UNITED STATES HOUSING AUTHORITY

BULLETIN NO. 20 ON POLICY AND PROCEDURE

(Revised July, 1939)

(Substituted for Bulletin No. 20 dated March 8, 1939)

SELECTING A METHOD OF HEATING

A. Objective

Heating systems for low-rent housing involve a variety of considerations, with one basic purpose - the provision of suitable heating at the least possible cost. Economy of capital costs is mandatory under the United States Housing Act which states that "projects will not be of elaborate or expensive design or material and economy will be promoted both in construction and administration." The Act further requires that rents (including the cost of heating) shall be within the financial reach of families of low income. Since the heating expense may represent a very material portion of the total rent, or total expenditure for rent and household operation, economy in operating expense of the heating system is essential.

B. Determining a Heating Method

The individual tenant-operated heating unit should always be given consideration and, under conditions favorable to its use, this type should be the first tentative selection. As compared with the project-operated group or central plant, the individual tenant-operated unit has the following definite advantages:

1. The responsibility for fuel consumption is placed squarely on the tenant. It is obvious that when he pays directly for the fuel consumed, he will not be wasteful in his use of heat and will adjust it to his actual needs.

2. Tenant operation is substituted for the paid labor of others.

3. Simple, small individual plants are likely to be lower in first cost than large, frequently complex, project-operated plants. Under favorable climatic and fuel conditions the small heating units are likely to cost the tenant less in operating and maintenance expenses.

There are conditions, however, under which consideration must be given to the project-operated plant. In such cases, its capital cost and annual expense should be estimated and compared with the individual plant costs, and the advantages and disadvantages of the two types should be compared and weighed before a definite decision is made. For example, flats and apartments do not lend themselves readily to individual tenant-operated plants except when gas is available at a low rate. In very cold climates with a long heating season the more efficient performance of the larger project-operated plant may result in definitely lower operating expense. The project-operated plant or plants may have a distinct advantage in the anthracite regions (indicated in Zone 3 on the attached map) since such plants may often be operated with the smaller sizes of anthracite coal available locally in large quantities, whereas individual units may require the larger, more expensive sizes. The types of fuel available, possible methods of fuel purchase and distribution, the cost of project labor contingent upon different types of fuel, and other factors must be analyzed before making a final decision.

For purposes of general consideration the country may be roughly divided into three heating zones, as shown on the attached map. In the warmest of these, Zone 1, no heat other than that produced by the cooking stove should be needed. A water-heater may be provided in conjunction with the stove, or a separate water tank may be provided in the bathroom. In the next cooler area, Zone 2, a space heater in the living room should usually be sufficient and, except under unusual conditions, no consideration need be given to the project-operated plant. For two-story row houses, the space heater may be supplemented by a simple duct arrangement to direct the flow of heated air to the second floor.

In Zone 3, the most northerly, where a living room space heater may not be sufficient, various methods of heating may be considered and carefully compared. Preference, however, can generally be given to tenant-operated heating units except when analysis shows that costs strongly favor the project-operated plant.

Because of the technical considerations involved it is usually important to have the services of a qualified heating engineer in the preparation of this analysis, and in the final choice and the design of the heating system. An initial investment in qualified technical advice may pay for itself many times over in more accurate and dependable operating and maintenance estimates, greater speed in the preparation of working drawings, and greater operating economy and efficiency.

C. Factors Affecting Choice

1. Desirability of tenant responsibility.

2. Initial cost and its effect on annual expense. The comparative initial costs of providing space and chimneys for the individual dwelling heating unit or the project boiler plant or plants must not be forgotten.

3. Annual expense, including maintenance repairs and replacements: The choice of fuel used for domestic water-heating and the use of the same fuel for other purposes may affect this item.

4. Effect on site and building plan: The choice of tenant-operated heating units requiring delivery of fuel to the individual dwellings may control the layout of service drives, and consequently influence the cost of utilities. Similarly, the requirements of economical distribution for the project-operated plant may influence the layout of buildings.

5. Continued availability of fuel and probable trend of its price.

6. Local practice, acceptability, and availability.

7. Climate.

8. Labor rates and related factors.

9. Safety and cleanliness of operation.

10. Rate of obsolescence.

11. Effect on insurance rate.

Some of these factors relate to the type of system, some to the fuel, some to both. There may be other factors in particular cases.

D. <u>Types of Systems</u>

In the selection and design of the heating system consideration should be given to the fact that a continuous temperature of 70° F. in all rooms is not considered an absolute essential for health and comfort. Since outside design temperatures are reached for comparatively short periods of time during the average heating season, a temperature range (inside room temperature minus outside design temperature) 5° to 10° F. lower than that generally accepted for the locality may be used in calculating heat losses. For example, in cities where there is a generally accepted design temperature of 0° F., the project design range can be reduced (from 0° to 70° F.) to + 5° to 65° F. Local conditions must be considered carefully before reductions in the accepted range are established.

Consideration should also be given to the characteristics of fuels which affect the feasibility of a particular method of heating. Among these are:

Coal requires storage space and means for ash disposal, and this may restrict its use for individual dwelling unit plants above the first floor.

Gas involves no storage or handling difficulties and, when low enough in price, makes the individual unit available for any type of dwelling. One hundred percent check metering may be necessary, however, to insure economical operation and the initial costs and operating expense of individual gas-fired units with check metering should be weighed against the costs of an automatic project-operated gas-fired system.

Oil requires storage space. For the individual plant, a 50-gallon drum which is set on a stand outside the kitchen door, may be provided.

1. Individual Tenant-Operated Unit

In Zone 2 and frequently in Zone 3, this should be the favored type. In climates more favorable to the project-operated plant, the comparative economy of total fuel expense and the difficulties of fuel storage and handling must be considered.

The common types of individual units and characteristics which affect their use are:

(a) Fireplace or Circulator: When cold weather is occasional and not severe this is the only method of heating which is justified. Fireplaces may be the ordinary masonry type or may have a metal chamber to permit the warming and circulating of air, and may have ducts to other rooms. Circulators may burn any fuel depending upon local practice, availability, cost, and storage and handling facilities.

(b) Stove: This type does not permit uniform heat distribution or temperature control but may be considered generally suitable in Zone 1, and wherever very low cost and very low rent are the aims.

(c) Gravity Warm Air: This type is low in first cost, and requires a minimum of maintenance and adjustment. Basement space is required. The pipeless variety is very low in first cost, but only partially effective in distribution. More effective distribution may be obtained by the use of ducts.

(d) Forced Warm Air: Distribution is very effective in this type. No basement is required, and when it is gas or oil fired, very little space is necessary.

(e) One Pipe Steam with radiators: This type is slightly higher in cost than gravity warm air and requires basement space.

(f) Hot Water: This type is slightly higher in first cost than one pipe steam and is very satisfactory in operation, particularly when a steady, moderate supply of heat is wanted.

2. Central or Group Project-Operated Plants

These types may be justified usually only under the following conditions:

(a) Concentration of dwelling units in flats and apartments and, to a lesser extent, in row houses.

(b) Climate requiring nearly continuous heating for four or more months.

The decision between a single central plant and two or more plants, each serving a group of buildings, will be affected by:

(a) The size, arrangement and topography of the project.

(b) The types of fuel available at low prices.

(c) Labor rates and related factors.

Group plants are usually more desirable than a large central plant. They can ordinarily be located in basements with chimneys related to the buildings, thereby eliminating the high initial cost of a separate building and high chimney. Fuels such as oil or gas may be readily handled, regardless of the number, size and location of the plants. Group plants should be interconnected, wherever feasible, to permit more flexible operation which will result in greater economy in the low-demand months. This is particularly important where coal is the fuel used. The site plan should therefore be arranged to permit nearly uniform sizing of the group plants and their location for economical interconnection.

A large central plant will usually require a separate building and high chimney. This may be undesirable from a site planning point of view or for architectural reasons. The delivery, storage, and handling of coal and the disposal of ashes, however, may be efficiently handled in such a plant.

