A COMBUSTION HANDBOOK

FOR CANADIAN FUELS

VOLUME 3. COAL. PART 1

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CANADIAN COMBUSTION
RESEARCH LABORATORY

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FOREWORD

The Fuels Research Centre of the Mines Branch and its predecessor, the Fuels and Mining Practice Division, have collected over a period of more than sixty years analytical data on properties of Canadian fossil fuels. Concurrently, the Canadian Combustion Research Laboratory of the Fuels Research Centre, in carrying out numerous boiler acceptance tests, has prepared accurate data on combustion air requirements, flue gas volumes and boiler heat losses for many of these fuels. In addition, the laboratory has been active in research on many aspects of domestic, commercial and industrial combustion, and has contributed to recent technological advances relating to fireside corrosion and air pollution.

Having these analytical, calculated and research data and, furthermore, having access to data-processing computers, the laboratory undertook to prepare a handbook for the use of Canadian fuel-related industries. Each of the main fuels—coal, oil and gas—is dealt with in a separate volume and, for each fuel analysis, combustion and heat loss data are provided in simple, accurate charts. The use of these charts is illustrated by examples where appropriate. Recent information relating to fireside corrosion and air pollution is also provided.

The need for such a handbook has been demonstrated by the popularity of Volume 1/Fuel Oil, published in 1969, and Volume 2/Gaseous Fuels, published in 1973. Indeed, there have been many queries concerning the projected volume on coal, and we are pleased to respond with the publication of Volume 3/Coal. To meet the needs of Canadian users as far as possible, this volume includes data on more than two dozen U.S. coals.

It is not claimed that the three volumes of the handbook include every coal, oil or gas used in Canada, but it is planned to publish periodic addenda as omissions or new fuel sources are brought to the authors' attention. Thus, we request the cooperation of the users of the handbook in pointing out shortcomings.

D. F. Coates
Director, Mines Branch

Ottawa, May 1974

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1. INTRODUCTION

Those concerned with the utilization of fossil fuels have frequent need of combustion calculations. Air pollution authorities use them to establish the potential pollutant emissions of a particular fuel; designers and consulting engineers use them to size gas handling systems for fuel burning installations; boiler and burner manufacturers use them to design burners and furnaces and to select equipment for draft systems; and owners and operators of combustion equipment use them to determine efficiency of operation, with a view to conserving fuel. Often both the background information and facilities are inadequate to carry out complete sets of calculations for all the fuels that are likely to be encountered, and they are performed only on an individual basis, as specific problems arise. This introduces duplication and, because combustion calculations are inherently cumbersome, approximations and rules of thumb have been employed, often substantially affecting the accuracy of the results.

This combustion handbook was prepared by the staff of the Canadian Combustion Research Laboratory (CCRL). CCRL is in the unique position of possessing considerable experience in the application of combustion calculations, particularly to heating plant equipment and to pilot-scale research equipment, as well as having access to a wealth of fuel analyses.

The handbook attempts to include all fuels used in commercial quantities in Canada. The combustion data for each specific fuel are presented in the form of a set of easy-to-use graphs. These graphs show:

(a) The weight and volume of combustion air required and flue gas produced per unit of fuel for a range of temperature and excess air conditions.

(b) The heat losses resulting from combustion of the fuel for a range of conditions, calculated according to the American Society of Mechanical Engineers (ASME) Power Test Code.

(c) The theoretical concentrations of carbon dioxide, oxygen and sulphur dioxide in the flue gas.

Use of these graphs eliminates most of the laborious calculations usually associated with the design of a combustion system and the determination of its efficiency. Although the handbook has been aimed primarily at boiler combustion systems, its usefulness extends to many other systems where fossil fuels are consumed.

The handbook has been published in three volumes, one for fuel oils, one for gaseous fuels, and the present one for coals. In each volume, the graphs are preceded by a section giving instructions for their use, along with detailed examples. Also included is information common to all combustion analyses, such as a psychrometric chart and a chart showing boiler radiation loss.

This volume attempts to cover all the "commercially significant" coals used in Canada, both of native origin and those imported from the United States. The proximate and ultimate analyses and heating values of all the Canadian coals included in the handbook were determined by members of the Solid Fuels Analysis and Standardization Section, Hydrocarbon Group, Fuels Research Centre. The properties of the American coals were determined from Canadian users' analyses and from U.S. Bureau of Mines bulletins.

The term "commercially significant" is admittedly subjective. To provide the information most likely to be needed, and yet avoid an unwieldly volume of data, it was decided to include in the handbook those coals being mined at a rate greater than 25,000 tons per year. Thus, due to special situations or changing production rates, important coals may have been omitted. Therefore the authors are prepared to publish addenda as further needs are brought to their attention.

2. SCOPE OF THE HANDBOOK

As previously explained, for each coal used in commercial quantities in Canada this handbook offers a set of graphs giving combustion and heat loss data, using one pound of dry coal as the basic unit of fuel. The detailed method of calculation is given in Appendix A. Each set of graphs is preceded by a table giving the name, origin and size of the coal in question, its proximate and ultimate analyses on the dry basis, the typical range of moisture content, and conversion factors relating to the higher heating value.

The subject of heating value requires clarification. In North America, heating values of solid fuels are determined according to American Society for Testing Materials (ASTM) Standard Methods[1,2], which use a bomb calorimeter. Thus the combustion takes place under constant volume conditions, and any moisture in the combustion products is condensed. The result is called the *gross calorific value.* The ASTM method is convenient and gives reproducible results, but in a steam generator the fuel is burned under constant pressure conditions, not constant volume, and the calorific value will be different from the gross calorific value determined by the bomb calorimeter, because of changes in the internal energy of the combustion products. The ASME Power Test Code[3] accordingly specifies a calculation by which the gross calorific value is corrected for constant pressure conditions. The new value is called the *higher heating value* and this is what should be used in the ASME heat loss and efficiency calculations. However, the correction is small, usually well below the limits of accuracy for the bomb calorimeter determination, and the correction can only be made if the hydrogen content of the fuel has been established by ultimate analysis. For convenience and simplicity, this handbook follows the rather common practice of using the gross calorific value in place of the higher heating value.

The organization of the coals in the handbook also bears some explanation. Traditionally, coals have been identified by means such as the name of the mine, or the name of the mining company and the pit number, or the name of the seam from which the coal was taken, or a geographic place name in the mining area. To this is commonly added a size designation, which may be a subjective description such as "stove size", or a precise description of a screen fraction such as "1 1/2 in. round x 1/2 in. square". A petrographic classification may also be given, e.g. "high-volatile A bituminous", and a variety of other properties may be indicated by terms such as "strongly caking", "free burning", "low ash fusion", etc. This is all very confusing to the uninitiated, but it reflects the fact that coal is a highly heterogeneous material, and in spite of the many analytical procedures which have been developed over the past 75 years, we still cannot predict the combustion performance of coals with complete reliability.

This handbook does not attempt to advise on the selection of coals for particular applications. It simply provides the detailed combustion and heat loss data that are required once a selection has been made. Nor is there an attempt to improve the confusing system of identification described above. However, for convenience, the various coals have been organized according to province or state of origin, and the various products under each coal name have been grouped together. Thus, each chart bears alphanumeric identifier (e.g., NS 3-2) of which the letters indicate the province or state of origin, according to the following list:

NS:	Nova Scotia	USK:	Kentucky
NB:	New Brunswick	USO:	Ohio
O:	Ontario	USP:	Pennsylvania
S:	Saskatchewan	USV:	Virginia
ABC:	Alberta and British Columbia	USWV:	West Virginia

The first number in the identifier represents a particular coal name or company, such as Dominion or Forestburg, and the order is in no way a reflection of quality. The second number in the identifier designates different sizes of the same coal. The complete list of coals dealt with in this handbook is given in the Table of Contents.

Because of the approach of metrication, some thought was given to publishing this handbook in dual units. However, this would have led to cumbersome and confusing graphs. Furthermore, the issue of which metric units we will ultimately use is not yet completely settled.

It was concluded that for the immediate future, at least, the handbook would be more useful in English units, and a metric version will be prepared when the need arises. For convenience, however, Système International (S.I.) units are summarized in Table 1 and metric conversion factors are given in Table 2.

3. EXPLANATION OF COMBUSTION DATA GRAPHS

3.1 Explanation of Figure 1

In each set of graphs, Figure 1 shows the weight of combustion air required, along with the weights of dry and total flue gas produced, for the combustion of one pound of dry coal versus the per cent of total combustion air. Total combustion air is defined as the per cent of air relative to stoichiometric conditions, or the per cent excess air plus 100. Flue gas analysis may be related to total combustion air by either the carbon dioxide (CO_2) curve or the oxygen (O_2) curve.

Combustion calculations for coal are complicated by its variable moisture content. One way to deal with it is to assume an average moisture content for the calculations. Another is to base the calculations on dry coal, and make corrections for the actual moisture level. The latter method, albeit more involved, is more accurate and was therefore chosen for this handbook. Thus, although the graphs are based on dry coal, the moisture in the coal is frequently a significant factor. As a rough rule of thumb, percentage error in uncorrected total flue gas volumes will be low by about one-fifth of the coal moisture expressed as a percentage. Thus, for accuracy within 1 per cent, corrections should be made for moisture contents of 5 per cent or more. The examples showing how this is done should be studied carefully.

The graphs also neglect random variations in the moisture content of the combustion air. The effect is usually less than 1 per cent, and therefore is not very significant. However, corrections for moisture in the air can be applied, if desired, as shown in Section 3.4.

It is important that the terms "dry flue gas" and "total flue gas", as they are used in this handbook, be clearly understood. *Dry flue gas* represents the moisture-free components of the flue gas, i.e. CO_2, O_2, N_2, SO_2, etc. *Total flue gas* represents the preceding components plus the moisture resulting from the combustion of hydrogen in the coal. However, total flue gas does *not* include coal moisture or moisture in the combustion air.

3.2 Explanation of Figure 2

This graph shows the volumes, at different temperatures, of the dry combustion air required and the total flue gas produced, along with the dry flue gas at 32°F produced when one pound of dry coal is burned, plotted against total combustion air. The volumes shown are for a standard pressure of 29.92 inches of mercury. Corrections for other pressures may be made by applying a correction factor from Figure A, as has been done in Example 1, or simply by applying the Perfect Gas Law, $\frac{PV}{T}$ = constant, taking care to use absolute temperatures (i.e., °R = °F + 460).

To obtain the wet flue gas volume produced when one pound of wet coal is burned, corrections must be made for the moisture in the coal and, if high accuracy is required, for the moisture in the combustion air.

3.3 Direct Application of Combustion Data

For designers of combustion equipment, this handbook provides a rapid method of sizing forced-draft and induced-draft

TABLE 1

Summary of Système International (S.I.) Units

The Basic Units

		symbol	*French*
Length	metre	m	mètre
Mass	kilogram	kg	kilogramme
Time	second	s	seconde
Electric current	ampere	A	ampère
Thermodynamic temperature	kelvin	K	kelvin
Luminous intensity	candela	cd	candela

The Supplementary Units

Plane angle	radian	rad	radian
Solid angle	steradian	sr	stéradian

The Preferred Prefixes

	symbol	*meaning*	*origin*	
tera-	T	10^{12}	Greek	teras
giga-	G	10^{9}	”	gigas
mega-	M	10^{6}	”	megas
kilo-	k	10^{3}	”	kilioi
milli-	m	10^{-3}	Latin	mille
micro-	μ	10^{-6}	Greek	mikros
nano-	n	10^{-9}	Latin	nanus
pico-	p	10^{-12}	”	pico
femto-	f	10^{-15}	Danish	femten
atto-	a	10^{-18}	”	atten

Derived Units without Special Names (selection only)

Area	m^2
Volume	m^3
Velocity	m/s
Acceleration	m/s^2
Density	kg/m^3
Volume flow rate	m^3/s
Surface tension	N/m
Dynamic viscosity	Pa•s
Kinematic viscosity	m^2/s
Electric resistivity	Ω•m
Electric conductivity	S/m
Electric field strength	V/m
Magnetic field strength	A/m
Magnetic permeability	H/m
Specific heat	J/(kg•K)
Thermal conductivity	W/(m•K)
Luminance	cd/m^2

Derived Units with Special Names

		symbol	*dérivation*
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$kg{\cdot}m/s^2$
Pressure	pascal	Pa	N/m^2
Energy	joule	J	N•m
Power	watt	W	J/s
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Electric conductance	siemens	S	Ω^{-1}
Electric charge	coulomb	C	A•s
Capacitance	farad	F	C/V
Magnetic flux	weber	Wb	V•s
Magnetic flux density	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd•sr
Illumination	lux	lx	lm/m^2
Temperature	degree Celsius	°C	K – 273,15

Units which deviate from strict S.I. principles:

Pressure	bar	bar	10^5 Pa
Volume (for liquids and gases)	litre	*l*	dm^3

TABLE 2

English to Metric Conversion Factors

	from:	*to:*	*multiply by:*	*reciprocal:*
length	inch	mm	25,4	0,039 37
	inch	cm	2,54	0,393 70
	ft.	m	0,304 8	3,280 84
	yd.	m	0,914 4	1,093 61
	mile	km	1,609 34	0,621 37
	int. naut. mile	km	1,852	0,539 96
	micron	µm	1	1
	millimicron	nm	1	1
	angstrom	nm	0,1	10
	x-unit	pm	0,1	10
area	sq. inch	cm^2	6,451 6	1,155 00
	sq. ft.	m^2	0,092 90	10,763 91
	sq. yd.	m^2	0,836 13	1,195 99
	acre	ha	0,404 69	2,471 05
	sq. mile	km^2	2,589 99	0,386 10
volume	cu. inch	cm^3	16,387 06	0,061 02
	cu. ft.	m^3	0,028 32	35,314 67
	cu. yd.	m^3	0,764 55	1,307 95
	register ton	m^3	2,831 68	0,353 15
	acre-ft.	m^3	1233,482	8,107 x 10^{-4}
capacity *Imp. measure*	minim	*ml*	0,059 19	16,893 60
	fluid oz.	*ml*	28,413 06	0,035 20
	pint	*l*	0,568 26	1,795 75
	quart	*l*	1,136 52	0,879 88
	gallon	*l*	4,546 09	0,219 97
	bushel	h*l*	0,363 69	2,749 62
weight or mass	grain	mg	64,798 91	0,015 43
	dram	g	1,771 84	0,564 38
avoirdupois	oz.	g	28,349 52	0,035 27
avoirdupois	lb.	kg	0,453 59	2,204 62
short	cwt.	kg	45,359 24	0,022 05
short	ton	t (metric)	0,907 18	1,102 31
troy or apothecary	oz.	g	31,103 48	0,032 15
troy or apothecary	lb.	kg	0,373 24	2,679 23
frequency	cps	Hz	1	1
velocity	ips	m/s	0,025 4	39,370 1
	fps	m/s	0,304 8	3,280 84
	fpm	m/s	0,005 08	196,850
	mph	m/s	0,447 04	2,236 94
	mph	km/h	1,609 34	0,621 37
acceleration	in/s^2	m/s^2	0,025 4	39,370 1
	ft/s^2	m/s^2	0,304 8	3,280 84
magnetic flux	maxwell	weber (Wb)	10^{-8}	10^{8}
	maxwell	nanoweber (n Wb)	10	0,1
mag, flux density	gauss	tesla (T)	10^{-4}	10^{4}
	gauss	mT	0,1	10

	from:	*to:*	*multiply by:*	*reciprocal:*
force	ounce-force	N	0,278 01	3,596 94
	pound-force	N	4,448 22	0,224 81
	kip	kN	4,448 22	0,224 81
	poundal	N	0,138 25	7,233 01
	dyne	µN	10	0,1
	kilogram-force (kp)	N	9,806 65	0,101 97
pressure	psi	kPa	6,894 76	0,145 04
	pound-force/ft.^{2}	Pa	47,880 26	0,020 89
	ksi	MPa	6,894 76	0,148 04
	short ton-force/in.^{2}	MPa	13,789 49	0,072 52
	kp/m^2	Pa	9,806 65	0,101 97
	kp/cm^2 technical at.	kPa	98,066 5	0,010 20
	dyn/cm^2	Pa	0,1	10
	bar	Pa	10^{5}	10^{-5}
hydrostatic units	mm of mercury (torr)	mbar	1,333 22	0,750 06
	normal atmosphere	bar	1,013 25	0,986 92
	inches of mercury	mbar	33,863 9	29,530 0
	mm of water (4° C)	Pa	9,806 65	0,101 97
	in. of water (conv.)	mbar	2,490 89	0,401 46
energy	ft.-lb.-force	J	1,355 82	0,737 56
	Btu (int.)	kJ	1,055 06	0,947 82
	therm	MJ	105,506	9,478 x 10^{-3}
	horsepower-hour	MJ	2,684 52	0,372 51
	calorie (int)	J	4,186 8	0,238 85
	erg	J	0,1	10
	kgf-m	J	9,806 65	0,101 97
	kWh	MJ	3,6	0,277 78
	watt-hour	kJ	3,6	0,277 78
	electron-volt	aJ	0,160 21	6,242
power	Btu/h (int.)	W	0,239 07	3,412 14
	Btu/s (int.)	kW	1,055 06	0,947 82
	ft.-pound-force/h	mW	0,376 62	2,655 22
	HP metric	kW	0,735 50	1,359 62
	HP electr.	kW	0,746	1,340 48
	HP mech. (UK)	kW	0,745 70	1,341 02
	HP boiler	kW	9,809 5	0,101 94
	kp m/s	W	9,806 65	0,101 97
conductance	mho	siemens (s)	1	1

fans, without having to carry out the tedious calculations usually required. In sizing fans, good engineering practice requires that a safety margin be added to the calculated requirements. Commonly accepted values are 15 per cent on volume and 30 per cent on pressure, although more liberal values are sometimes used. Figures 1 and 2 will yield only the calculated requirements. To remind the designer to apply a safety margin, in the examples the notation "plus margin" has been added to the results obtained from the graphs.

Example 1 – Fan Sizing with Corrections for Coal Moisture and Elevation

A pulverized-coal-fired boiler is being designed to burn 12 tons per hour of -3/8 in. coal from the Forestburg Collieries in Alberta. The as-received moisture is assumed to be 25%. It is also assumed that the flue gas temperature will be 300°F, the CO_2 concentration in the flue gas will be 13.6%, and the average air temperature at the inlet to the forced-draft fan will be 60°F. It is desired to find the capacities in pounds per hour and in cubic feet per minute (cfm) of (a) the forced-draft fan and (b) the induced-draft fan. Values are required for both sea level and an elevation of 3000 ft above sea level.

Solution

The graphs for -3/8 in. coal from Forestburg Collieries are found in Set ABC 9-2. Because of the coal moisture, the fuel input to the boiler actually consists of

dry coal = 12 x 2000 x 0.75 = 18,000 lb/hr
moisture = 12 x 2000 x 0.25 = 6,000 lb/hr
= 0.333 lb/lb dry coal

It must be kept in mind that the forced-draft fan does not have to handle the coal moisture, but the induced-draft fan does.

(a) *Forced-Draft Fan*

From Figure 1 or Figure 2, at 13.6% CO_2,
total combustion air (TCA) . . . . = 140%

From Figure 1, at 140% TCA,
wt of dry air per lb dry coal . . . . = 12.1 lb

From Figure 2, at 60°F and 140% TCA,
vol of dry air per lb dry coal . . . . = 158 cu ft

Req'd capacity of forced-draft fan at sea level

$= 12.1 \times 18{,}000 = \underline{217{,}800 \text{ lb/hr}}$ plus margin

$= \dfrac{158 \times 18{,}000}{60} = \underline{47{,}400 \text{ cfm at } 60^\circ\text{F and } 29.92 \text{ in. Hg}}$ plus margin

At 3000 ft above sea level, the required weight is unchanged, but the required volume increases.

From Figure A (p. 25), 3000 ft above sea level is equivalent to about 26.8 in. Hg, and a correction factor of $\dfrac{29.92}{26.8}$ or 1.116 must be applied to the volume.

Req'd capacity of forced-draft fan
= 47,400 x 1.116 = $\underline{52{,}900 \text{ cfm at } 60^\circ\text{F and } 26.8 \text{ in. Hg}}$ plus margin

(b) *Induced-Draft Fan*

From Figure 1, at 140% TCA,
wt of total flue gas per lb dry coal . . . . = 13.0 lb

From Figure 2, at 300°F and 140% TCA,
vol of total flue gas per lb dry coal . . . . = 240 cu ft

From Input calculation, 12 tons coal at 25% moisture,
moisture per lb dry coal . . . . = 0.333 lb

From Figure B (p. 26), at 300°F,
vol of 1 lb of water vapour . . . . = 30.5 cu ft
vol of water vapour per lb dry coal
= 30.5 x 0.333 = 10.16 cu ft

Req'd capacity of induced-draft fan at sea level

$= (13.0 + 0.333) \times 18{,}000 = \underline{240{,}000 \text{ lb/hr}}$ plus margin

$= \dfrac{(240 + 10.16) \times 18{,}000}{60} = \underline{75{,}050 \text{ cfm at } 300^\circ\text{F and } 29.92 \text{ in. Hg}}$ plus margin

The flue gas volume is corrected for altitude in the same way as the combustion air volume.

Req'd capacity of forced-draft fan
= 75,050 x 1.116 = $\underline{83{,}750 \text{ cfm at } 60^\circ\text{F and } 26.8 \text{ in. Hg}}$ plus margin

Example 2 – Fan Sizing With Correction for Coal Moisture

An existing stoker-fired boiler is to be fired with Old Sydney 3/4 in. x 1/4 in. coal. A maximum fuel input of 40 million Btu/hr is required. It is expected that the maximum coal moisture will be 8%. The flue gas temperature at full load is 500°F, and combustion air is drawn from the boiler room at 80°F. The forced-draft fan has a capacity of 12,000 cfm at 80°F and 29.92 in. Hg. The induced-draft fan has a capacity of 18,000 cfm at 500°F and 29.92 in. Hg. Are these fans adequate for the maximum load and the maximum moisture, if excess air is to be at least 35%?

Solution

The graphs for Old Syndey 3/4 in. x 1/4 in. coal are found in Set NS 6-2. Note that fuel input is given as Btu required, rather than as the weight of as-fired coal. It is therefore necessary to calculate the weight of dry coal required, and then calculate the additional weight due to the coal moisture. From the data sheet preceding the set of graphs,

Calorific Value = 14,640 Btu/lb dry coal

$$\text{Maximum firing rate of dry coal} = \frac{40{,}000{,}000}{14{,}640} = 2732 \text{ lb/hr}$$

$$\text{Associated coal moisture at } 8\% = \frac{0.08}{0.92}(2732) = 238 \text{ lb/hr}$$

(a) *Forced-Draft Fan*

From Figure 2, at 80°F and 135% TCA,
vol of dry air per lb dry coal . . . . = 204 cu ft

Req'd capacity of forced-draft fan at sea level

$$= \frac{204 \times 2732}{60} = \underline{9290 \text{ cfm}} \text{ plus margin}$$

(b) *Induced-Draft Fan*

From Figure 2, at 500°F and 135% TCA,
vol of total flue gas per lb dry coal . . . . = 376 cu ft

From Figure B (p. 26), at 500°F,
vol of 1 lb of water vapour . . . . = 38.8 cu ft

Req'd capacity of induced-draft fan, assuming dry fuel,

$$= \frac{376 \times 2732}{60} = \underline{17{,}120 \text{ cfm at } 500°\text{F and } 29.92 \text{ in. Hg}} \text{ plus margin}$$

Req'd capacity of induced-draft fan, assuming a maximum fuel moisture of 8%,

$$= 17{,}120 + \frac{238 \times 38.8}{60} = \underline{17{,}274 \text{ cfm at } 500°\text{F and } 29.92 \text{ in. Hg}} \text{ plus margin}$$

The following conclusions can be drawn:

1. The forced-draft fan has sufficient capacity, and the safety margin is $\frac{12{,}000\text{-}9280}{9280} \times 100 = 29.3\%$
2. The induced-draft fan has sufficient capacity, but the safety margin is only $\frac{18{,}000\text{-}17{,}274}{17{,}274} \times 100 = 4.2\%$

This means that excess air must be carefully controlled at full load.

