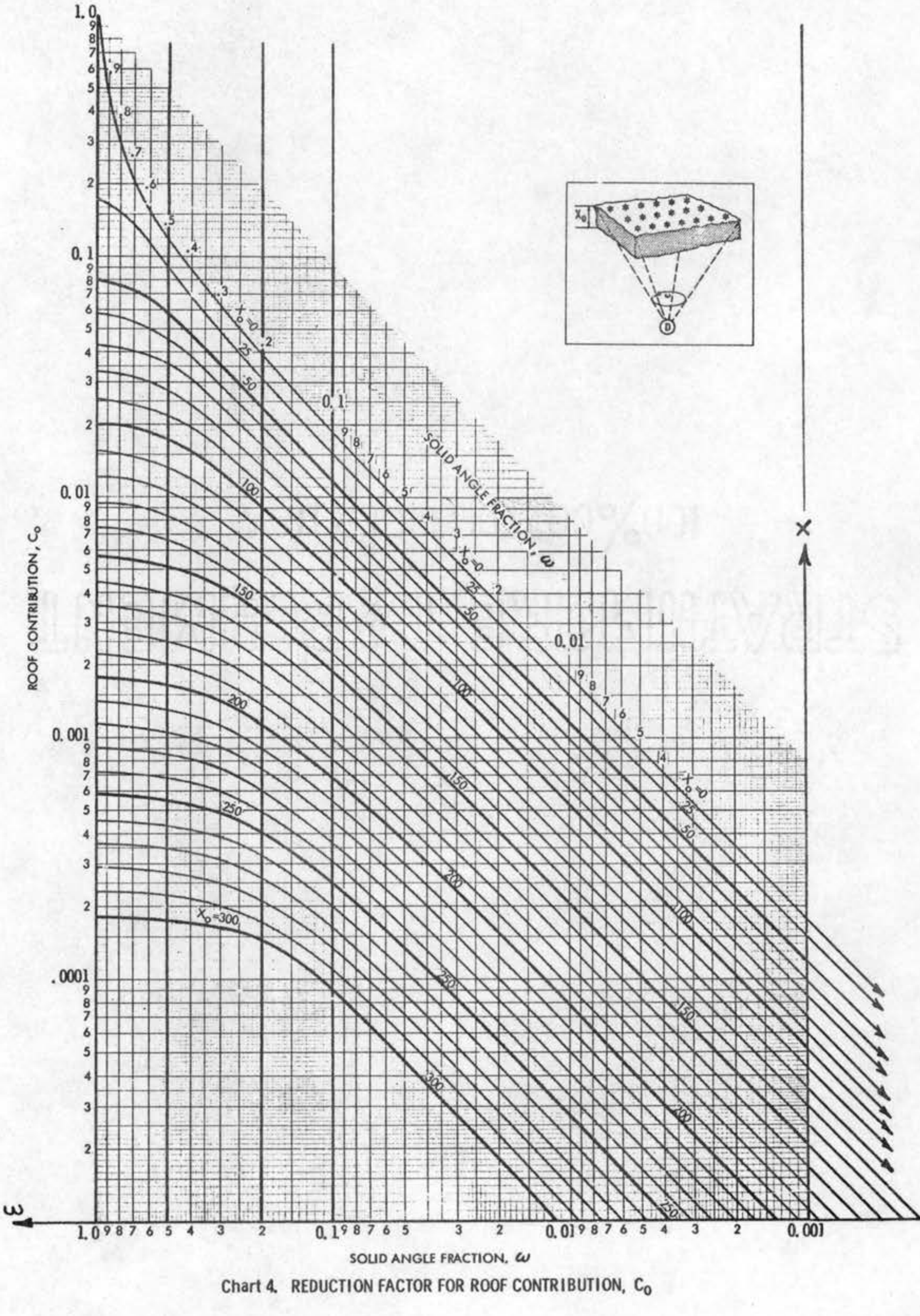


Chart 3 . Solid Angle Fraction Contours, ω.