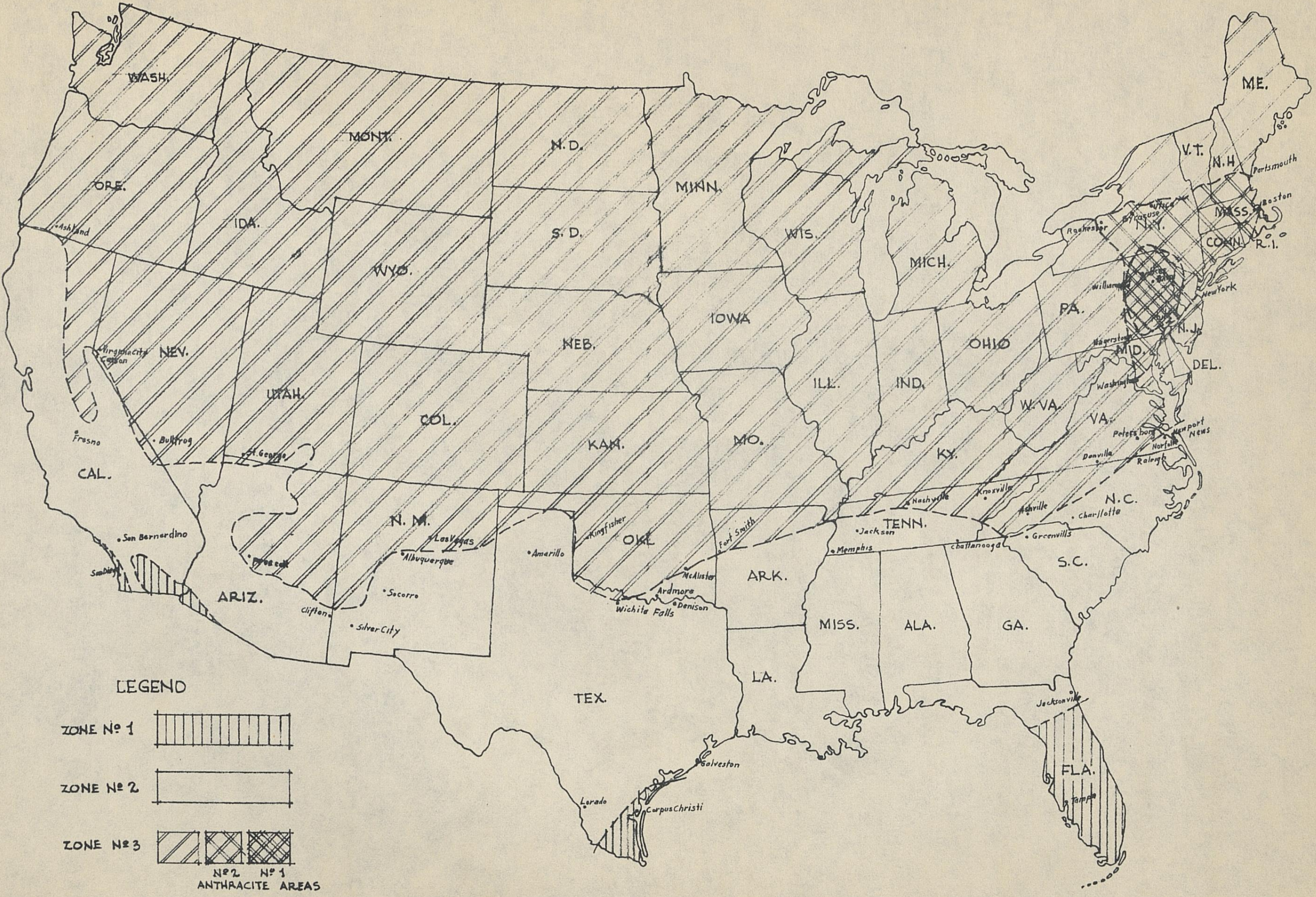
Economic Analysis, Design, and Contract Documents:

Recommendations for good practice in the preparation of an economic analysis and the design of project-operated heating systems are covered in the Appendix to this bulletin.

Nathan Straus

NATHAN STRAUS,
Administrator.

September 25, 1939



NOTES

AREA Nº 1 IS THE CENTER OF THE ANTHRACITE INDUSTRY

AREA Nº 2 EMBRACES THE BALANCE OF THE ANTHRACITE MARKET, HOWEVER PRICES WILL INCREASE DUE TO TRANSPORTATION COSTS.

APPENDIX

Economic Analysis of Heating Methods.

Design of Project-Operated Central and Group Heating Plants.

Fuel Consumption Formulae.

The factors which influence the choice of a heating method are discussed in the foregoing Policy and Procedure Bulletin No. 20, "Selecting a Method of Heating." Important among these factors is the comparative economy of the various feasible methods.

The first part of this appendix to Bulleton No. 20 presents a detailed method of studying the comparative economy of various methods of heating. The second part makes recommendations on practices and methods in the design of project-operated group and central plants, for use by the designing engineer. The third part contains fuel consumption formulae. These recommendations apply only to central or group plants and should be considered only where careful analysis, as outlined in Bulletin No. 20, has clearly indicated the desirability of project-operated central and group plants.

PART I - ECONOMIC ANALYSIS

A. Comparative Cost Analysis

Several suitable methods of heating having been tentatively selected a comparative cost analysis should be made in order to determine which will result in the least expense to the tenant. The underlying principles involved in this analysis are simple and require no explanation. There are, however, certain common errors concerning which a reminder may be helpful.

Perhaps the most prevalent mistake is to overlook items of expense which are indirectly involved in the use of a specific type of fuel or heating plant. If, for example, coal fired gravity warm air systems are being considered, the cost of a basement or other space, coal storage space, chimneys, and possibly additional roads for the delivery of coal and removal of ashes, should be included.

If individual, group and central plants are being compared, there should be included not only the costs of boilers, breeching, auxiliary equipment, and piping, but also fuel storage space or tankage, construction costs of boiler and storage rooms and smoke stack, and heat insulation of boiler room ceiling. There may also be the cost of supply and return mains, with their supports and heat insulation and trenches or tunnels to nearby buildings and lines to hot water heaters.

The central plant should be charged with its building and smoke stack, as well as complete plant, distribution and return systems, and possibly cost of land occupied if additional land has to be acquired to accommodate the central plant.

With respect to items such as maintenance and replacement, the expense for which may vary widely, the greatest care should be taken to avoid estimates which are either unfairly pessimistic or unduly hopeful.

In general, the present prevailing costs will form the basis of computations, but unusual price conditions should be discounted and the long range trend anticipated wherever possible.

B. Forms for Analysis

Convenient forms for preparing the economic heating analysis are attached hereto. These are designed to facilitate separate analysis of plant and fuel costs.

Following are the items which are included in the attached economic analysis charts to determine the initial costs and annual operating expense:

TABLE I - INITIAL COSTS

Central-Group-Building Plants

A. Radiation and/or Pipe; Unit Heaters, Ducts and Grilles-in Buildings. Cost of heating system within the buildings, exclusive of equipment, auxiliaries and piping within the boiler room. Radiation can be estimated by reference to Table III of the charts.

B. Distribution (Yard). Cost of underground piping installation.

C. Plant Equipment. Cost of equipment, auxiliaries and piping within the boiler room. Automatic firing and fuel handling equipment should be noted separately. Building plants might include one boiler room per building or one boiler room per two or three small buildings.

Unit Plants

D-E-F-G. Cost of heating equipment for individual plants only. Items D, E and F might apply to warm air systems or circulators. Vents under D include fresh air connections. Items E, F and G are applied to steam or hot water heating systems.

Central-Group-Building - Unit Plants (Related Items)

H. Plumbing Connections. Cost of water and drainage required for heating system.

I. Gas Piping. Cost of proportionate share of gas piping applied to heating system.

J. Electric Outlets. Cost of electrical work necessary for heating system.

K. Chimneys. Cost of masonry flues, stacks and foundations.

L. Structures. Cost of structures, additional to dwelling facilities, necessary to house boiler and auxiliary equipment for central, group or building plants; closets, utility rooms, partitions, etc., for individual dwelling unit plants.

M. Fuel Storage. Cost of facilities for storing fuel. Fuel oil tanks concerned with the immediate operation of the plant or plants need not be included here.

N. Extra Roads. Cost of extra roads required in the delivery of fuel or removal of ash.

O. Net Initial Cost (Heating). Total of above items, each of which should include the sub-contractors expense and profit. However, it should not include general contractor's added percentage.

P. Gross Heating Cost. Net initial cost plus general contractor's added percentage.

Domestic Hot Water

Q. to X. (inclusive): Costs of supplying domestic hot water. The same procedure should be followed as outlined heretofore for heating. It is necessary to note that when domestic hot water is supplied through generators deriving its source of heat from boilers used also for space heating, the cost of the extra boiler capacity and heating distribution should be included in items A, B and C.

Y. - Gross Cost (Heating plus Domestic Hot Water). The summation of items P. and X.

TABLE II. ANNUAL OPERATING EXPENSE

Heating and Domestic Hot Water

a. through d. Maintenance, Repair and Replacement. The product derived by multiplying the initial costs from Table I by the factors set up for the respective items in Table IV. Related items generally refer to plumbing connections, gas piping and electric outlets.

e. The total of all maintenance, repair and replacement expense.

f. Fuel. Formulae have been prepared for estimating fuel consumption which are incorporated in this Bulletin. The influence on the rate structure in the use of gas for space heating and domestic hot water in coordination with that required for cooking and refrigeration should be applied in the analysis. Where the electric consumption for the operation of auxiliary heating equipment is a substantial amount, its influence on the electric rate structure should be thoroughly considered.

g. Labor. In high pressure boiler plant operation it may be necessary to employ the services of a competent first class licensed engineer. Local regulations may require such services continuously while the plant is in operation or for supervisory purposes only. In the latter case a portion only of the engineer's time might be devoted to the plant. In any event, it might be advisable to charge at full time the services of second class licensed engineers.