3. The maximum expected coal moisture of 8% increases the load on the induced-draft fan by
$\frac{17{,}274\text{-}17{,}120}{17{,}120} \times 100 = 0.90\%$

Example 3 – Effect of Excess Air on Flue Gas Volume

A stoker-fired boiler is fired with Cascade (Canmore) 1 1/4 in. x 1/2 in. coal having 4% moisture as fired. It normally operates with 9% O_2 in the flue gas and a stack temperature of 480°F. If the excess air is reduced to give 5.5% O_2 in the flue gas, and this results in a 30°F drop in the stack temperature, what will be the reduction in the volume of the flue gas?

Solution

The graphs for Cascade 1 1/4 in. x 1/2 in. coal are found in Set ABC 1-1. The coal moisture is low enough that it can be ignored for calculations not requiring high accuracy. In this case, the problem is one of finding a difference in volume due to excess air and temperature, with fuel moisture constant. Therefore even a high fuel moisture would have only a small effect. Atmospheric pressure can be ignored for the same reason.

From Figure 2, 9% O_2 corresponds to 174% TCA.

From Figure 2, 5.5% O_2 corresponds to 135% TCA.

From Figure 2, at 480°F and 174% TCA,
vol of total flue gas per lb dry coal . . . . = 465 cu ft

From Figure 2, at 450°F (480°-30°) and 135% TCA,
vol of total flue gas per lb dry coal . . . . = 350 cu ft

Reduction in volume of flue gas

= 465-350 = <u>115 cu ft/lb dry coal</u>

$$= \frac{115}{465} \times 100 = \underline{24.7\%}$$

3.4 Correction for Moisture in the Combustion Air

Moisture in the combustion air increases the weight and volume of gas handled by the systems for the combustion air and the flue gas. Unless the weight of moisture exceeds 70 grains per pound of dry air, it may be neglected without introducing an error greater than 1 per cent. If it is decided to apply a correction, the relative humidity of the combustion air must be determined using a sling psychrometer, after which the weight of moisture can be determined from tables or from a psychrometric chart, as shown in Example 4. It should be pointed out that the psychrometric chart in this handbook has been drawn for a pressure of 29.92 in. Hg, and becomes progressively less accurate as atmospheric pressure deviates from that point. However, the inaccuracy should not be significant unless the pressure deviation is substantial or a high degree of accuracy is required. In such cases the weight of moisture per pound of air may be calculated using Carrier's formulae.[4]

Example 4 – Correction for Moisture in Air

For the case given in Example 1, correct the weights and volumes of combustion air and flue gas when the combustion air has a relative humidity of 70% under standard atmospheric pressure.

Solution

(a) *Forced-Draft Fan*

From Example 1, at standard atmospheric pressure (sea level), req'd capacity of forced-draft fan, dry air basis

= 217,800 lb/hr
= 47,400 cfm at 60°F and 29.92 in. Hg

From the psychrometric chart, at 60°F and 70% relative humidity (RH),
wt of moisture per lb of dry air = 0.00775 lb
specific vol (cu ft per lb of dry air) = 13.25 cu ft

From the psychrometric chart, at 60°F and 0% RH,
specific vol (cu ft per lb of dry air) = 13.09 cu ft

Req'd capacity of forced-draft fan, moist air basis,

$$= 217{,}800 \times 1.00775 = \underline{219{,}500 \text{ lb/hr}} \text{ plus margin}$$

$$= 47{,}400 \times \frac{13.25}{13.09} = \underline{47{,}980 \text{ cfm at } 60°\text{F and } 29.92 \text{ in. Hg}} \text{ plus margin}$$

(b) *Induced-Draft Fan*

The moisture in the combustion air which is handled by the forced-draft fan must also be handled by the induced-draft fan. Therefore, the weight of flue gas will increase by the same amount as the weight of combustion air. However, the increase in volume will be different because the flue gas is at a different temperature than the combustion air.

From Example 1, at standard atmospheric pressure, req'd capacity of induced-draft fan, dry air basis,

= 240,000 lb/hr
= 75,050 cfm at 300°F and 29.92 in. Hg

From Figure B (p. 26), at 300°F,
vol of 1 lb of water vapour = 30.5 cu ft

From Example 4, part (a),
wt of moisture in combustion air = 219,500-217,800
= 1700 lb/hr

Req'd capacity of induced-draft fan, moist air basis,

$$= 240{,}000 + 1700 = \underline{241{,}700 \text{ lb/hr}} \text{ plus margin}$$

$$= 75{,}050 + \left(\frac{1700 \times 30.5}{60}\right) = \underline{75{,}910 \text{ cfm at } 300°\text{F and } 29.92 \text{ in. Hg}} \text{ plus margin}$$

4. EXPLANATION OF HEAT LOSS GRAPHS

4.1 Explanation of Figure 3

In each set of graphs, Figure 3 shows the heat loss, in per cent of fuel input, represented by the sensible heat in the dry flue gas leaving the system. This loss is dependent on the excess air level and the temperature of the flue gas above the combustion air temperature. Hence, heat loss has been plotted against total combustion air for a range of temperature differentials. CO_2 and O_2 curves have been included to conveniently relate flue gas analysis to combustion air. A curve giving the per cent by volume of SO_2 in the flue gas as a function of the combustion air has also been included.

4.2 Explanation of Figure 4

Figure 4 shows the heat loss, in per cent of fuel input, due to the moisture in the coal. Heat is required to raise the fuel moisture to boiling temperature, evaporate it, and superheat the vapour to the final flue gas temperature. Thus the loss is dependent upon the fuel temperature, the moisture content of the fuel, and the stack temperature. The heat loss is found from Figure 4 in the following way:

1. Find the appropriate fuel temperature on the lower part of the side margin.
2. From this point, move horizontally to the appropriate fuel moisture line.
3. Then move vertically upward to the appropriate stack temperature line.
4. Finally, move horizontally to the left margin and read off the heat loss.

Example 5 – Heat Loss Due to Coal Moisture

Estevan lignite, 2 in. x 1/8 in., produced by the Battle River Coal Company, is burned on a travelling-grate stoker. The initial fuel temperature is 60°F and the flue gas temperature is 500°F. What is the heat loss due to coal moisture when the as-fired moisture is 35%?

Solution

The coal in question is represented by Set S 1-3.

From Figure 4, at fuel temp. of 60°F, fuel moisture of 35%, and stack temp. of 500°F,
heat loss due to coal moisture = 6.07%

4.3 Explanation of Figure 5

Figure 5 shows the heat loss, as a per cent of fuel input, due to moisture in the flue gas formed from the combustion of hydrogen in the coal. Since it is North American practice to use the higher heating values, this loss comprises the heat necessary to evaporate the moisture from hydrogen, and superheat it to the stack temperature. Hence, for a fixed hydrogen content in the fuel, the loss depends upon both the stack temperature and the combustion air temperature. It is commonly called the "hydrogen loss".

4.4 Explanation of Figure 6

Figure 6 gives the heat loss, in per cent of fuel input, versus per cent combustible in the refuse. It is assumed that the unburned combustible is entirely carbon, and has a heating value of 14,500 Btu/lb. Thus, for a particular coal, the loss is only dependent upon the per cent of unburned combustible in the refuse and this percentage must be determined by an ash analysis.

Figure 6 can be used directly for combustion systems having only one major ash collection point, such as the grate ash from under-feed stokers or the fly ash from pulverized-fired systems. However, many systems have two or more major ash collection points, and the amount of unburned combustible may be different in each. In that case each ash stream should be weighed, and the values from Figure 6 should be prorated, as shown in Example 6.

Example 6 – Heat Loss Due to Unburned Combustible, Calculated for Two Ash Streams

A spreader-fired travelling grate burns Dominion-St. Lawrence Mix, 1 1/4 in. x 0, coal. At the end of a combustion test, 400 lb of ash are removed from the ashpit, and 120 lb of ash are removed from the dust collector hopper. Subsequently, analysis shows that unburned "combustible" in the grate ash is 9%, and in the fly ash is 28%. What is the total loss due to unburned combustible?

Solution

The coal in question is represented by Set NS 3-1. The heat loss in each ash stream must be prorated on the basis of pure ash content, but the "ash" removed from the boiler and weighed is really a mixture of ash and unburned combustible. Therefore corrections must be made to obtain the weight of pure ash.

Wt of pure ash removed from grate

$$= 400 \times \frac{(100\text{-}9)}{100} = 364 \text{ lb}$$

Wt of pure ash removed from dust collector hopper

$$= 120 \times \frac{(100\text{-}28)}{100} = 86.4 \text{ lb}$$

Total wt of pure ash $= 364 + 86.4 = 450.4$ lb

From Figure 6,
loss at 9% combustible = 0.9%
loss at 28% combustible = 3.4%

Heat loss due to unburned combustible,

in grate ash $= 0.9 \times \frac{364}{450.4} = 0.73\%$

in fly ash $= 3.4 \times \frac{86.4}{450.4} = 0.65\%$

Total $= \underline{1.38\%}$

4.5 Explanation of Figure 7

Figure 7 shows the heat loss, in per cent of fuel input, due to carbon monoxide in the flue gas resulting from incomplete combustion. This loss increases with increasing CO concentration and with decreasing CO_2 concentration. That is, for a given CO concentration, the loss is higher if excess air is present. However, with modern firing systems, properly operated, combustion should be complete unless the excess air is less than 10 per cent. Therefore, Figure 7 has been simplified by considering only the case where there is negligible excess air. For a given CO concentration, if the excess air level were actually 5 per cent instead of 0 per cent, the error resulting from the use of Figure 7 would be about 2 per cent of the indicated heat loss.

4.6 Heat Loss Due to Radiation and Convection from the Boiler

This loss can be fairly significant, particularly for small boilers, but it is difficult to determine accurately. To do so involves establishing the area and emissivity of all surfaces exposed to ambient air, their temperature above ambient, and the air velocity over them. However, a convenient and widely accepted method of approximating this loss is provided by Figure C (p. 28), the standard Radiation Loss Chart published by the American Boiler Manufacturers' Association (ABMA). This chart assumes a temperature differential of 50°F between surface and ambient, an air velocity of 100 feet per minute (fpm) over the surface and an emissivity of 0.95. Its accuracy increases with the size of the boiler in question. The chart takes into account the number of water-cooled walls in the generator, because water-cooled walls have a lower temperature and hence a lower radiation loss than do refractory walls. Most modern watertube boilers have three or four water-cooled walls, and package firetube scotch-type boilers may be treated as having four such walls.

The heat losses obtained using the ABMA chart can be corrected for higher air velocities and higher surface-to-ambient temperature differentials using the correction factors given in Figure D (p. 29). This involves establishing the average boiler casing temperature, preferably with a contact thermometer, measuring the ambient air temperature, and measuring the air velocity over the boiler casing by a vane anemometer or other such instrument. This procedure is demonstrated in Example 10.

4.7 Other Heat Losses

To determine efficiency, this handbook applies the ASME Indirect Method, otherwise called the heat loss method, whereby the heat losses are measured in terms of per cent of fuel input. For a complete discussion of boiler heat losses the reader is referred to the ASME Power Test Code for Steam Generating Units.[3]

In addition to those just discussed, coal-fired systems may have several other heat losses, whose importance will vary with the system. Some of these are given below.

4.7.1 Heat Loss Due to Moisture in the Combustion Air

The moisture in the air is already in vapour phase, but it must be heated from the combustion air temperature to the stack temperature. Therefore the loss depends upon the weight of moisture per pound of air, the weight of air per pound of fuel, and the net temperature rise through the combustion system. It is shown in Example 10 how this loss can be calculated.

4.7.2 Heat Loss Due to Sensible Heat in the Ash

Generally some sensible heat is lost with the ash. This is most obvious for slag-tap systems, where molten ash at perhaps 2500°F is drained from the boiler into a quench tank. However, some sensible heat is also lost when dry ash, having a higher temperature than the combustion air, is removed from the boiler. Even if the ash is allowed to cool in the ashpit or dust collector hopper prior to removal, it is unlikely that the heat radiated from the ashpit or hopper is included in the estimate of boiler radiation and convection loss.

The sensible heat lost with the ash can be calculated fairly easily for a slag-tap system, provided one knows the weight of ash removed as slag, its average tapping temperature, and its specific heat for the range from combustion air temperature to tapping temperature. However, calculating the heat lost from fly ash cooled in a precipitator hopper is likely to require some rather arbitrary assumptions even if the specific heat is known.

4.7.3 Heat Loss Due to Leakage of Hot Air or Flue Gas

Small, stoker-fired boilers are usually operated with a slightly negative furnace pressure, so leakage of hot air or gas is not a problem. However, large units may have pressurized furnaces, and usually have auxiliary equipment such as air heaters and pulverizers. Thus the possible sources of leakage are multiplied. The loss, of course, is dependent on the temperature and volume of the leakage. It is likely to be very difficult to measure accurately, but in a well-maintained system it should be small enough to ignore.

4.7.4 Heat Loss Due to Radiation and Convection from Auxiliary Equipment

The ABMA Radiation Loss Chart (Figure C, p. 28) does not include heat lost from auxiliaries such as air heaters and pulverizers, which are outside the main boiler casing. Heat loss from the surfaces of such devices can be calculated approximately, using the method given in Appendix B.

4.7.5 Allowance for Unmeasured Losses

In the great majority of boiler heat balances the four losses described in Sections 4.7.1–4.7.4 are not estimated separately. This is because they are often very difficult to calculate accurately and, in any case, they together comprise only a small portion of the total heat loss. Instead, it is much more convenient, and usually sufficiently accurate, to cover these items in the heat balance by an "allowance for unmeasured losses" of 0.5 to 1.0 per cent. The lower value would be appropriate for a small, stoker-fired boiler, while the higher value might be appropriate for a large boiler where leakage and radiation from auxiliaries are more significant, or for a slag-tap boiler where heat is lost in the molten ash.

4.8 Application of Heat Loss Data to Boiler Efficiency

To obtain an approximate heat balance using this combustion handbook, the following information is required:

1. Sufficient information about the source of the coal to identify the set number in the coal index.
2. The as-fired moisture of the coal.
3. The maximum continuous output rating of the boiler (Btu/hr).
4. The actual output of the boiler (Btu/hr).
5. The flue gas temperature (°F).
6. The combustion air temperature (°F).
7. Analysis of the flue gas for CO_2 or O_2 and CO (% by vol).
8. The temperature of the coal (°F).
9. The per cent of combustible in the ash. If there is more than one ash stream, the per cent combustible in each stream must be determined and the weight ratios of the streams must be determined.

Assuming the foregoing information is measured to state-of-the-art tolerances, the accuracy of the heat balance will depend mainly on the size of the combustion system or boiler. This is due to the fact that the percentage of radiation and convection loss rises sharply with decreasing heat output; the accuracy with which the loss may be estimated from the ABMA chart decreases proportionally. For boilers operating at a full-load output of 20 million Btu/hr or higher, the loss can usually be estimated to within 0.5 per cent of the total heat input. For smaller boilers, or those operating at low loads, the estimated radiation and convection loss is accurate to within 1 to 2 per cent of the total heat input.

Example 7 – Boiler Efficiency

A watertube boiler is rated at 60,000 lb/hr of steam at 125 psig, dry and saturated, with a feedwater temperature of 200°F. It burns Acadia 3/4 in. x 3/16 in. coal from Nova Scotia, by means of a chain-grate stoker. The coal has an as-fired moisture content of 8%. Test measurements yield the following data:

Per Cent of Full-Load Rating	50	75	100
Stack temperature (°F)	380	400	430
Combustion air temperature (°F)	80	80	80
CO_2 in flue gas (% by vol)	11.0	13.0	15.0
CO in flue gas (% by vol)	0	0	0.2
Fuel temperature (°F)	60	60	60
Unburned combustible in ash (%)	8.5	10.0	18.5

Find the boiler efficiency at 50%, 75% and 100% of full-load rating, neglecting heat loss due to moisture in the air, but assuming unmeasured losses = 0.5% of fuel input.

Solution

The coal in question is dealt with in Set NS 1-1.

From Steam Tables*, heat absorbed,
Btu/lb steam = 1193 – 168 . . . . = 1025

Therefore, full-load rating in Btu/hr
= $60 \times 10^3 \times 1.025 \times 10^3$ . . . . . . = 61.5×10^6

(a) *Heat Balance at Full-Load Rating*

Heat output = 61.5×10^6 Btu/hr

Total combustion air (TCA) from CO_2 curve of Figure 1 = 123%

*In calculating heat balances on boilers, reference must be made occasionally to steam tables such as those found in *Thermodynamic Properties of Steam* by J. H. Keenan and F. G. Keyes. Published by John Wiley & Sons, Inc., 1936.

Heat Losses

1. Dry flue gas loss, from Figure 3, at 123% TCA and temp. diff. = 430 – 80 = 350°F	=	8.20%
2. Loss due to moisture in coal, from Figure 4, at 8% moisture, fuel temp. of 60°F and stack temp. of 430°F	=	0.81%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 80°F and stack temp. of 430°F	=	3.77%
4. Loss due to combustible in ash, from Figure 6, at 18.5% combustible	=	3.00%
5. Loss due to CO in flue gas, from Figure 7, at 0.2% CO	=	0.64%
6. Radiation and convection loss, from ABMA Radiation Loss Chart (Figure C), assuming 4 water-cooled walls, at rated output of 61.5×10^6 Btu/hr	=	0.61%
7. Unmeasured losses (assumed).........	=	0.50%
Total losses	=	17.53%

Therefore, boiler efficiency = 100.00 – 17.53 = 82.47%

(b) *Heat Balance at 75% of Full-Load Rating*

Heat output = $0.75 \times 61.5 \times 10^6$ = 46.1×10^6 Btu/hr
TCA at 13.0% CO_2 from Figure 1 = 141%

Heat Losses

1. Dry flue gas loss, from Figure 3, at 141% TCA and temp. diff. = 400 – 80 = 320°F	=	8.60%
2. Loss due to moisture in coal, from Figure 4, at 8% moisture, fuel temp. of 60°F and stack temp. of 400°F	=	0.80%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 80°F and stack temp. of 400°F .	=	3.72%
4. Loss due to combustible in ash, from Figure 6, at 10% combustible	=	1.50%
5. Loss due to CO in flue gas at 0% CO	=	0.00%
6. Radiation and convection loss, from ABMA Radiation Loss Chart (Figure C), assuming 4 water-cooled walls, at output of 46.1×10^6 Btu/hr, and rated at 61.5×10^6 Btu/hr	=	0.90%
7. Unmeasured losses (assumed)	=	0.50%
Total losses	=	16.02%

Therefore, boiler efficiency = 100.00 – 16.02 = 83.98%

(c) *Heat Balance at 50% of Full-Load Rating*

Heat output = $0.50 \times 61.5 \times 10^6$ = 30.75×10^6 Btu/hr
TCA at 11.0% CO_2 from Figure 1 = 166%

Heat Losses

1. Dry flue gas loss, from Figure 3, at 166% TCA and temp. diff. = 380 – 80 = 300°F ..	=	9.45%
2. Loss due to moisture in coal, from Figure 4, at 8% moisture, fuel temp. of 60°F and stack temp. of 380°F	=	0.79%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 80°F and stack temp. of 380°F.	=	3.70%
4. Loss due to combustible in ash, from Figure 6, at 8.5% combustible	=	1.20%
5. Loss due to CO in flue gas at 0% CO	=	0.00%
6. Radiation and convection loss, from ABMA Radiation Loss Chart (Figure C), assuming 4 water-cooled walls, at output of 30.75 x 10^6 Btu/hr, and rated at 61.5×10^6 Btu/hr .	=	1.35%
7. Unmeasured losses (assumed)	=	0.50%
Total losses	=	16.99%

Therefore, boiler efficiency = 100.00 – 16.99 = 83.01%

Summary of results from Example 7

Per Cent of Full-Load Rating	50	75	100
	Heat Loss (%)		
1. Dry flue gas loss	9.45	8.60	8.20
2. Loss due to moisture in coal	0.79	0.80	0.81
3. Hydrogen loss	3.70	3.72	3.77
4. Loss due to combustible in ash	1.20	1.50	3.00
5. Loss due to CO in flue gas	0.00	0.00	0.64
6. Radiation and convection loss	1.35	0.90	0.61
7. Unmeasured losses (assumed)	0.50	0.50	0.50
Total losses	16.99	16.02	17.53
Boiler Efficiency (%)	83.01	83.98	82.47

Example 8 – Efficiency Gain Due to Reduction in Excess Air

A stoker-fired, high-temperature water generator, rated at 20 million Btu/hr, burns 2 in. x 0 Balmer Seam coal from Crowsnest Industries, Ltd. The as-fired moisture content of the coal is 4.5%, and the fuel temperature is 75°F. Under full-load conditions, the generator normally operates at 55% excess air, a stack temperature of 525°F, no CO in the flue gas, and 7.5% combustible in the grate ash. What will be the gain in efficiency if the excess air is reduced to 35%, resulting in a stack temperature of 475°F, 0.15% CO in the flue gas, and 11.0% combustible in the ash? Assume a combustion air temperature of 75°F, and unmeasured losses of 0.5%.

Solution

The coal in question is dealt with in Set ABC 4-2.

(a) *Heat Balance Under Normal Conditions*

1. Dry flue gas loss, from Figure 3, at 155% TCA and temp. diff. = 525 – 75 = 450°F = 13.15%
2. Loss due to moisture in coal, from Figure 4, at 4.5% moisture, fuel temp. of 75°F and stack temp. of 525°F . . . . = 0.41%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 75°F and stack temp. of 525°F. . . . . = 3.42%
4. Loss due to combustible in ash, from Figure 6, at 7.5% combustible . . . . = 0.90%
5. Loss due to CO in flue gas at 0% CO. . . . . = 0.00%
6. Radiation and convection loss, from ABMA Radiation Loss Chart (Figure C), assuming 4 water-cooled walls, at rated output of 20 x 10^6 Btu/hr . . . . = 1.05%
7. Unmeasured losses (assumed) . . . . = 0.50%

Total losses = 19.43%

Efficiency under normal conditions = 100.00 – 19.43 . . . . = 80.57%

(b) *Heat Balance Under Reduced Excess Air Conditions*

1. Dry flue gas loss, from Figure 3, at 135% TCA and temp. diff. = 475 – 75 = 400°F = 10.22%
2. Loss due to moisture in coal, from Figure 4, at 4.5% moisture, fuel temp. of 75°F and stack temp. of 475°F . . . . = 0.40%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 75°F and stack temp. of 475°F . . . . = 3.37%
4. Loss due to combustible in ash, from Figure 6, at 11.0% combustible . . . . = 1.20%
5. Loss due to CO in flue gas, from Figure 7, at 0.15% CO . . . . = 0.48%
6. Radiation and convection loss, as before . . = 1.05%
7. Unmeasured losses (assumed) . . . . = 0.50%

Total losses = 17.22%

Efficiency under reduced excess air conditions = 100.00 – 17.22 . . . . = 82.78%

Efficiency gain due to reduction in excess air = 82.78 – 80.57 . . . . = 2.21%

Example 9 – Effect of Economizer on Efficiency

A pulverized-fired boiler is being designed to burn Avon Minto slack coal, 1/4 in. x 0, having 5.00% moisture. The combustion air and fuel both enter the system at 70°F. Flue gas leaves the boiler at 500°F, and contains 4.0% O_2. What will be the gain in efficiency if an air heater is added which reduces the flue gas temperature to 350°F?