SOLID ANGLE FRACTION, ω

Chart 4. REDUCTION FACTOR FOR ROOF CONTRIBUTION, C_o

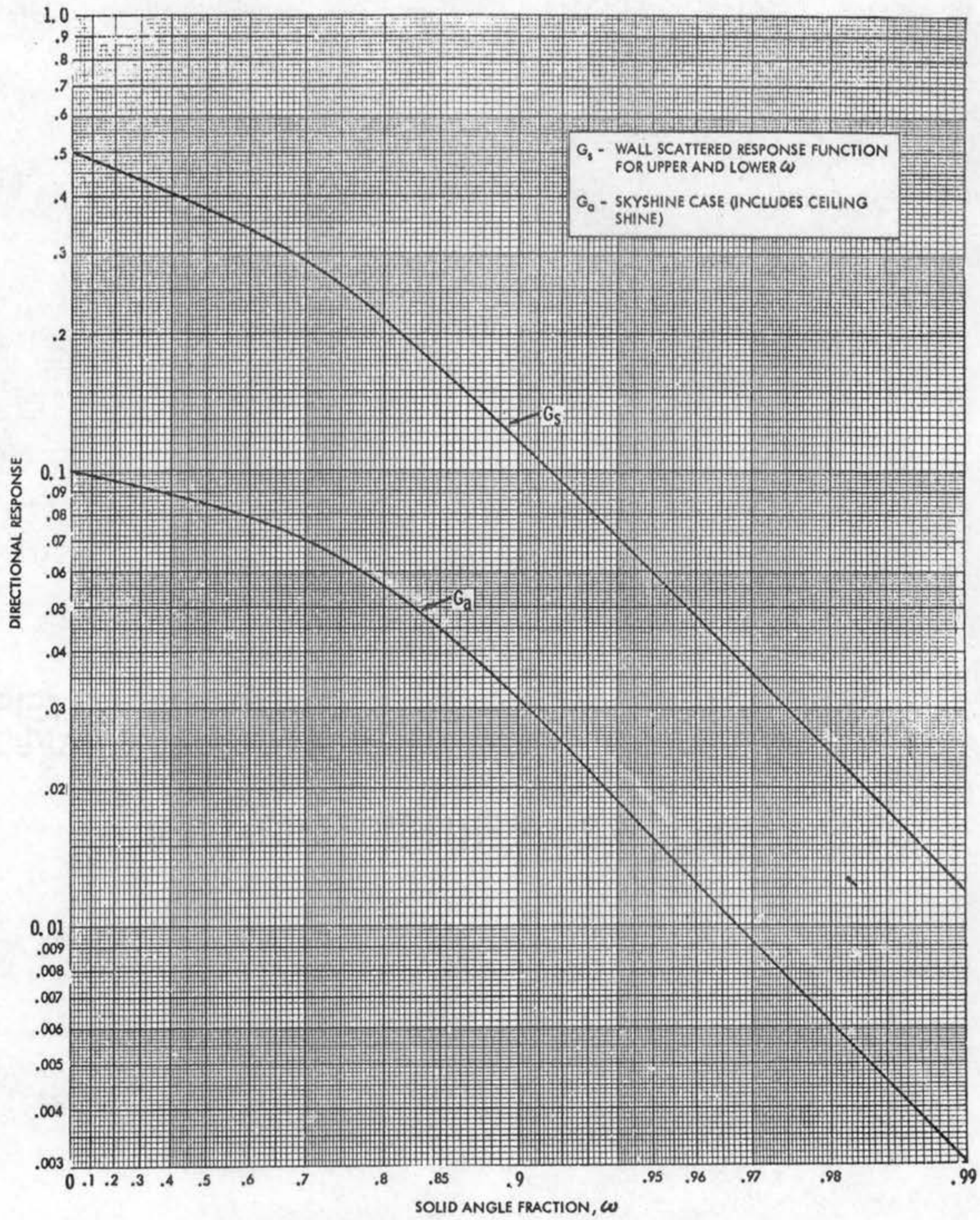


Chart 5. DIRECTIONAL RESPONSES, GROUND CONTRIBUTION, G_s & G_a

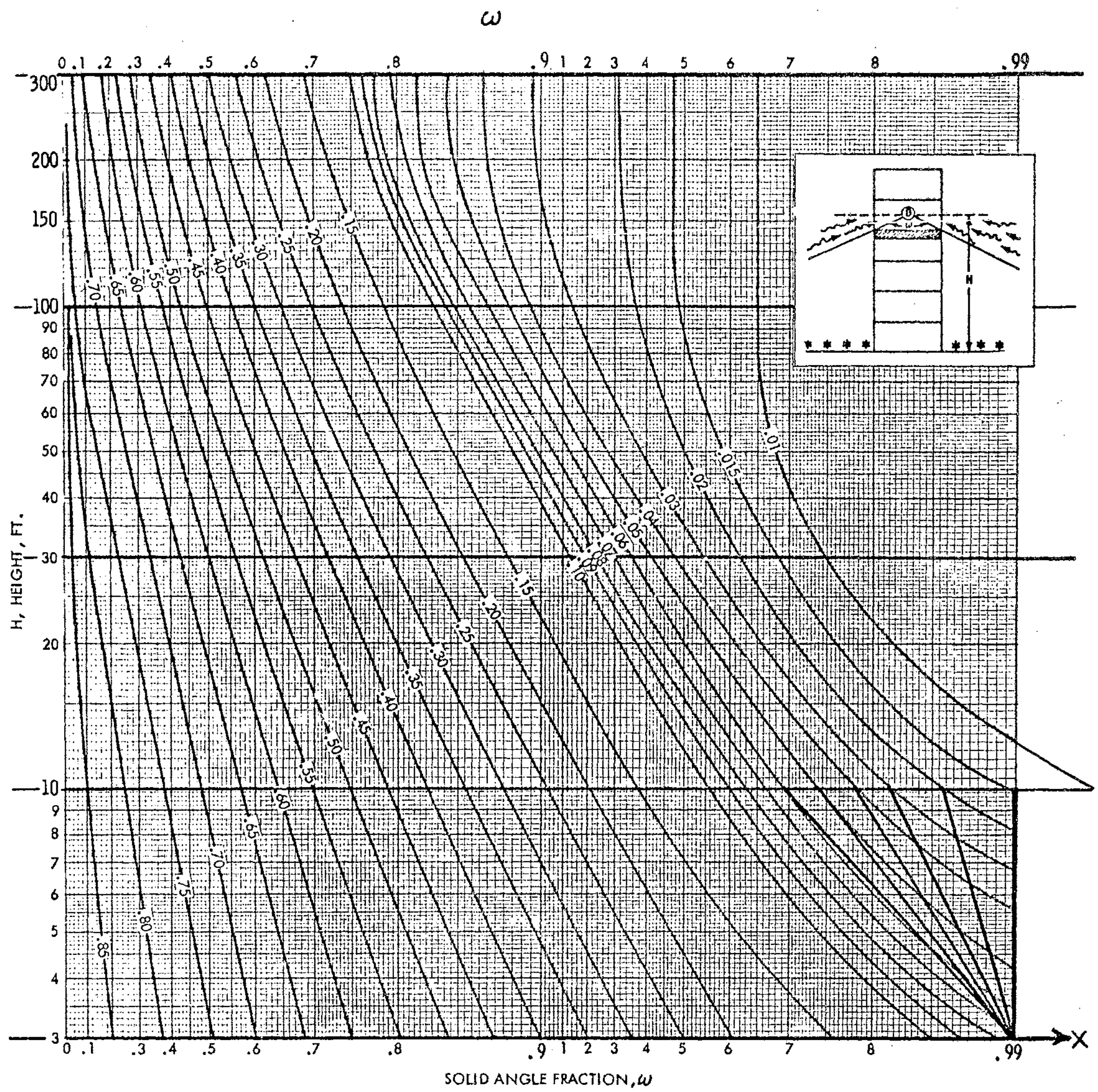


Chart 6. DIRECTIONAL RESPONSE FOR DIRECT RADIATION, G_d, FOR VARIOUS HEIGHTS

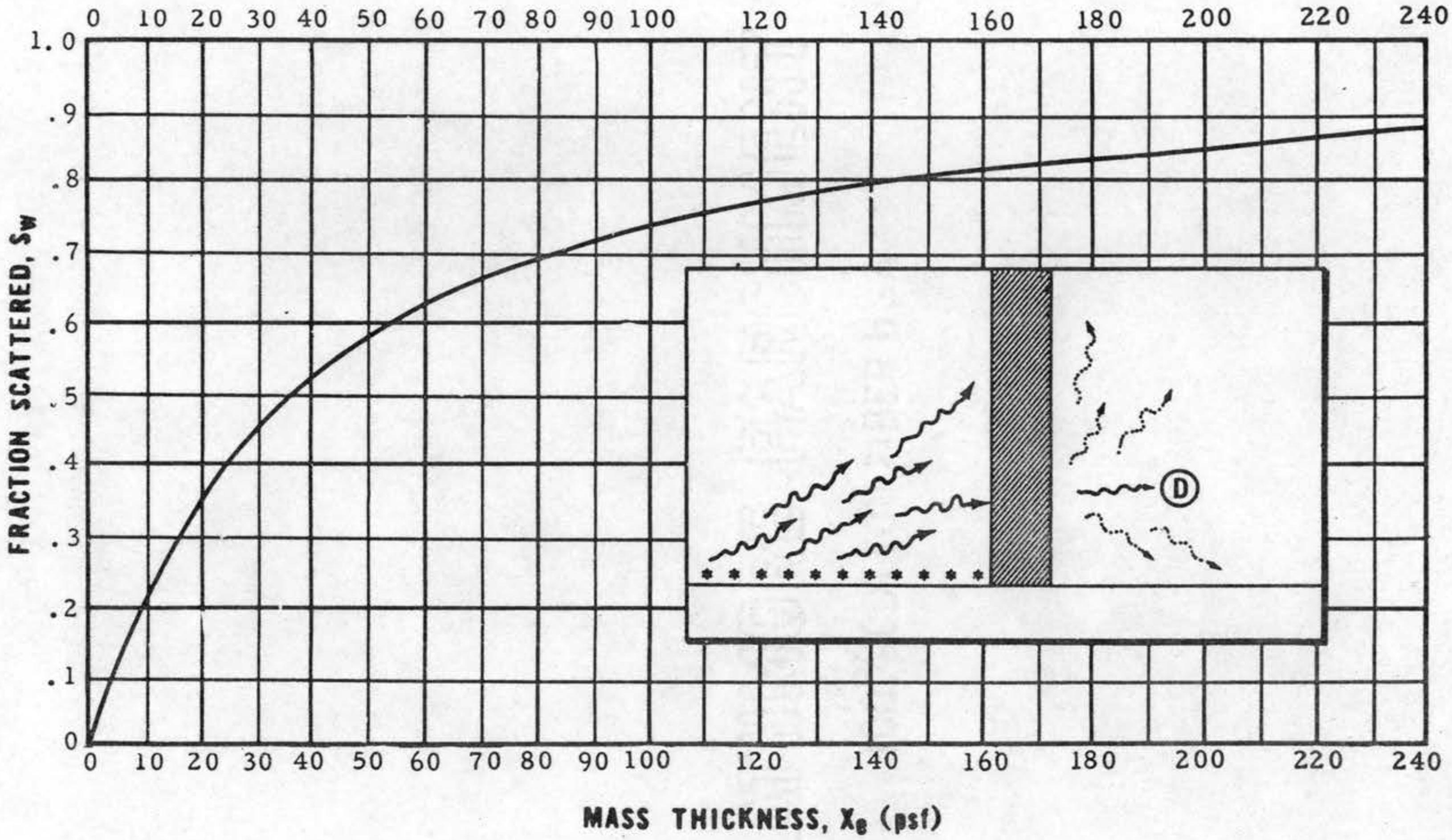


Chart 7. Fraction of Emergent Radiation Scattered in Wall Barrier, S_w

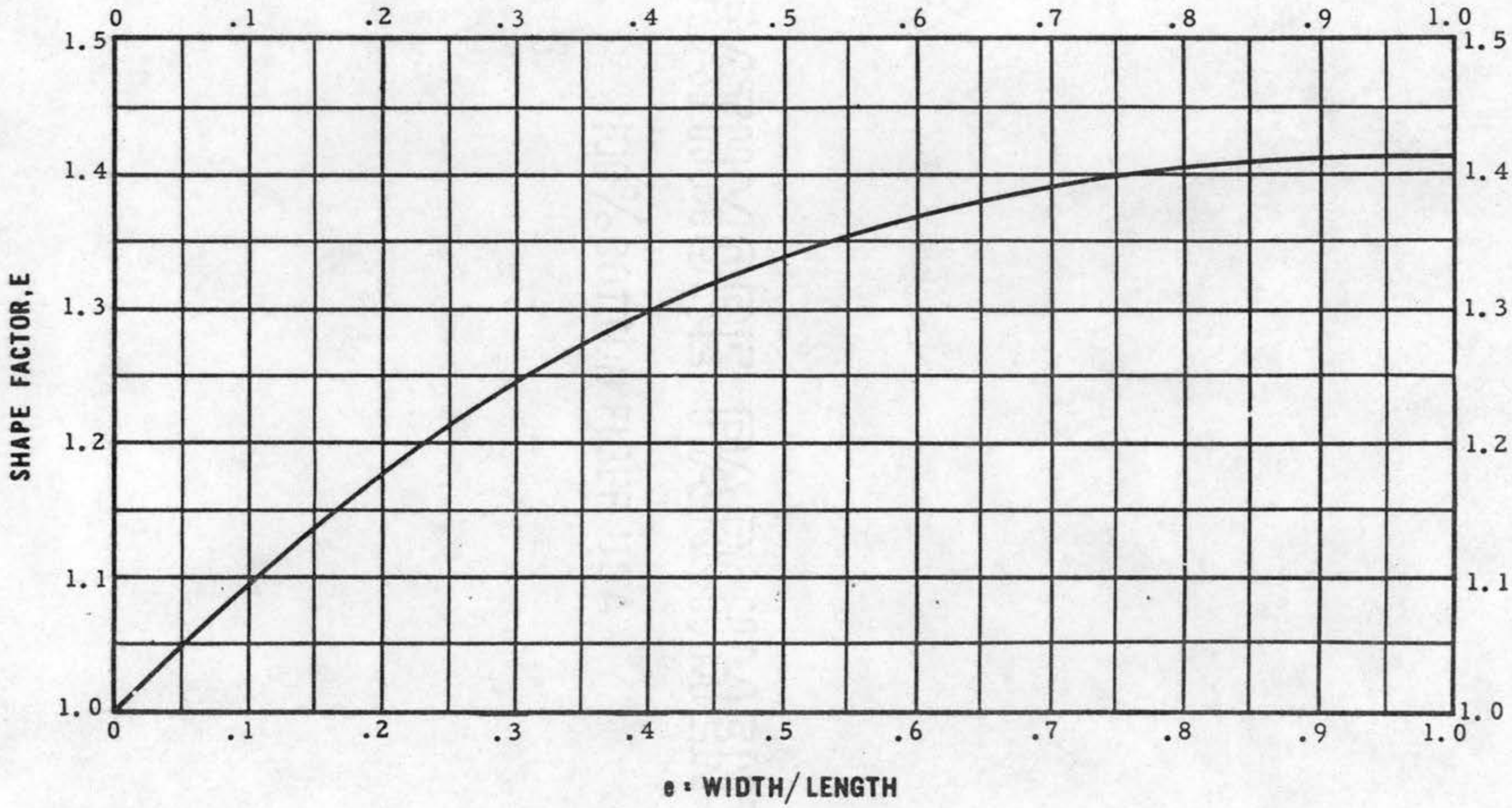


Chart 8. Shape Factor for Wall-scattered Radiation, E

Subprogram Chart 1

The first subprogram designated Chart 1 deals with converting various mass thicknesses of interior partition barrier factor to ground contribution, interior partition barrier factor to roof contribution, floor barrier factor to ground contribution, and ceiling barrier factor to ground contribution.

Two hundred forty-eight values of reduction factors have been entered into common storage of the digital computer. The mass thickness values read into this subprogram by the main program are tested against the Chart 1 mass thicknesses until a Chart 1 mass thickness value is reached that nearly equals the mass thickness supplied from the main program. All four curves on this chart are handled in this manner.

Subprogram Chart 2

The Chart 2 subprogram has been divided into four areas in which the curve segments are short enough to be assumed as straight lines. This subprogram tests the first degree equation of each curve segment with values of height and wall mass thickness which are supplied in the form of data from the main program. One hundred thirty-seven reduction factor values corresponding to the endpoints of these curve segments within the subareas of Chart 2 are read into common storage before main program execution occurs.

For increasing masses, the decreasing barrier reduction factor returned to the main program is found to represent a rising protection value.

Subprogram Chart 3

When the main program establishes building width-to-length ratios and building height-to-length ratios, these ratios are interpreted as solid angle fraction contours by the subprogram designated Chart 3.

One hundred forty-three values of height-to-length ratios are inserted into common storage to represent the end points of curve segments assumed to be straight lines due to each complete curve's being segmented into four parts. The subprogram next tests the height-to-length ratio introduced by the main program against the Chart 3 height-to-length ratio until both ratios are most nearly equal. Then the solid angle fraction corresponding to the chosen Chart 3 height-to-length ratio is selected. As the length-to-width ratio and the height-to-length ratio increase, the solid angle fraction decreases.

Subprogram Chart 4

Subprogram Chart 4 is also divided into four areas as is done in approximating Chart 3. The curves passing through these four areas are more easily approximated as straight lines when they are segmented into the shorter lengths. One hundred forty segment end point values are entered into common storage before main program execution starts.

A straight line equation is utilized that will supply the Chart 4 ordinate intercept value, known in this case as the reduction factor for roof contribution. The main program supplies a value for roof mass thickness and the Chart 3 solid angle fraction to this subprogram in order to receive roof contribution in return.

Roof contribution has its greatest rate of change when roof mass is increased from zero to twenty-five pounds per square foot, and when the given solid angle fraction is at a maximum value.

Subprogram Chart 5

Before the main program can compute the total ground contribution equations, it must supply the previously called Chart 3 solid angle fractions as data to the Chart 5 subprogram in order to receive from Chart 5 the directional response for the skyshine case and the directional responses of wall scatter for upper and lower solid angle fractions. Eighty-four values of directional response are read into common storage before main program execution begins. Out of common storage, three Chart 5 directional response values corresponding nearest to those solid angle fractions supplied by the main program will be returned to the main program for use in calculating total ground contribution.

Both scatter and skyshine curves are assumed to be insensitive to height, while the basic skyshine curve includes a factor to account for radiation reflected from the ceiling.

Subprogram Chart 6

Subprogram Chart 6 is also divided into four parallel chart areas that enable more accurate straight line simulations of the curve segments. One hundred twenty-nine values of curve segment end points representing solid angle fractions are read into common storage and are tested against the solid angle fractions and heights introduced from the main program.

The most significant change in the directional response for direct radiation at various heights occurs on the first floor because the solid angle fraction is increasing while still in its smallest magnitude. Chart 2 is assumed to consider height effects on skyshine, thereby allowing Chart 6 to ignore this consideration.

Subprogram Chart 7

When the main program has need of the fraction of emergent radiation scattered in a wall barrier, it will call Subprogram Chart 7. Due to the rapid initial rise in fraction scattered values, the first eight mass thickness increments have been taken as half the increment values of the last twenty mass thickness quantities. Up to forty poinds per square foot, mass thickness increments are taken in five-pounds-per-square-foot intervals. Ten-pounds-per-square-foot intervals mark the mass thickness values from forty pounds per square foot to two hundred forty pounds per square foot.

For all practical purposes, some amount of emergent radiation will always exist, no matter how thick the wall is. However, the initial rise of the fraction scattered curve is so rapid that over 50 per cent of the gamma radiation has been scattered in a wall of forty pounds per square foot, and 75 per cent has been scattered in a wall of one hundred pounds per square foot. Above one hundred pounds per square foot the curve levels off so that little additional shielding affect is achieved by adding more mass thickness to the barrier.

Subprogram Chart 8

When the main program has determined a building width-to-length ratio for a particular cycle of operation, the main program calls for Subprogram Chart 8. This program is a collection of twenty shape factors, one of which is sent to the main program upon being activated by the chart width-to-length ratio closest in value to that of the building. The shape factor shows that for a given floor area, the protection against radiation decreases as a floor shape elongates or as the shape factor decreases.

In other words, for a given floor area, protection against radiation decreases as a floor shape elongates or as the shape factor decreases. Also, for a given floor area, the most protection can be gained from a square plan, which is not always allowed, due to previously-mentioned area requirements and site restrictions.

After calling the appropriate chart subprograms into the main program, the PA and AP values as defined below are inserted into the total ground contribution reduction factor equations. The three ground contribution equations are for the cases as follows:

1) The ground contribution is smeared from the floor above the detector story.

CGA = BEXE * BOXOPR * ((GAPR5 - GA5) * (1. - SW7) + (GSUPR5 - GSU5) * SW7 * E8) * (1. - AP) + (GAPR5 - GA5) * AP * BEO * BOXOPR

2) The ground contribution of the detector story considers the percent of apertures PA instead of the more general AP.

CG = (BEXE * ((GD6 + GA5 - PA * GAA5) * (1. - SW7) + (GSU5 + GSL5 - PA * GSUA5) * SW7 * E8) + PA * GAA5 * BEO) * BIXI

3) The contribution is smeared from the floor below the detector story.

CGB = BEXE * BFXF * ((GDPR6 - GD6) * (1. - SW7) + (GSLPR5 - GSL5) * SW7 * E8) * (1. - AP) + (GDPR6 - GD6) * AP * BEO * BFXF

Total ground contribution for a typical floor would be the sum of the contribution of the detector story and its two adjacent floors smeared according to the following equation:

CGALL = CGA + CG + CGB

Two conditions of roof contribution exist. One is for the top story and the other case is for the story below the top story. For any more stories lying below the two mentioned floors, roof contribution is negligible, and is therefore neglected. The roof contribution equation for the top story, whose terms are later defined, is as follows:

CONTTL = RFWCO + (RFCO - RFWCO) * BIXIPR

The roof contribution equation for the next story below is as follows:

COTOTL = CONTRF + (RFCONT - CONTRF) * BIXIPR

CHAPTER IV

EXAMPLE PROBLEM FOR OKLAHOMA CITY

Interviews were conducted with Oklahoma City area manufacturers of three construction types in order to verify cost data and their determinants as derived by the author of this paper. These interviews were with Harold Adams and Mr. Rose of Acme Brick Company, Owen Donaldson of Harter Concrete Products, and Bart Bemusdaffer of Sublett and Associates. This chapter relates data and information from these interviews.

Because the main program assumes identical wall types for each floor, only one wall material and percentage of apertures is used at a time. To illustrate this feasibility methodology for the Oklahoma City area, three wall types are considered. They are load-bearing brick masonry, precast concrete panels, and metal sandwich panels.

Load-Bearing Brick Masonry

Brick masonry for a multistory wall is the first building type to be compared with others mentioned later. A base percentage of one hundred corresponds to the price of a finished masonry wall for a one- to twelve-story building. For stories above the twelfth floor, cost percentages are added to the base percentage as follows.

These unit masonry wall costs are entered into the program as data along with the desired percentage of open wall area to total wall area.

The use of concrete block back-up is replacing red common back-up, although the brick provides a better fire stop. The following tables allow three percent for breakage.

Table 4.1. Common Brick with ½" Joints[1]

1030 Common Brick delivered at $40 per M	$ 41.20
Mortar 16 C.F. (Material Only) @65¢ per C.F.	10.40
Scaffold and Hoist	3.75
Mason, 13 hours @$4.50	59.50
Helper, 9 hours @$2.15	19.35
IN PLACE PER THOUSAND	$133.20
for double wythe 12.67 brick per S.F. 79 S.F. equals 1000 brick	
IN PLACE PER SQUARE FOOT	$ 1.90

[1]Adams

Table 4.2. Select Common As Face Brick[2]

This case has ½" tooled concave joints and common bond.

1030 Brick delivered @$52. per M	$ 53.50
Mortar Material 13 C.F. @65¢	8.45
Scaffold and Hoist	7.50
Mason, 13 hours @$4.50	58.50
Helper, 9 hours @$2.15	19.35
IN PLACE PER THOUSAND	$147.30

for single wythe...6.33 brick per S.F.
158 S.F. equals 1000 brick

IN PLACE PER S.F	$ .94

Table 4.3. Brick Veneer[3]

One thousand brick lay-up 150 S.F. with ½" joints with waste included.

1000 Brick (Select Common) delivered @$60. per M	$ 60.00
Mortar 13 C.F. @65¢	8.45
Scaffold and Hoist	7.50
70 Copper Ties @5¢	3.50
Labor on ties, 2 hours @$4.50	9.00
Mason, 15 hours @$4.50	67.50
Helper, 9 hours @$2.15	19.35
IN PLACE PER THOUSAND	$175.30
IN PLACE PER SQUARE FOOT	1.16

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[2] Rose

[3] Rose

Table 4.4. Brick & Mortar Quantities[4]

NUMBER OF BRICK PER S.F. OF WALL - SINGLE WYTHE						MORTAR w/waste CF per M bricks	
TYPE BRICK	ACTUAL SIZE L	H	W	3/8" JOINT	1/2" JOINT	1 WYTHE	2 WYTHE
COMMON	8	2-1/4	3-3/4	6.67	6.33	12.9	16.5
ROMAN	12	1-1/2	4		6.	15.0	19.2
SCR	11-1/2	2-1/6	5-1/2		4.5	17.3	22.9
NORMAN	11-1/2	2-1/4	3-1/2		4.5	15.8	21.4
JUMBO	11-1/2	3-1/2	3-1/2		3.0	13.6	22.0
JUMBO	11-1/2	3-1/2	7-1/2		3.0	17.3	--
KINGSIZE	9-5/8	2-5/8	4-1/2		4.8	14.0	18.0[5]

The above quantities are for running bond. For other bonds, add to face brick:

COMMON, FULL HEADER EVERY 5th COURSE add 20%

COMMON, FULL HEADER EVERY 6th COURSE add 16.7%

ENGLISH, FULL HEADER EVERY 2nd COURSE add 50%

FLEMISH, FULL HEADER EVERY COURSE add 33.3%

FLEMISH, FULL HEADER EVERY 6th COURSE add 5.6%

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[4] Godfrey, p. 108.