In low pressure plant operation licensed men are generally not required unless stipulated by ordinance or labor organization.

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ECONOMIC HEATING ANALYSIS
COMPARATIVE INITIAL AND ANNUAL OPERATION COSTS

FEDERAL WORKS AGENCY
UNITED STATES HOUSING AUTHORITY

PROJECT ________
LOCATION ________
STATUS ________

DWELLING UNITS ____ HEATED CUBE ____
NO. OF ROOMS ____ CUBE PER ROOM ____
ROOM RATIO ____

DESIGN TEMPERATURE ____
DEGREE DAYS ____

BUILDINGS
NO ____ STORY ____
NO ____ STORY ____
NO ____ STORY ____

COMPUTED BY ____
CHECKED BY ____

DOCKET NO. ____
SHEET NO. ____
FROM ____ TO ____
DATE ____ 19 ____

TABLE I - INITIAL COSTS			A	B.	C.	D.
ITEMS	SCHEME	HTG.				
		DOM. H.W.				
	SYSTEM - HTG.					
	NO. OF PLANTS					
	E.D.R.	HEATING				
		DOM. H.W.				
		TOTAL				
	B.H.P. TOTAL					
	TYPE OF FUEL	HEATING				
		DOM. H.W.				
CEN-GROUP-BLDG-PLANTS	A	IN BLDGS. 1. RADIATION AND/OR PIPE				
		2. UNIT HEATERS-DUCTS-GRILLES				
	B	DISTRIBUTION (YARD)				
		1. INTERMEDIATE PRESSURE				
		2. LOW PRESSURE				
	C	PLANT EQUIPMENT				
		1. BOILERS, PUMPS, AUXILIARIES.				
		2. FUEL FIRING				
		3. FUEL HANDLING				
UNIT PLANTS	D	DUCTS, GRILLES AND VENTS				
	E	RADIATION AND PIPE				
	F	HEATER OR FURNACE				
	G	CONTROLS				
HEATING - RELATED ITEMS	H	PLUMBING CONNECTIONS				
	I	GAS PIPING				
		1- IN BUILDINGS				
		2- OUTSIDE BUILDINGS				
	J	ELECTRIC OUTLETS				
	K	CHIMNEYS				
	L	STRUCTURES				
		1- SEPARATE BUILDING				
		2- BASEMENT CONSTRUCTION				
		3- CLOSETS, PARTITIONS, ETC.				
	M	FUEL STORAGE				
	N	EXTRA ROADS				
	O	NET INITIAL COST (HEATING)				
	P	GROSS HTG. COST ("O"+ %) (GEN'L. CONTRS. EXP. AND PROFIT)				
DOMESTIC HOT WATER	Q	HEATER AND TANK				
	R	GENERATORS - PUMPS				
	S	HOT WATER PIPING				
	T	GAS PIPING				
	U	ELECTRIC OUTLETS				
	V	CHIMNEYS OR VENTS				
	W	NET INITIAL COST (DOM. H.W.)				
	X	GROSS DOM. H.W. COST ("W"+ %)				
	Y	GROSS COST=HTG.+DOM.H.W. (P+X)				

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ECONOMIC HEATING ANALYSIS

FEDERAL WORKS AGENCY
UNITED STATES HOUSING AUTHORITY

DOCKET NO. ______
SHEET NO. ______
FROM ______ TO ______
DATE ______ 19 ______

TABLE II-ANNUAL OPERATING EXPENSE			A.	B.	C.	D.
ITEMS	SCHEME	HEATING				
		DOM. H.W.				
	SYSTEM	HEATING				
	FUEL AND PRICE	HEATING				
		DOM. H.W.				
	HEAT VALUE-BTU	HEATING				
		DOM. H.W.				
	FUEL CONSUMPTION	HEATING				
		DOM. H.W.				
	ELECTRIC POWER K.W.H.	HEATING				
		DOM. H.W.				
	EFFICIENCY OF FUEL AS FIRED	HEATING				
		DOM. H.W.				
HEATING	a MAINT. & REPAIR	1. FUEL FIRING & FUEL HANDLING (CENTRAL-GROUP-BUILDING PLANTS)				
		2. OTHER HEATING EQUIPMENT (CENTRAL-GROUP-BUILDING-PLANTS)				
		3. UNIT PLANTS				
		4. RELATED ITEMS				
		5. STRUCTURES				
	b REPLACEMENT	1. FUEL FIRING & FUEL HANDLING (CENTRAL-GROUP-BUILDING-PLANTS)				
		2. OTHER HEATING EQUIPMENT (CENTRAL-GROUP BUILDING-PLANTS)				
		3. UNIT PLANTS				
		4. RELATED ITEMS				
DOMESTIC HOT WATER	c MAINT-REP.	1. HEATER OR GENERATOR				
		2. PIPING-GAS & WATER				
		3. RELATED ITEMS				
	d REPLACE.	1 HEATER OR GENERATOR				
		2 PIPING-GAS & WATER				
		3 RELATED ITEMS				
HEATING AND DOMESTIC HOT WATER	e	TOTALS-MAINTENANCE-REPAIR REPLACEMENT ("a" THRU "d")				
	f	FUEL 1. HEATING				
		FUEL 2. DOMESTIC H.W.				
	g	LABOR	—CHIEF— Mo.@—	—CHIEF— Mo.@—	—CHIEF— Mo.@—	—CHIEF— Mo.@—
			—MEN— Mo.@—	—MEN— Mo.@—	—MEN— Mo.@—	—MEN— Mo.@—
			—MEN— Mo.@—	—MEN— Mo.@—	—MEN— Mo.@—	—MEN— Mo.@—
		1. HEATING (PLUS ___ % INSURANCE)				
		2. DOM. H.W. (PLUS ___ % INSURANCE)				
	h	ASH DISPOSAL				
	i	ELECTRIC POWER				
	j	WATER AND SUPPLIES				
	k	NET ANNUAL OPERATION ("e" THRU "j")				
	l	NET PER ROOM PER YEAR				
	m	NET PER ROOM PER MONTH				
	n	DEBT SERVICE (0.0017 x ___ -TABLE I)				
	o	GROSS ANNUAL OPERATION ("k" + "n")				
	p	GROSS PER ROOM PER MO.				

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ECONOMIC HEATING ANALYSIS

FEDERAL WORKS AGENCY
UNITED STATES HOUSING AUTHORITY

DOCKET NO. ______
SHEET NO. ______
FROM ______ TO ______
DATE ______ 19 ______

TABLE-III CUBIC FEET OF USABLE SPACE PER SQUARE FOOT OF EQUIVALENT DIRECT STEAM RADIATION

DESIGN TEMP. DEG. "F"	INSIDE TEMP. DEG. "F"	TEMP. DIFF. DEG. "F"	ONE STORY BUILDING	TWO STORY BUILDING	THREE STORY BUILDING	FOUR STORY BUILDING	SIX STORY BUILDING
+20	70	50	48	61	67	71	75
+15	70	55	46	58	63	67	70
+10	70	60	44	54	60	63	66
+5	70	65	41	51	56	60	62
0	70	70	38	47	52	55	58
-5	70	75	35	43	48	51	53
-10	70	80	32	41	44	47	49
-15	70	85	29	37	41	43	45
-20	70	90	26	33	37	39	42

TABLE-IV MAINTENANCE & REPAIR — REPLACEMENT FACTORS

		SCHEME	ITEMS		MAINTENANCE AND REPAIR		REPLACEMENT AT 2% INTEREST	EXPECTED LIFE IN YEARS
					UNDER 300 UNITS	OVER 300 UNITS		
HEATING	A	CENTRAL PLANT HIGH PRESSURE. STEAM OR FORCED HOT WATER	FUEL FIRING & HANDLING	UNIT HEATERS	0.0225	0.02	0.0412	20
			OTHER HEATING EQUIPMENT		0.0225	0.02	0.0175	38
			RELATED ITEMS		0.0175	0.015	0.01	55
			STRUCTURES		0.0075	0.0075		
	B	GROUP PLANTS OR CENTRAL PLANT (LOW PRESSURE) STEAM OR FORCED HOT WATER	FUEL FIRING & HANDLING	UNIT HEATERS	0.0225	0.02	0.0412	20
			OTHER HEATING EQUIPMENT		0.0225	0.02	0.02	35
			RELATED ITEMS		0.0175	0.015	0.01	55
			STRUCTURES		0.005	0.005		
	C	INDIVIDUAL BUILDING PLANTS (LOW PRESSURE) STEAM OR HOT WATER	FUEL FIRING & HANDLING	UNIT HEATERS	0.0225	0.02	0.0412	20
			OTHER HEATING EQUIPMENT		0.0225	0.02	0.0225	32
			RELATED ITEMS		0.0175	0.015	0.01	55
			STRUCTURES		0.005	0.005		
	D	INDIVIDUAL DWELLING UNIT PLANT SYSTEMS	GRAVITY WARM AIR		0.02	0.02	0.0578	15
			FORCED WARM AIR (GAS FIRED)		0.02	0.02	0.0312	25
			GRAVITY STEAM OR HOT WATER		0.02	0.02	0.0166	40
			CIRCULATORS		0.02	0.02	0.0913	10
			STRUCTURES		0.01	0.01		
	E	DOMESTIC HOT WATER	HEATER AND TANK		0.0225	0.02	0.0578	15
			GENERATORS — PUMPS		0.0225	0.02	0.0412	20
			PIPING - GAS AND WATER		0.0125	0.01	0.01	55
			RELATED ITEMS		0.0175	0.015		