Solution

The coal in question is dealt with in Set NB 1-3. Not all of the losses are dependent on the stack temperature. Since it is desired to establish the increase in efficiency due to a decrease in stack temperature, only the losses affected by stack temperature need be considered. These are the dry flue gas loss, the loss due to moisture in the coal, and the loss due to moisture from the combustion of hydrogen.

From Figure 1, 4% O_2 represents 123% TCA.

(a) *Losses Without Air Heater*

1. Dry flue gas loss, from Figure 3, at 123% TCA and temp. diff. = 500 – 70 = 430°F. . = 9.95%
2. Loss due to moisture in coal, from Figure 4, at 5.0% moisture, fuel temp. of 70°F and stack temp. of 500°F . . . . = 0.49%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 70°F and stack temp. of 500°F . . . . = 4.03%

Total losses = 14.47%

(b) *Losses With Air Heater*

1. Dry flue gas loss, from Figure 3, at 123% TCA and temp. diff. = 350 – 70 = 280°F = 6.50%
2. Loss due to moisture in coal, from Figure 4, at 5.0% moisture, fuel temp. of 70°F and stack temp. of 350°F . . . . = 0.46%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 70°F and stack temp. of 350°F . . . . = 3.81%

Total losses = 10.77%

Gain in efficiency due to air heater = 14.47 – 10.77 . . . . = 3.70%

Example 10 – Loss Due to Moisture in Combustion Air, and Corrections to Radiation and Convection Loss

A pulverized-fired boiler burns bug-dust lignite (– 1/2 in.) supplied by Battle River Coal Company, Ltd., in Estevan. The coal is at 65°F and contains 38% moisture. The boiler is rated at 200,000 lb of steam/hr, at 1500 psig and 1000°F. Feedwater temperature to the system is 180°F. Combustion air temperature is 85°F, with a relative humidity of 80%. At full load, the stack gases contain 5.0% O_2, no CO, and the stack temperature is 300°F. The fly ash contains 15% combustible. The average boiler casing temperature is 170°F, and the air velocity over the boiler casing is 8 ft/s. Find the boiler efficiency as accurately as possible, under full-load conditions.

Solution

The coal in question is dealt with in Set S 1-2.

From steam tables, heat absorbed,
Btu/lb steam = 1490 – 148 . . . . = 1342

Therefore, full-load rating in Btu/hr
= 200 x 10^3 x 1.342 x 10^3 . . . . = 268 x 10^6 Btu/hr

From Figure 1, 5.0% O_2 represents 131% TCA.

Heat Losses

1. Dry flue gas loss, from Figure 3, at 131% TCA and temp. diff. = 300 – 85 = 215°F . . . . = 5.40%
2. Loss due to moisture in coal, from Figure 4, at 38% moisture, fuel temp. of 65°F and stack temp. of 300°F . . . . = 6.80%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 85°F and stack temp. of 300°F . . = 3.74%
4. Loss due to combustible in ash, from Figure 6, at 15% combustible . . . . = 2.60%
5. Loss due to CO in flue gas at 0% CO . . . . = 0.00%
6. Corrected radiation and convection loss: Radiation and convection loss, from ABMA Radiation Loss Chart (Figure C), assuming 4 water-cooled walls, at rated output of 268 x 10^6 Btu/hr = 0.35%

   From Figure D (p. 29), at boiler casing temp. diff. of 170 – 85 = 85°F, and air velocity of 8 fps,
   transmission loss = 350 Btu/sq ft hr

   Also from Figure D, at design conditions of ABMA chart (temp. diff. of 50°F and air velocity of 100 fpm,
   transmission loss = 135 Btu/sq ft hr

   Therefore, correction factor for ABMA chart $= \frac{350}{135}$

   and corrected radiation and convection loss
   $= \frac{350}{135} \times 0.35$ . . . . = 0.91%

7. Loss due to moisture in combustion air:

   From psychrometric chart, at 85°F and 80% RH,
   lb moisture/lb dry air = 0.0211

   From Figure 1, at 131% TCA,
   lb dry air/lb dry coal = 11.05

   Therefore, lb moisture/lb dry coal
   = 0.0211 x 11.05 = 0.2332

   Heat required to superheat moisture to stack temp., per lb dry coal, assuming specific heat = 0.46,
   = 0.46 x 0.2332 x (300 – 85) = 23.06 Btu/lb dry coal

   From the analyses table for Set S 1-2,
   calorific value = 10,960 Btu/lb dry coal

   Therefore, heat loss $= \frac{23.06}{10{,}960} \times 100$ . . . . = 0.21%

8. Unmeasured losses, assuming 0.5% to cover radiation from auxiliaries and sensible heat in ash, ... = 0.50%

Total losses = 20.16%

Boiler efficiency under full-load conditions
= 100.00 – 20.16 . . . . = 79.84%

Example 11 – Effect of Air Infiltration on Efficiency

Some old balanced-draft boilers have settings which allow substantial air infiltration, often resulting in a serious decrease in operating efficiency and excessive fuel consumption. In this example, Drummond No. 1 Nova Scotia 3/4 in. x 0 coal, containing 4% moisture as-fired, is burned on a chain-grate stoker. Gas analyses carried out at the furnace outlet and in the breeching show CO_2 concentrations of 12.0% and 9.2% respectively. The flue gas temperature at the stack is 450°F and the combustion air temperature is 75°F. What effect does the air infiltration have on boiler efficiency?

Solution

The coal in question is dealt with in Set NS 4-1. Two extreme cases, which bracket all other possible situations, will be considered. The air may infiltrate into either the first pass or the last pass. For these two conditions, the dry flue gas loss, the loss due to moisture in coal, and the hydrogen loss will be affected differently. Before dealing with each case separately, it will be convenient to calculate the apparent losses under conditions measured at the breeching, that is, CO_2 = 9.2%, flue gas temp. = 450°F, combustion air temp. = 75°F. From Figure 1, 9.2% CO_2 represents 197% TCA.

Apparent Heat Losses

1. Dry flue gas loss, from Figure 3, at 197% TCA and temp. diff. = 450 – 75 = 375°F	= 14.40%
2. Loss due to moisture in coal, from Figure 4, at 4.0% moisture, fuel temp. of 60°F (assumed) and stack temp. of 450°F	= 0.47%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 75°F and stack temp. of 450°F ..	= 4.28%
Total apparent losses	= 19.15%

Note: The other losses due to combustible in refuse, radiation and convection from the boiler surfaces, etc., are not considered here because they are not affected by the infiltration.

(a) *Air Infiltrating into Last Pass*

If the air infiltrates through leaks in the last pass, the effect on operating efficiency will be small, because the tube banks have already reduced the gas to its normal final temperature, and the air is simply diluting the flue gas entering the stack. However, error will result if the efficiency is calculated from the stack temperature and excess air level measured in the diluted gas. The indicated stack temperature will be reduced by dilution, making the efficiency appear higher than it actually is; on the other hand, the indicated excess air will be higher than the actual value, making the efficiency appear lower than it actually is. Thus, the apparent losses calculated previously are in error. Those conditions which represent the actual operating efficiency of the boiler can be estimated as follows.

CO_2 measured at furnace outlet = 12.0%

From Figure 1, this represents 152% TCA.

Also from Figure 1,

total flue gas at 197% TCA	= 18.00 lb/lb dry coal
total flue gas at 152% TCA	= 14.05 lb/lb dry coal

Therefore, infiltration = 18.00 – 14.05 = 3.95 lb/lb dry coal

The "true" temperature of the flue gas, that is, its temperature before dilution by infiltration, can be determined from the following enthalpy balance:

enthalpy of 3.95 lb air at 75°F + enthalpy of 14.05 lb flue gas at true temp. = enthalpy of 18.00 lb flue gas at 450°F

For the present purpose, it can be assumed with reasonable accuracy that air and flue gas have the same specific heat and that it does not change with temperature. Then the above relationship reduces to one involving only weight and temperature differential. However, a reference temperature must be chosen, and it is convenient to use absolute zero.

Then $[3.95 \times (75 + 460)] + [14.05 \times (\text{true temp., }°F + 460)] = [18.00 \times (450 + 460)]$ from which true temp. (°F) = 1015 – 460 = 555°F

Thus, the true conditions are: TCA = 152%, stack temp. = 555°F, and combustion air temp. = 75°F

Losses Under True Conditions

1. Dry flue gas loss, from Figure 3, at 152% TCA and temp. diff. = 555 – 75 = 480°F	= 14.30%
2. Loss due to moisture in coal, from Figure 4, at 4.0% moisture, fuel temp. of 60°F (assumed) and stack temp. of 555°F	= 0.49%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 75°F and stack temp. of 555°F	= 4.46%
Total true losses	= 19.25%

Therefore, infiltration makes the efficiency appear higher than it actually is by 19.25 – 19.15 = 0.10%

It should not be assumed from this example that infiltration at the last pass will always cause efficiency to be slightly over estimated. It simply illustrates qualitatively that in this situation the changes tend to cancel each other.

(b) *Air Infiltrating into First Pass*

If the air infiltrates through leaks in the first pass, it reduces the efficiency of the combustion system, because part of the heat in the flue gas is used to bring the air up to the flue gas temperature, reducing the latter in the process. The air and flue gas then give up heat to the convection banks of the boiler and are thereby cooled to the stack temperature. As a first approximation, it can be said that the heat loss due to infiltration is equal to the heat required to bring the infiltrating air from ambient temperature up to stack temperature. This loss is readily determined as follows:

First Approximation of Efficiency Loss

Dry flue gas loss, at 197% TCA (9.2% CO_2) and stack temp. of 450°F, as determined previously	= 14.40%
Dry flue gas loss, from Figure 3, at 152% TCA (12.0% CO_2) and temp. diff. = 450–75 = 375°F	= 11.20%
Therefore, infiltration reduces efficiency by 14.40 – 11.20	= 3.20%

The foregoing method actually underestimates the drop in efficiency, because the infiltrating air increases the mass flow through the convection bank, resulting in a higher stack temperature than would actually prevail if the infiltration did not occur. The relationship between mass flow and stack temperature cannot be conveniently calculated. However, for a given boiler at a given load, it is easy to establish by experiment a correlation between excess air and stack temperature, which can be used to estimate the effect of infiltration on stack temperature.

For example, if it had been established that the stack temperature dropped by 25°F for every 1% increase in CO_2, losses could be determined for the following infiltration-free conditions: TCA = 152%, stack temp. = 450 – 25(12.0 – 9.2) = 380°F, combustion air temp. = 75°F

Accurate Assessment of Efficiency Loss

1. Dry flue gas, from Figure 3, at 152% TCA and temp. diff. of 305°F (380–75)	=	9.10%
2. Loss due to moisture in coal, from Figure 4, at 4.0% moisture, fuel temp. of 60°F (assumed) and stack temp. of 380°F	=	0.45%
3. Hydrogen loss, from Figure 5, at combustion air temp. of 75°F and stack temp. of 380°F	=	4.16%
Total infiltration-free losses	=	13.71%
Therefore, infiltration reduces efficiency by 19.15 – 13.71	=	5.44%

Note that the figure of 19.15% was calculated at the beginning of this example as the apparent loss. It is also the true loss for the case where air infiltrates into the first pass.

4.9 Accuracy Limitations of Heat Balances

It will have been observed that, in the foregoing examples, heat losses have been recorded to two decimal places. Unfortunately, this does not mean that the heat balances are accurate to the nearest 0.01%. The subject of significant figures is frequently controversial; in this case two decimal places were decided upon because some of the heat loss graphs can normally be read to that accuracy. These include the hydrogen loss, the loss due to CO, and, at least for low-moisture coals, the loss due to moisture in the coal. The other graphs can normally be read to an accuracy of at least 0.1%, except for the Radiation Loss Chart, where larger errors may result in estimating this loss for small- and medium-sized boilers. Error is also introduced if the actual coal analysis does not exactly match the analysis used for the calculations. Nonetheless, if measurements are taken carefully to tolerances usual in the trade, heat balances obtained by the methods given in this handbook should be accurate within 1.0 to 1.5%. This compares satisfactorily with the direct method, which depends on steam flow meters that are seldom as accurate as ±1.0%, and on a measurement of coal weight which, even if accurate, is susceptible to variations in moisture.

5. APPLICATION TO AIR POLLUTION PROBLEMS

5.1 Pollution Emissions

Flue gases from the combustion of coal may contain a number of pollutants, such as CO, SO_2, SO_3, nitrogen oxides, particulate matter containing acid soot, and unburned hydrocarbons, including polycyclics, olefins and paraffins. All of these pollutants are harmful in concentrations well below 1 per cent by volume. Whether or not CO_2 should also be considered a pollutant is debatable. It is a non-poisonous product which is necessary to the photosynthesis process for healthy vegetation, yet it dilutes the oxygen necessary for our life and may well alter the heat balance of the earth with respect to space. In any case, the concentration of CO_2 can be predicted using Figure 1, 2 or 3. The volumetric concentration of SO_2 versus the total combustion air is given in Figure 3, and Example 12 shows how the emission rate can be calculated.

The concentrations of other pollutants cannot be accurately predicted merely from the fuel analysis and excess air level. The formation of nitric oxide, for example, depends on both flame temperature and organic nitrogen content of the fuel. The extensive literature on this subject shows that the flue gas from coal-fired furnaces may contain from 200 to 1500 parts per million (ppm) of nitric oxide. However, if the nitric oxide concentration is determined by measurement, the handbook facilitates calculation of the emission rate.

The measurement of particulate emissions in flue gas is an involved process, and in many parts of Canada there is legislation specifying in detail how such measurements are to be carried out. Because of the complexity of the equipment and sophistication of the techniques, measurement of particulates is limited to teams of experts, and is therefore not dealt with in this handbook. Interested parties should consult the appropriate air pollution authorities.

Example 12 – Calculation of Pollutant Emissions

A pulverized-coal-fired boiler burns 5 tons/hr of coal from the MacIntyre Porcupine Mine, having a moisture content of 3.5% as fired. The boiler operates at 30% excess air. Flue gas analysis shows 400 ppm of NO on the dry basis. What are the emissions of CO_2, SO_2 and NO in lb/hr?

Solution

The coal in question is dealt with in Set ABC 6-1.

Firing rate of dry coal = 5 x 2000 x (100.0 – 3.5) = 9,650 lb/hr

Flue gas components are analyzed as volumetric percentages or fractions of the dry flue gas. The problem is one of converting volume fractions to weight per lb of coal. It is convenient to use the curve in Figure 2 which shows the volume of dry flue gas at 32°F per lb of coal.

From Figure 2, at 130% TCA,
vol of dry flue gas at 32°F per lb coal = 175 cu ft

The following information is also required:

molecular wt of CO_2 = 44.01
molecular wt of SO_2 = 64.01

molecular wt of NO = 30.008
molecular vol (cu ft at 32°F) = 359

(a) *Wt of CO_2*

From Figure 2, at 130% TCA,
CO_2 in dry flue gas = 14.3%

Vol of CO_2 at 32°F/lb dry coal

$$= \frac{14.3}{100} \times 175 = 25.02 \text{ cu ft}$$

Wt of CO_2/ lb dry coal

$$= 25.02 \times \frac{44.01}{359} = 3.07 \text{ lb}$$

Hourly CO_2 emission = 3.07 x 9650 = 29,625 lb/hr

(b) *Wt of SO_2*

From Figure 3, at 130% TCA,
SO_2 in dry flue gas = 0.0265%

Vol of SO_2 at 32°F/lb dry coal

$$= \frac{0.0265}{100} \times 175 = 0.0464 \text{ cu ft}$$

Wt of SO_2/lb dry coal

$$= 0.0464 \times \frac{64.01}{359} = 0.00827 \text{ lb}$$

Hourly SO_2 emission = 0.00827 x 9650 = 79.8 lb/hr

(c) *Wt of NO*

Measured concentration of NO = 400 ppm

Vol of NO at 32°F/lb dry coal

$$= \frac{400}{10^6} \times 175 = 0.070 \text{ cu ft}$$

Wt of NO/lb dry coal

$$= 0.070 \times \frac{30.008}{359} = 0.00585$$

Hourly NO emission = 0.00585 x 9650 = 56.5 lb/hr

5.2 Plume Rise Calculations

The calculation of plume rise is dealt with extensively in air pollution literature. One particularly useful paper is that by Whaley.[4] It presents a simple yet reliable method for estimating the dispersion of combustion effluents from chimneys. In this handbook, no attempt is made to present the actual plume rise calculations. Rather, it is shown only how the handbook can facilitate such calculations.

To calculate the plume rise, the sensible heat lost up the stack must be determined. This loss is made up of four possible components:

(1) The dry flue gas loss

(2) The sensible portion of the loss due to moisture from the combustion of hydrogen

(3) The sensible portion of the loss due to moisture in the coal

(4) The loss due to moisture in the combustion air.

For relatively dry fuel and air, the total loss may be approximated by multiplying the dry flue gas loss by the weight ratio of the total flue gas to the dry flue gas, as shown in Example 13. For convenience, the sensible heat loss will be calculated as a percentage of fuel input. The actual loss can then be readily calculated from the firing rate.

Example 13 – Approximate Sensible Heat Loss

A plant burning dry coke produced by the Great Canadian Oil Sands plant operates with 40% excess air and a stack temperature of 350°F. The combustion air temperature is 50°F. Find the approximate sensible heat loss.

Solution

The fuel in question is dealt with in Set ABC 5-1.
Dry flue gas loss, from Figure 3, at 140% TCA
and temp. diff. of 300°F (350 – 50) . . . . = 7.95°F

From Figure 1, at 140% TCA,
dry flue gas/lb dry fuel . . . . = 15.95 lb

From Figure 1, at 140% TCA,
total flue gas/lb dry fuel . . . . = 16.30 lb

Approx. sensible heat loss $= 7.95 \times \frac{16.30}{15.95} = 8.12\%$

It may be noted that in the above example the fuel has a very low hydrogen content, therefore the dry flue gas loss alone would have been a close approximation to the sensible heat loss. However, for fuels having higher hydrogen content, the procedure shown in Example 13 incorporates an approximation, in that water vapour is assumed to have the same specific heat as dry flue gas. A more refined calculation would have to take the different values for specific heat into account. The ASME uses the following values:

for dry flue gas: . . . . 0.24 Btu/lb°F

for water vapour at low vapour pressures and temperatures up to 575°F: . . . . 0.46 Btu/lb°F

for water up to 212°F: . . . . 1.00 Btu/lb°F

Example 14 – Accurate Determination of Sensible Heat Loss

Foster coal from Armstrong County, Pennsylvania, is burned with 30% excess air and a stack temperature of 300°F. The coal contains 5.0% moisture, and enters the system at 50°F. Combustion air enters the system at 80°F and 80% RH. What is the sensible heat loss?

Solution

The coal in question is dealt with in Set US P-6.

From the table of analyses for this coal,
calorific value = 13,270 Btu/lb dry coal.

1. Dry flue gas loss:

   From Figure 3, at 130% TCA and temp. diff. of 220°F (300–80) . . . . = 5.25%

2. Sensible heat in moisture from combustion of hydrogen:

   From Figure 1, at 130% TCA,
   total flue gas/lb dry coal . . . . = 13.70 lb

   From Figure 1, at 130% TCA,
   dry flue gas/lb dry coal . . . . = 13.25 lb

   Moisture lb/dry coal . . . . = 0.45 lb

   Assuming specific heat of 1.00 up to 212°F, and 0.46 above 212°F,
   sensible heat loss = 0.45 x [(212 – 80) + (300 – 212) (0.46)]
   = 77.62 Btu/lb coal

   $$= \frac{77.62 \times 100}{13,270} = 0.585\%$$

3. Sensible heat in moisture in coal:

   The coal contains 5.0% moisture,

   therefore, moisture/lb dry coal $= \frac{5.0}{95} = 0.053$ lb

   This is heated from the coal temp. to the stack temp.

   Assuming specific heat of 1.00 for temperatures up to 212°F, and 0.46 above 212°F,
   Sensible heat loss = 0.053 [(212 – 50) + (300 – 212) (0.46)]
   = 10.73 Btu/lb dry coal

   $$= \frac{10.73 \times 100}{13,270} = 0.081\%$$

4. Sensible heat in moisture in combustion air:

   From Figure 1, at 130% TCA,
   dry air/lb dry coal . . . . = 12.85 lb

   From psychrometric chart at 80°F and 80% RH,
   moisture/lb dry air . . . . = 0.0176 lb

   Moisture/lb dry coal = 0.0176 x 12.85 . . . . . . = 0.226 lb

   Sensible heat loss = 0.226 x (300 – 80) x 0.46
   = 22.9 Btu/lb dry coal

   $$= \frac{22.9 \times 100}{13,270} = 0.172\%$$

Total sensible heat loss
= 5.25 + 0.585 + 0.081 + 0.172 = 6.09%

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APPENDIX A

SAMPLE COMBUSTION AND HEAT LOSS CALCULATIONS

A.1 Fuel Properties

Fuel: Dominion Slack Coal, 3/4 in. x 0, represented as NS 3-6

A.1.1 Ultimate Analysis (lb/lb dry coal)

Moisture	0.000
Carbon	0.778
Hydrogen	0.051
Sulphur	0.028
Nitrogen	0.013
Ash	0.081
Oxygen (by difference)	0.049
	1.000

Calorific Value (Btu/lb) = 14070

A.2 Combustion Calculations (Assuming Atmospheric Pressure = 29.92 in.Hg)

A.2.1 Stoichiometric Air Required per lb Dry Coal

Combustible	*O_2 from air (lb)*
C = 32/12.011 x 0.778	= 2.073
H = 8/1.008 x 0.051	= 0.405
S = 32/32.066 x 0.028	= 0.028
Total	= 2.506
Less O_2 in coal	= 0.049
O_2 from air (lb/lb coal)	= 2.457
Associated N_2 = 76.85/23.15 x 2.457	= 8.155
Dry air (lb/lb coal)	= 10.612

A.2.2 Combustion Air for a Range of Total Air

Sp. vol of dry air at 40°F = 12.59 cu ft/lb dry air
60°F = 13.10
80°F = 13.60
100°F = 14.11
120°F = 14.62

Total air (%)	100	140	160	200
Dry air (lb/lb coal)	10.613	14.858	16.981	21.226
Air temp. (°F)	*Dry air (cu ft/lb dry coal)*			
40	133.6	187.1	213.8	267.2
60	139.0	194.6	222.5	278.1
80	144.3	202.1	230.9	288.7
100	149.7	209.6	239.6	299.5
120	155.2	217.2	248.3	310.3

A.2.3. Stoichiometric Products of Combustion by Weight

Dry Coal and Dry Air Basis

Dry Products

C = 0.0778 + 2.073	= 2.851	(CO_2)
N_2 = 0.013 + 8.155	= 8.168	(N_2)
S = 0.028 + 0.028	= 0.056	(SO_2)
Dry flue gas (lb/lb coal)	11.075	

Wet Products

H_2 = 0.051 + 0.405	= 0.456	(H_2O)
Total flue gas*, (lb/lb coal)	11.531	

*The term "total flue gas" is taken to mean the dry products plus the moisture from the combustion of hydrogen but excluding moisture from coal or air.