[5] Rose

Table 4.5. Concrete Panel Size Limits
and Hardware Costs

THICKNESS t	MAXIMUM[6] LENGTHS x	MAXIMUM[7] WIDTH y	MAXIMUM AREAS x*y	HARDWARE[7] COST	HARDWARE COSTS/sf
2 in.	6 ft.	6'0"	36 sf	$ 3.00	$.083
2-1/2	8	8'6"	68	5.00	.074
3	10	8'6"	85	7.00	.073
3-1/2	13	8'6"	110	8.00	.073
4	15	8'6"	127	9.00	.071
4-1/2	18	8'6"	153	10.00	.066
5	23	8'6"	195	12.00	.062
5-1/2	25	8'6"	212	14.00	.066
6	27	8'6"	229	16.00	.07
6-1/2	30	8'6"	255	18.00	.07
7	35	8'6"	297	20.00	.068
7-1/2	38	8'6"	323	22.00	.068
8	40	8'6"	340	24.00	.07

[6] Mosai, p. H2

[7] Donaldson

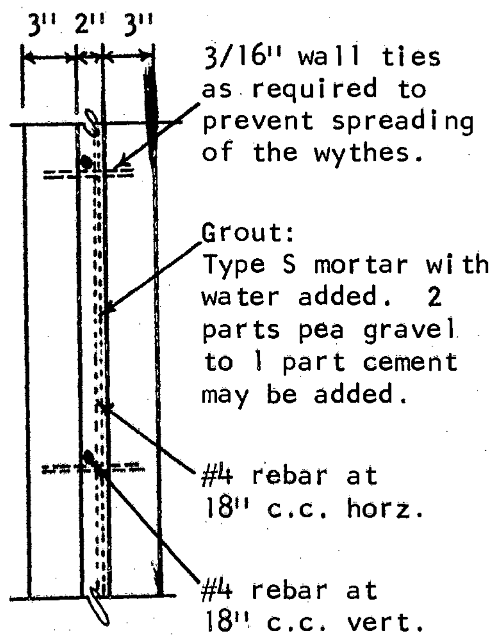
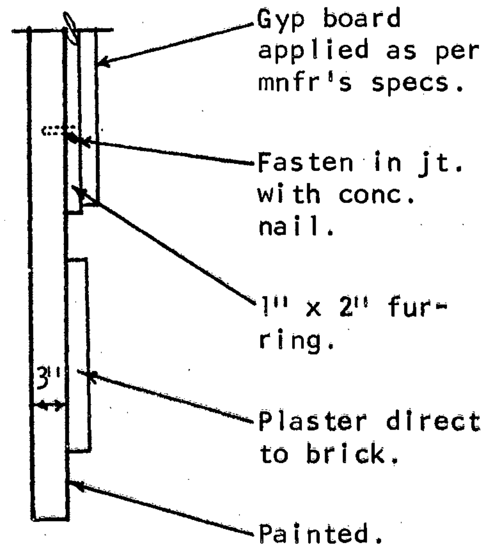
The new "King Size" brick of dimensions 9-5/8" x 2-5/8" x 3" can be laid up much quicker than common brick with as good or better satisfaction from the owner. This time savings is realised mainly by the mason, but it is in effect a raise in his pay check because he can work fewer hours for the same wall area covered. It is for this reason that masons can continue to hold their prices to maintain a higher profit while the other building trades must raise prices with the times. Eventually, of course, the masons will raise their prices too, but their price rises have been delayed by introduction of the king size brick. The savings to the Oklahoma City area mason can be shown as follows:

88¢ per S.F. * 4.8 brick per S.F. = $4.22

75¢ per S.F. * 7.0 brick per S.F. = $5.25

This is a 25% savings in cost to the mason which will allow him to be much more competitive to other building trades. For the computer program example, a two-wythe 8" "king size" reinforced wall at 79psf and a one-wythe 3" "king size" partition at 30 psf at common brick prices is utilized in the form of data input. Standard wall sections of the types referred to follow on the next page.

Figure 4.1. Masonry Wall Section

EXTERIOR LOAD BEARING REINFORCED WALL	INTERIOR LOAD BEARING PARTITION
	

	Exterior	Interior
WEIGHT (psf)	79	30
BRICK PER S.F.	9.6	4.8
ALLOWABLE LOAD CONCENTRIC - k/ft	16.1[8]	8.1[9]
LATERAL SUPPORT REQUIRED (feet)	17.7[8]	7.0[9]

[8]Uniform Building Code, '64 ed.

[9]Southern Stnd. Building Code, '65 ed.

Precast Concrete Wall Panels

They are either solid or insulated and are covered with plain, colored, or textured finishes. Transportation limitations hold the width to eight feet six inches. As shown in Figure 4.2 and Table 4.5, maximum panel size for a given thickness is limited by the panel length. Hardware costs range from $3.00 per set to about $25.00 per set, depending upon the panel size being used and the number of adjustment screws per panel. These unit hardware costs are generally constant as shown in Table 4.5. The hardware cost of $.07 per square foot is added to Godfrey's figure of $.25 per square foot, which mentions only caulking and grouting.

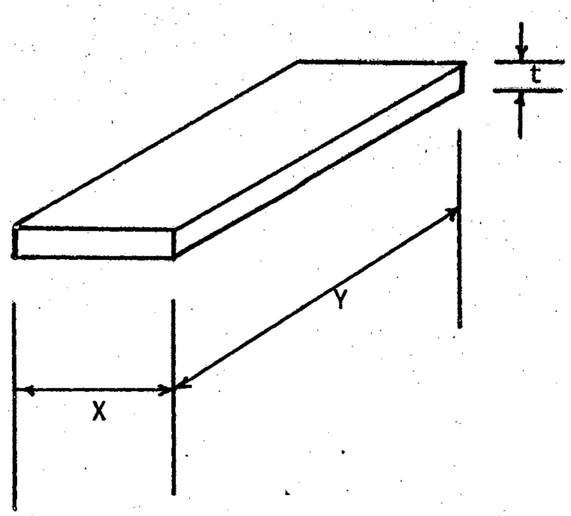


Figure 4.2. Concrete Panel Dimensions for Table 4.5

If maximum aggregate size is 1-1/2", use 3" minimum thickness panels. Large aggregate will increase required panel thickness. Table 4.6 is based on panel sizes being fifty square feet with a gray grouted and rubbed finish.[10]

Table 4.6. Concrete Panel Cost Factors

3" - $2.00/sf	5" - $2.20 sf	7" - $2.65/sf
4" - $2.15/sf	6" - $2.40/sf	8" - $2.80/sf

ADD $.40/sf for white grout and rubbed finish.

ADD $1.25/sf for exposed local aggregate.

ADD $1.25 and up for exposed glass or exposed stone.

Sandwich Panels - ADD

	1"	1-1/2"	2"
Styrofoam	$.13/sf	$.20/sf	$.26/sf
Urethane	$.27/sf	$.40/sf	$.54/sf

Erection is done by a crane and a seven-man crew that can place five hundred square feet per eight-hour day.

SOLID 3" WHITE GROUT AND RUBBED FINISH..........................	$2.40
CAULKING, GROUT, BOLTS, etc.....................................	.32
ERECT, PLUMB, ALIGN, etc.[11]	.85
IN PLACE PER SQUARE FOOT..	$3.57

[10] Donaldson

[11] Godfrey, p. 130.

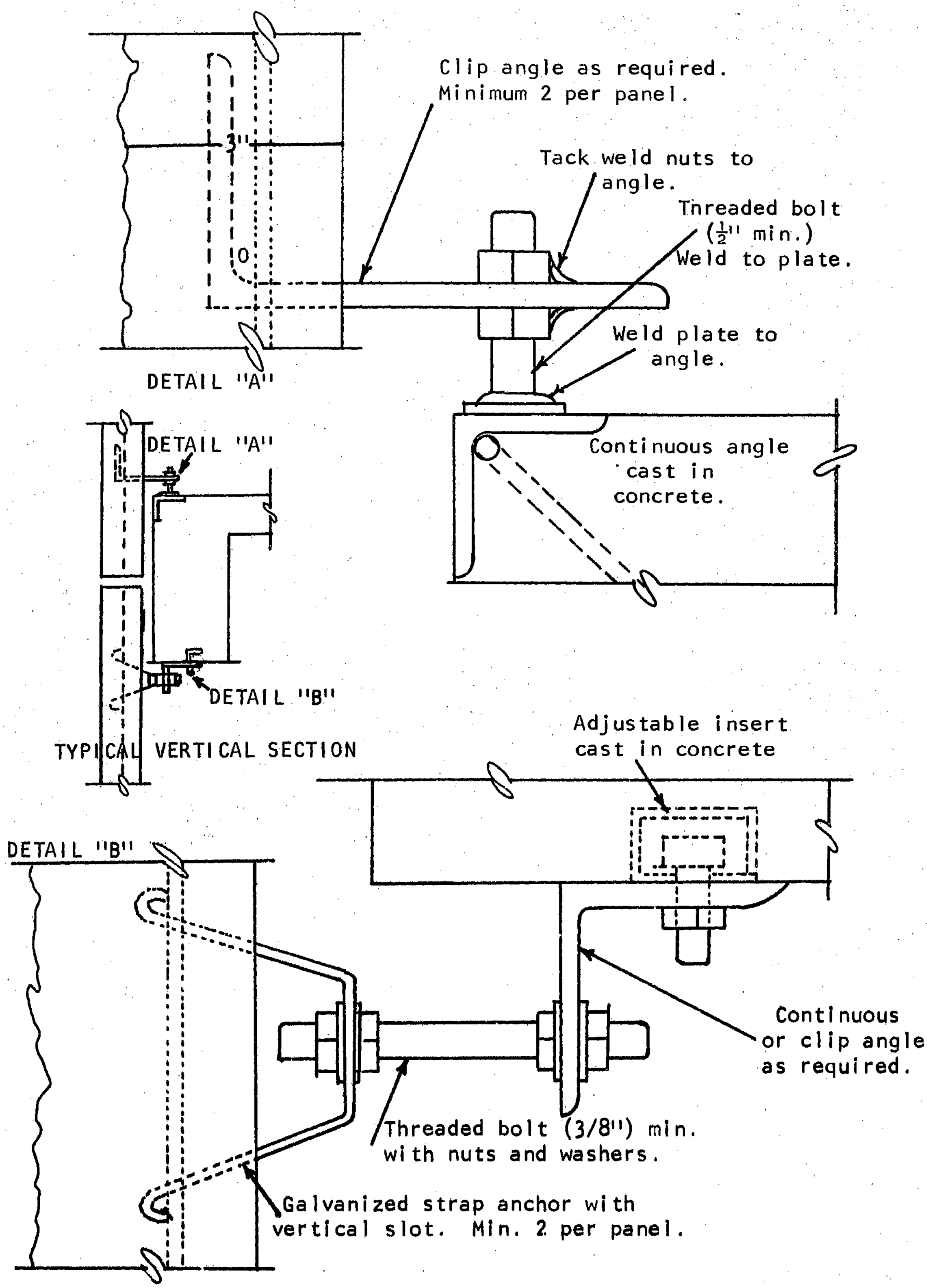


Figure 4.3. Concrete Panel Wall Section Utilized

No allowance has been made for supporting steel framework. On one story buildings, panels may rest on grade beams and require only fasteners and wind bracing. On upper floors, the panels are assumed to be attached to the face of the building and not shoved into any cavities. Glazed areas are assumed to cost $5.00/sf.[12]

Because metal sandwich-panel-installation labor rises from $.35 per square foot to $.50 per square foot as a building grows in height, it is assumed that the $.85 per square foot erecting labor for concrete panels increases by a similar percentage to a value of $1.15 per square foot on the higher buildings. This provides a total installed cost range from $3.57 per square foot to $3.87 per square foot to be distributed as shown in comparison with the metal panels in a table following the next discussion on metal sandwich panels. Three-inch thick panels weighing thirty-eight pounds per square foot are to be used in ten-foot lengths for the example computer problem.

Metal Sandwich Panels[13]

Colored porcelain-enameled facing panels are available in sizes up to 60' x 1'. The insulated panels are 1-1/2" to 3-1/4" thick, and come in a variety of colors and finishes. Panels (in-place) cost from $1.85/sf for 8,000 to 10,000 square feet jobs, to an additional 20 percent/sf on jobs of 5,000 square feet or less. A usual figure of about $3.10 for porcelain exterior face to a $5.00 stainless finish exists with a plant production cost facgor of one to 1.25 times the quoted

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[12] Bemusdaffer

[13] Ibid.

WALCON 'S' PANEL

20 gauge steel interior face

20 gauge steel exterior face

10' 3" span

Above values based on 20 psf wind load and maximum deflection of 1/180 span as suggested by Walcon Corporation metal wall systems.

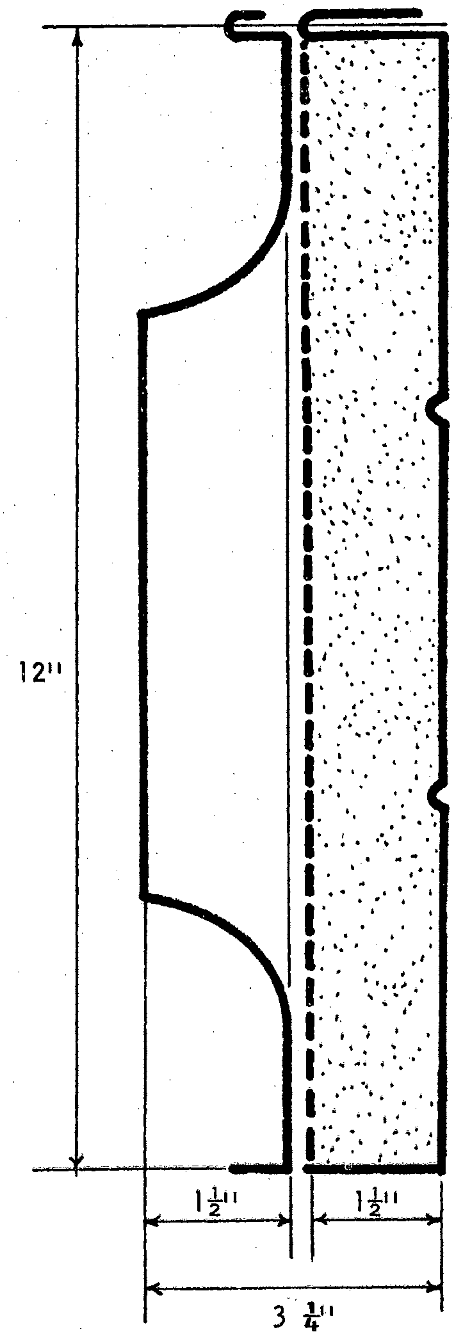

Figure 4.4. Metal Sandwich Panel Wall Section Utilized

prices. Weighing between four and five pounds per square foot, the most-generally used corrugated aluminum of both faces is estimated to cost $1.50/sf to $2.00/sf for jobs less than 2,000 square feet. Colored or white baked enamel costs $.08 to $.35 per square foot more than mill finish.[14]

The cost to field assemble and install these panels including accessories, labor, and equipment runs from $.40 a square foot on one-story buildings, to $.55 per square foot on multistory structures. New patented connectors speed erection but overall cost in-place is about the same due to the high cost of connectors.[18] All of the above figures include usual flashings but do not include any supporting framework. Windows cost approximately $5.00/sf plus the cost of steel framing, sills, and heads. Installation of metal panels ranges from $.35 to $.50/sf.

The panels can be erected with a crane on top of a building or with mobile cranes now in popular use. Height is less a cost factor in metal sandwich panels than in masonry or precast concrete panels due to easier handling ability and lighter weight. Ten-foot long panels are generally the most economically installed panels and are used in the example problem with a weight of five pounds per square foot.

A colored baked enamel finish adding $.35 per square foot to the basic $1.50 will bring the price to $1.85 per square foot. Adding $.35 per square foot for installation, the total installed panel price varies from $2.20 per square foot to $2.35 per square foot on the tall buildings. These costs are shown in Table 4.7.