NOTES: THE STEAM RADIATION DERIVED FROM THE FACTORS IN TABLE III IS TO BE USED FOR PRELIMINARY PURPOSES ONLY IN PREPARING AN ECONOMIC ANALYSIS, AND NOT FOR INDIVIDUAL ROOM CALCULATIONS. HOT WATER HEATING RADIATION CAN BE TRANSPOSED FROM THE RESULTANT FIGURES. THE FACTORS IN TABLE IV ARE BASIC ONLY; THEY MAY BE VARIED TO SUIT LOCAL CONDITIONS AND THE TYPE AND QUALITY OF THE HEATING OR DOMESTIC HOT WATER SYSTEM. UNIT HEATERS UNDER "A", "B", AND "C" IN TABLE IV APPLY TO THE STEAM OR HOT WATER TYPE. GAS OPERATED HEATERS ARE INCLUDED UNDER D.

When a plant or plants necessitate a twenty-four daily operation, the personnel per shift (with the exception of the chief engineer if permitted by regulation) can be multiplied by 3-1/2 times, which should compensate for relief time. If, on the other hand, the plant or plants do not require operation on this basis, the staff could be reduced proportionately, with the necessary relief labor of approximately 16-2/3 per cent per man added. It is advisable that in preparing an analysis of different heating schemes before a selection is made, only that portion of the firemen actually required in the operation of the plant need be applied to it.

Labor during the non-heating season can be reduced commensurate with the scheme of heating domestic hot water and the tenant requirements.

h. Ash Disposal. The expense of removing the ash from the project.

i. Electric Power. The expense of kilowatt hour consumption of all electric motor driven equipment.

j. Water and Supplies. The expense of water incidental to plant operation and supplies such as waste, lubricating oil, etc.

k. Net Annual Operation. The total of all operating expense (items e through j).

l. Net per Room per Year. The net annual operation (item k) divided by the number of rooms.

m. Net per Room per Month. The net monthly operation divided by the number of rooms.

n. Debt Service. The product of 0.0017 (which is the difference between the annual subsidy of 3.5 per cent and the interest and amortization of 3.67 per cent) by the Gross Costs in Table I of Heating (item P), Domestic Hot Water (item X) or the total of Heating and Domestic Hot Water (item Y), dependent upon the nature of the analysis. No allowance has been made in the chart to compensate for any changes in these rates, since the influence of such fluctuations on the heating and/or domestic hot water per room per month operating expense would be negligible.

o. Gross Annual Operation. The summation of items k and n.

p. Gross per Room per Month. The gross monthly operation divided by the number of rooms.

C. Selecting the Fuel

Choice of fuel is dependent in a large measure on local availability and cost. Other considerations are cleanliness and ease of handling. As the choice of fuel may affect the site plan and the management policy, an early fuel cost analysis should be made. A recommended form for preparing such an analysis is included in the "Economic Heating Analysis" chart attached, additional copies of which may be obtained upon application to the United States Housing Authority at Washington, D. C.

Low fuel prices are generally required to make individual heating units practical. There are several ways in which retail fuel prices may be lowered: purchase by the project at wholesale prices and resale to the tenants; group purchase sponsored by a "Tenants Association"; or purchase through the department which makes municipal purchases of fuel. The cost of handling fuel, including storage, weighing, delivering and billing, must be considered in any study of fuel purchasing methods. Fuel storage by the tenant may constitute a problem.

In the selection of fuel, especially coal, consideration should be given to a possible rise in price. The price of coal today is lower than it has been in a number of years.

PART II - DESIGNING THE PROJECT OPERATED GROUP AND CENTRAL PLANTS

Recommendations and suggestions for the design of heating plants are presented herein. The United States Housing Authority recognizes that there are various satisfactory methods of handling particular design features, and these suggestions are not to be considered the only acceptable ones.

A. The Central Plant

1. Boilers

Central plants; design to operate at 80 to 100 pounds pressure, with not less than three boilers; water tube boilers, at 150 percent of rating; portable fire box boilers, at 100 percent of rating. Normal rating should not exceed 500 H.P. except where more than four boilers are required.

Boilers up to 100 H.P.: fire box type.

Boilers 100 H.P. to 300 H.P.: either straight water tube, or low head three drum bent tube.

Boilers above 300 H.P.: either straight water tube, or high head four drum bent tube.

Insulation of settings on coal burning boilers 300 H.P. and over will be improved by providing air-cooled walls. For oil or gas fuel, settings may have solid walls and air-cooled floors. For straight tube boilers, provide solid end and side walls 22 inches thick with full floating bridge wall to take care of expansion. Provide for expansion in the setting walls as well as proper clearance between drums and settings and supporting structural members. Support boilers independently of brick setting.

Provide for easy cleaning of all water and fire surfaces. Provide soot blowers on water tube, horizontal return tubular, and portable type fire box boilers burning bituminous coal.

Include water treatment facilities where necessary.

Provide for easy removal of ashes; if pulverized coal firing is used, provide a method for trapping and removal of fly ash.

A clear space of 14'-0" minimum is recommended between boiler fronts and the wall of the building, not less than 6'-0" between the rear of the boilers and the wall of the building, and not less than 6'-0" between each boiler for air-cooled walls and 5'-0" for all others. Each boiler should have an individual setting.

Provide proper ventilation over the top of all boilers. This can best be accomplished by a monitor over each boiler with pivoted sash and extended operating device.

2. Steam Outlets

The steam outlet of each boiler carrying in excess of 15 pounds gauge pressure should have an automatic stop and check valve at the boiler, and globe or angle valve at the header. One or more openings for future flanged connections may be provided on boiler drums.

3. Cat Walks

Provide cat walks with ladders so that all points on boilers which must be serviced may be reached.

4. Stacks

Base peak boiler loads on a chosen minimum outside temperature.

Stack diameters should be the most economical size, calculated for peak load demand at 20° F. above design temperature with provisions for further extension if contemplated.

Design for fifty percent excess air under peak load demand for oil and 90 percent excess air for coal.

At least two-tenths of an inch of draft is needed in the combustion chamber for forced draft equipment when burning either coal or oil.

Specific recommendations for natural draft fuel oil burning equipment will be furnished by the United States Housing Authority on request.

Where either oil or gas is used, it is advisable to calculate the stack size on the basis of burning coal with and without cinder trap.

5. Overhead Bunkers

Overhead coal bunkers in central plants: design with a capacity of not less than 10 percent of the estimated maximum annual coal consumption.

Where more storage is desirable, provide outside storage spaces for an additional 5 to 10 percent. These may be surrounded by a masonry wall at least 6'-0" high.

In localities where the analysis of the coal shows a content of three percent or more of sulphur, use overhead bunkers either of concrete or metal coated on the inside with at least 1/8 inch of a bitumastic paint or a tile lining set in hot mastic.

6. <u>Underground Coal Storage</u>

Where underground storage is provided, the coal holes should be raised about four inches above the trucking grade. They should be sufficient in number and so located that at least two-thirds of the total volume of storage can be filled without hand trimming. Openings from these underground storage bins to the boiler rooms should have a metal door, to be closed when coal is being placed in the bin.

Underground storage is recommended only where the total annual consumption is less than 3500 tons.

7. <u>Coal Handling Equipment</u>

Traveling weigh larries, electrically operated, should have capacities of not less than 1,500 pounds for boilers up to 250 H.P., and 2,000 pounds for boilers above 250 H.P., and should be equipped with switches to limit the horizontal travel. Electric motors for weigh larries and other coal handling equipment should preferably be the fully enclosed, fan cooled type. The use of this equipment ought to be limited to projects where the total annual coal consumption exceeds 3500 tons.

Coal hoppers for stoker feeds: design for 1,000 pounds for boilers up to 250 H.P., and 1,500 pounds for boilers over 250 H.P. Stokers may be equipped with fully-enclosed, fan-cooled electric motors or steam turbines, or may be hydraulically operated.

Monorails may be supported from roof trusses of boiler rooms, but should be placed so that the bottom of bucket, when raised to its unloading position, will not be over 18 inches above the top of the stoker hopper, to limit the swinging of the bucket.

Hoists should have electric lift and travel, and two lifting cables placed on either side of the bucket to prevent the bucket from turning when being raised.