A.2.4 Products of Combustion and % CO_2 for a Range of Total Air

At Stoichiometric

lb/lb coal ÷ mol. wt x mol. vol = cu ft at 32°F / (lb coal)

Dry Products

CO_2	2.851 ÷ 44.011 x 359	=	23.26
N_2	8.168 ÷ 28.014 x 359	=	104.67
SO_2	0.056 ÷ 64.066 x 359	=	0.31
	11.075		128.24

Wet Products

H_2O from H_2 in coal	0.456 ÷ 18.016 x 359	=	9.09
Total flue gas, (lb/lb coal)	11.531		137.33

For 20% Excess Air *lb/lb coal*

Additional O_2 = 0.2 x 2.457 = 0.4914 ÷ 32 x 359 = 5.51

Additional N_2 = 0.2 x 8.155 = 1.631 ÷ 28.016 x 359 = 20.90

Additional Dry Products = 2.120 26.41

Total Air (%)	Dry Flue Gas (lb/lb coal)	Dry Flue Gas (cu ft at 32°F)	Total Flue Gas (lb/lb coal	Total Flue Gas (cu ft at 32°F)	CO_2, (% by vol, dry gas basis)	O_2, (% by vol, dry gas basis)	SO_2, (% by vol, dry gas basis)
100	11.07	128.24	11.53	137.33	18.14	0.00	0.242
120	13.19	154.65	13.65	163.73	15.04	3.56	0.200
140	15.31	181.07	15.77	190.16	12.85	6.09	0.171
160	17.44	207.48	17.90	216.57	11.21	7.97	0.149
180	19.56	233.89	20.02	242.98	9.94	9.44	0.133
200	21.69	260.31	22.15	269.40	8.94	10.59	0.119

A.2.5 Volume of Products of Combustion for a Range of Total Air and Temperature

$$\text{Correction for } 200°F = \frac{460 + 200}{460 + 32} = 1.3415$$

250°F	1.4431
300°F	1.5447
350°F	1.6463
400°F	1.7480
450°F	1.8496
500°F	1.9512
550°F	2.0528
600°F	2.1545
650°F	2.2561

Total Flue Gas (cu ft/lb coal)

Gas Temperature (°F)	Total Air (%) 100	140	160	200
32	137.32	190.14	216.55	269.38
200	184.14	254.98	290.40	361.24
250	198.15	274.37	312.49	388.71
300	212.16	293.77	334.58	416.19
350	226.03	312.97	356.45	443.40
400	240.03	332.37	378.54	470.87
450	254.04	351.76	400.62	498.35
500	267.91	370.97	422.50	525.56
550	281.91	390.36	444.59	553.03
600	295.78	409.57	466.46	580.24
650	309.79	428.96	488.55	607.72

A.3 Heat Loss Calculations

A.3.1 Dry Flue Gas Loss

In Btu/lb coal = lb dry gas/lb dry coal x 0.24 x (stack temp. – combustion air temp.)

In % = above x 100 ÷ calorific value of dry coal

Note: Both the weight of dry gas/lb coal and the calorific value vary directly with the moisture content; hence, the % heat loss is independent of the coal moisture content.

Stack temp. – comb. air temp. (°F)	Total Air, %	Heat Loss % 100	140	160	200
	lb dry gas / lb coal	11.07	15.32	17.44	21.69
100		1.89	2.61	2.98	3.70
150		2.83	3.92	4.46	5.55
200		3.78	5.23	5.95	7.40
250		4.72	6.53	7.44	9.25
300		5.67	7.84	8.93	11.10
350		6.61	9.15	10.41	12.95
400		7.56	10.45	11.90	14.80
450		8.50	11.76	13.39	16.65
500		9.45	13.07	14.88	18.50
550		10.39	14.37	16.36	20.34
600		11.33	15.68	17.85	22.19
650		12.28	16.98	19.34	24.04

A.3.2 Heat Loss Due to Moisture in Fuel

In Btu/lb coal, if final gas temp. is below 575°F,

$$= \frac{\text{lb moisture}}{\text{lb coal as fired}} \times (1089 - \text{fuel temp.} + 0.46 \times \text{stack temp.})$$

In Btu/lb coal, if final gas temp. is above 575°F,

$$= \frac{\text{lb moisture}}{\text{lb coal as fired}} \times (1066 - \text{fuel temp.} + 0.50 \times \text{stack temp.})$$

In % = above x 100 ÷ calorific value of coal as fired.

Moisture in Coal (%)	Calorific Value (Btu/lb coal as fired)	Fuel temp. (°F)	Heat Loss (%) Stack temp. (°F) 200	400	600
2	13789	40	0.166	0.179	0.193
		80	0.160	0.173	0.187
		120	0.154	0.167	0.181
4	13507	40	0.338	0.365	0.393
		80	0.326	0.354	0.381
		120	0.315	0.342	0.370
6	13226	40	0.518	0.560	0.602
		80	0.500	0.542	0.584
		120	0.482	0.523	0.566
8	12944	40	0.706	0.762	0.821
		80	0.681	0.738	0.796
		120	0.657	0.713	0.771
10	12663	40	0.902	0.974	1.048
		80	0.871	0.943	1.017
		120	0.839	0.911	0.985
12	12382	40	1.107	1.196	1.287
		80	1.068	1.157	1.248
		120	1.030	1.118	1.209

A.3.3 Heat Loss Due to Combustion of H_2

In Btu/lb coal, if stack temp. is below 575°F,

$$= 9 \times \frac{\text{lb } H_2}{\text{lb dry coal}} \times (1089 - \text{comb air temp.} + 0.46 \times \text{stack temp.})$$

In Btu/lb coal, if stack temp. is above 575°F,

$$= 9 \times \frac{\text{lb } H_2}{\text{lb dry coal}} \times (1066 - \text{comb air temp.} + 0.50 \times \text{stack temp.})$$

In % = above x 100 ÷ calorific value of dry coal

Note: Both the hydrogen content and the calorific value vary directly with the moisture content; hence, the % heat loss is independent of the coal moisture content.

Flue Gas Temperature (°F)	Heat Loss (%) Combustion Air Temperature (°F) 40	60	80	100	120
200	3.73	3.66	3.60	3.53	3.47
250	3.80	3.73	3.67	3.60	3.54
300	3.87	3.81	3.74	3.68	3.61
350	3.95	3.88	3.82	3.75	3.69
400	4.02	3.96	3.89	3.83	3.76
450	4.10	4.03	3.97	3.90	3.84
500	4.18	4.11	4.05	3.98	3.92
550	4.25	4.19	4.12	4.06	3.99
600	4.33	4.27	4.20	4.14	4.07
650	4.41	4.34	4.28	4.21	4.15

A.3.4 Heat Loss Due to Combustible in Refuse

wt of refuse = wt of ash + wt of combustible (i.e. comb.).

$$\frac{\text{lb comb.}}{\text{lb coal}} = \frac{\text{lb comb.}}{\text{lb refuse}} \times \left(\frac{\text{lb ash}}{\text{lb coal}} + \frac{\text{lb comb.}}{\text{lb coal}}\right)$$

$$\frac{\text{lb comb.}}{\text{lb coal.}} - \left(\frac{\text{lb comb.}}{\text{lb refuse}} \times \frac{\text{lb comb}}{\text{lb coal}}\right) = \left(\frac{\text{lb comb.}}{\text{lb refuse}} \times \frac{\text{lb ash}}{\text{lb coal}}\right)$$

$$\frac{\text{lb comb.}}{\text{lb coal}} = \frac{\left(\frac{\text{lb comb.}}{\text{lb refuse}} \times \frac{\text{lb ash}}{\text{lb coal}}\right)}{\left\{1 - \frac{\text{lb comb.}}{\text{lb refuse}}\right\}}$$

Heat loss in Btu = above x 14,600

in % = heat loss in Btu x 100 ÷ calorific value

Ash content $= 0.081 \frac{\text{lb}}{\text{lb}}$

Calorific value $= 14{,}070 \frac{\text{Btu}}{\text{lb}}$

Note: Both the ash content and the calorific value vary directly with the moisture content; hence, the % heat loss is independent of the moisture content.

Combustible in refuse (%)	Heat loss (%)
5	0.44
10	0.93
15	1.48
20	2.10
25	2.80
30	3.60
35	4.53
40	5.60
45	6.88
50	8.41
55	10.27
60	12.61

A.3.5 Heat Loss Due to CO

$$\text{In Btu/lb coal} = \frac{CO}{CO_2 + CO} \times 10160 \times \frac{\text{lb carbon}}{\text{lb coal}}$$

In % = above x 100 ÷ calorific value of dry coal

Assume complete mixing, i.e. CO_2 + CO always = 18.13

CO (%)	Heat Loss (%)
0.5	1.55
1.0	3.10
1.5	4.65
2.0	6.20

Note: Both the carbon content and the calorific value vary directly with the moisture content; hence, the % heat loss is independent of the coal moisture content.

APPENDIX B

RADIATION AND CONVECTION LOSSES

B.1 Theory of Heat Loss due to Radiation and Convection

If a surface is exposed to still air having a lower temperature than the surface, it loses heat by radiation and by natural convection. The natural convection currents develop because, as the layer of air next to the surface becomes heated, it becomes more buoyant, and is displaced by unheated air. If the surface is placed in an air stream, then natural convection is replaced by forced convection, and the rate of heat loss is increased.

To calculate the heat losses due to radiation and convection, the following formulae may be applied*:

Note: $°R = °F + 460$

Radiation loss: $h_r = 17.4 \times 10^{-10} \times \epsilon (T_1^4 - T_2^4)$

where h_r = heat loss by radiation, Btu/hr/sq ft
ϵ = emissivity
T_1 = surface temperature, °R
T_2 = air temperature, °R

Natural convection loss: $h_c = 0.53C \left(\frac{1}{T_{avg}}\right)^{0.18} dt^{1.27}$

where h_c = heat loss by natural convection, Btu/hr/sq ft
C = a constant depending on the shape of the surface (for a vertical surface, C = 1.39. For the crown of a furnace, C = 1.79.)
T_{avg} = average of wall temperature and air temperature, °R
dt = wall temperature – air temperature, °F

Forced convection loss: $h_{fc} = 1 + 0.225\ V$

where h_{fc} = heat transmission, Btu/hr/sq ft/°F
V = air velocity, ft/s

It should be noted that in using the last formula, to get the heat loss by forced convection in Btu/hr/sq ft, the value of h_{fc} must be multiplied by (surface temperature – air temperature, °F).

Figure C was prepared using the formulae for radiation loss and forced convection loss. The radiation loss is independent of air velocity, and was calculated for an emissivity of 0.95. The forced convection losses were calculated for various temperature differences and velocities, and to these were added the radiation losses at the corresponding temperature differences. Thus the curves show the total loss due to radiation and forced convection. However, they only apply for a surface with an emissivity of 0.95.

*Taken from p. 169, *Manual of ASTM Standards on Refractory Materials*, 8th edn., Nov. 1957. Publ. ASTM, 1916 Race Street, Philadelphia 3, Pa. U.S.A.

B.2 Emissivity Values

A great deal of research has been carried out to establish the emissivity of various materials. The following table lists values for some of the common materials used in the construction of combustion equipment*.

TABLE B.1

Normal Total Emissivity of Various Surfaces

Surface	t, °F**	Emissivity**
Metals and their Oxides		
Aluminum		
Polished	212	0.095
Commercial sheet	212	0.09
Heavily oxidized	200-940	0.20-0.31
Aluminum oxide	530-930	0.63-0.42
Aluminum oxide	930-1520	0.42-0.26
Aluminum alloy 75 ST cleaned with toluene, then methanol, repeatedly heated and cooled	450-900	0.22-0.16
Aluminum alloy 24 ST cleaned with toluene, then methanol, repeatedly heated and cooled	450-910	0.17-0.15
Brass		
Polished	100-600	0.10
Rolled plate, natural surface	72	0.06
Dull plate	120-660	0.22
Oxidized by heating at 1110°F	390-1110	0.61-0.59
Chromium, polished	100-2000	0.08-0.36
Copper		
Polished	242	0.023
Commercial, scraped shiny, but not mirrorlike	72	0.072
Plate, heated long time, covered with thick oxide layer	77	0.78
Plate heated at 1110°F	390-1110	0.57
Gold, pure, highly polished	440-1160	0.018-0.035
Inconel		
Type X, cleaned with toluene, then methanol, repeatedly heated and cooled	450-1620	0.55-0.78
Type B, cleaned with toluene, then methanol, repeatedly heated and cooled	450-1620	0.35-0.55

*Selected from a compilation by H.C. Hottel, published in Table A.23 of *Heat Transmission*, 3rd edn., 1954 by W.H. MacAdams, McGraw-Hill Book Co., Inc.

**When temperatures and emissivities appear in pairs separated by dashes, they correspond, and linear interpolation is possible.

Surface	t, °F*	Emissivity*
Iron and Steel Metallic Surfaces		
Steel, polished	212	0.066
Iron, polished	800-1880	0.14-0.38
Cast iron, polished	392	0.21
Smooth sheet iron	1650-1900	0.55-0.60
Mild steel, cleaned with toluene, then ethanol, repeatedly heated and cooled	450-1950	0.20-0.32
Iron and Steel Oxidized Surfaces		
Iron plate, completely rusted	67	0.69
Iron, dark grey surface	212	0.31
Rolled sheet steel	70	0.66
Cast iron, oxidized at 1100°F	390-1110	0.64-0.78
Steel, oxidized at 1100°F	390-1110	0.79
Iron oxide	930-2190	0.85-0.89
Sheet steel, strong, rough oxide layer	75	0.80
Sheet steel, dense, shiny oxide layer	75	0.82
Cast iron, rough, strongly oxidized	100-480	0.95
Wrought iron, dull, oxidized	70-680	0.94
Steel plate, rough	100-700	0.94-0.97
Lead, grey oxidized	75	0.28
Lead, oxidized at 300°F	390	0.63
Magnesium oxide	530-1520	0.55-0.20
Magnesium oxide	1650-3100	0.20
Monel metal, oxidized at 1110°F	390-1110	0.41-0.46
K Monel 5700, cleaned with toluene, then ethanol, repeatedly heated and cooled	450-1610	0.46-0.65
Nickel, polished	212	0.072
Nickel plate, oxidized by heating at 1110°F	390-1110	0.37-0.48
Nichrome wire, bright	120-1830	0.65-0.79
Nichrome wire, oxidized	120-930	0.95-0.98
Platinum, pure, polished plate	440-1160	0.054-0.104
Silver, polished, pure	440-1160	0.020-0.032
Stainless Steels		
Polished	212	0.074
Type 301, cleaned with toluene, then ethanol, repeatedly heated and cooled	450-1740	0.57-0.55
Type 316, cleaned with toluene, then ethanol, repeatedly heated and cooled	450-1600	0.57-0.66
Type 347, cleaned with toluene, then ethanol, repeatedly heated and cooled	450-1650	0.52-0.65

* When temperatures and emissivities appear in pairs separated by dashes, they correspond, and linear interpolation is possible.

Surface	t, °F*	Emissivity*
Type 310, brown splotched, oxidized from furnace service	420-980	0.90-0.97
Tin, bright	122	0.06
Tin, commercial tin-plated sheet iron	212	0.07-0.08
Zinc		
Commercial 99.1% pure, polished	440-620	0.045-0.053
Galvanized sheet iron, fairly bright	82	0.23
Galvanized sheet iron, grey oxidized	75	0.28
Refractories, Building Materials, Paints and Miscellaneous		
Alumina		
Mean grain size 10 microns	1850-2850	0.30-0.18
Mean grain size 50 microns	1850-2850	0.39-0.28
Mean grain size 100 microns	1850-2850	0.50-0.40
Asbestos board	74	0.96
Asbestos paper	100-700	0.93-0.94
Brick		
Red, rough, but no gross irregularities	70	0.93
Building	1832	0.45
Fireclay	1832	0.75
Carbon		
Filament	1900-2560	0.526
Rough plate	212-608	0.77
Rough plate	608-932	0.77-0.72
Lampblack, rough deposit	212-932	0.84-0.78
Graphite, pressed, filed surface	480-950	0.98
Carborundum (87 SiC, density 2.3)	1850-2550	0.92-0.82
Concrete tiles	1832	0.63
Enamel, white fused, on iron	66	0.90
Glass, pyrex, lead and soda	500-1000	0.95-0.85
Gypsum, 0.02 in. thick, on smooth or blackened plate	70	0.903
Magnesite refractory brick	1832	0.38
Marble, light grey, polished	72	0.93
Oak, planed	70	0.90
Paints, Lacquers, Varnishes		
Snow-white enamel varnish on rough iron plate	73	0.906
Black shiny lacquer, sprayed on iron	76	0.875
Black matte shellac	170-295	0.91

* When temperatures and emissivities appear in pairs separated by dashes, they correspond, and linear interpolation is possible.

Surface	t, °F*	Emissivity*
Black or white lacquer	100-200	0.80-0.95
Flat black lacquer	100-200	0.96-0.98
Oil paints, 16 different, all colours	212	0.92-0.96
Aluminum paints and lacquers, 10% Al, 22% lacquer body on rough or smooth surfaces	212	0.52
Other Al paints, varying age and Al content	212	0.27-0.67
Al lacquer, varnish binder, on rough plate	70	0.39
Al paint, after heating to 620°F	300-600	0.35
Radiator paint, white, cream, bleach	212	0.79,0.77,0.84
Radiator paint, bronze	212	0.51
Lacquer coatings, 0.001–0.015 in. thick on aluminum alloys	100-300	0.87-0.97
Clear silicone vehicle coatings 0.001–0.015 in. thick on mild steel	500	0.66
Aluminum paint with silicone vehicle, 2 coats on Inconel	500	0.29
Plaster, rough lime	50-190	0.91
Porcelain, glazed	72	0.92
Quartz, rough, fused	70	0.93
Roofing paper	69	0.91
Rubber, hard, glossy plate	74	0.94
Rubber, soft, grey, rough (reclaimed)	76	0.86
Silica, mean grain size 10 microns	1850-2850	0.42-0.33
Silica, grain size 70–600 microns	1850-2850	0.62-0.46

B.3 Calculation of Loss due to Radiation and Convection

From the heat loss formulae and the table of emissivity values given in the foregoing sections, the heat loss due to radiation and convection from a boiler or other large object can be calculated fairly accurately, provided surface temperature, ambient temperature and air velocity are measured over all the surfaces. The procedure for calculating the heat loss is best demonstrated by the following simple example:

Example B.1

A coal-fired boiler having a heat input of 80 million Btu/hr has an air heater with the dimensions shown in Figure B.1. It is insulated all around, and the outer fabric has a fresh coat of aluminum paint. However, the sloped surfaces at the top are covered with coal dust, and the sloped surfaces at the bottom have old paint. Measurements of temperature and velocity show considerable spatial variation, but the following figures are considered to be reasonable averages:

* When temperatures and emissivities appear in pairs separated by dashes, they correspond, and linear interpolation is possible.

Area	Surface temp. (°F)	Air temp. (°F)	Air velocity (ft/s)
1. Front, upper half (64 sq ft)	180	100	natural convection
2. Front, lower half (64 sq ft)	170	80	natural convection
3. R. side, upper half (95 sq ft)	175	90	10
4. R. side, lower half (95 sq ft)	170	80	10
5. Rear, upper half (80 sq ft)	180	95	8
6. Rear, lower half (80 sq ft)	175	90	7
7. L. side, upper half (95 sq ft)	182	95	6
8. L. side, lower half (95 sq ft)	178	92	5
9. Bottom slopes (68 sq ft)	165	78	0
10. Top slopes (68 sq ft)	185	98	7

Find the total radiation and convection heat loss, in Btu/hr and % of heat input, ignoring losses from the gas and air ducts.

Solution

From the discussion at the beginning of this appendix, the following three formulae are applicable:

Radiation Loss: h_r (Btu/sq ft hr) = $17.4 \times 10^{-10} \times \epsilon (T_1{}^4 - T_2{}^4)$

Natural Convection Loss: h_c (Btu/sq ft hr) = $0.53\ C \left(\frac{1}{T_{avg}}\right)^{0.18} dt^{1.27}$

Forced Convection Loss: h_{fc} (Btu/sq ft hr °F) = $1 + 0.225V$

From Table B.1, emissivities may be selected as follows:

for the sides:	$\epsilon = 0.27$	(fresh aluminum paint)
for the bottom:	$\epsilon = 0.67$	(old aluminum paint)
for the top:	$\epsilon = 0.84$	(treat as rough deposit of lamp black)

These formulae and emissivity values must be appropriately applied to each of the ten surfaces.

1. Front upper half:

Total radiation loss = (surface area) x h_r
Total radiation loss = $64 \times 17.4 \times 10^{-10} \times 0.27\ (640^4 - 560^4)$
= 2088 Btu/hr

Total natural convection loss

$= 64 \times 0.53 \times 1.39 \times \left(\frac{1}{600}\right)^{0.18} \times 80^{1.27}$ = 3893 Btu/hr

(for a vertical surface, C = 1.39)

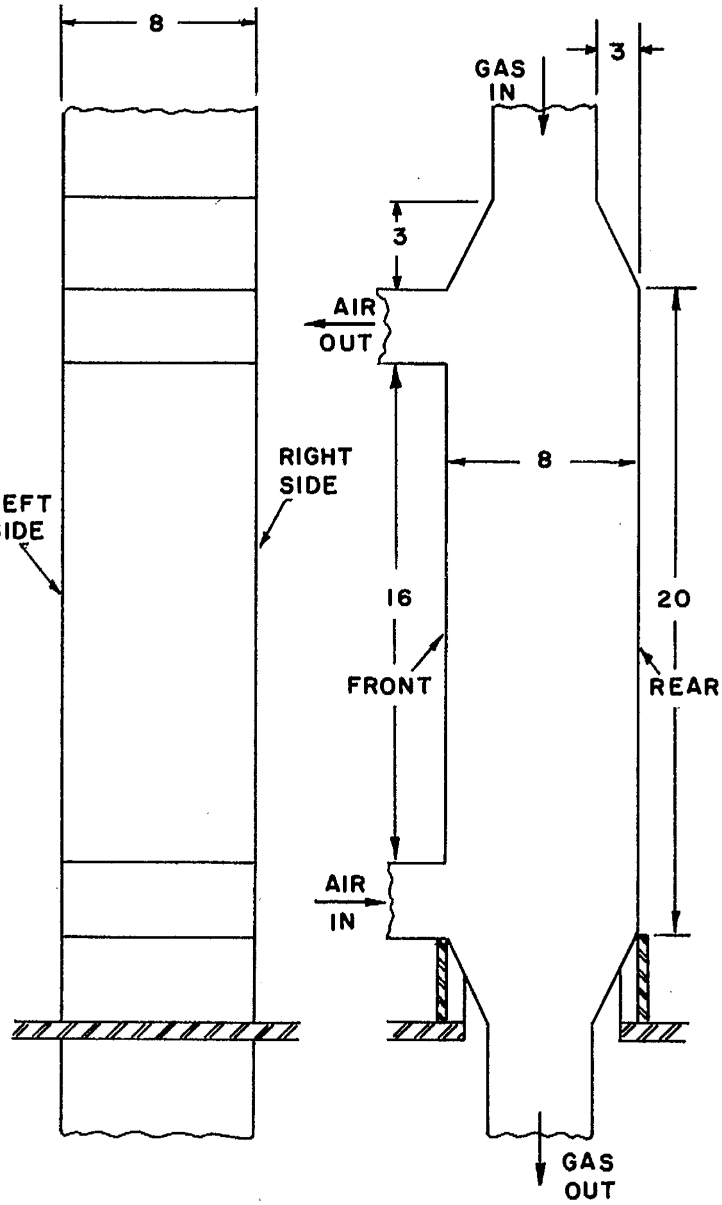


FIGURE B·1· DIMENSIONS OF AIR HEATER IN EXAMPLE B·1·

2. Front, lower half:

Total radiation loss = $64 \times 17.4 \times 10^{-10} \times 0.27 (630^4 - 540^4)$
= 2180 Btu/hr

Total natural convection loss
$= 64 \times 0.53 \times 1.39 \times \left(\frac{1}{585}\right)^{0.18} \times 90^{1.27}$ = 4542 Btu/hr

3. Right side, upper half:

Total radiation loss = $95 \times 17.4 \times 10^{-10} \times 0.27 (635^4 - 550^4)$
= 3173 Btu/hr

Total forced convection loss = $95 \times 85 \times [1 + 0.225 (10)]$
= 26,244 Btu/hr

4. Right side, lower half:

Total radiation loss = $95 \times 17.4 \times 10^{-10} \times 0.27 (630^4 - 540^4)$
= 3236 Btu/hr

Total forced convection loss = $95 \times 90 \times [1 + 0.225 (10)]$
= 27,787 Btu/hr

5. Rear, upper half:

Total radiation loss = $80 \times 17.4 \times 10^{-10} \times 0.27 (640^4 - 555^4)$
= 2740 Btu/hr

Total forced convection loss = $80 \times 85 \times [1 + 0.225 (8)]$
= 19,040 Btu/hr

6. Rear, lower half:

Total radiation loss = $80 \times 17.4 \times 10^{-10} \times 0.27 (635^4 - 550^4)$
= 2672 Btu/hr

Total forced convection loss = $80 \times 85 \times [1 + 0.225 (7)]$
= 17,510 Btu/hr

7. Left side, upper half:

Total radiation loss = $95 \times 17.4 \times 10^{-10} \times 0.27 (642^4 - 555^4)$
= 3347 Btu/hr

Total forced convection loss = $95 \times 87 \times [1 + 0.225 (6)]$
= 19,423 Btu/hr

8. Left side, lower half:

Total radiation loss = $95 \times 17.4 \times 10^{-10} \times 0.27 (638^4 - 552^4)$
= 3251 Btu/hr

Total forced convection loss = $95 \times 86 \times [1 + 0.225 (5)]$
= 17,361 Btu/hr

9. Bottom slopes:

Total radiation loss = $68 \times 17.4 \times 10^{-10} \times 0.67 (625^4 - 538^4)$
= 5455 Btu/hr

There is no convection loss because air circulation is blocked by skirts.