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[14] Bemusdaffer

Table 4.7. Skin Costs With Respect to Height

HEIGHT IN STORIES	METAL[15] PANEL COST/sf	CONCRETE[16] PANEL COST/sf
1- 5	$2.20	$3.57
6-10	2.22	3.65
11-15	2.24	3.69
16-20	2.26	3.72
21-25	2.28	3.75
26-30	2.29	3.78
31-35	2.31	3.81
36-40	2.32	3.84
41-45	2.34	3.86
46-50	2.35	3.87

[15] Bemusdaffer

[16] Donaldson

CHAPTER V

SUMMARY AND CONCLUSIONS

Problems and their results encountered in working with this thesis are to be summarized in Chapter V and in Figure 5.1 along with suggestions for using the feasibility method with a wider range of variables. These problems are illustrated so that continuing work done in this field may be boosted with the enclosed suggestions.

A major problem to be met is deciding which of the vast number of variables to assume constant so that a workable solution can be obtained from those variables remaining to be considered. One suggested program would vary the wall mass thickness on the lower floors while the building height increases and limit the building height by the material's strength and the structural system being used.

Other cost factors that can be considered are the projected maintenance costs over a specified building life span, a factor representing multiple use efficiencies during times of no emergency, and reduction in useable floor area percentage as a building goes higher. The percentage of floor area reduction is due to the increased space that must be devoted to vertical circulation or mechanical equipment areas. Further related studies should consider the many more variables in erecting a building and in the costs of constructing a building.

One major problem is the providing of accurate input data for costs of building construction. Cooperation by the manufacturers was found to be quite helpful on this thesis, but for commercial purposes, maybe this information may not be so easily obtained. In order for the cost data to be fed into this program, it is suggested that a computer tape containing the needed construction types cost data be used with updated multiplication factors that represent various localities, fabrication schedules, and transportation costs. More extensive research can be done to establish a reliable source list of construction cost data for different locations of the country. This project would be a thesis in itself.

Results are shown for several site conditions in relation to the three types of materials described in Chapter IV. Table 5.1 shows the various site conditions used in the program input. The first condition, line A, shown in Table 5.1 shows the effects of an available site area which is smaller than the required floor area in the building at a very high unit site cost. These conditions approximate a prime downtown situation. The program output in Figure 5.1A comes from the site conditions in line A of Table 5.1. This output shows that the exterior reinforced masonry is the most economical material with respect to radiation shielding protection afforded. Although the cost per unit minimum required protection factor is at a minimum for the tall building with a metal sandwich skin, only seven people can be provided a minimum safety factor of forty as compared to one hundred thirteen people in an eight-inch masonry building and thirty-four people enclosed by three-inch concrete panels. These figures are for fifty percent AP and fifty percent PA. When the number of people facilitated is considered along with the average protection factor provided by the shelter, both concrete and metal become more expensive than the reinforced masonry walls.

Additional program runs are made while making variations in unit site costs and available site areas.

Figure 5.1B shows results from line B of Table 5.1 while all other variables are the same as in the A program run. The B run assumes an available site area larger than the required building areas. The site cost is reduced to a low value of unit cost in the line with prices in outlying areas of the central city.

Metal sandwich panels are found to be the most economical for the condition 5.1D while brick is most economical in the other three conditions. The concrete panels usually run second to brick, which is generally most economical. The ratio of cost to protection for metal panels relative to concrete and masonry varies greatly in the four cases mentioned in Figure 5.1.

Using the straight line method as shown in Appendix A can have ten percent error, which is acceptable for proposed buildings. The largest errors occur where input values have a relatively small rate of change. Thus, the overall error becomes negligible. These subprograms were tested with ten values scattered throughout the chart limits and valid answers corresponding to the real chart values were returned. This procedure is used for all eight subprograms.

The computer, although a timesaver, can over-simplify a problem because of its limited memory space, but computer accuracy is useful for time projection purposes.

Table 5.1. Four Site Conditions

LINE NUMBER	REQ'D OPEN AREA sf	REQ'D CLOSED AREA sf	LENGTH OF SITE feet	WIDTH OF SITE feet	COST OF SITE $/sf	MINIMUM REQUIRED PROTECTION FACTOR
A	10,000	40,000	150	50	25.	40
B	10,000	40,000	1500	500	.25	40
C	10,000	40,000	150	50	.25	40
D	10,000	40,000	1500	500	25.	40

EXTERIOR REINFORCED MASONRY --- INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	6641.35

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	125.00	50.00	0.00	0.00	0.00	5973.07

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
73.00	43.04
63.00	42.21

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	111.11	50.00	1137.78	7650.71	191.08	5435.03

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
113.78	22.76	67.24

Figure 5.1A1

EXTERIOR CONCRETE PANELS---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	6946.00

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	125.00	50.00	0.00	0.00	0.00	6292.28

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	111.11	50.00	0.00	0.00	0.00	5768.25

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	100.00	50.00	0.00	0.00	0.00	5335.01

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
11.00	90.91	50.00	0.00	0.00	0.00	4975.18

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
103.00	41.16

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
12.00	83.33	50.00	346.67	2947.88	537.44	4657.77

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
34.67	6.93	85.03

Figure 5.1A2

EXTERIOR METAL SANDWICH---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	6722.59
8.00	125.00	50.00	0.00	0.00	0.00	6058.20
9.00	111.11	50.00	0.00	0.00	0.00	5523.88
10.00	100.00	50.00	0.00	0.00	0.00	5080.64
11.00	90.91	50.00	0.00	0.00	0.00	4707.32
12.00	83.33	50.00	0.00	0.00	0.00	4380.12
13.00	76.92	50.00	0.00	0.00	0.00	4092.09
14.00	71.43	50.00	0.00	0.00	0.00	3833.92

Figure 5.1A3

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
15.00	66.67	50.00	0.00	0.00	0.00	3599.62

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
16.00	62.50	50.00	0.00	0.00	0.00	3391.19

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
17.00	58.82	50.00	0.00	0.00	0.00	3191.40

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
18.00	55.56	50.00	0.00	0.00	0.00	3008.37

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
19.00	52.63	50.00	0.00	0.00	0.00	2832.77

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
20.00	50.00	50.00	0.00	0.00	0.00	2669.57

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
183.00	40.40

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
21.00	48.80	48.80	70.36	1234.69	1463.52	2574.33

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
7.04	1.41	175.48

END-OF-DATA ENCOUNTERED ON SYSTEM INPUT FILE.

Figure 5.1A4

EXTERIOR REINFORCED MASONRY --- INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	2425.97

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
2.00	158.11	158.11	0.00	0.00	0.00	1643.08

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
3.00	129.10	129.10	0.00	0.00	0.00	1421.20

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
4.00	111.80	111.80	0.00	0.00	0.00	1330.94

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
5.00	100.00	100.00	0.00	0.00	0.00	1286.07

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
43.00	41.51
33.00	41.24

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
6.00	91.29	91.29	820.59	1826.89	61.41	1259.75

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
82.06	16.41	22.26

Figure 5.1B1

EXTERIOR CONCRETE PANELS---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	2425.97

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
2.00	158.11	158.11	0.00	0.00	0.00	1747.62

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
3.00	129.10	129.10	0.00	0.00	0.00	1569.03

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
4.00	111.80	111.80	0.00	0.00	0.00	1512.00

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
5.00	100.00	100.00	0.00	0.00	0.00	1495.14

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
6.00	91.29	91.29	0.00	0.00	0.00	1503.50

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	84.52	84.52	0.00	0.00	0.00	1508.44

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	79.06	79.06	0.00	0.00	0.00	1514.74

Figure 5.1B2

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	74.54	74.54	0.00	0.00	0.00	1520.44

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
83.00	40.07

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	70.71	70.71	245.69	993.09	248.22	1524.61

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
24.57	4.91	40.42

Figure 5.1B3

EXTERIOR METAL SANDWICH---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	2425.97

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
2.00	158.11	158.11	0.00	0.00	0.00	1671.03

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
3.00	129.10	129.10	0.00	0.00	0.00	1460.72

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
4.00	111.80	111.80	0.00	0.00	0.00	1379.35

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
5.00	100.00	100.00	0.00	0.00	0.00	1341.97

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
6.00	91.29	91.29	0.00	0.00	0.00	1324.75

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	84.52	84.52	0.00	0.00	0.00	1312.63

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	79.06	79.06	0.00	0.00	0.00	1303.24

Figure 5.1B4

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	74.54	74.54	0.00	0.00	0.00	1294.34

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	70.71	70.71	0.00	0.00	0.00	1284.79

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
11.00	67.42	67.42	0.00	0.00	0.00	1277.56

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
12.00	64.55	64.55	0.00	0.00	0.00	1265.44

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
103.00	40.03

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
13.00	62.02	62.02	176.14	615.17	284.37	1252.24

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
17.61	3.52	34.93

END-OF-DATA ENCOUNTERED ON SYSTEM INPUT FILE.

Figure 5.1B5

EXTERIOR REINFORCED MASONRY --- INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	2221.71

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	125.00	50.00	0.00	0.00	0.00	2105.89

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
73.00	43.04
63.00	42.21

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	111.11	50.00	1137.78	2811.85	70.23	1997.53

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
113.78	22.76	24.71

Figure 5.1C1

EXTERIOR CONCRETE PANELS---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	2526.36

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	125.00	50.00	0.00	0.00	0.00	2425.10

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	111.11	50.00	0.00	0.00	0.00	2330.75

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	100.00	50.00	0.00	0.00	0.00	2241.26

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
11.00	90.91	50.00	0.00	0.00	0.00	2162.68

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
103.00	41.16

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
12.00	83.33	50.00	346.67	1316.20	239.96	2079.65

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
34.67	6.93	37.97

Figure 5.1C2

EXTERIOR METAL SANDWICH---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	142.86	50.00	0.00	0.00	0.00	2302.95
8.00	125.00	50.00	0.00	0.00	0.00	2191.01
9.00	111.11	50.00	0.00	0.00	0.00	2086.38
10.00	100.00	50.00	0.00	0.00	0.00	1986.89
11.00	90.91	50.00	0.00	0.00	0.00	1894.82
12.00	83.33	50.00	0.00	0.00	0.00	1801.99
13.00	76.92	50.00	0.00	0.00	0.00	1712.28
14.00	71.43	50.00	0.00	0.00	0.00	1624.10

Figure 5.103

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
15.00	66.67	50.00	0.00	0.00	0.00	1537.12

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
16.00	62.50	50.00	0.00	0.00	0.00	1457.59

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
17.00	58.82	50.00	0.00	0.00	0.00	1371.55

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
18.00	55.56	50.00	0.00	0.00	0.00	1289.62

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
19.00	52.63	50.00	0.00	0.00	0.00	1204.49

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
20.00	50.00	50.00	0.00	0.00	0.00	1122.69

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
183.00	40.40

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
21.00	48.80	48.80	70.36	528.11	625.99	1101.12

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
7.04	1.41	75.06

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Figure 5.104

EXTERIOR REINFORCED MASONRY --- INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	33363.47

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
2.00	158.11	158.11	0.00	0.00	0.00	17111.83

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
3.00	129.10	129.10	0.00	0.00	0.00	11733.70

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
4.00	111.80	111.80	0.00	0.00	0.00	9065.31

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
5.00	100.00	100.00	0.00	0.00	0.00	7473.57

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
43.00	41.51
33.00	41.24

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
6.00	91.29	91.29	820.59	9304.46	312.75	6416.00

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
82.06	16.41	113.39

Figure 5.1D1

EXTERIOR CONCRETE PANELS---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	33363.47

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
2.00	158.11	158.11	0.00	0.00	0.00	17216.37

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
3.00	129.10	129.10	0.00	0.00	0.00	11881.53

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
4.00	111.80	111.80	0.00	0.00	0.00	9246.37

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
5.00	100.00	100.00	0.00	0.00	0.00	7682.64

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
6.00	91.29	91.29	0.00	0.00	0.00	6659.75

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
7.00	84.52	84.52	0.00	0.00	0.00	5928.08

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
8.00	79.06	79.06	0.00	0.00	0.00	5381.93

Figure 5.1D2

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	74.54	74.54	0.00	0.00	0.00	4957.94

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
83.00	40.07

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	70.71	70.71	245.69	3008.27	751.91	4618.36

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
24.57	4.91	122.44

Figure 5.1D3

EXTERIOR METAL SANDWICH---INTERIOR MASONRY PARTITIONS

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
1.00	223.61	223.61	0.00	0.00	0.00	33363.47
2.00	158.11	158.11	0.00	0.00	0.00	17139.78
3.00	129.10	129.10	0.00	0.00	0.00	11773.22
4.00	111.80	111.80	0.00	0.00	0.00	9113.72
5.00	100.00	100.00	0.00	0.00	0.00	7529.47
6.00	91.29	91.29	0.00	0.00	0.00	6481.00
7.00	84.52	84.52	0.00	0.00	0.00	5732.27
8.00	79.06	79.06	0.00	0.00	0.00	5170.43

Figure 5.1D4

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
9.00	74.54	74.54	0.00	0.00	0.00	4731.84

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
10.00	70.71	70.71	0.00	0.00	0.00	4378.54

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
11.00	67.42	67.42	0.00	0.00	0.00	4090.06

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
12.00	64.55	64.55	0.00	0.00	0.00	3843.56

HEIGHTS PROVIDING MINIMUM PROTECTION	PROTECTION FACTOR
103.00	40.03

NUMBER OF FLOORS	LENGTH OF BUILDING	WIDTH OF BUILDING	TOTAL PROTECTED AREA	COST PER AVG. PROT FAC	COST PER SHIELDED AREA	COST PER UNIT MIN. PF
13.00	62.02	62.02	176.14	1784.28	824.81	3632.04

CAPACITY OF PEOPLE WITH VENTILATION	WITHOUT VENTILATION	COST FOR PROTECTION
17.61	3.52	101.30

END-OF-DATA ENCOUNTERED ON SYSTEM INPUT FILE.

Figure 5.1D5

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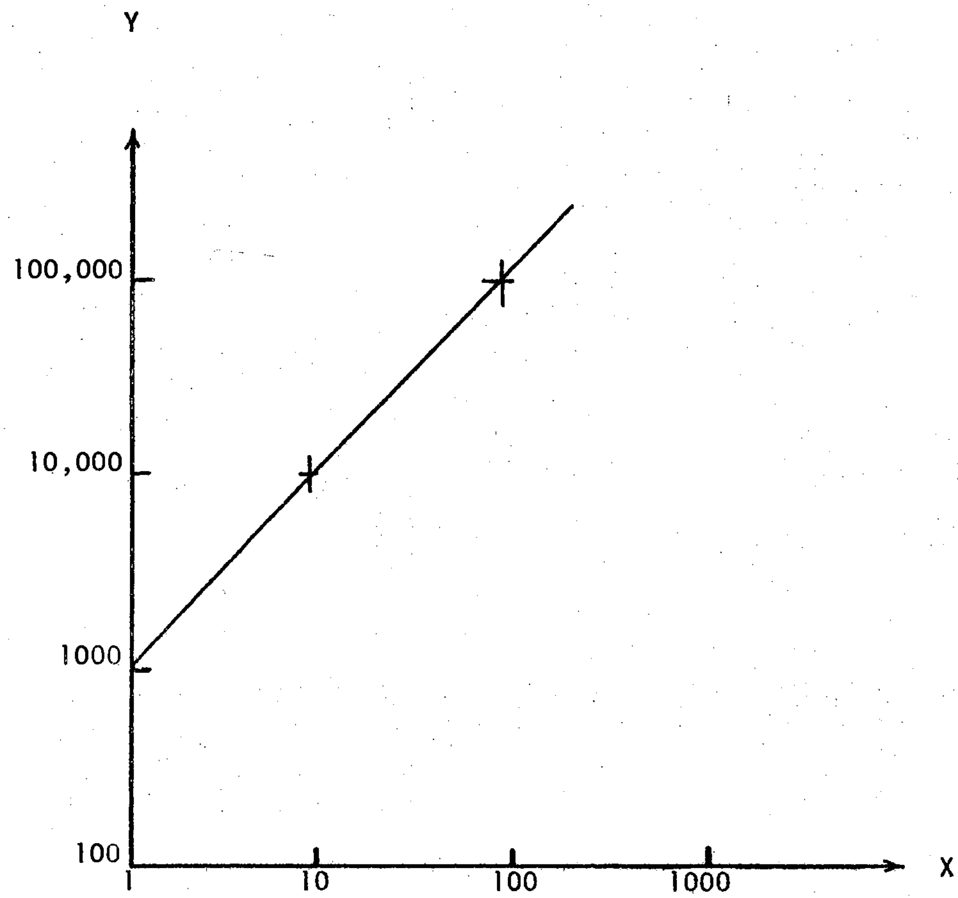
APPENDIX A.