The bucket should have at least 1,000 pound capacity with a side bottom dump and gate of the clam shell type operated with a wheel, rack and pinion. The wheel should operate through a knuckle joint so that it can be reached when bucket is raised or lowered. Weighing sections should be placed in the monorails and the longitudinal travel of buckets limited to 50 feet per minute maximum.

Drums of hoist should be grooved for rope and not flat.

8. <u>Ash Handling Equipment</u>

When the annual coal consumption is up to 2,200 tons, consideration must be given to the method of ash disposal.

When the annual coal consumption is above 2,200 tons, a pneumatic or preferably a mechanical system of ash handling is desirable.

Where cinder traps are used, provide for disposal of fly ash through the ash handling system. Dispose of the fly ash from the rear hopper of the boiler through the ash handling system, or return into the boiler furnace for burning the combustibles.

9. Instrument Boards and Instruments

The following instrument boards are recommended for heating plants burning in excess of 2500 tons annually:

(a). One main instrument board located in the boiler room as directed. Instruments on this board may include:

(1) Electric clock, 6 inch diameter.
(2) Smoke density indicator and recorder where required.
(3) Recording and integrating steam flow meter, for yard distribution system only.
(4) Steam pressure gauge indicating boiler pressure.
(5) Steam pressure gauge indicating yard distribution system.

(b). An instrument board for each boiler, located adjacent to the boiler as directed. Instruments on this board may include:

(1) CO_2 Recorder.
(2) Exit gas recording pyrometer.
(3) Indicating and integrating steam flow meter.
(4) Steam pressure gauge furnished under boiler trimmings.
(5) Draft gauge that will comply with the draft requirements by having the requisite number of pointers.

10. Draft Control

Control of each boiler should be obtained independently through its own uptake damper.

Arrange main stack damper for hand control with locking quadrant.

11. Test Openings

It is well to provide insertion points in breeching at stack for pyrometers for taking test temperatures.

12. Feed Water Heaters

Use feed water heaters of the deaerating type, operating at not less than 215° F., with a reserve storage capacity of not less than five minutes between overflow and cold water make up inlet.

13. <u>Condensate Receiving Tank</u>

In all cases a condensate receiving or surge tank should be used having a capacity of thirty-minute storage between overflow and automatic float controlling make-up water.

Where space conditions will not permit the use of a receiving tank, the feed water heater should have not less than twenty minutes storage capacity between the overflow and float valve make-up.

A cold water bypass should be arranged on the boiler feed pump suction, for the purposes of boiler wash, for reducing feed water temperatures, and for the operation of hydraulic tube cleaners. The pumps should be arranged to maintain feed water service to any boiler, while another boiler is being given hydraulic service.

14. <u>Boiler Feed Pumps for Central Plants</u>

With installed boiler horse power up to 400 H.P., two pumps are recommended.

With installed boiler horse power from 400 to 1200 H.P., three pumps are recommended.

With installed boiler horse power over 1200 H.P., special consideration should be given to the number of pumps.

No pump should have a capacity greater than 75 percent of the peak demand and all pumps should be steam driven.

When three or more pumps are installed, one should be sized to take care of the summer load when operating normally.

Valve all equipment furnished in duplicate so that either or both may be operated singly or together.

15. <u>Primary Pressure Reducing Valves</u>

Mount the primary pressure reducing valve assembly in a horizontal position, on one of the side walls, rather than in a horizontal position near a ceiling. Provide platforms for servicing.

Experience has shown that three or more pressure reducing valves, arranged so that one valve can take care of the entire hot water load in the summer, provide a more flexible installation. As a basis for calculation, the following may be used as a guide:

Assume a heating load of 12,520 pounds of steam per hour, a hot water load of 4,550 pounds of steam per hour, equal to 17,070 pounds of steam per hour plus 10 percent for line losses,--a total of 18,777 pounds of steam per hour.

The pressure reducing valve to take care of the hot water load should be adequate for 4,550 pounds of steam per hour, plus 10 percent line loss, --a total of 5,000 pounds of steam per hour.

Subtracting this from 18,777 pounds of steam per hour leaves 13,777 pounds per hour to be taken care of by two pressure reducing valves, one valve to take care of 75 percent of this and the other to take care of the balance.

By this arrangement, the valves may be opened or closed to meet the increase or decrease of the demand steam load. In no case should these valves be larger than 8 inches.

Protect all pressure reducing valve stations by a battery of pop safety valves having a capacity of 60 percent of the steam demand load.

B. The Group Plant

Group plants are usually preferable to individual building plants, although the latter may be practical for very large buildings. Design recommendations for group plants are generally applicable to individual building plants. Group plants should be located to allow economical interconnection to insure flexibility under mild weather and summer load operation.

Boilers in these plants should be of the portable fire box type sized at 100 percent of rated capacity. Each plant should have at least two boilers, with the capacity of each boiler not to exceed 12,000 square feet of direct radiation.

1. Piping at Group Boiler Plants

For single or two pipe gravity steam heating systems, equip boilers with regular Hartford loops, and valve so that any or all boilers may be operated or drained without interruption of service.

2. Boiler Feed Pumps for Group Plants

Whenever possible, arrange group plants carrying up to 15 pounds gauge pressure so that the vacuum pumps can discharge water of condensation directly to the boilers. Where this is impractical, use single stage motor driven boiler feed pumps.

3. Steam Outlets on Boilers for Group Plants

Equip steam outlet of each boiler carrying up to 15 pounds gauge pressure with one globe valve in each connection.

4. Motor Truck Scales

Where it is not possible to secure certified weights of coal deliveries, include motor truck scales of the beam type, installed in pits, if feasible.

The scales should have a capacity of not less than 70,000 pounds.

C. The Distribution Lines

The design of the heating distribution system should not be deferred until after the site plan has become set. Both the character and extent of the distribution system may be influenced by close cooperation between the heating engineer and the site planner from the beginning. Buildings arranged compactly will achieve economy in heating distribution. Where plenty of land is available, it is more economical to concentrate the area not needed for housing in a single large unit than to space the buildings widely over the entire site.

Underground steam and return distribution should be direct; design layouts to take care of expansion at the point of entrance into each building, where possible.

Reduce the number of steam drip traps, located in yard steam manholes to a minimum, and wherever possible provide for dripping yard steam mains by traps placed inside the nearest basement.

Where pipe expansion must be provided for underground lines, use welding fittings and straight pipe expansion bends, installed in minimum design non-accessible expansion chamber.

Underground piping should be installed in a simple type of conduit, consisting either of split-tile, built-up tile, pre-cast lightweight concrete with a continuous concrete base and gravel backing where required, sponge-felt asbestos pipe covering with integral waterproof jacket, or of a combination casing and covering conduit constructed of standard thickness 85 percent magnesia pipe covering without canvas wrap, sealed into an inner core by application of a uniformly thick layer of high melting point asphalt between the outer surface of the magnesia insulation and the outside metal jacket.

Any and all other types of conduit of equal or lesser cost should be given full consideration. All conduit installations should be specified to be substantially in accordance with the manufacturers' commercial standards.

D. Heating within the Buildings

1. Radiation and Risers

Supply and return risers: expose and arrange to serve two radiators on each floor wherever possible.

Arrange connections for both supply and return on same end of radiator, nearest to risers.

Install radiator supply and return branches above floor in fireproof floor construction.

Install radiator supply branches above floor, in wood joist floor construction, and return branches under flooring for stability. Floor joists may be notched near bearing for this purpose. All connections through floors, walls or partitions should have sleeves and escutcheons.

The amount of radiation for each radiator called for on the riser diagram or schedule should be the minimum required.

No radiator should be installed which does not provide at least the amount of radiation called for on riser diagram or schedule. This is to be based on the manufacturers' catalog ratings for cast iron, except that the sizes given may vary slightly to suit manufacturers' standards, provided the total radiation specified for any one individual dwelling unit is not decreased.

Wherever possible, used exposed risers for heating kitchens and bathrooms.

E. <u>Drying Room Heating</u>

Construct clothes drying rooms in groups adjacent to laundries, locate as close as practical to hot water generator rooms, and equip with unit heaters delivering 120° air and supplied either with steam or with hot water from the domestic hot water supply system.

When steam is used, the supply should be taken from the hot side of the zone control valve so that heat may be available during the summer season. When hot water is used, the unit heaters may be supplied from the basement hot water mains.

Drying rooms should have exhaust fans capable of exhausting at least six changes per hour.

When laundries are adjacent to drying rooms, the exhaust fans may get the majority of their supply through the laundries. Insulate the ceiling of all drying rooms to protect the rooms above from the heat of the drying rooms.

Consideration should be given to the installation of cabinet type drying units in lieu of drying rooms, as substantial reductions in cost of such equipment have recently been effected through redesign. This type of drier, using either gas or electricity, requires much less basement space, and substantially increases available laundry facilities through more rapid clothes drying.