10. Top slopes:

Total radiation loss = $68 \times 17.4 \times 10^{-10} \times 0.84 (645^4 - 558^4)$
= 7566 Btu/hr

Total forced convection loss = $68 \times 87 \times [1 + 0.225 (7)]$
= 15,234 Btu/hr

Total losses = 186,741 Btu/hr

$$= \frac{186{,}741 \times 100}{80 \times 10^6} = 0.233\%$$

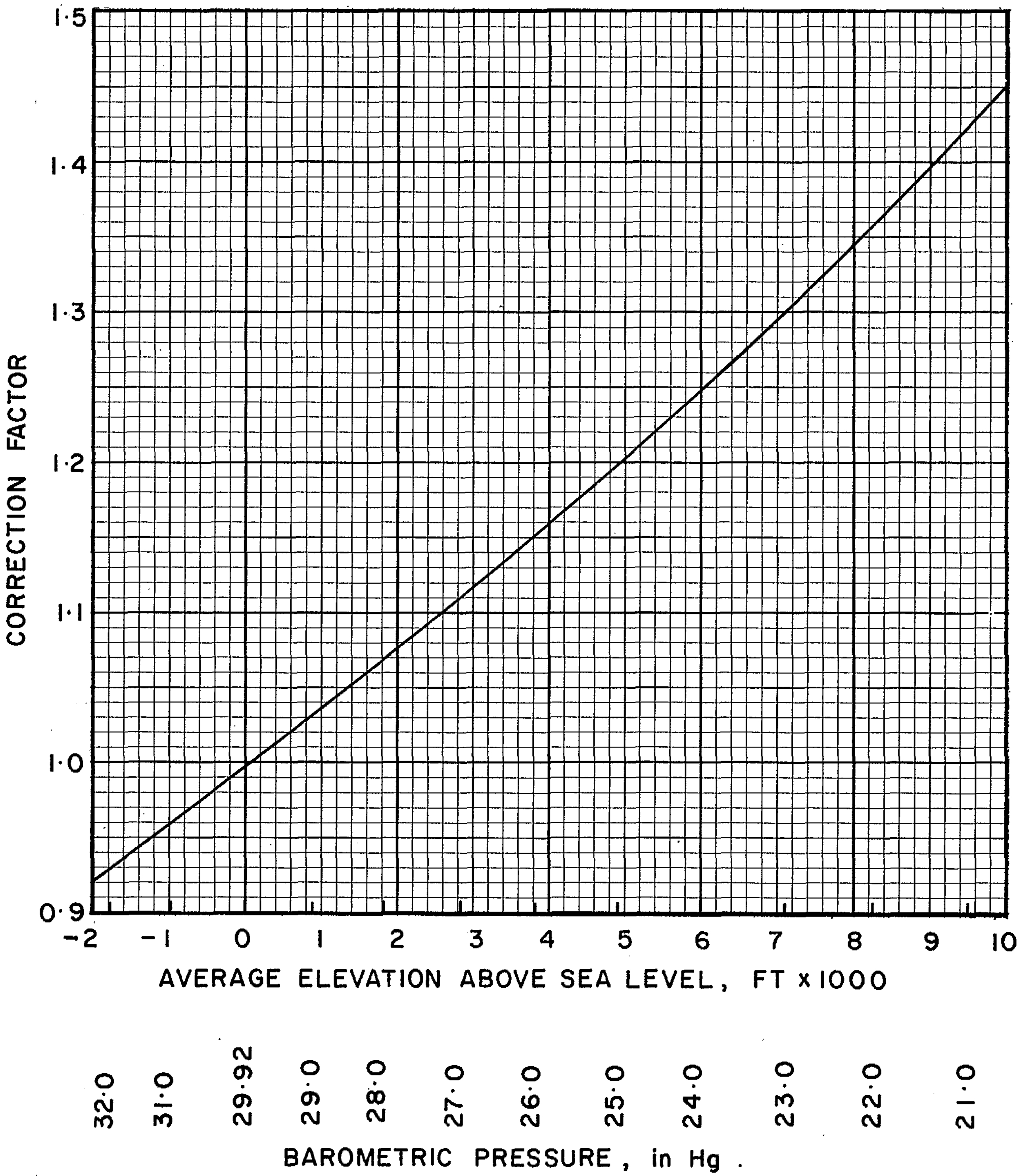


FIGURE A. ELEVATION CORRECTION FACTORS TO BE APPLIED TO THE VOLUMES OF COMBUSTION AIR AND FLUE GAS OBTAINED FROM FIGURE 2 WHEN ATMOSPHERIC PRESSURE IS OTHER THAN 29·92 in Hg.

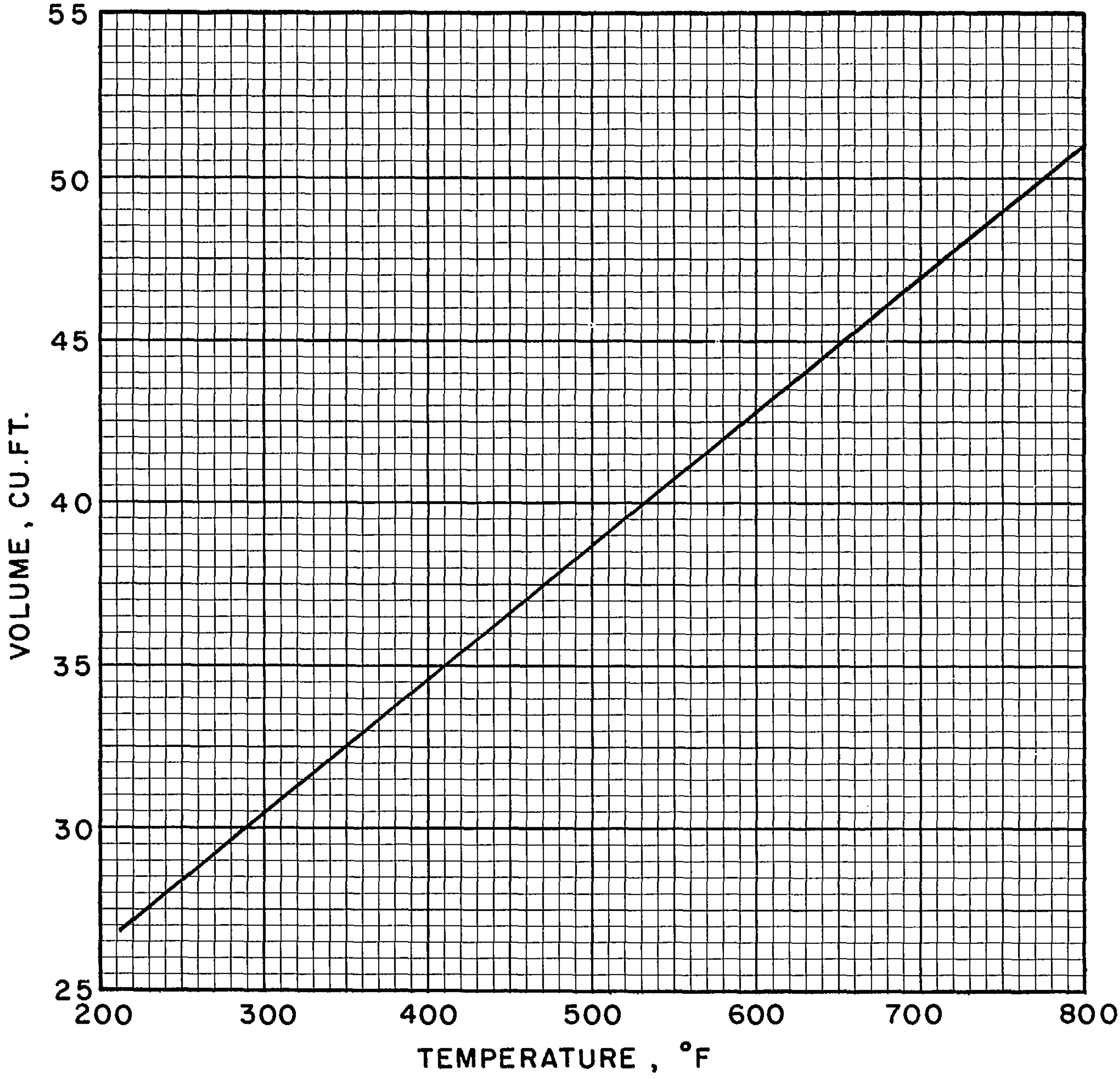


FIGURE B. VOLUME OF 1 LB OF WATER VAPOUR VS TEMPERATURE AT 29·92 IN·Hg·

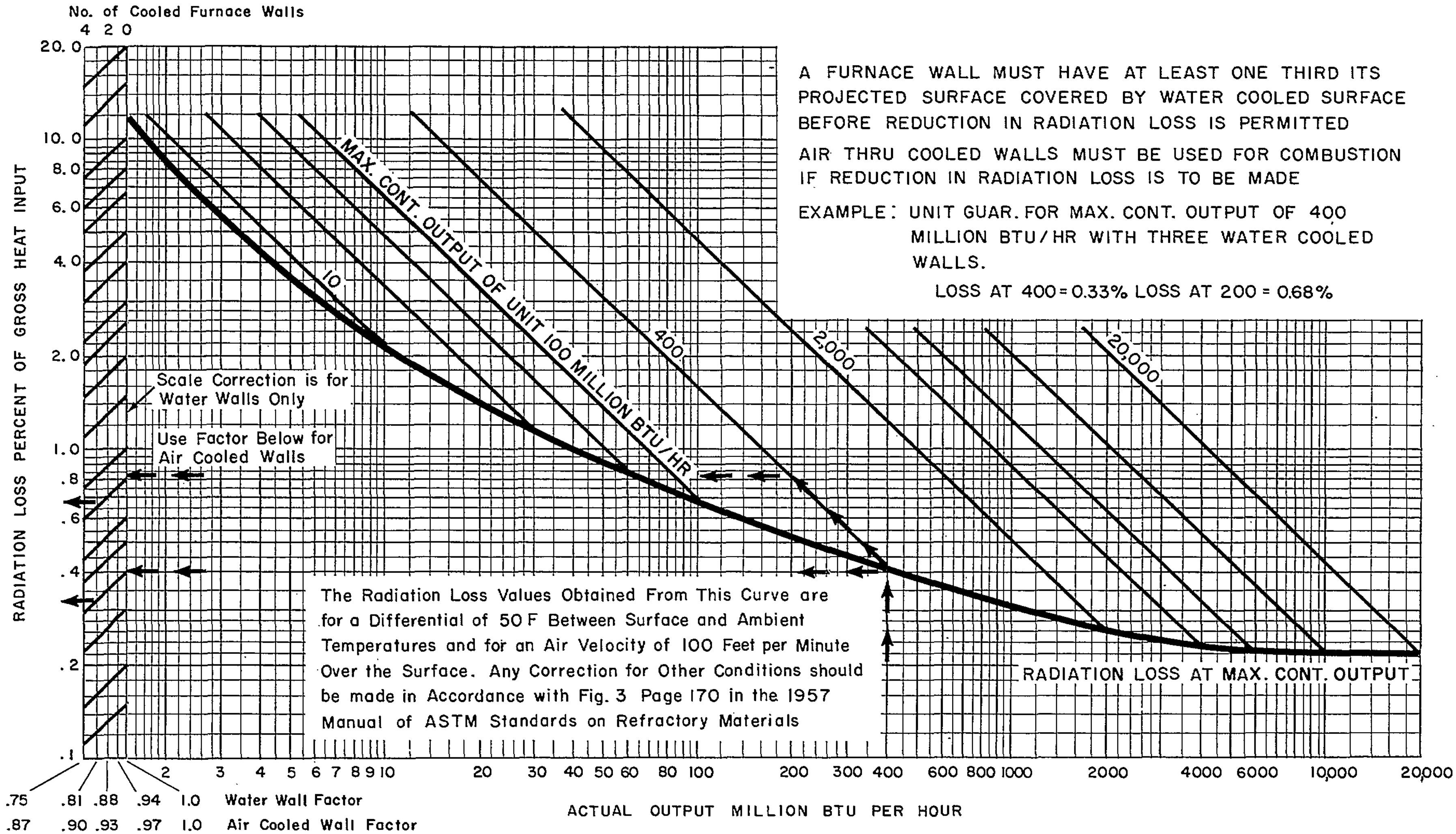


FIGURE C RADIATION AND CONVECTION HEAT LOSS CHART, ASSUMING EMISSIVITY = 0·95
PUBLISHED BY COURTESY OF THE AMERICAN BOILER MANUFACTURERS ASSOCIATION.

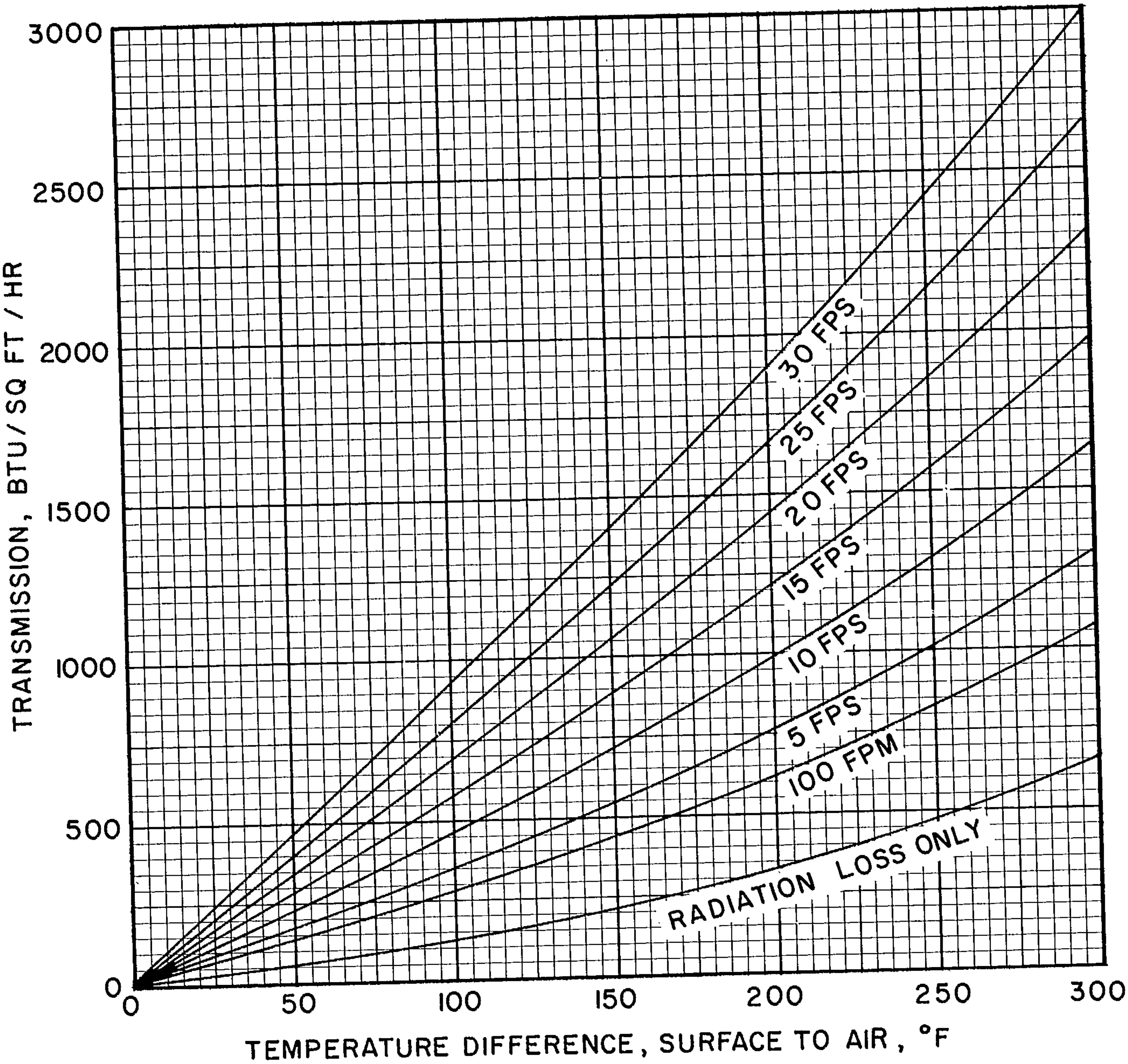


FIGURE D SURFACE HEAT TRANSMISSION FOR A RANGE OF AIR VELOCITIES BASED ON AN EMISSIVITY OF 0·95 AND AN AIR TEMPERATURE OF 70° F. PUBLISHED BY COURTESY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

COAL NS 1-1, ACADIA, PICTOU COUNTY, 3/4 x 3/16 in.

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.1196
Volatile Matter	0.2869
Fixed Carbon	0.5935
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7653
Hydrogen (H)	0.0460
Sulphur (S)	0.0047
Nitrogen (N)	0.0195
Oxygen (O)	0.0449
Ash	0.1196
Total	1.0000

Gross Calorific Value

Btu/lb:	13250
Btu/short ton:	26.5×10^6
Btu/long ton:	29.7×10^6
MJ/kg:	30.81

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	75.47	lb	
10^6 Btu	=	0.03774	short tons	
10^6 Btu	=	0.0337	long tons	