CHART LINE EQUATION DEVELOPMENT

Given: Log Scale Charts in OCD Manual TR-20, Volume 1.

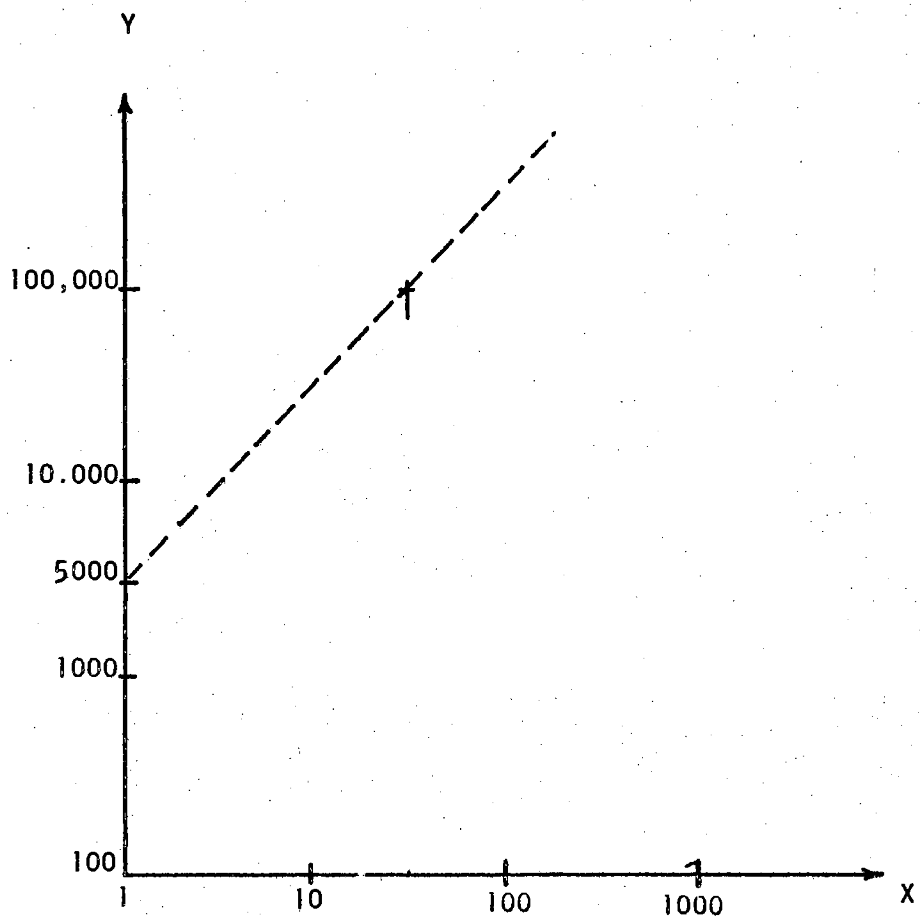
Required to Formulate: X value for any given Y value of the chart curves.

For the figures A.1 through A.5, a straight line equation format is used so that m is the value of slope and b is the Y-intercept value.



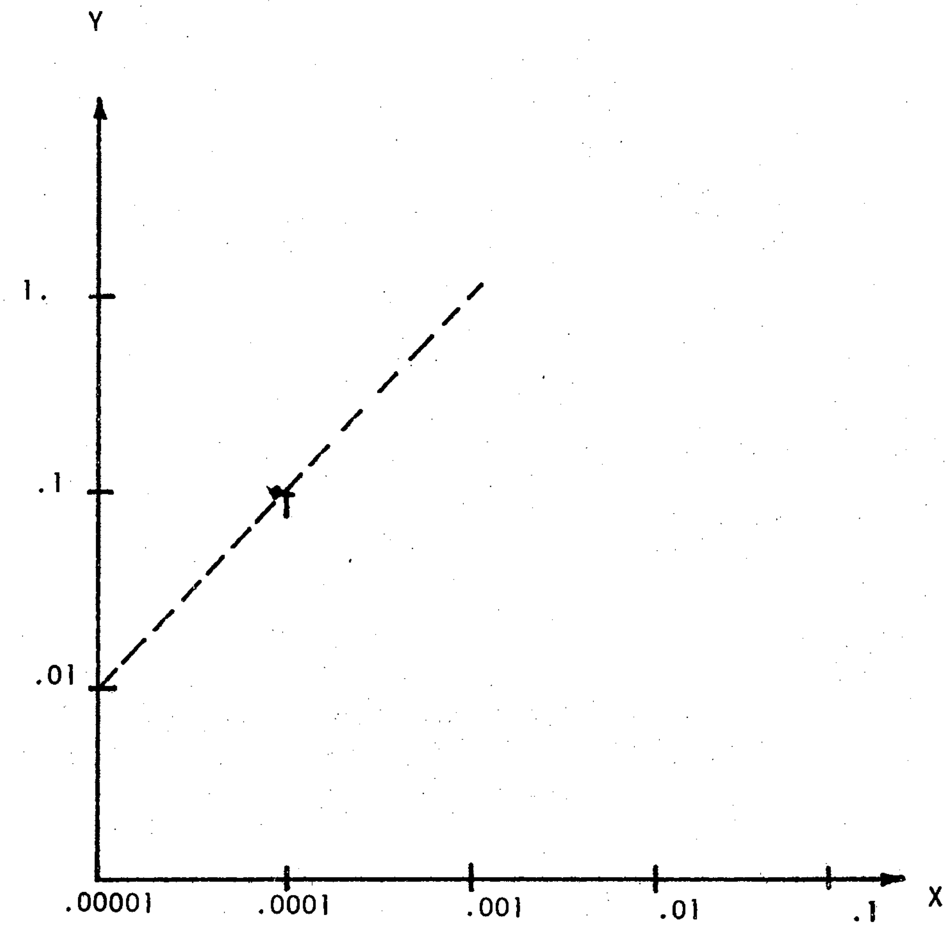
Y = mX + b, m = (10,000 - 1000)/(10 - 1) = 1000, b = 1000 - 1 - X = (Y - 1000)/1000

Figure A.1



Y = mX + b, m = (50,000 - 5000)/(10 - 1) = 5000, b = 5000 - 1 - X = (Y - 5000)/5000

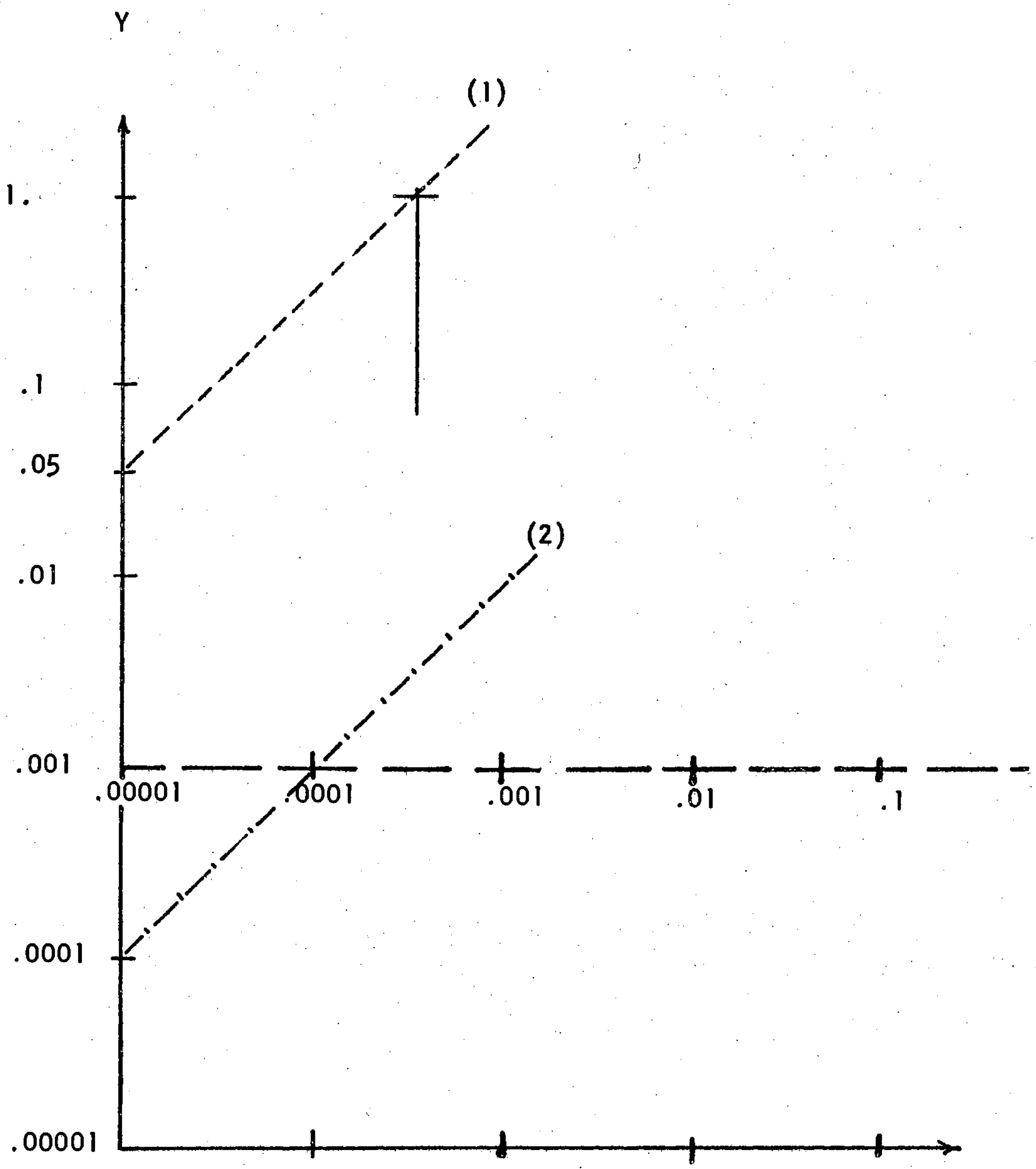
Figure A.2



$Y = mX + b$, $m = (.1 - .01)/(.0001 - .00001) = 1000$, $b = .01$

$- .00001 - X = (Y - .01)/1000$

Figure A.3



line one:

$Y = mX + b$, $m = (.5 - .05)/(.0001 - .00001) = 5000$, $b = .05$

$-.00001 - X = (Y - .05)/5000 = .00009$

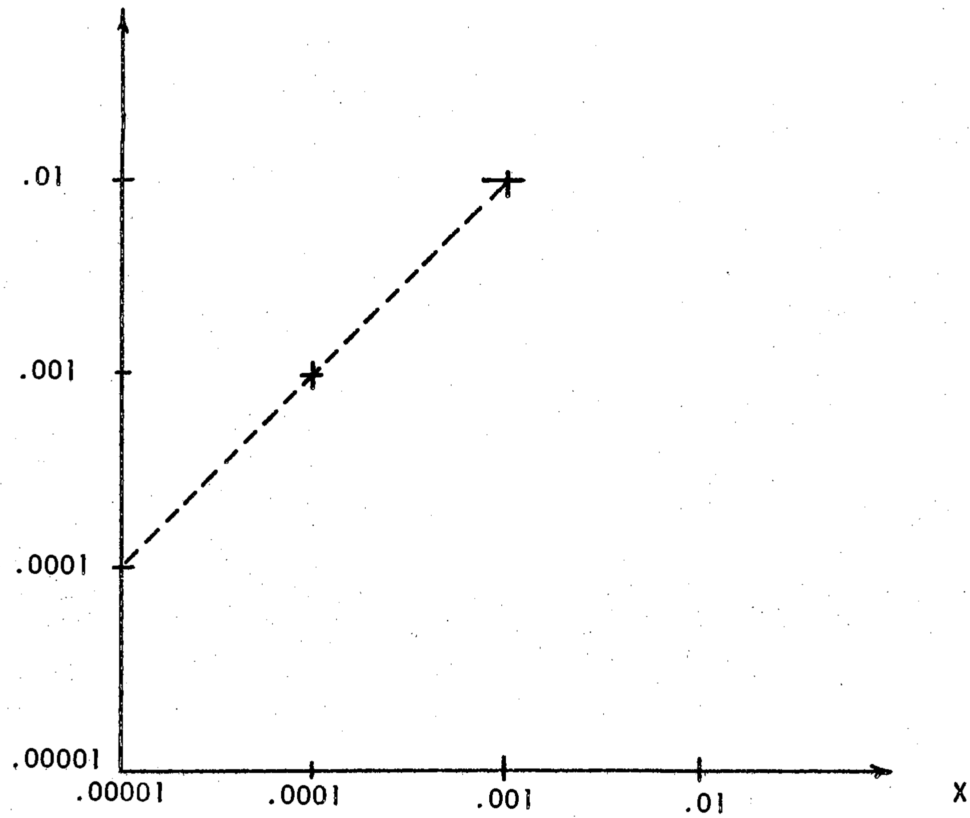
line two:

$Y = mX + b$, $m = (.001 - .0001)/(.0001 - .00001) = .1$, $b = .0001$

$X - .00001 = (Y - .0001)/.1 = (.001 - .0001)/.1 = .009$

Figure A.4

Y = Solid Angle Fraction



Roof Contribution

Y = mX + b, m = (.001 - .0001)/(.0001 - .00001) = 10, b = .0001 - .00001 + X = (Y - ,0001)/10 = (.001 - .0001)/10 = .00009

Figure A.5 Chart Four

APPENDIX B

PROCESSING SEQUENCE OF BUILDINGS AND FLOORS

Referring to Figure B.1, building 1 is first processed. Then floor 1 followed by floor 2 of building 2 is processed. Next floor 1, followed by floor 2, which is followed by floor 3, is processed in a three-story building. Finally, in building N, floor 1 is followed by floor 2, which is followed by floor 3, and so on until floor N is reached in an N-story building. The floors are numbered from the top, starting with the number one, down to the bottom floor, which is numbered N for a building with N number of stories.