List of Recommended Authorities

Heat Loss Calculations: latest edition of the American Society of Heating and Ventilating Engineers' Code of Minimum Requirements of Heat for Buildings.

As a matter of practical application the following inside temperatures may be figured:

Living quarters	70° F.
Sleeping quarters	67° F.
Kitchens	67° F.
Bathrooms	67° F.

The small sizes of rooms in USHA projects make possible the placement of radiators on inside walls rather than under the windows. This practice is recommended for all rooms except living rooms, where radiators may be placed under the windows. It permits a simplified system of steam and return piping in the basement and, as a result, economies in the cost of the installation.

Cast Iron Radiator Sizes: manufacturer's catalog ratings.

Because of the many variables involved in the calculation of heat losses through walls, ceilings, floors and glass, in localities where the design temperature is 0° F to 70° F the heat loss can be figured on the basis of +5° F of the design temperature to 65° F. However, the boiler size should be figured on the basis of a heat loss of 0° F to 70° F. This also applies to other design temperatures, for example locations where the design temperature is -20° F to 70° F. Here the boilers can be sized at this calculation of heat loss, and the radiation sized on the basis of -15° F to 65° F.

Non-Ferrous Convector Sizes: Convector Manufacturer's Certified Ratings.

Cast Iron Convector Sizes: certified condensate tests, plus the allowable additional capacity based on thermal head interpolations in accordance with the Convector Manufacturer's Certified rating method.

Boilers: latest Boiler Code of the American Society of Mechanical Engineers, the Steel Heating Boiler Institute, and the A.S.H.V.E. Standard Code for Rating Heating Plants.

Warm Air Heating Design: Investigations of Warm Air Furnaces and Heating Systems made by the University of Illinois in Cooperation with the National Warm-Air Heating Association.

Symbols: the A.S.H.V.E. and the American Standards Association.

See also A.S.H.V.E. "Code of Minimum Requirements of Heat for Building," and "Instructions for the Operation, Care and Repair of Boilers," Navy Department, Bureau of Engineering.

PART III - PREPARING THE CONTRACT DOCUMENTS

All heating plans and specifications should be in sufficient detail so that a minimum of shop drawings will be necessary.

A. The Working Drawings

Ample space should be provided for piping and particular care be taken to avoid structural interferences and conflicts between the different branches of the mechanical trades. Mechanical drawings should be generally diagrammatic, with all piping and equipment shown as nearly as possible in the location in which it is to be installed.

The use of a common trench for buried heating and hot water lines wherever possible should be encouraged.

Pipes should not be located in exterior walls where there is danger of freezing, unless proper protection is provided.

Pipe sleeves and openings should be shown on the structural or architectural drawings for all pipes passing through footings, masonry floors or exterior walls below grade. The elevations of sleeves need not be given except where passing through waterproofing finishes, which require special sleeve construction. In full basements there should be provided not less than 6'-3" clear head room under bottom of lowest pipe.

B. The Specifications: Materials

Piping:

Steam piping	steel copper bearing steel
Dry return piping	steel copper bearing steel
Wet condensate piping	wrought iron charcoal iron copper molybdenum extra strong steel
Boiler feed piping	extra heavy wrought iron " " charcoal " for high pressure boilers standard weight wrought iron " " charcoal " for low pressure boilers

Cast fittings: threaded or flanged cast iron or brass of cast iron steam pattern.

Welding fittings: wrought iron or copper molybdenum alloy may be used interchangeably for wrought iron or copper molybdenum pipe. Welding elbows should have a face to center dimension equal to not less than one and one half nominal diameters of the pipe to which they are connected. Other kinds of piping to have welding fittings of the same material as the pipe.

Pipe joints: in buildings: joints 1-1/4 inch and smaller, screwed; 1-1/2 inch to 6 inches inclusive, screwed or welded; 8 inches and larger, flanged or welded; underground: 1-1/2 inch and larger, welded.

Valves: 3/4 inch and smaller, globe valves; 1 inch and larger, generally gate valves; 2 inches and smaller, brass; 2-1/2 inches and larger, iron body brass mounted; 5 inches and smaller, screwed; 6 inches and larger, flanged.

Brass metal for globe valves should have a minimum copper content of 80 percent and a maximum lead content of 5-1/2 percent.

C. <u>Outline of a Typical Specification</u>

1. General note - covering general conditions, and other subdivisions of the specifications.
2. Correction of faulty materials and workmanship.
3. Work included, schedule of general requirements; work not included.
4. Drawings - schedule, correlation to specifications, and shop drawings.
5. Testing requirements, prior tests, inspections, guarantee.
6. Temporary heat requirements.
7. Removal of debris during and at completion of contract.
8. Coordination of work with other trades.
9. Permits, certificates of approval, etc.
10. Excavation and backfill, grades and elevations.
11. Description of installation and materials for heating system within building.
12. Description of installation and materials for heating system outside of building.
13. Description and installation of boilers; type, construction, capacity, meters, and controls.
14. Foundations, pits for boilers, and other concrete work for equipment.
15. Smoke breeching - dampers, supports.
16. Boiler trimmings and tools.
17. Refractory, sand, cement, lime, etc.
18. Chimney construction and draft available.
19. Oil burners.
20. Oil pumps - motors, controls, and description of piping.
21. Oil heaters, relief valves, oil tanks, meters.
22. Soot blowers, type and description.

23. Safety devices, for boilers, oil burners and water supply.
24. Exhaust heads.
25. Vacuum pumps, motors, controls.
26. Pressure reducing valves, strainers, safety valves.
27. System of heating controls.
28. Radiation.
29. Radiator valves, thermostatic traps, radiator hangers.
30. Heating supply mains.
31. Return mains - steam traps, combination float and thermostatic traps.
32. Pipe and fittings.
33. Joints.
34. Unions, gaskets, bolts and nuts.
35. Valves, escutcheons.
36. Metal U covers for pipes in fill.
37. Pipe nipples.
38. Open ends.
39. Pipe sleeves.
40. Trenches and covers.
41. Hangers, anchors-guides, inserts, etc.
42. Steam connections to hot water generators.
43. Expansion provisions.
44. Welding for pipe and fittings.
45. Insulation for boilers and other equipment.
46. Insulation for boiler room including hanging ceiling if necessary and ventilating equipment.
47. Painting.
48. Unit heaters, motors, controls.
49. Ventilating fans, motors, controls.
50. Exhaust fans, motors, controls.
51. Sheet metal work.
52. Grilles, registers.
53. Factory inspections.
54. Testing boilers, pumps, fans, etc.
55. Testing of piping within building.
56. Testing of underground distributions.
57. Special equipment, accessories.
58. Voltage and other characteristics of electrical service.

D. Steam Space Heaters

Include all necessary steam and return connections, thermostatic traps and shut-off valve, and an automatic controlled valve.

The heating element (of non-ferrous tubes and fins, with ferrous or non-ferrous headers) should be suitable for a steam working pressure of two pounds per square inch gauge with air entering at 67 degrees F. When operating at full speed and maximum capacity, the final temperature should not exceed 125 degrees; when operating at less than full speed and maximum capacities specified, the final temperature should be not less than 110 degrees F.

With the fan off, the space heater with the thermal head available should be capable of releasing approximately 25 percent of the total heat output. It should be of the blow through type with direct connected motor and fan assembly, consisting of one or more forward curved double inlet fans mounted on the extended shaft of a three speed motor. The motor must be quiet running regardless of the speed at which it operates.

Use standard air, measured at the inlet, for the cubic feet of air per minute to be recirculated through the space heaters.

Complete suggested specifications may be obtained upon application to the United States Housing Authority, Washington, D. C.

E. System of Heating Controls

The purpose of the heating control system is to provide a heating system in which the circulation of steam will be equalized either by an adjustable orifice made as an integral part of the radiator valve or as a properly sized removable regulating plate in each radiator valve assembly. Any other means may be used which will insure receipt of steam by all radiators at the same time, proportionately. The systems of zone control may be as follows:

1. Continuous Flow System

(a) Floating or throttling type.

(b) A valve which functions in progressive steps of opening and closing.

Description of Continuous Flow System.

(a) To be capable of circulating steam at variable sub-atmospheric steam pressures and steam temperatures by means of a floating or throttling type continuous flow electric or air operated control valve taking steam direct from supply at up to 15 pounds pressure above atmosphere.

(b) To be capable of controlling the quantity of steam supplied so as to heat the radiators fractionally to vary their heat output by means of a continuous flow electric or air operated control valve taking steam direct from supply at up to 15 pounds pressure above atmosphere.

Panel Boards.

(1) To be of the automatic type with heat balancer and selector or other suitable equipment.

(2) To be of the automatic type with outside thermostat and selector.

2. On and Off System

(a) A valve that is opened and closed periodically.

(b) A valve that functions to produce pulsating steam flow.

Description of On and Off System.

(a) To be capable of controlling automatically the quantity of steam supplied by intermittently opening and closing the control valve for fixed cycles during which the valve is opened, automatically selected by an outside thermostat, electric or air operated control valve taking steam from supply at up to 15 pounds pressure above atmosphere.