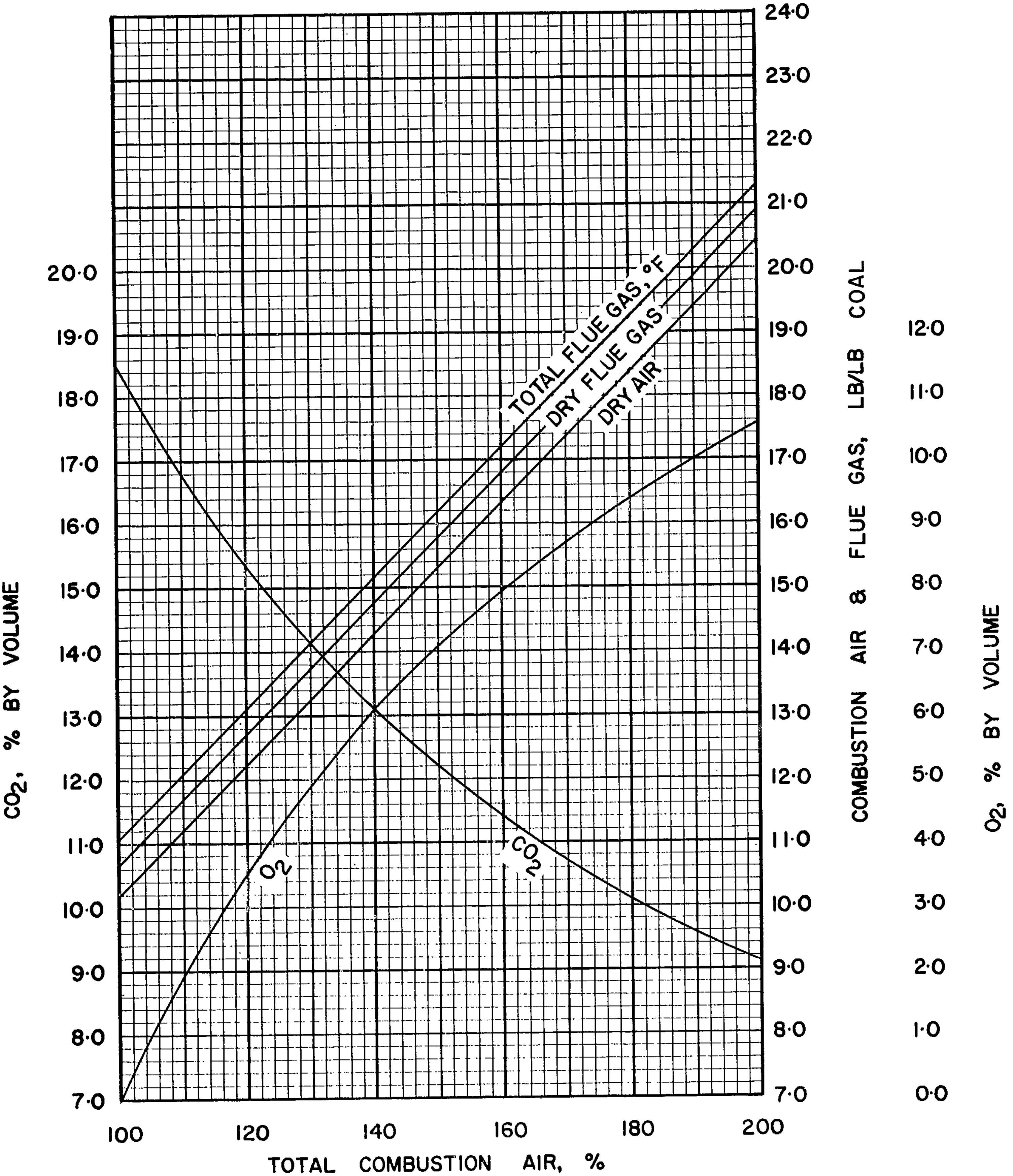


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·1·1

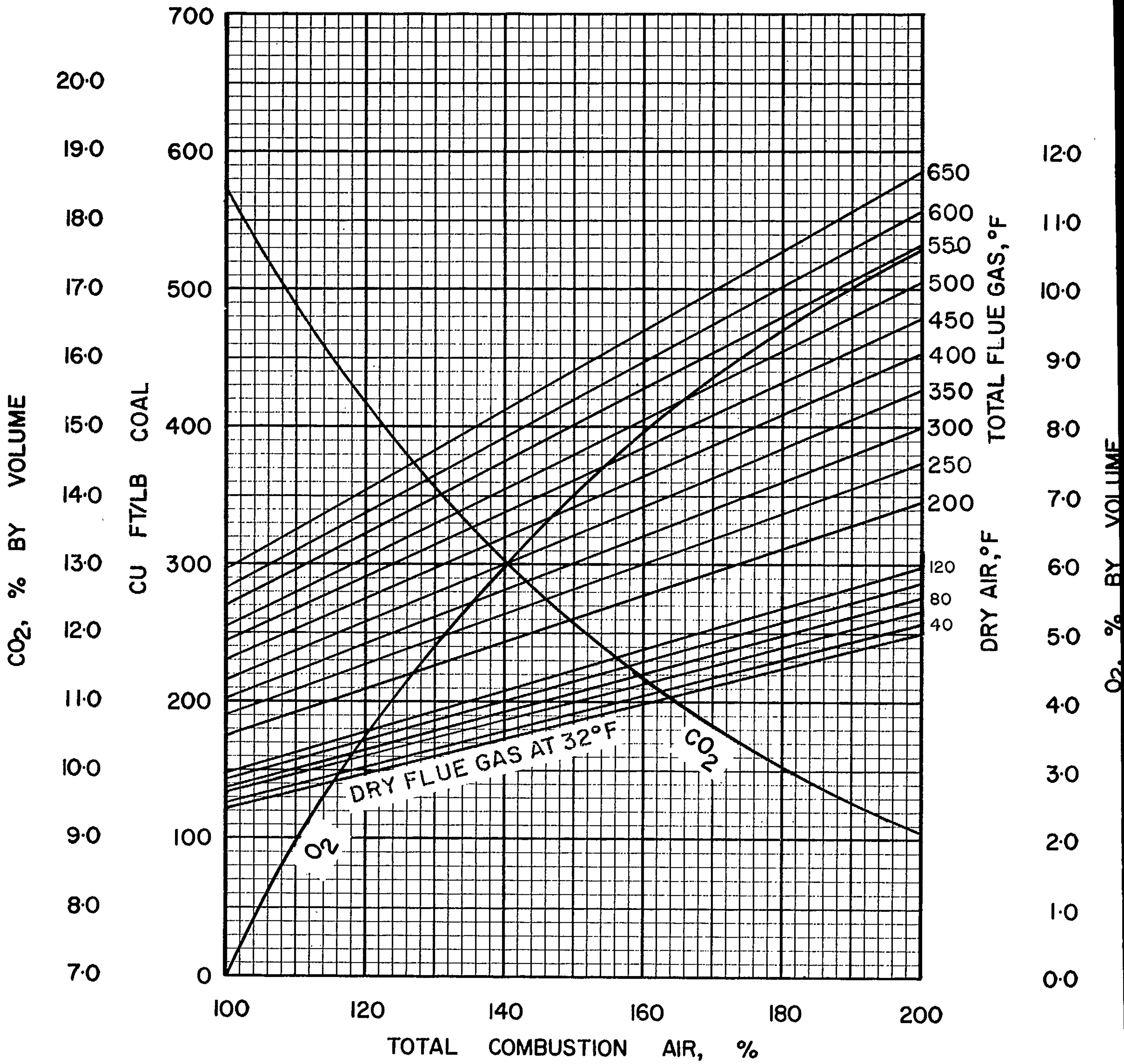


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·1·1

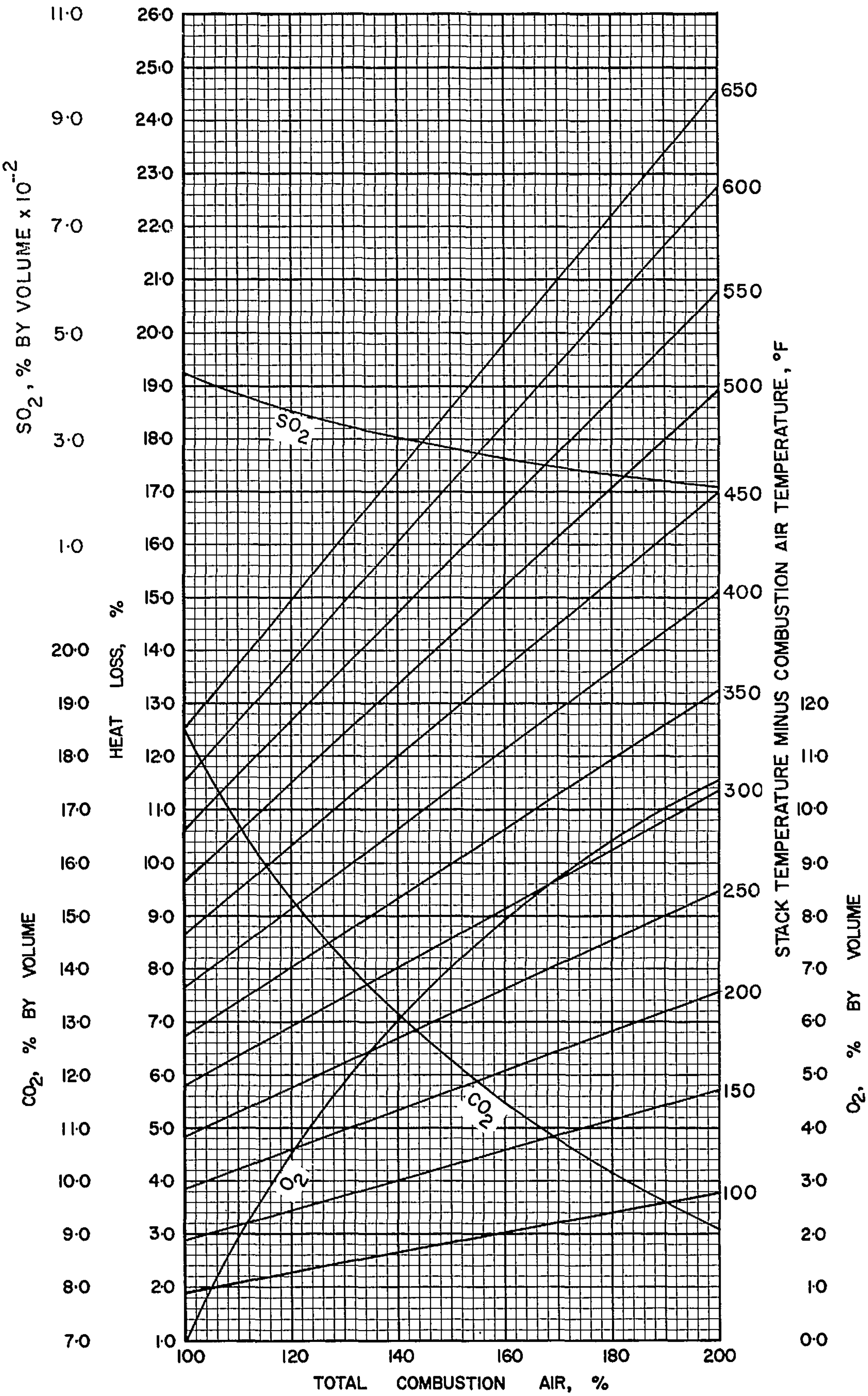


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·1·1

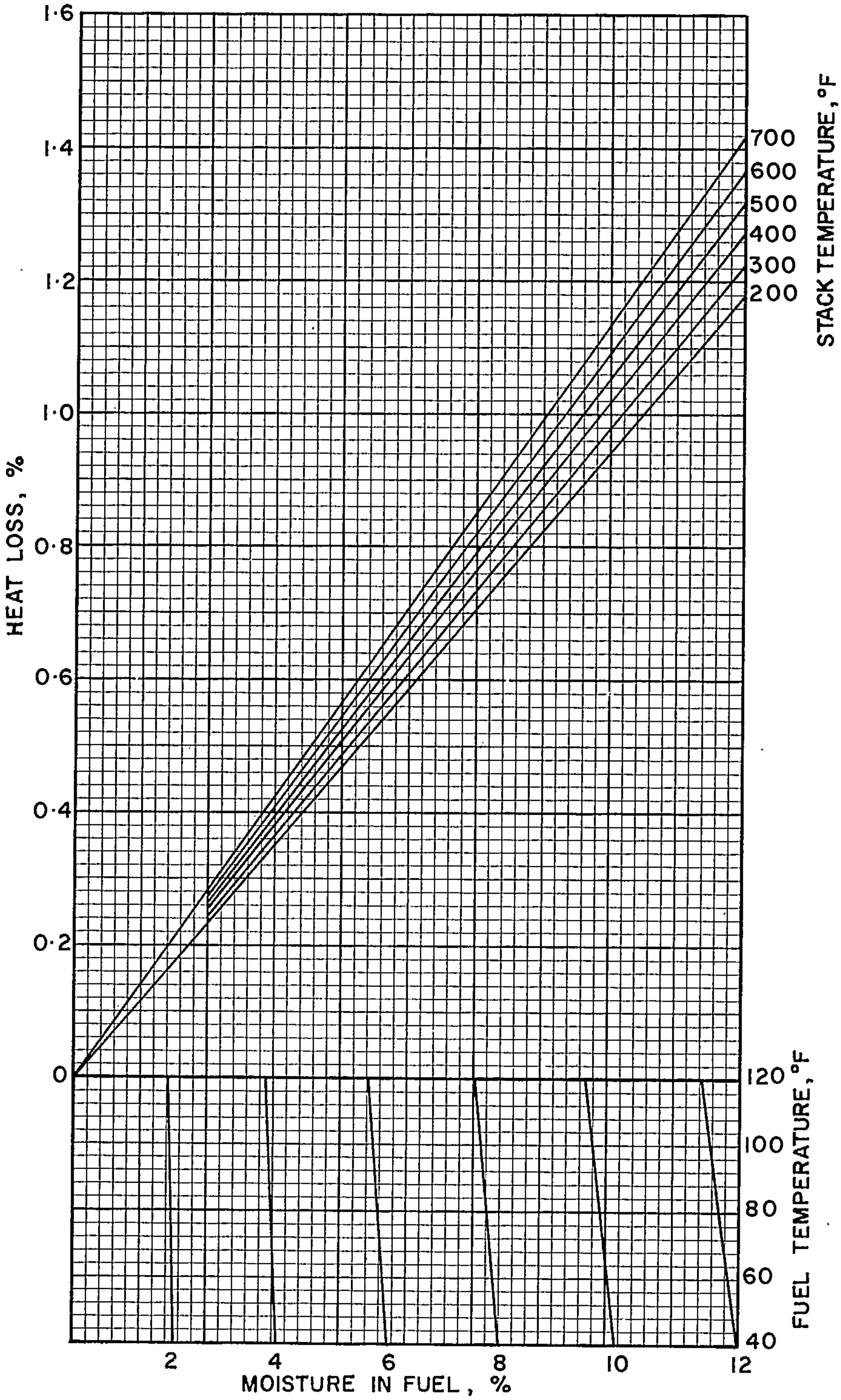


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·I·I

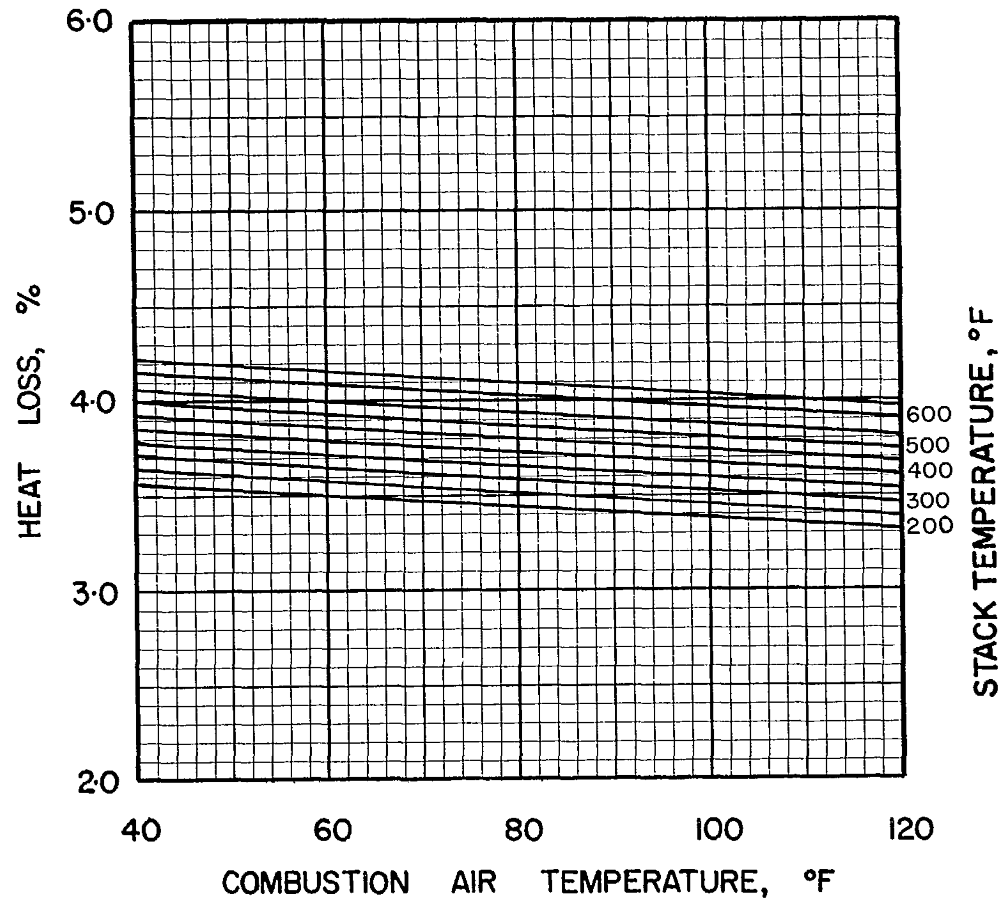


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·1·1

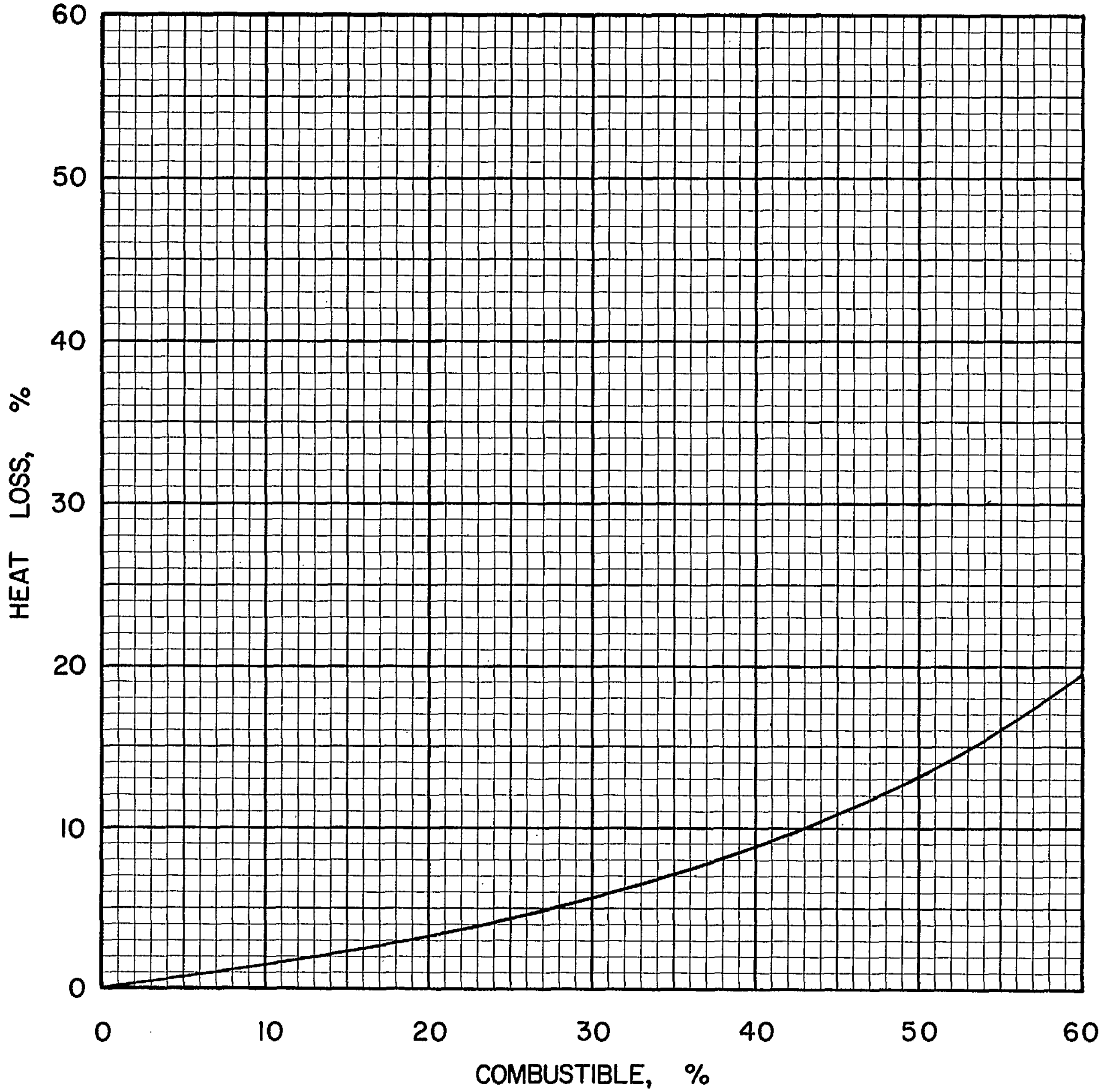


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·1·1

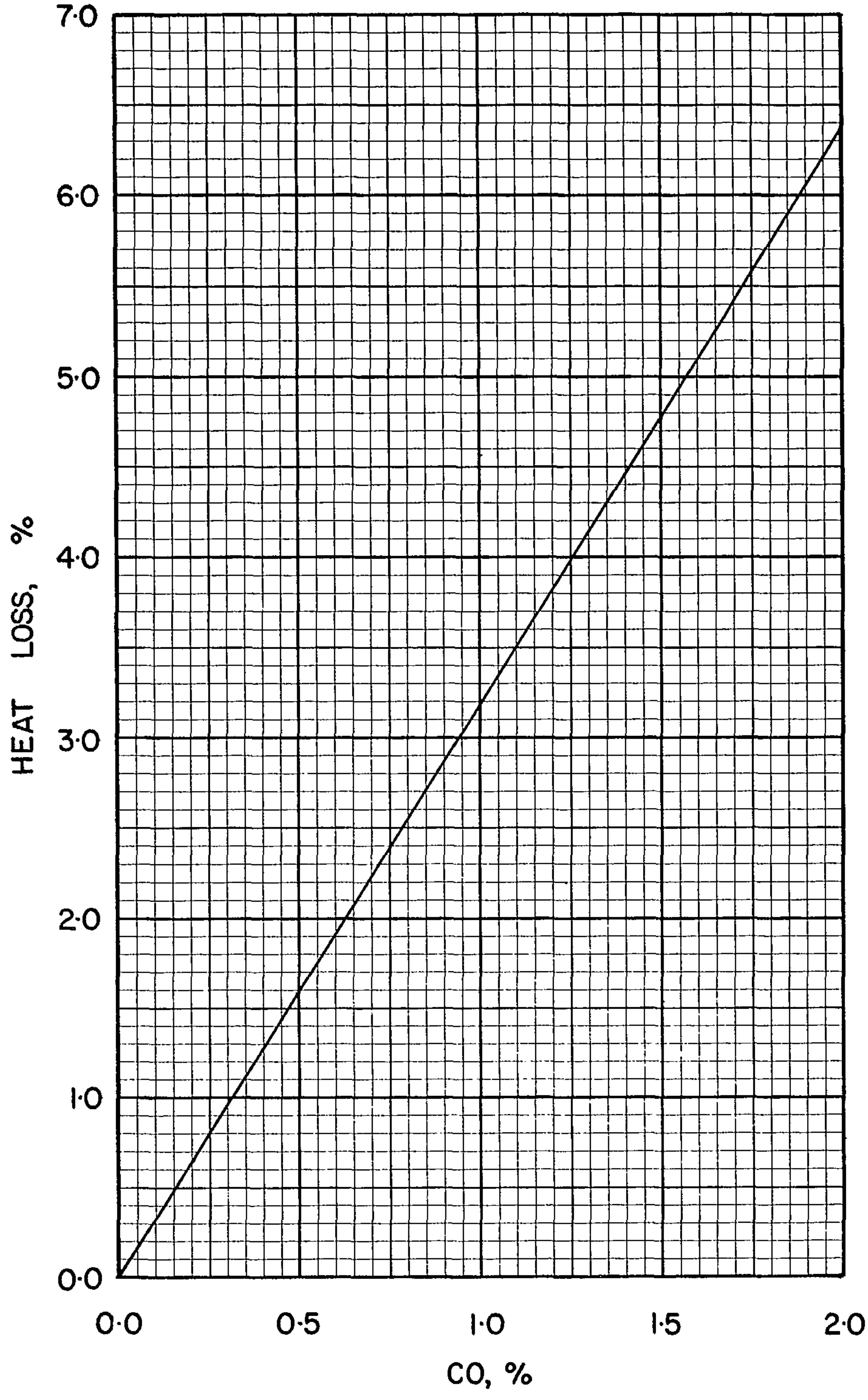


FIGURE 7· HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·1·1

COAL NS 1-2, ACADIA, PICTOU COUNTY, 3/16 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.1346
Volatile Matter	0.2769
Fixed Carbon	0.5885
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7814
Hydrogen (H)	0.0447
Sulphur (S)	0.0066
Nitrogen (N)	0.0184
Oxygen (O)	0.0143
Ash	0.1346
Total	1.0000

Gross Calorific Value

Btu/lb:	12830
Btu/short ton:	25.66×10^6
Btu/long ton:	28.74×10^6
MJ/kg:	29.84

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 77.94	lb	
10^6 Btu	= 0.03897	short tons	
10^6 Btu	= 0.03480	long tons	