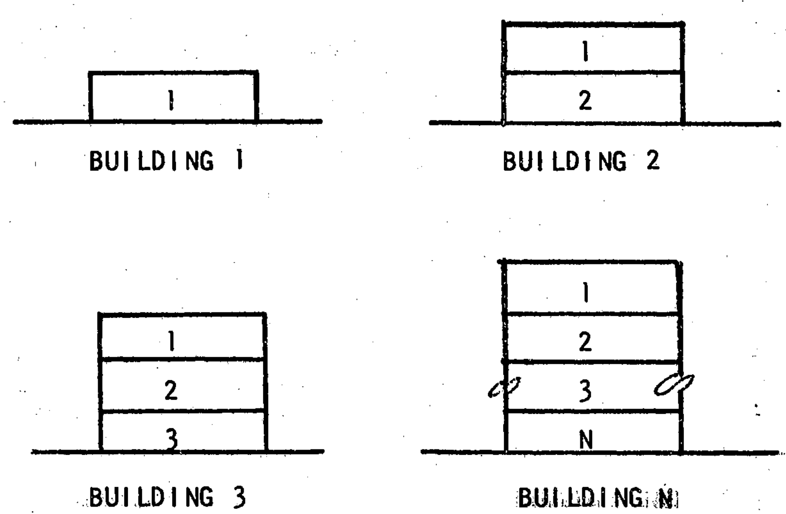
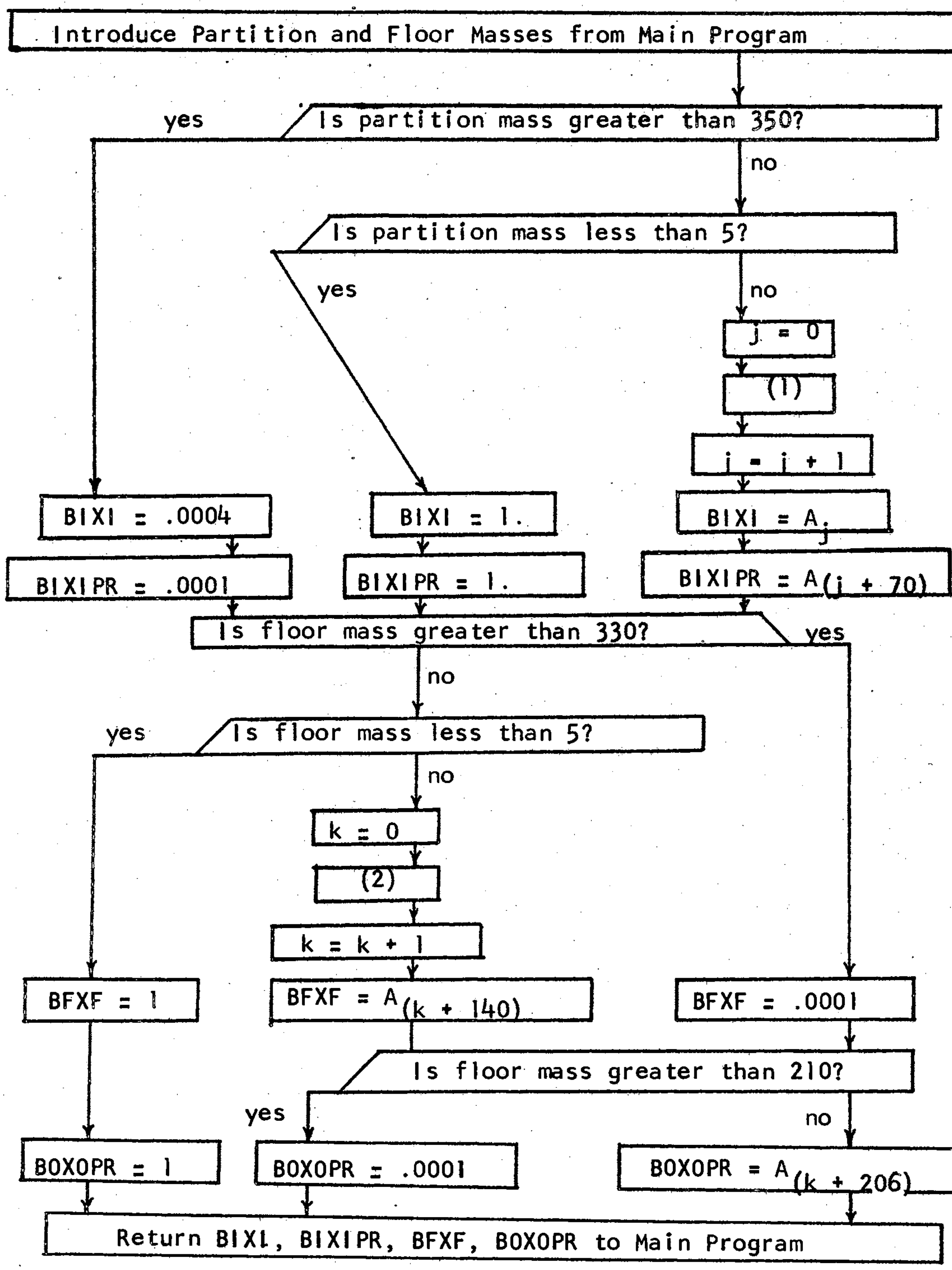


Figure B.1

APPENDIX C

SUBPROGRAM FLOW CHARTS

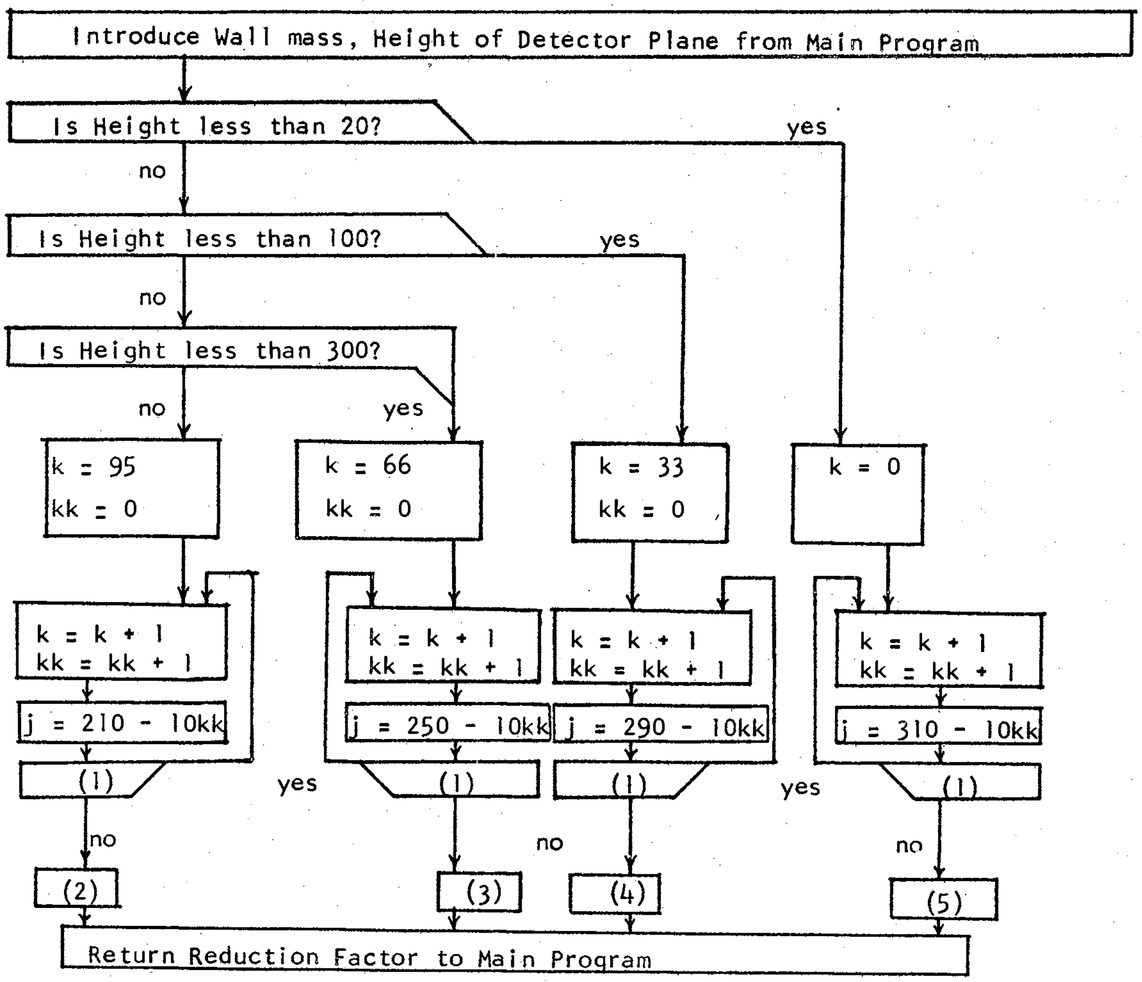
Figures C.1 to C.8 are the computer flow charts for Chart 1 to Chart 8 in *Shelter Design and Analysis* as described in Chapter III. Because computer programming techniques frequently change, the flow chart is considered to be more useful than the program itself.



(1) Do next block - partition mass/5 times.

(2) Do next block - floor mass/5 times.

Figure C.1. Flow Chart for Subprogram Chart 1



(1) Is wall mass less than j?

(2) Reduction Factor $= B_k - (\text{Height} - 3)(B_k - B_{(k+31)})/17$

(3) " " $= B_k - (\text{Height} - 20)(B_k - B_{(k+29)})/80$

(4) " " $= B_k - (\text{Height} - 100)(B_k - B_{(k+25)})/200$

(5) " " $= B_k - (\text{Height} - 300)(B_k - B_{(k+21)})/700$

Figure C.2. Flow Chart for Subprogram <u>Chart 2</u>

Legend for Figure C.3

(1) Is e larger than .4?

(2) Is e larger than .1?

(3) Is e larger than .04?

(4) $X = A_{(I + 20)} - (.04 - e)(A_{(I + 20)} - A_I)/.03$

(5) $X = A_{(I + 28)} - (.1 - e)(A_{(I + 28)} - A_I)/.06$

(6) $X = A_{(I + 29)} - (.4 - e)(A_{(I + 29)} - A_I)/.3$

(7) $X = A_{(I + 32)} - (1. - e)(A_{(I + 32)} - A_I)/.6$

(8) Is X larger than Z?

(9) Angle = F * .001

(10) Angle = (2F - 2) * .001

(11) Angle = (2F - 12) * .01

(12) Angle = (5F - 45) * .01

(13) Angle = (10F - 110) * .01

(14) Angle = (5F - 20) * .01

(15) Angle = (2F + 40) * .01

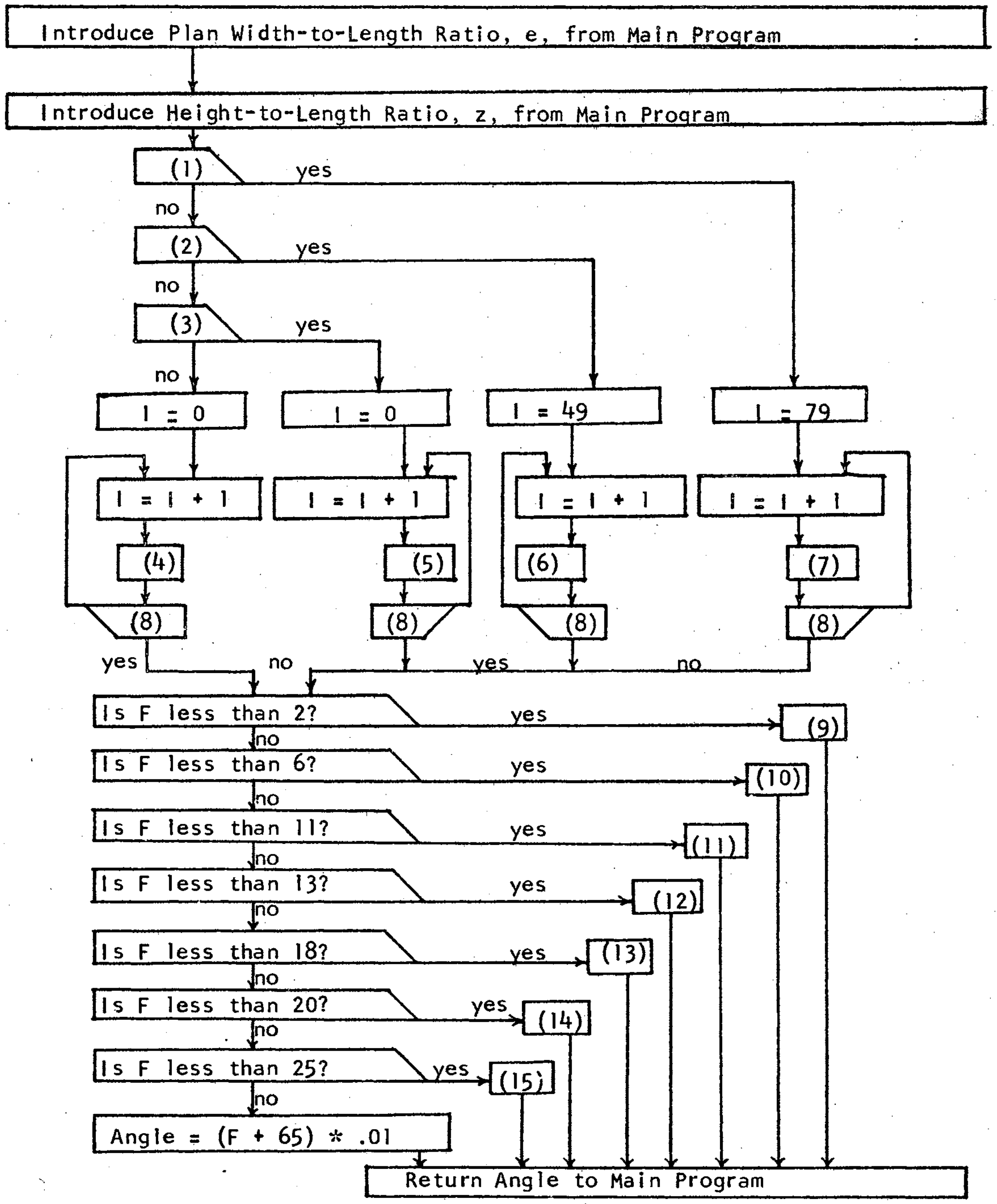


Figure C.3. Flow Chart for Subprogram Chart 3

Legend for Figure C.4

(1) Does Roof Mass equal 0?

(2) Is Roof Mass less than 25?

(3) Is Roof Mass larger than j?