(b) To be capable of controlling automatically the quantity of steam supplied by intermittently opening and closing the control valve for periods of time with these periods automatically selected by a combination of outside and radiator temperatures or outside and inside temperatures, electric or air operated control valve taking steam from supply at up to 15 pounds above atmosphere.

Panel Boards for both (a) and (b) to be of the automatic type to synchronize the action of the several zones.

Manual Control should be provided to increase or decrease the heat flow variably, for producing continuous steam flow and for shutting off the steam flow entirely and provide means for automatically shutting off the steam flow when the outside temperature rises above 65 degrees F.

3. The Combination System will include the principal functions of both No. 1 and No. 2 described heretofore.

Requirements for all Systems.

Each of the above systems should be balanced to synchronize the action of the several zones so as to produce an even load curve on the boiler plant. Demonstration should show this when the steam flow varies less than 20 percent (10 percent above and 10 percent below the average demand) in an interval of 20 minutes.

Comments on all Three Systems: The heating system must be tight enough so that a 15" vacuum produced on a cold system will not be reduced to less than 10 inches within 60 minutes after the pump has been stopped.

The heating system must circulate noiselessly and each radiator must heat throughout to the trap with a pressure differential range of 2 inches to 6 inches of mercury between the steam supply and the return.

Furthermore the control system must be capable of preventing overheating within the range of temperature of 75 degrees to 68 degrees F.

Zone control valves should be located so that each valve will have about the same steam demand. The variation should not exceed 10 percent.

Risers: When exposed in rooms, should be considered as heating surface.

Supply and Return Mains: Should pitch down and be free of pockets, sags or lifts throughout their entire run.

Complete suggested specifications may be had upon application to the United States Housing Authority, Washington, D. C.

PART III - FUEL CONSUMPTION FORMULAE

1. Explanatory Note: E.D.R. (Equivalent Direct Radiation) as used herein is the total heating surface used for space heating, including ferrous or non-ferrous radiators or convectors - pipe coils - exposed risers - unit heaters, etc.; one square foot E.D.R. being equal to a heat emission of 240 B.T.U. per hour.

The following fuel formulae are based on a 24-hour day operation. Deductions in fuel estimates should be made for night-shut-down. This deduction should be proportionate to the number of hours the plant is inoperative.

2. STEAM HEATING.

(a) Base formula for coal used for space heating:

$$\frac{\text{E.D.R. x Fuel Factor x Annual Degree Days}}{\text{2000 x Efficiency}} = \text{Tons per year}$$

For efficiencies in central or group plants, the following are suggested:

60% - Hand Firing
65% - Stoker Fired (low pressure)
70% - Stoker Fired (high pressure)

Fuel Factor = Pounds of coal per square foot radiation per degree day for corresponding design temperature and 100 per cent efficiency. (See Table No. 1)

(b) Base formula for gas used for space heating:

$$\frac{\text{E.D.R. x Fuel Factor x Annual Degree Days}}{\text{1000 x Efficiency (Use 75\%)}} = \text{M. cu. ft. gas per year.}$$

Fuel Factor = Cu. Ft. gas per sq. ft. Radiation per degree day for corresponding design temperature and 100% efficiency. (See Table No. 2)

(c) Base formula for oil used for space heating:

$$\frac{\text{E.D.R. x Fuel Factor x Annual Degree Days}}{\text{Efficiency (Use 75\%)}} = \text{Gals. oil per year.}$$

Fuel Factor = Gals. oil per sq. ft. Radiation per degree day for corresponding design temperature and 100% efficiency. (See Table No. 3)

(d) For formula for estimating district steam consumption; see paragraphs 9 (a), (b) and (c).

(e) For all space heating estimates during continuous operation, 20% should be added to the fuel consumption if zone control is omitted where the design temperature is 0° or higher Fahrenheit, and 15% where the design temperature is less than 0° F. Twelve (12) per cent should then be added to the fuel consumption to compensate for line losses in high pressure central plants and ten (10) per cent in low pressure central or group plants.

(f) The same base formulae outlined hereinbefore can be applied to individual building and individual dwelling unit plants for space heating estimates. The individual building plants scheme can also include a boiler plant serving two or three small buildings. The following efficiencies are suggested:

Hand Firing, Bituminous Coal	- 44%
Hand Firing, Anthracite Coal	- 52%
Stoker Fired, Bituminous Coal	- 50%
Stoker Fired, Anthracite Coal	- 55%
Gas	- 70%
Oil	- 65%

(g) Five (5) per cent should then be added to the fuel consumption to compensate for line losses in individual building plants.

(h) The line loss percentages suggested herein should be used for preliminary calculations only.

3. HOT WATER HEATING.

(a) The E.D.R. should be transposed in terms of its equivalent in steam radiation. The base formulae including compensation for line losses and for omission of zone control or other regulation set forth in paragraph 2 can then be applied.

(b) Formula for transposing Hot Water E.D.R. to Steam E.D.R.

$$\frac{\text{E.D.R. (Hot Water)} \times \text{B.T.U. per sq.ft.(Hot Water)}}{240} = \text{E.D.R.(Steam)}$$

4. WARM AIR HEATING (Forced and Gravity)

(a) The B.T.U. loss per hour should be transposed in terms of its equivalent in steam equivalent direct radiation by dividing by 240 (see explanatory note paragraph 1). The base formulae as outlined in paragraph 2 can then be applied for the steam or hot water coiled forced warm air unit heater system, for the individually fired forced or gravity heater systems. In all cases compensation should be made for line losses, and for omission of zone control or other regulation.

5. (a) Examples of use of space heating formulae:

Assume 15,000 steam E.D.R. (Low Pressure - Control Plant - Zone Controlled)

5,000 Degree days (Annual)
-10° to 70° F. Design Range
12,000 B.T.U. per lb. of Coal
1,000 B.T.U. per cu. ft. of Gas
140,000 B.T.U. per gal. of Oil

(b) Coal

$$\frac{\text{15,000 E.D.R. x 5,000 D.D. x .007 (Fuel Factor from Table 1)}}{1300} = \text{404 Tons Coal Per Year.}$$

Plus 10% line losses - 404 + 40.4 = 444.4 Tons per year.

(c) Gas

$$\frac{\text{150,000 E.D.R. x 5,000 D.D. x .084 (Fuel Factor from Table 2)}}{750} = \text{8,400 M. Cu. Ft. Gas per year.}$$

Plus 10% for Line Losses - 8,400 + 840 = 9,240 M. Cu. Ft. per year.

(d) Oil

$$\frac{\text{15,000 E.D.R. x 5,000 D.D. x .0006 (Fuel Factor from Table 3)}}{75} = \text{60,000 Gals. oil per year.}$$

Plus 10% for Line Losses - 60,000 + 6,000 = 66,000 Gals. oil per year.

6. (a) Base formula for fuel used for domestic hot water heated through steam coiled generators. (No. of Dwelling units x 60 gals. per day x 1.1. lbs. steam per gallon x 365 days per year x 960 B.T.U. per lb. steam) all divided by B.T.U. per unit of fuel used x 0.50 (50% assumed efficiency) Units of Fuel used per year.

(b) Coal

$$\frac{\text{D.U. x 60 x 1.1 x 365 x 960}}{\text{B.T.U. per lb. coal x .50 x 2,000 lbs. per ton}} = \text{Tons Coal Per Year.}$$

or in simplified form

$$\frac{\text{D.U. x 23,127}}{\text{B.T.U. per lb. coal}} = \text{Tons coal per year}$$

(c) Gas

$$\frac{\text{D.U. x 60 x 1.1 x 365 x 960}}{\text{B.T.U. per cu. ft. gas x .50 x 1,000}} = \text{M. cu. ft. gas per year}$$

or in simplified form

$$\frac{\text{D.U. x 46,254}}{\text{B.T.U. per cu. ft. Gas}} = \text{M. cu. ft. gas per year}$$

(d) Oil

$$\frac{\text{D.U. x 60 x 1.1 x 365 x 960}}{\text{B.T.U. per gallon oil x .50}} = \text{Gals oil per year.}$$

or in simplified form

$$\frac{\text{D.U. x 46,254,000}}{\text{B.T.U. per gallon oil}} = \text{Gals oil per year.}$$

(e) For domestic hot water heating fuel consumption where underground heat distribution for this purpose is required, the same compensation for line losses may be applied as noted in paragraph 2 (e). No heat line losses need be figured where hot water generators are installed in boiler plant buildings.

(f) The daily gallon consumption and line loss percentages suggested herein should be used for preliminary calculations only.

(g) For formulae for estimating district steam consumption, see paragraph 9 (d), (e) and (f).

7. (a) Examples of use of domestic water heating formulae:

Assume 100 Dwelling Units (Central Plant)
12,000 B.T.U. per lb. coal
1,000 B.T.U. per cu. ft. gas
140,000 B.T.U. per gallon oil
H. W. Generators are in boiler plant (no heat line losses figured).