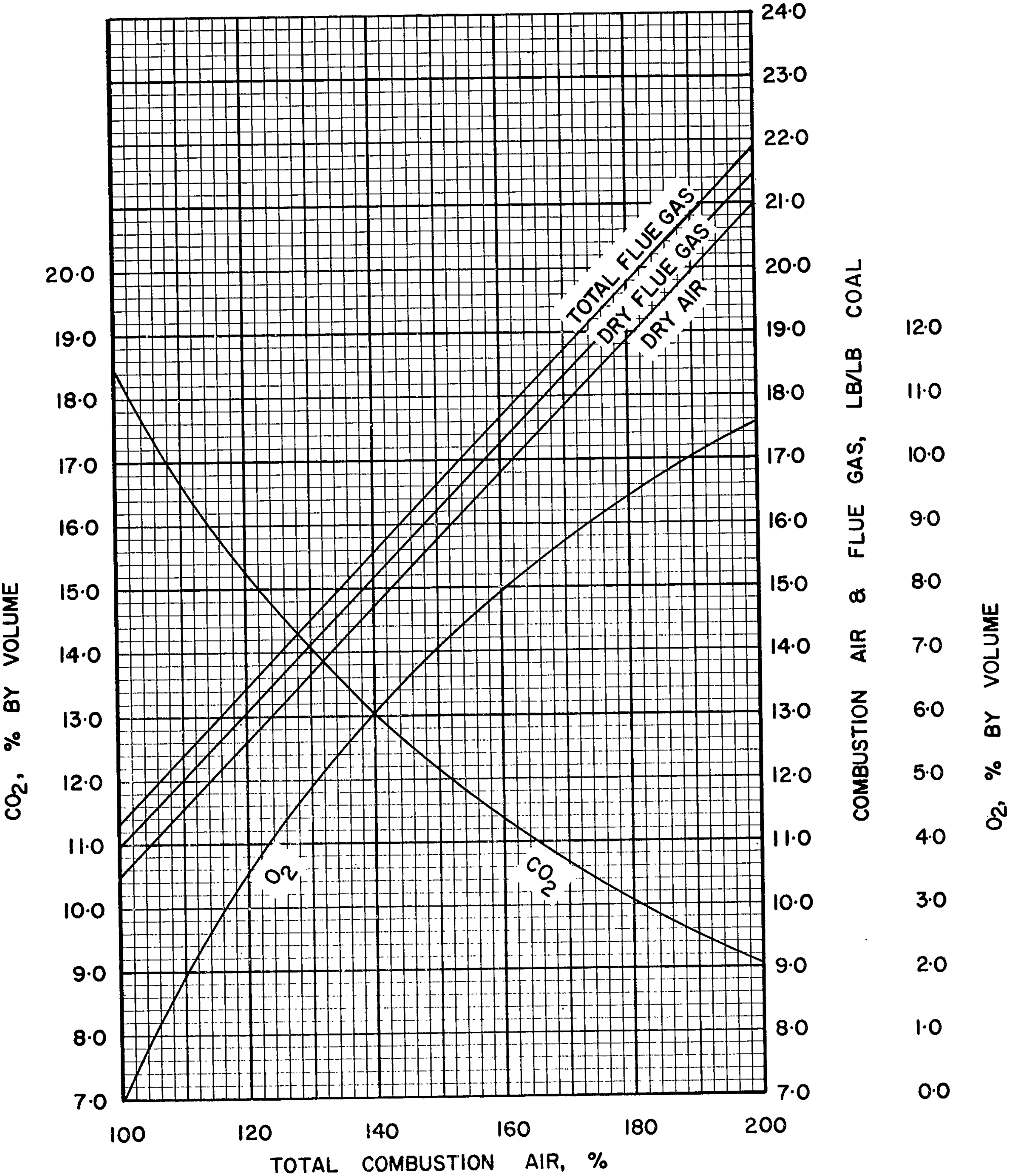
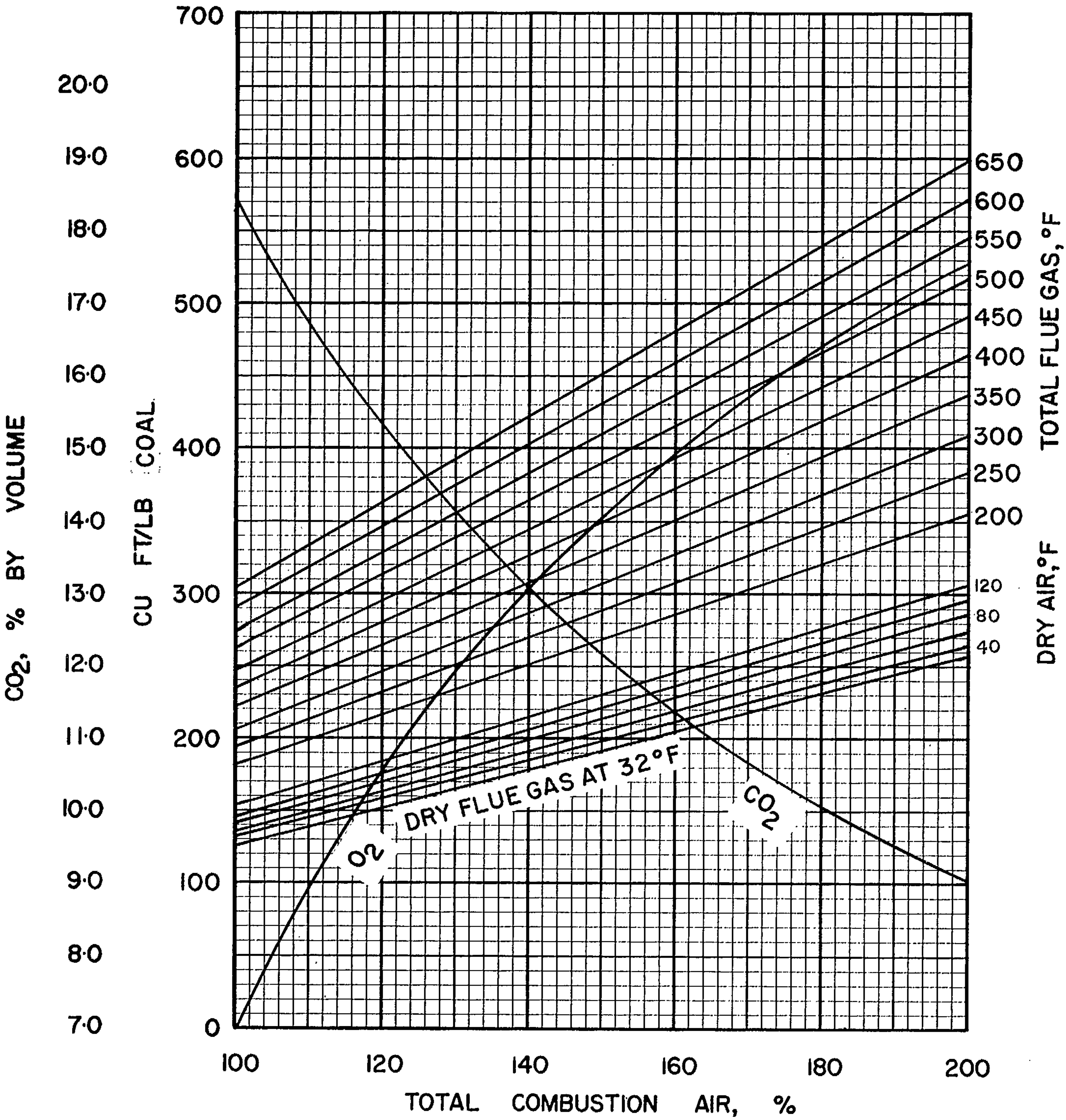


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·1·2



NS·1·2

FIGURE 2· COMBUSTION DATA, VOLUME BASIS

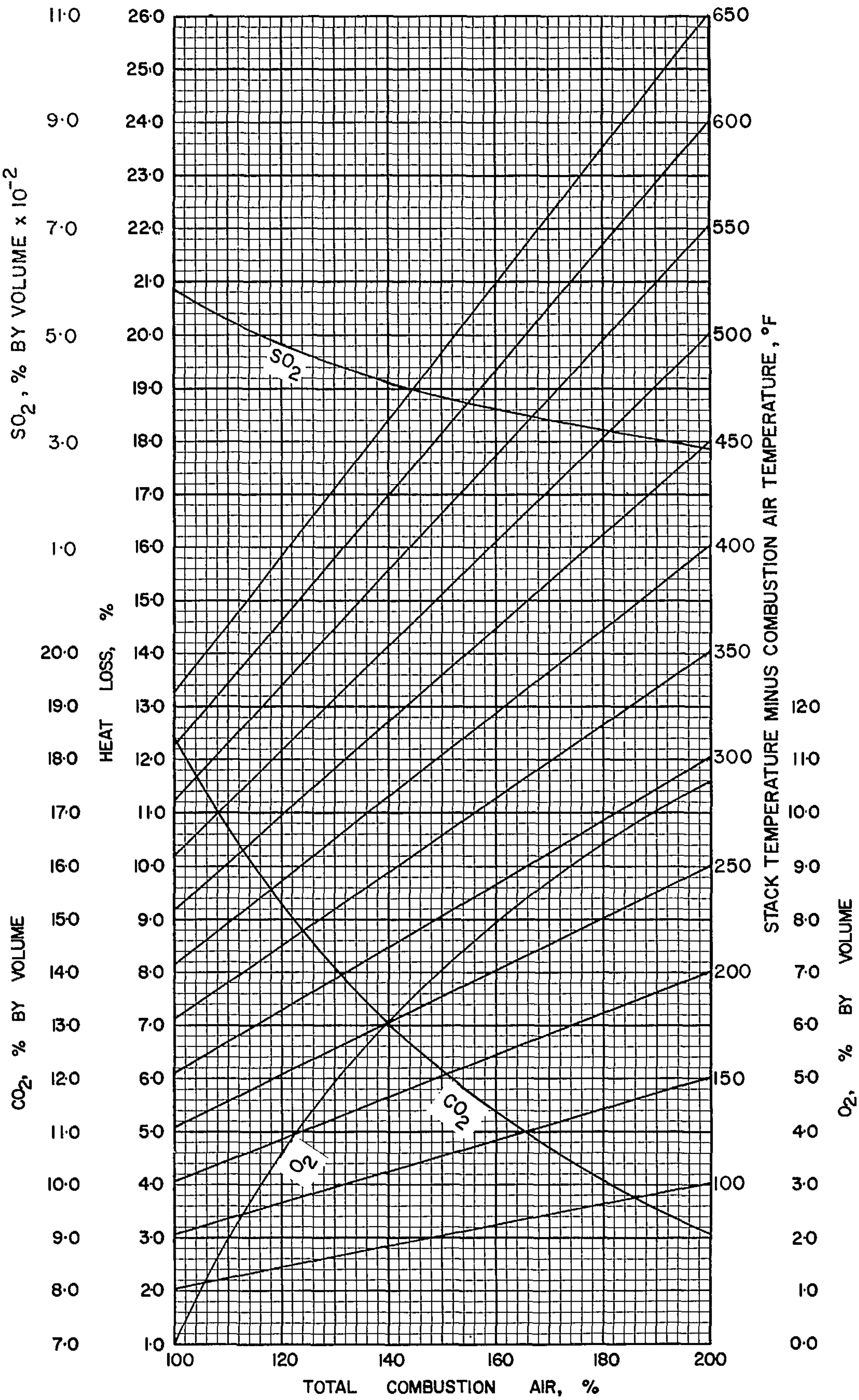


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·1·2

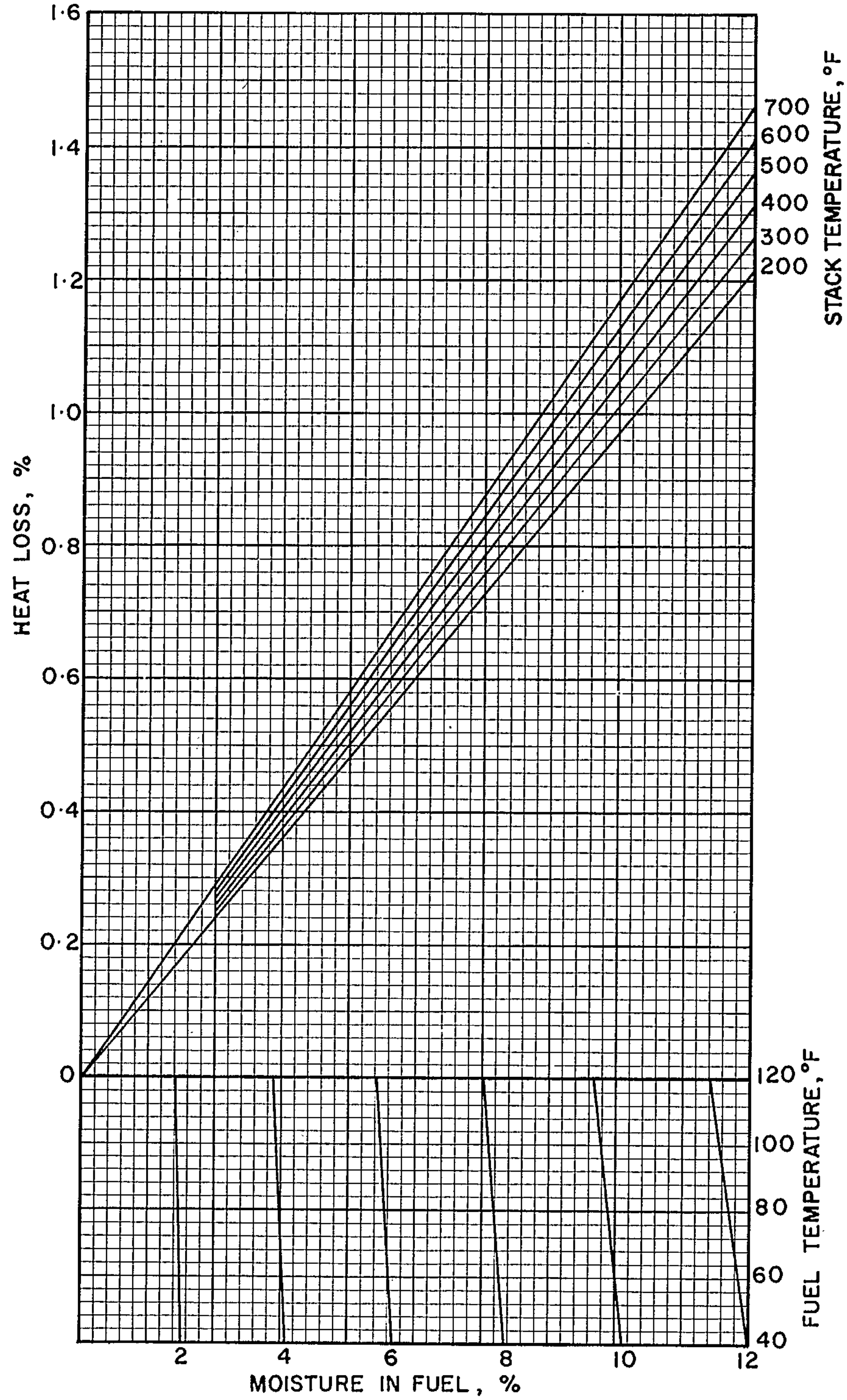


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·1·2

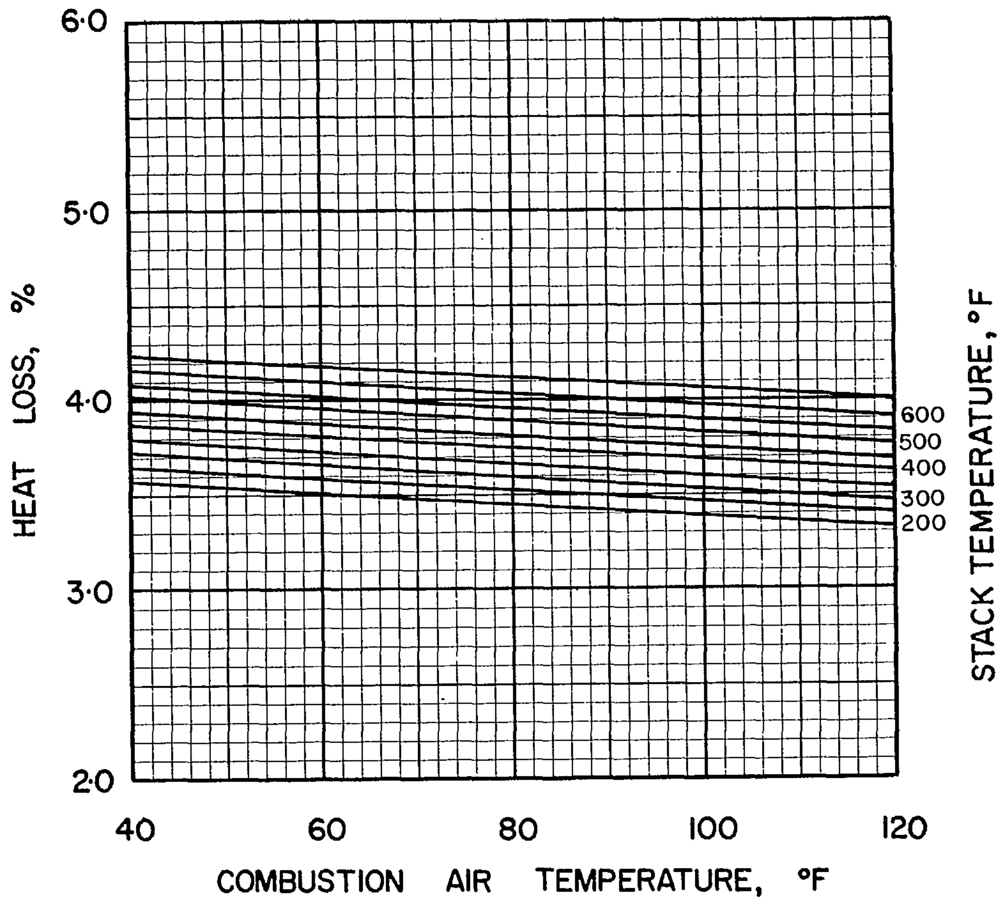


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·1·2

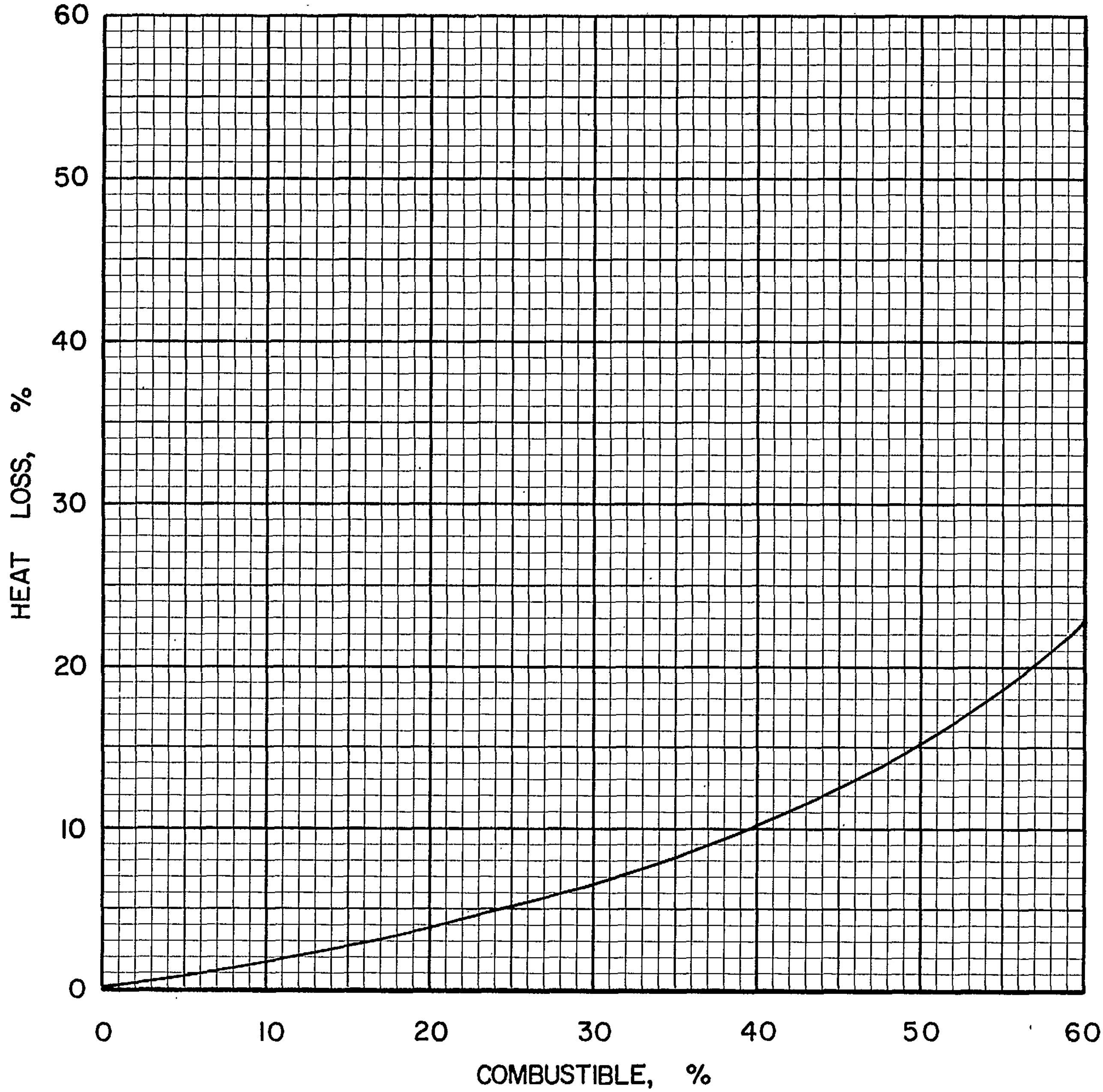


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·1·2

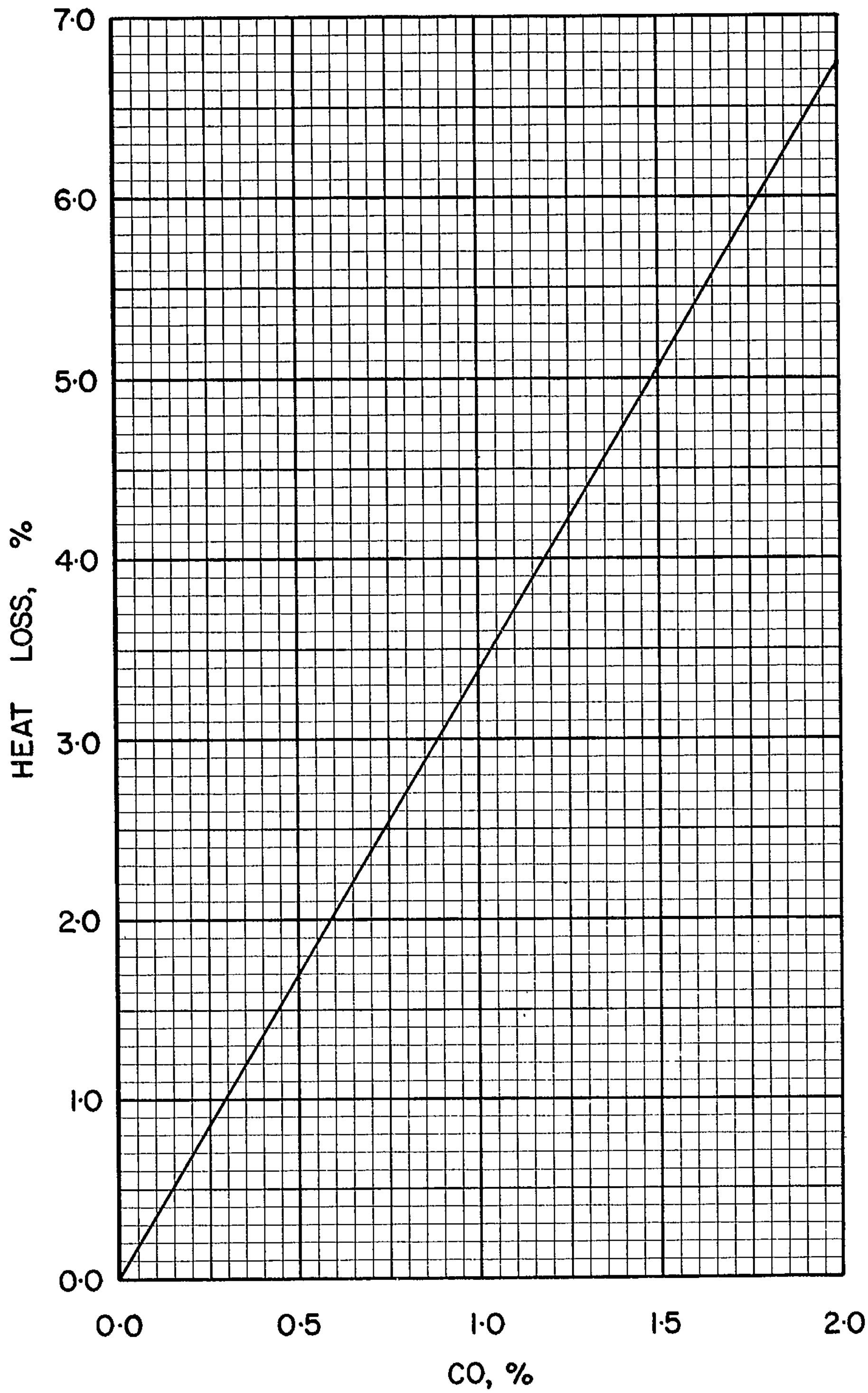


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·1·2

COAL NS 1-3, ACADIA, PICTOU COUNTY, 1 1/2 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.2553
Volatile Matter	0.2906
Fixed Carbon	0.4541
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6206
Hydrogen (H)	0.0384
Sulphur (S)	0.0076
Nitrogen (N)	0.0155
Oxygen (O)	0.0626
Ash	0.2553
Total	1.0000