(4) Roof Contribution = $.00001 - (\text{Angle} - B_k)/((10B_k - B_k)/.0009)$

(5) Roof Contribution = $B_k + (\text{Angle} - .1)/(.1/(B_{(k + 28)} - B_k))$

(6) Roof Contribution = $B_k + (\text{Angle} - .2)/(.3/(B_{(k + 28)} - B_k))$

(7) Roof Contribution = $B_k + (\text{Angle} - .5)/(.5/(B_{(k + 28)} - B_k))$

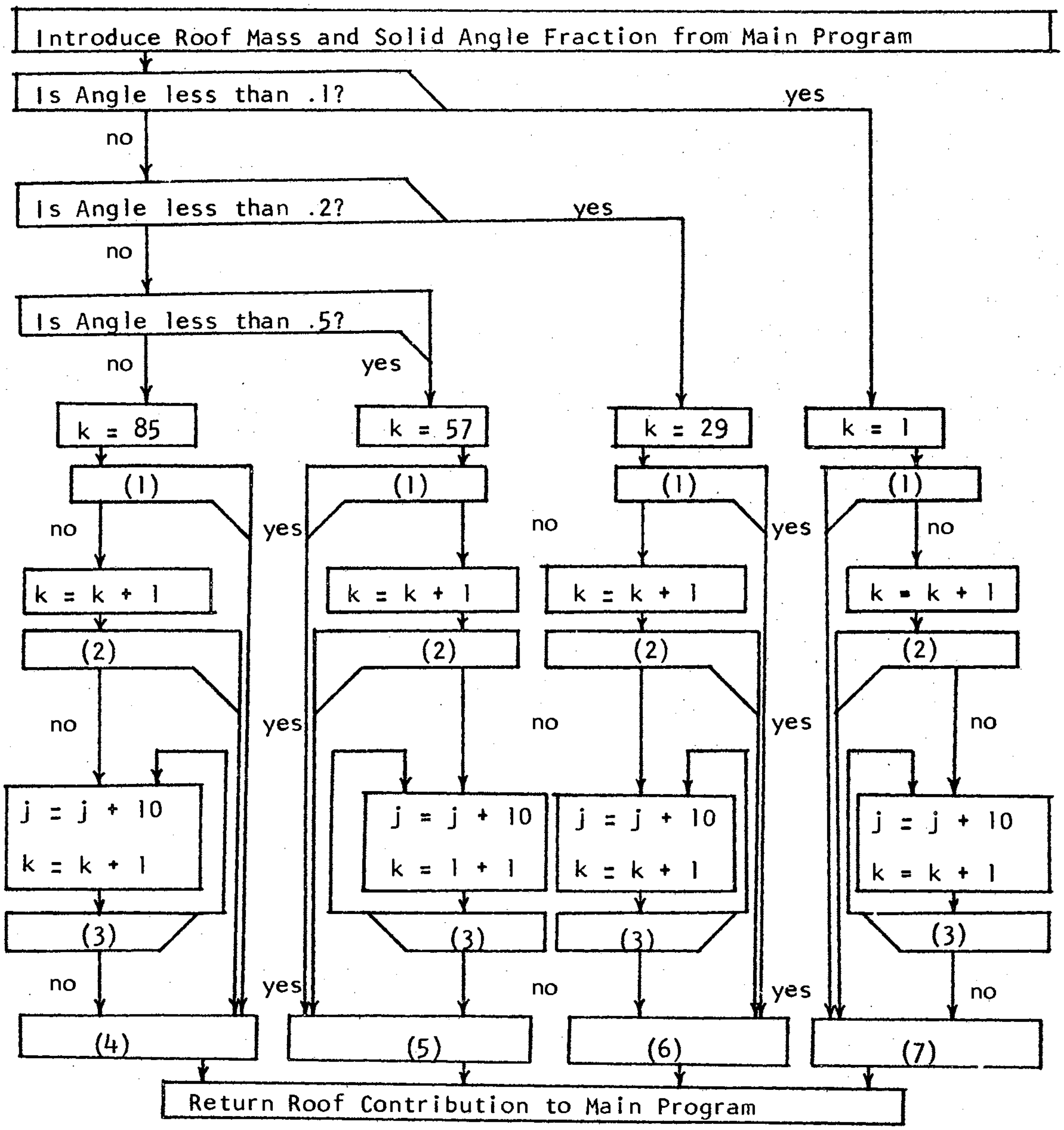


Figure C.4. Flow Chart for Subprogram Chart 4

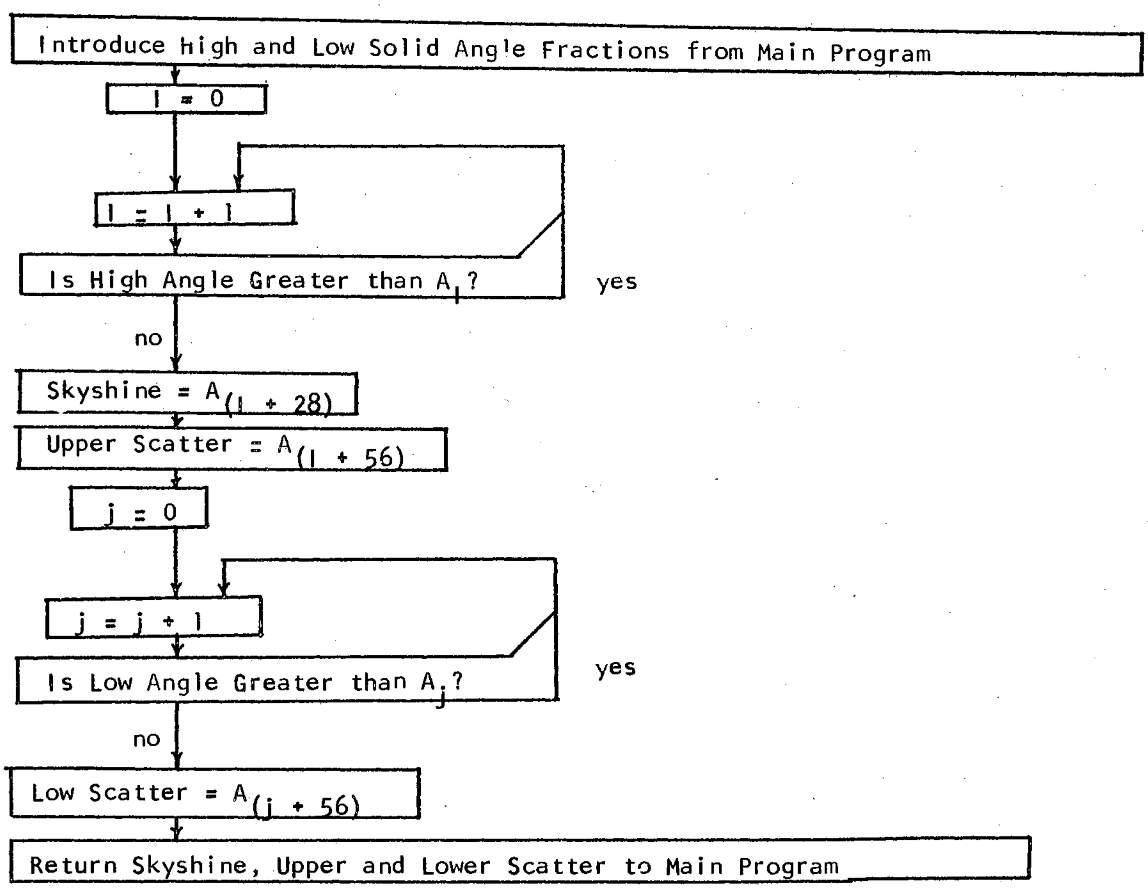


Figure C.5. Flow Chart for Subprogram Chart 5

Legend for Figure C.6

(1) Is A_I - (Height - 3)(A_I - $A_{(I + 25)}$)/7 less than Angle?

(2) Is A_I - (Height - 10)(A_I - $A_{(I + 26)}$)/20 less than Angle?

(3) Is A_I - (Height - 30)(A_I - $A_{(I + 26)}$)/70 less than Angle?

(4) Is A_I - (Height - 100)(A_I - $A_{(I + 26)}$)/200 less than Angle

(5) Ground Direct Response = 1 - (.15 - .05 (k - 1))

(6) Ground Direct Response = 1 - (.90 - .01 (k - 17))

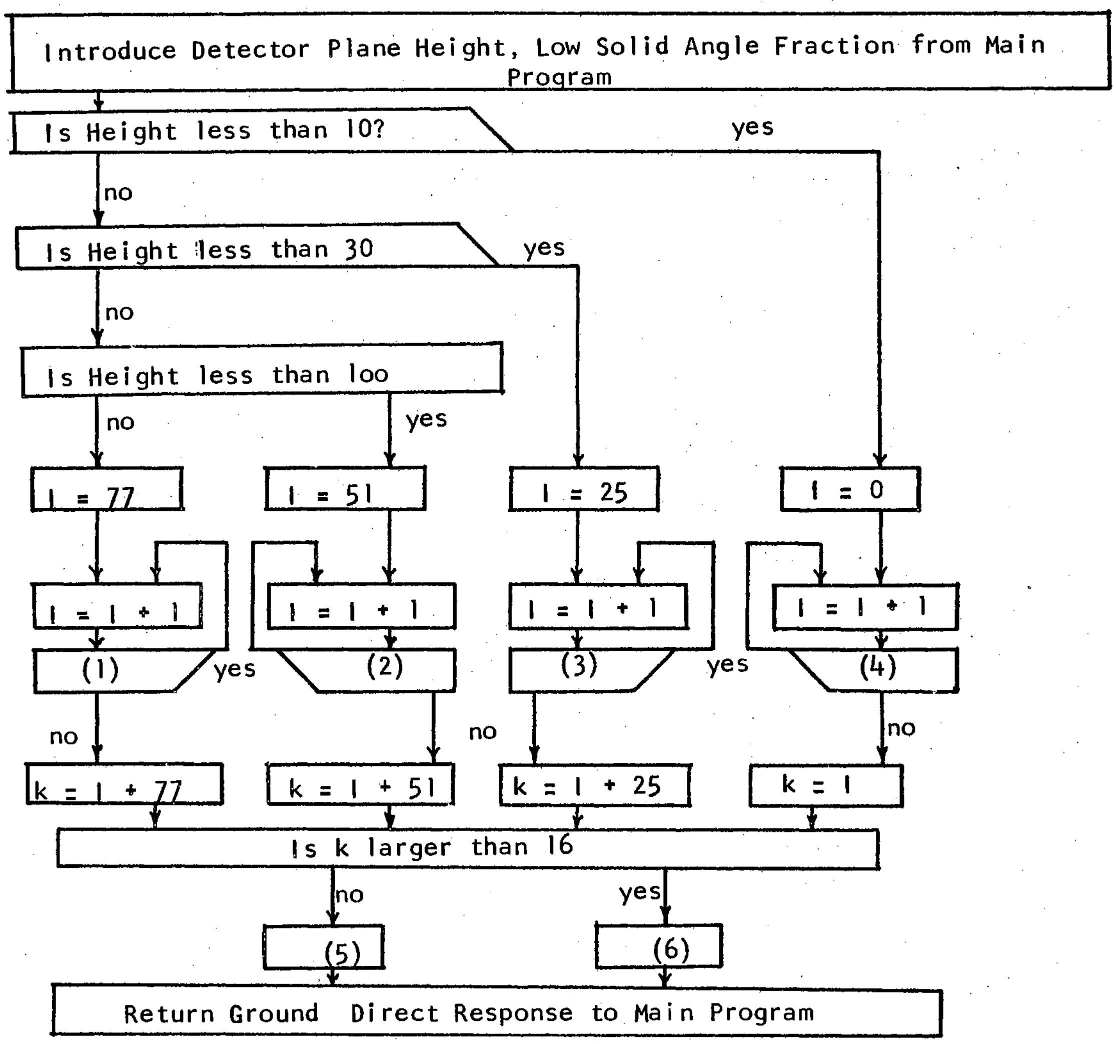


Figure C.6. Flow Chart for Subprogram Chart 6

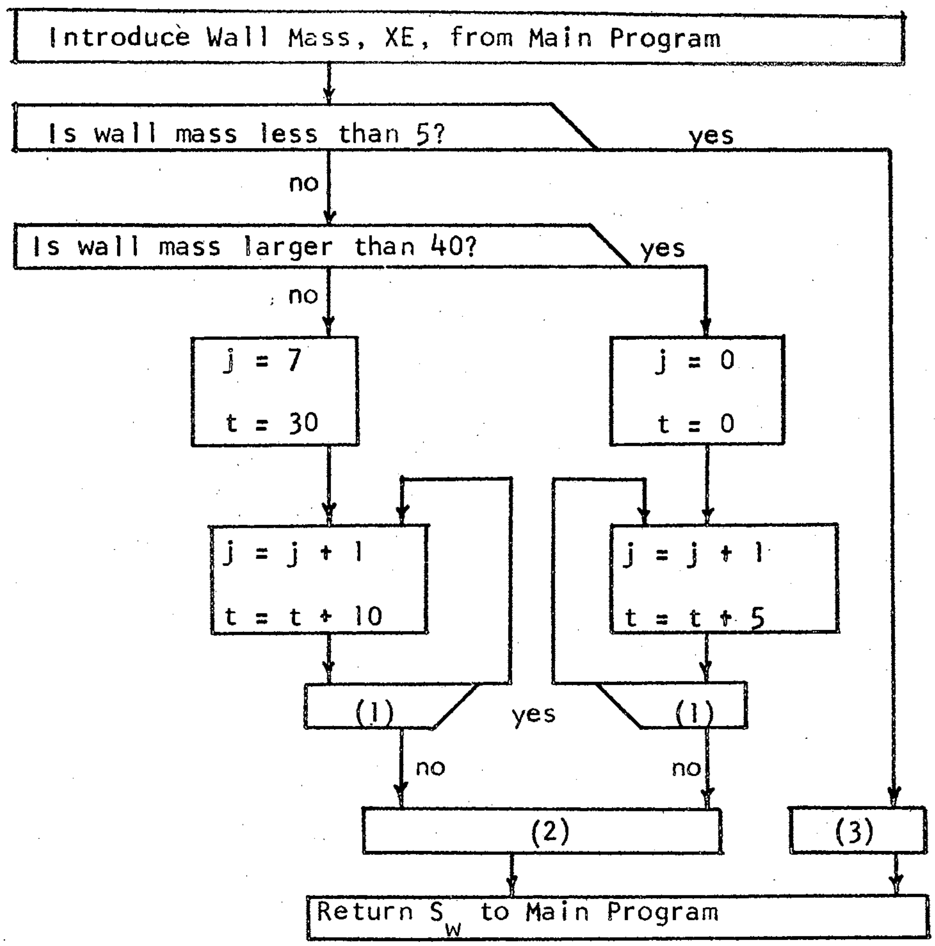


Figure C.7. Flow Chart for Subprogram Chart 7

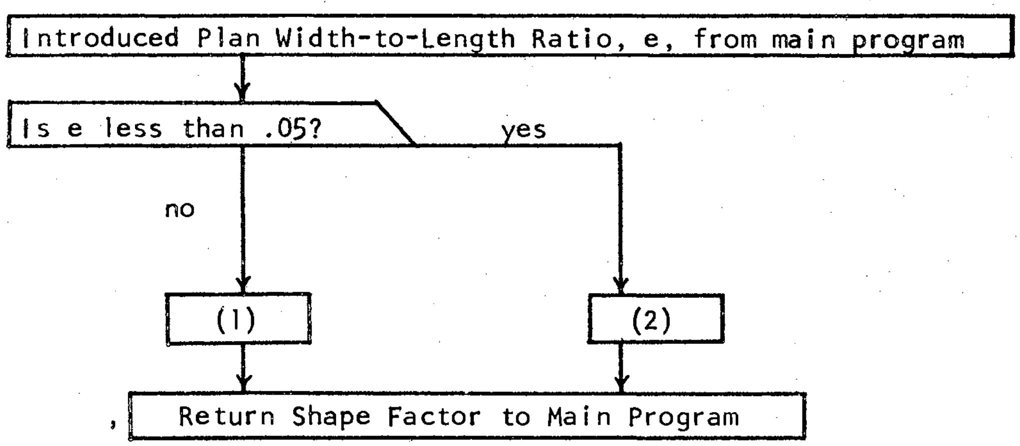
Legend for Figure C.7.

(1) Is wall mass larger than t?

(2) Radiation fraction scattered $S_w = A_j$

(3) Radiation fraction scattered $S_w = 0$

Figure C.8. Flow Chart for Subprogram Chart 8



(1) Shape Factor = A_{20e}

(2) Shape Factor = 1

APPENDIX D

MAIN PROGRAM FLOW CHARTS

Figure D.1 illustrates the logic used in programming the feasibility methodology by the use of a computer flow chart. The computer program itself is not listed because of today's rapidly advancing computer techniques in programming.