(b) Coal

$$\frac{100 \text{ x } 23{,}127}{12{,}000} = \text{192.8 Tons per year.}$$

(c) Gas

$$\frac{100 \text{ x } 46{,}254}{1{,}000} = \text{4625.4 M. cu.ft. gas per year.}$$

(d) Oil

$$\frac{100 \text{ x } 46{,}254{,}000}{140{,}000} = \text{33038 Gals oil per year.}$$

8. (a) Base formula for fuel used for domestic hot water heating through individual heaters (No. of Dwelling Units x 40 gallons per day

x 8-1/3 lbs. of water per gallon x 100° F. temperature rise x 365 days per year, all divided by B.T.U. per unit of fuel used x efficiency = Units of Fuel used per year. The water temperature rise is basic only. Initial water temperatures may vary dependent upon locality.

(b) Coal

$$\frac{\text{D.U. x 40 x 8-1/3 x 100 x 365}}{\text{B.T.U. per lb. coal x Eff. x 2,000}} = \text{Tons Coal per year.}$$

Use 35% Efficiency,
or in simplified form

$$\frac{\text{D.U. x 17,381}}{\text{B.T.U. per lb. coal}} = \text{Tons Coal per year.}$$

(c) Gas

$$\frac{\text{D.U. x 40 x 8-1/3 x 100 x 365}}{\text{B.T.U. per cu. ft. gas x Eff. x 1000}} = \text{M. cu. ft. gas per year}$$

Use 55% efficiency for flue type heater, or in simplified form

$$\frac{\text{D.U. x 22,120}}{\text{B.T.U. per cu. ft. gas}} = \text{M. cu. ft. gas per year.}$$

(d) Oil

$$\frac{\text{D.U. x 40 x 8-1/3 x 100 x 365}}{\text{B.T.U. per gallon oil x Eff.}} = \text{Gals. oil per year.}$$

Use 50% Efficiency

or in simplified form

$$\frac{\text{D.U. x 24,332,300}}{\text{B.T.U. per gallon oil}} = \text{Gals. oil per year.}$$

(e) Electricity

$$\frac{\text{D.U. x 40 x 8-1/3 x 100 x 365}}{\text{B.T.U. per KW hr. x Eff.}} = \text{KW Hrs. per year.}$$

Use 77% Efficiency; B.T.U. per KW Hr. = 3,412

or in simplified form

D.U. x 4,631 = K.W. Hrs. per year.

(f) The daily consumption suggested herein should be used for preliminary calculations only.

9. (a) Base formula for District Steam used for space heating:

$$\frac{\text{E.D.R. x 96 B.T.U. x monthly degree days x } 70^{\circ} \text{ Range}}{\text{960 B.T.U. x 1000 x Design Temp. Range}} = \text{M. lbs. steam}$$

for the particular month that the degree days are selected.

If no zone control is provided 20% should be added where the design temperature is 0° or higher Fahrenheit and 15% where the design temperature is less than 0° F. Twelve (12) per cent should be added for line losses, if these losses are to be absorbed by the project.

Note: The estimate for each month must be computed separately as District Steam Companies render bills monthly.

(b) Simplified Formula for District Steam (Space Heating)

$$\frac{\text{E.D.R. x monthly degree days x Factor (from table 4)}}{1000} = \text{M. lbs. steam per month}$$

Plus compensation for line losses and omission of zone control.

(c) The yearly total can be figured from this formula by substituting the annual degree days in lieu of the monthly degree days. Compensation for line losses and for omission of zone control should be made.

(d) Base Formula for District Steam used for domestic water heating.

$$\frac{\text{D.U. x 60 x 1.1 x 365}}{\text{12 x 1000}} = \text{M.lbs. steam per mo.}$$

The same line losses as applied to heating should be added where underground heat distribution for this purpose is required.

(e) Simplified formula for District Steam for domestic hot water.

D.U. x 2.007 = M. lbs. steam per month;
plus compensation for line losses.

(f) Simplified formula for District Steam for domestic hot water (Annual consumption).

D.U. x 24.084 = M. lbs. steam
plus compensation for line losses.

(g) Example: 604 D.U. 76,000 E.D.R. 0° - 70° Design Temp. Range - Zone Control - Hot water generators located in basement of certain buildings.

Space Heating - $\frac{76{,}000 \times \text{Degree Days} \times .1}{1000}$ = M. lbs. steam

where .1 = fuel factor

M. lbs steam = 7.6 x Degree days (see following degree day tabulation)

Plus 12% for line losses.

Domestic Hot Water = 604 D.U. x 2.007 = 1212.2

Plus 12% for line losses

10. Note: Origin of Constant 96 Used in Tables 1, 2 and 3.

"About 1926 a large number of actual fuel consumption figures (in cubic feet of gas per degree-day per square foot of steam radiation) was collected by gas utilities. These figures, averaged, were reduced to a figure (at 0° to 70° design conditions of 0.218 cu. ft. of 535 B.t.u. per cubic foot gas per square foot of steam radiation per degree-day, or, in other words, an input of 116.6 B.t.u. per sq. ft. of steam radiation per degree-day. Here was a figure which was actually obtained in the field and from which could be calculated a theoretical figure at 100% efficiency. It was assumed that these gas heating plants were operating at an overall efficiency of 82.5%, so that if the plants had been operating at an efficiency of 100% they would have required only 116.6 x 0.825 or 96 B.t.u. per sq. ft. of steam radiation per degree-day."

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Consequently the constant 96 B.T.U. per square foot of steam radiation per degree day is the basis of all fuel constants used in the following tables.

EXAMPLE FOR DEGREE DAYS TABULATION

1	2	3	4	5	6	7	8
			HEATING - M LBS. STEAM		DOM.H.W.-M LBS. STEAM		
MONTH	DEGREE DAYS	% TOTAL		COL.4 PLUS 12% LINE LOSSES		COL.6 PLUS 12% LINE LOSSES	TOTAL M LBS. STEAM COLS.5 PLUS 7
JANUARY	682	23.5	5,180	5,802	1,212	1,357	7,159
FEBRUARY	557	19.0	4,230	4,738	1,212	1,357	6,095
MARCH	388	13.5	2,950	3,304	1,212	1,357	4,661
APRIL	132	4.5	1,000	1,120	1,212	1,357	2,477
MAY					1,212	1,357	1,357
JUNE					1,212	1,357	1,357
JULY					1,212	1,357	1,357
AUGUST					1,212	1,357	1,357
SEPT.					1,212	1,357	1,357
OCT.	96	3.5	730	818	1,212	1,357	2,175
NOV.	396	13.5	3,000	3,360	1,212	1,357	4,717
DEC.	639	22.5	4,860	5,443	1,212	1,357	6,800
TOTAL	2,890	100.0	21,950	24,585	14,544	16,284	40,869

TABLE - 1

FUEL FACTOR TABLE

COAL PER SQ. FT. PER D.D. @ 100% EFF.

Coal or Coke	-20° F	-10° F	-5° F	0° F	+5° F	+10° F	+20° F
11,000 B.T.U.	.00678	.00764	.00813	.00872	.00938	.01018	.01222
11,500 B.T.U.	.00648	.0073	.0078	.00835	.00899	.00975	.0117
12,000 B.T.U.	.00622	.007	.00746	.008	.00862	.00933	.0112
12,500 B.T.U.	.00596	.00672	.00716	.00767	.00826	.00896	.01075
13,000 B.T.U.	.00574	.00646	.00689	.00738	.00795	.00862	.01034
13,500 B.T.U.	.00562	.00622	.00664	.00712	.00767	.0083	.00996
14,000 B.T.U.	.00532	.006	.00639	.00685	.00737	.0080	.0096
14,500 B.T.U.	.00514	.00578	.00617	.00662	.00712	.00772	.00926

TABLE - 2

CU. FT. GAS - PER SQ. FT. PER D.D. 100% EFF.

GAS	-20° F	-10° F	-5° F	0° F	+5° F	+10° F	+20° F
500 B.T.U.	.14933	.168	.179	.192	.2065	.224	.2688
1,000 B.T.U.	.07466	.084	.0896	.096	.1033	.112	.1344
1,040 B.T.U.	.07180	.08077	.0862	.0923	.0994	.10769	.12923

TABLE - 3

GAL. OIL - PER SQ. FT. PER D.D. 100% EFF.

OIL	-20° F	-10° F	-5° F	0° F	+5° F	+10° F	+20° F
140,000 B.T.U.	.000533	.0006	.00064	.0006857	.000737	.0008	.00096
148,000 B.T.U.	.000505	.000568	.000606	.000649	.0007	.000757	.0009081

TABLE - 4

POUNDS STEAM - PER SQ. FT. PER DEGREE DAY - 100% EFF.

	-20° F	-10° F	-5° F	0° F	+5° F	+10° F	+20° F
	.0778	.0875	.09334	.1	.1077	.11667	.14