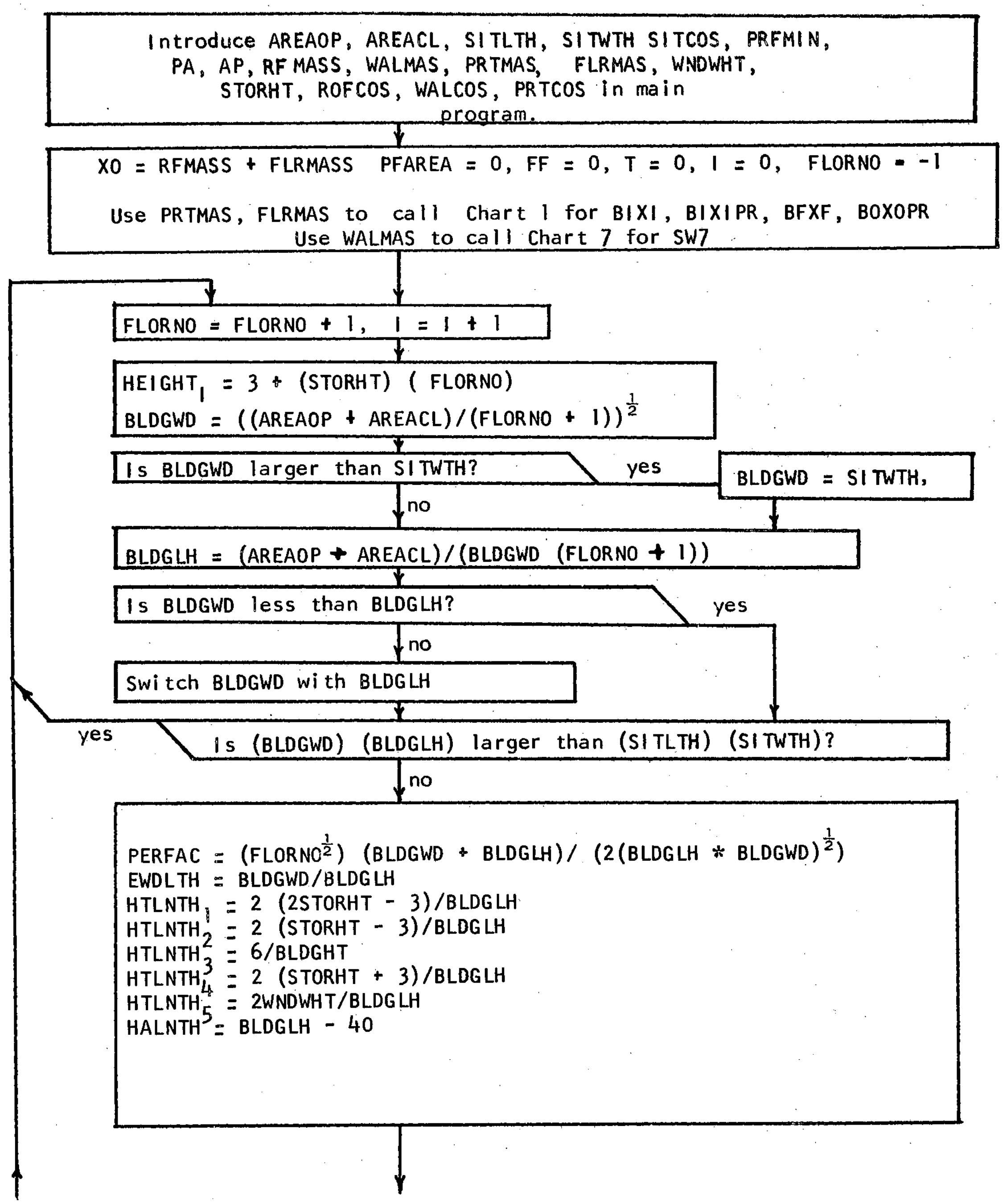


Figure D.1A. Flow Chart for Main Program

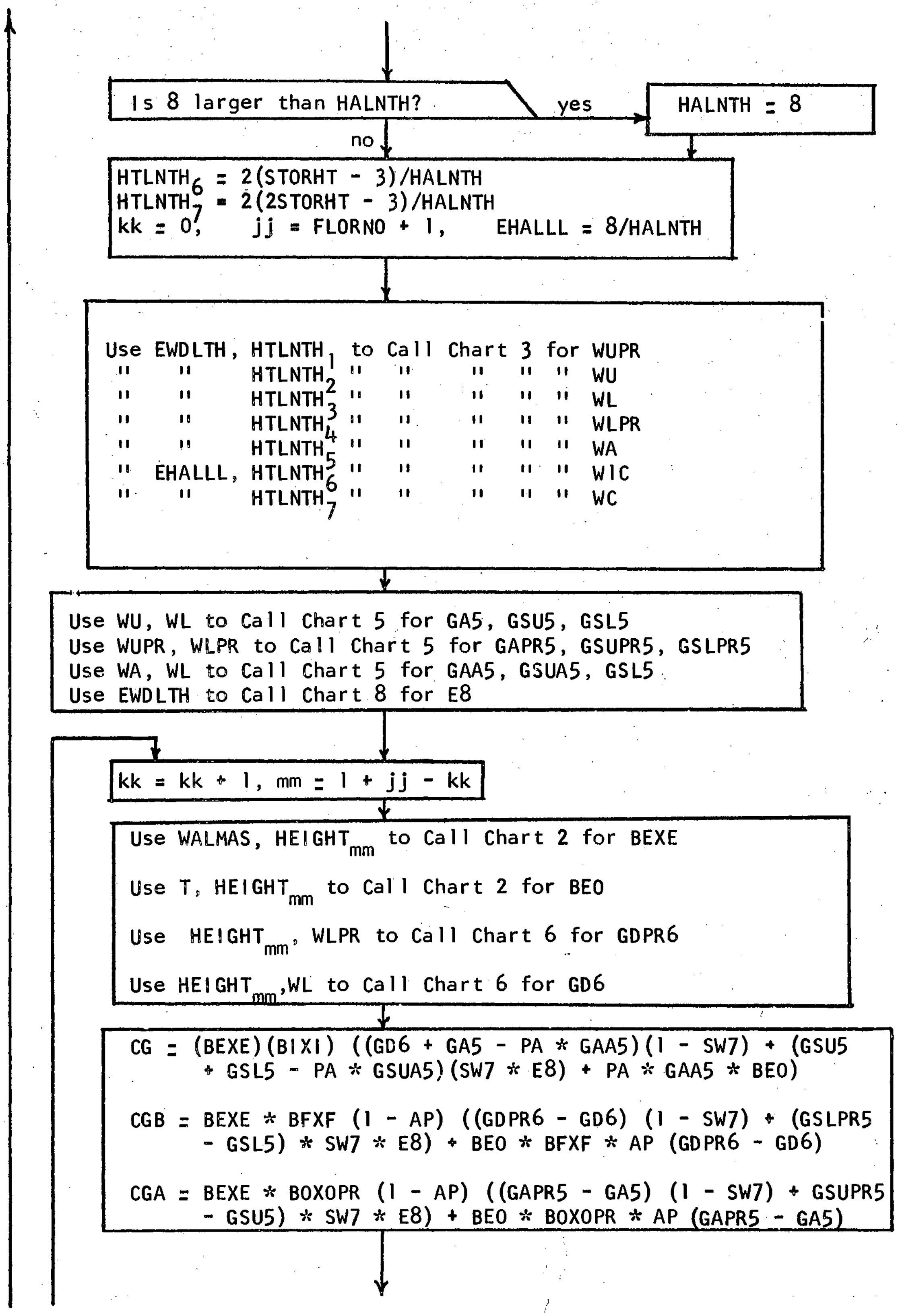


Figure D.1B. Flow Chart for Main Program

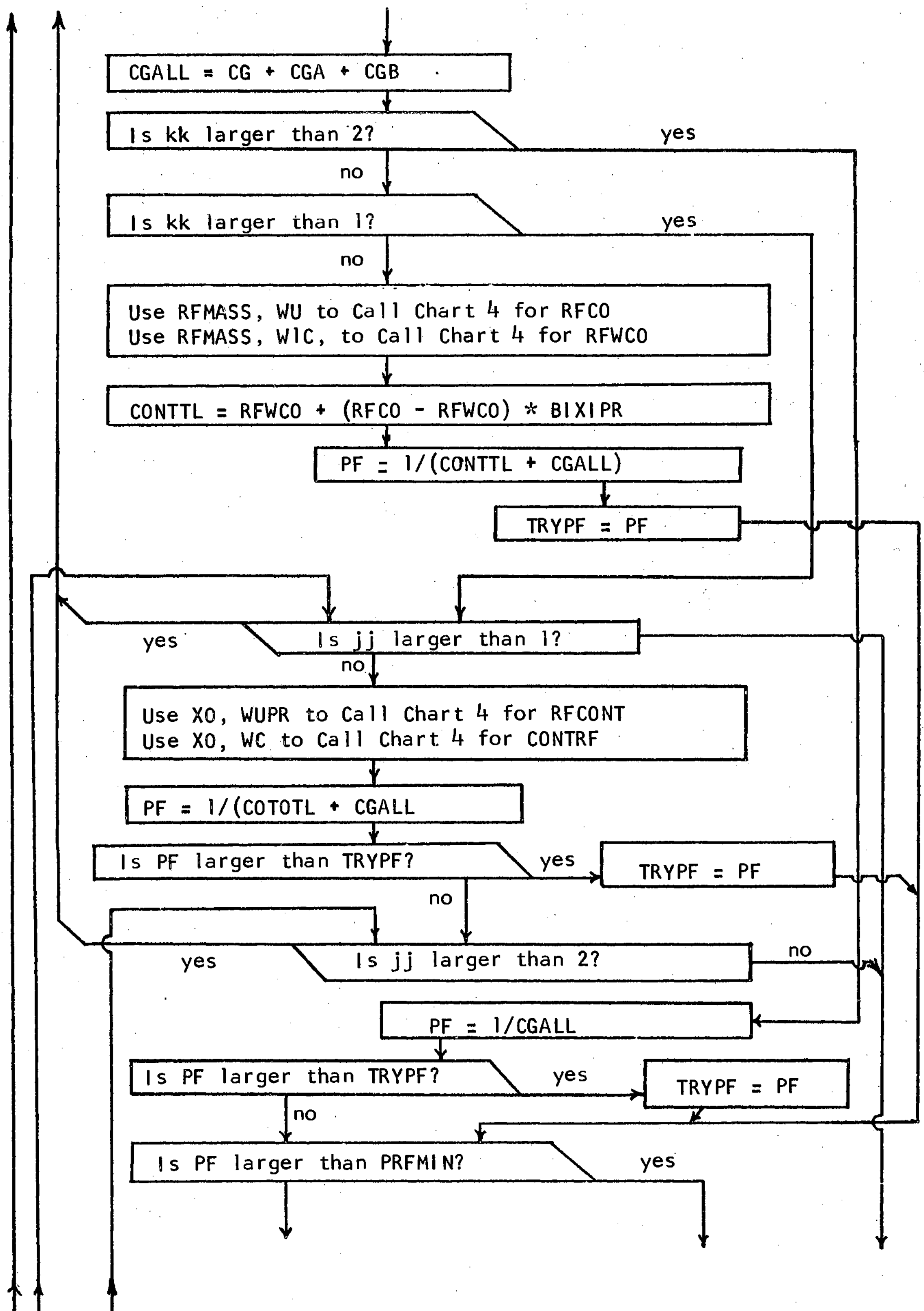


Figure D.1C. Flow Chart for Main Program

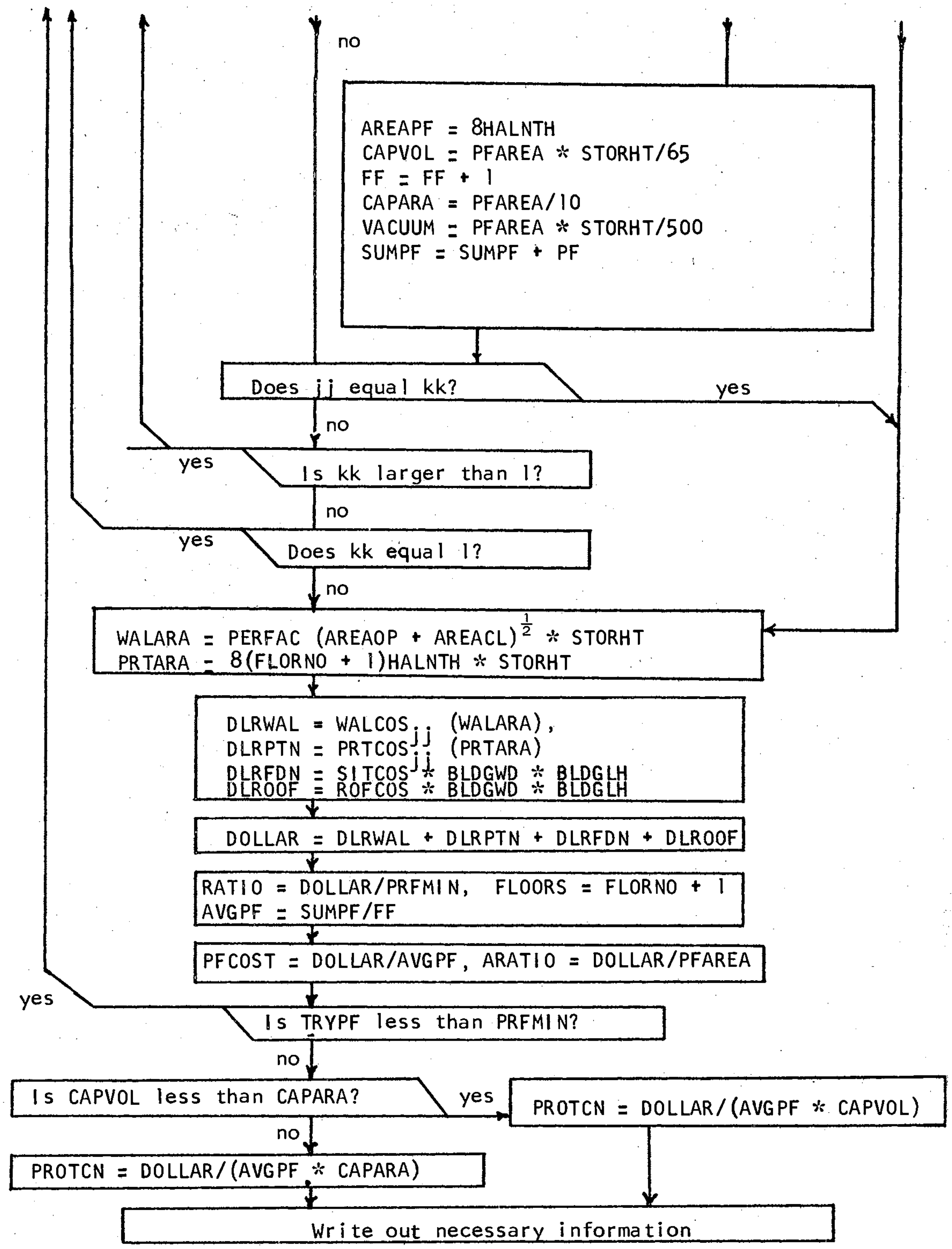


Figure D.1D. Flow Chart for Main Program

VITA

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