Gross Calorific Value

Btu/lb:	10670
Btu/short ton:	21.34×10^6
Btu/long ton:	23.90×10^6
MJ/kg:	24.81

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 93.72	lb	
10^6 Btu	= 0.04686	short tons	
10^6 Btu	= 0.04184	long tons	

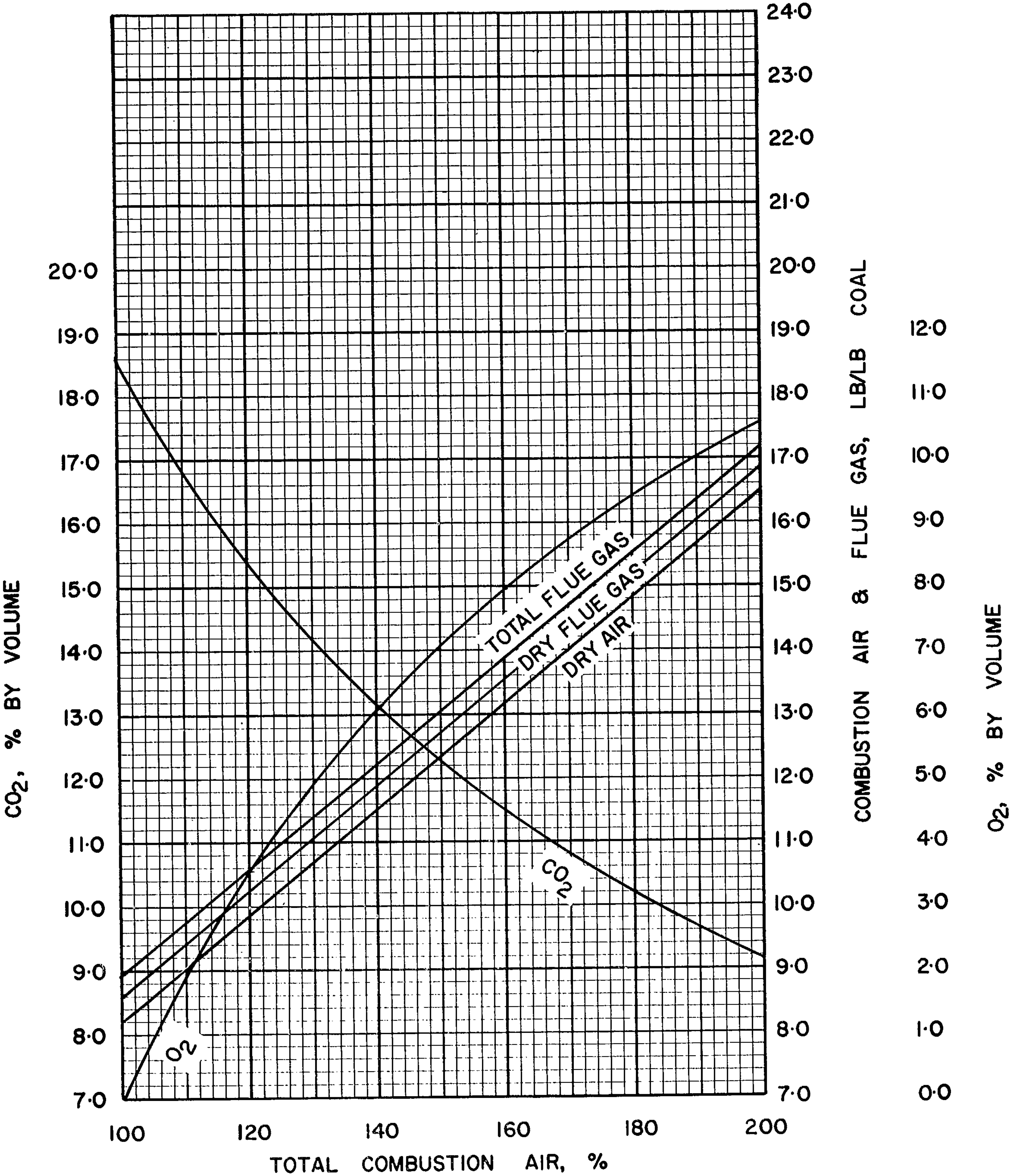
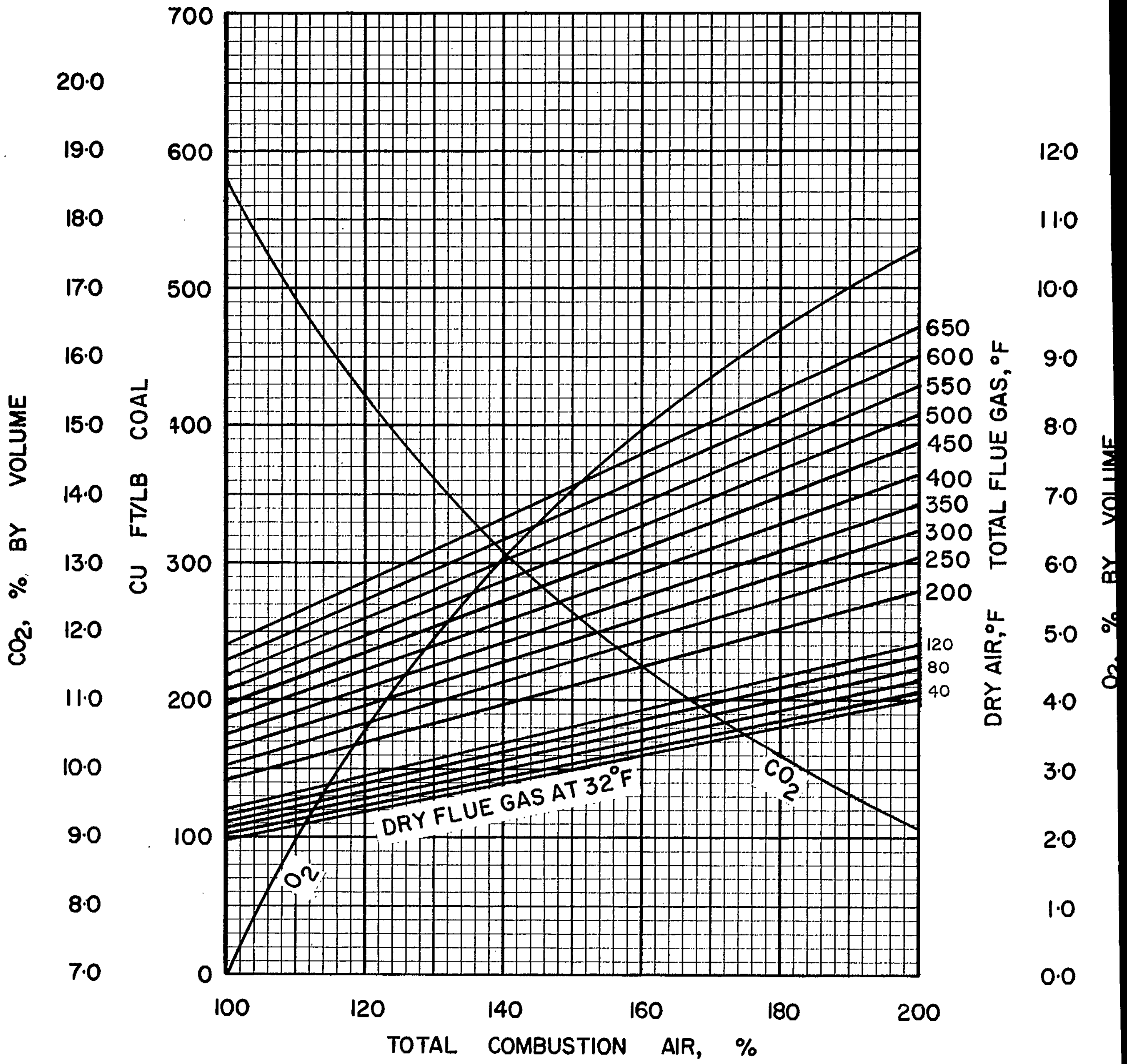


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·1·3



NS·1·3 FIGURE 2· COMBUSTION DATA, VOLUME BASIS

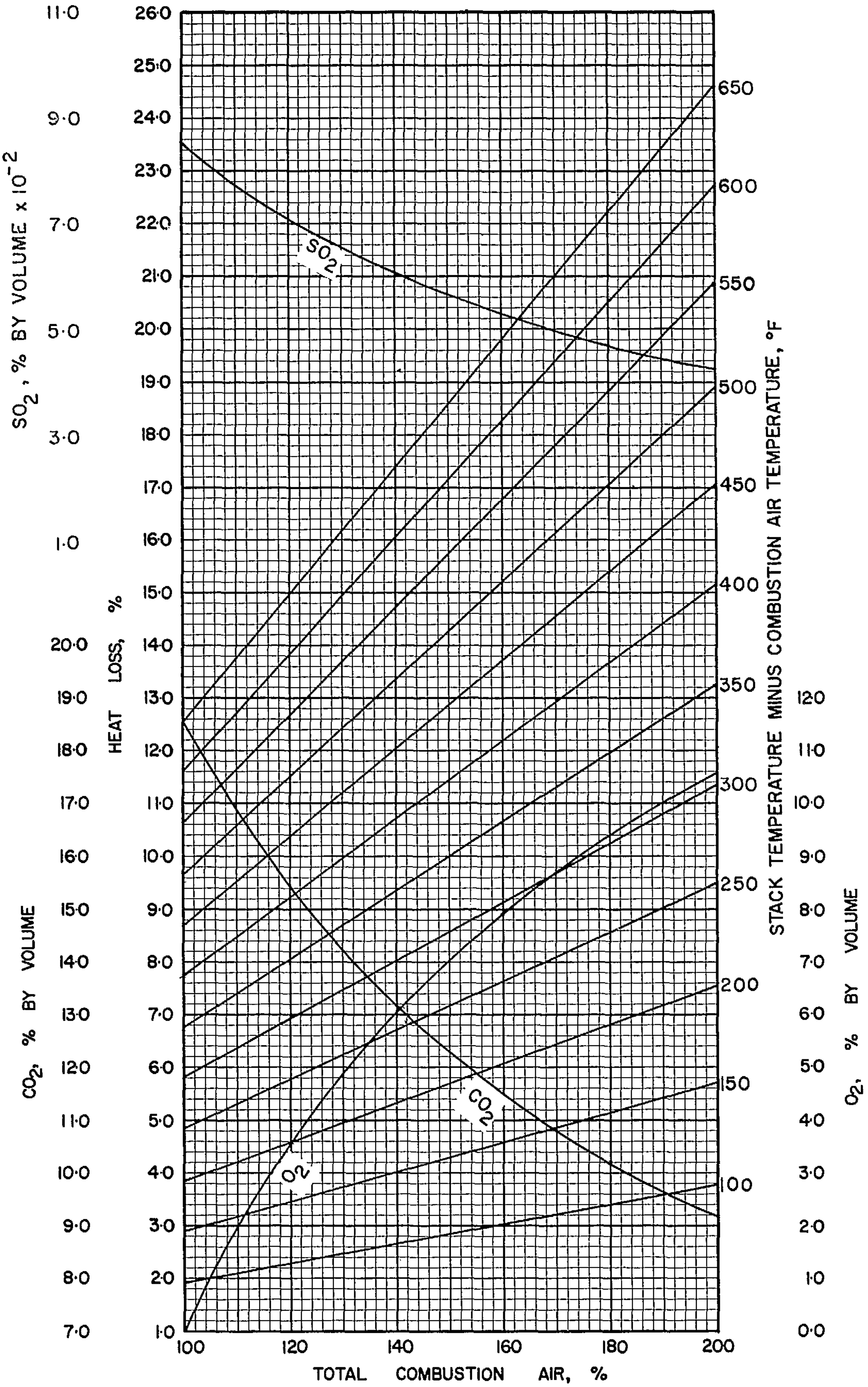


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·1·3

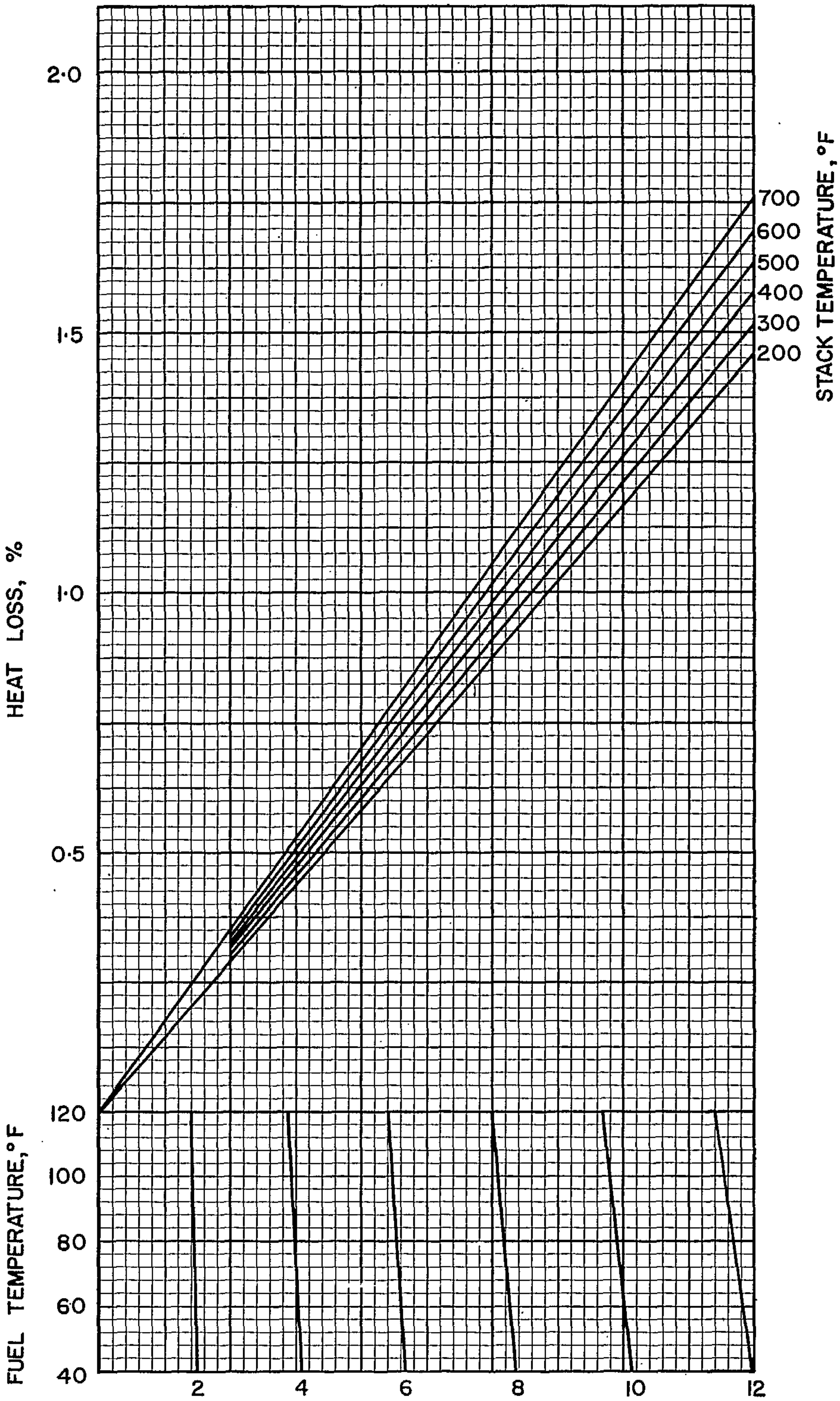


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·1·3

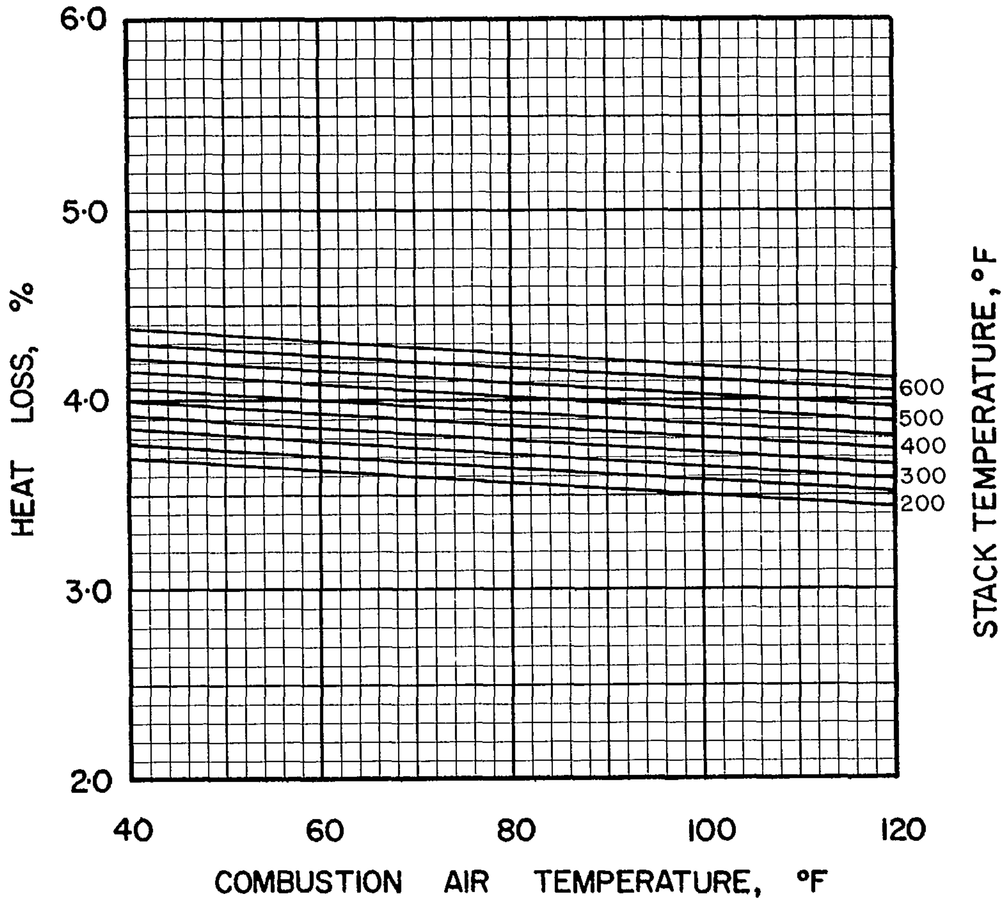


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS · 1 · 3

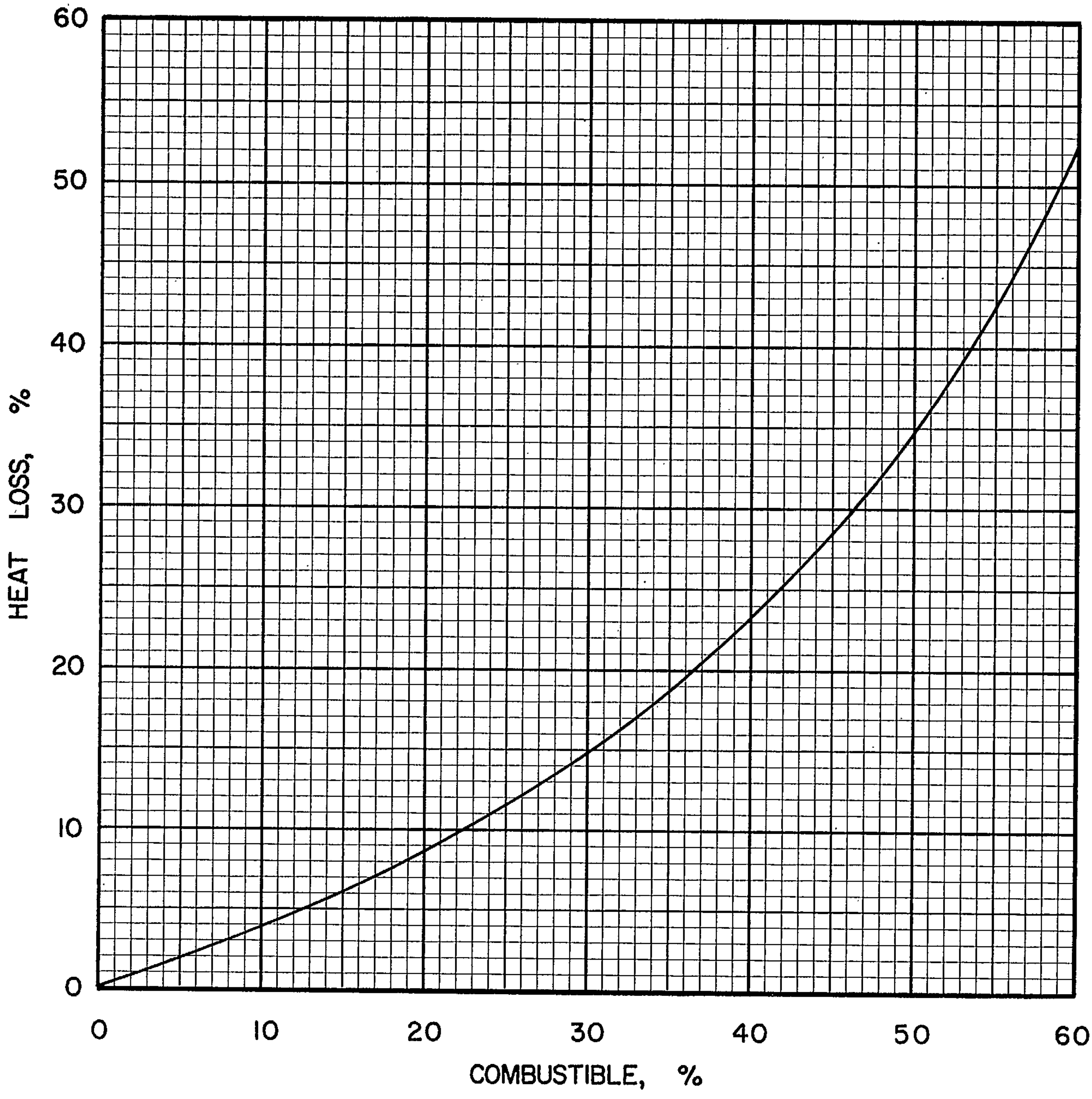


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS · 1 · 3

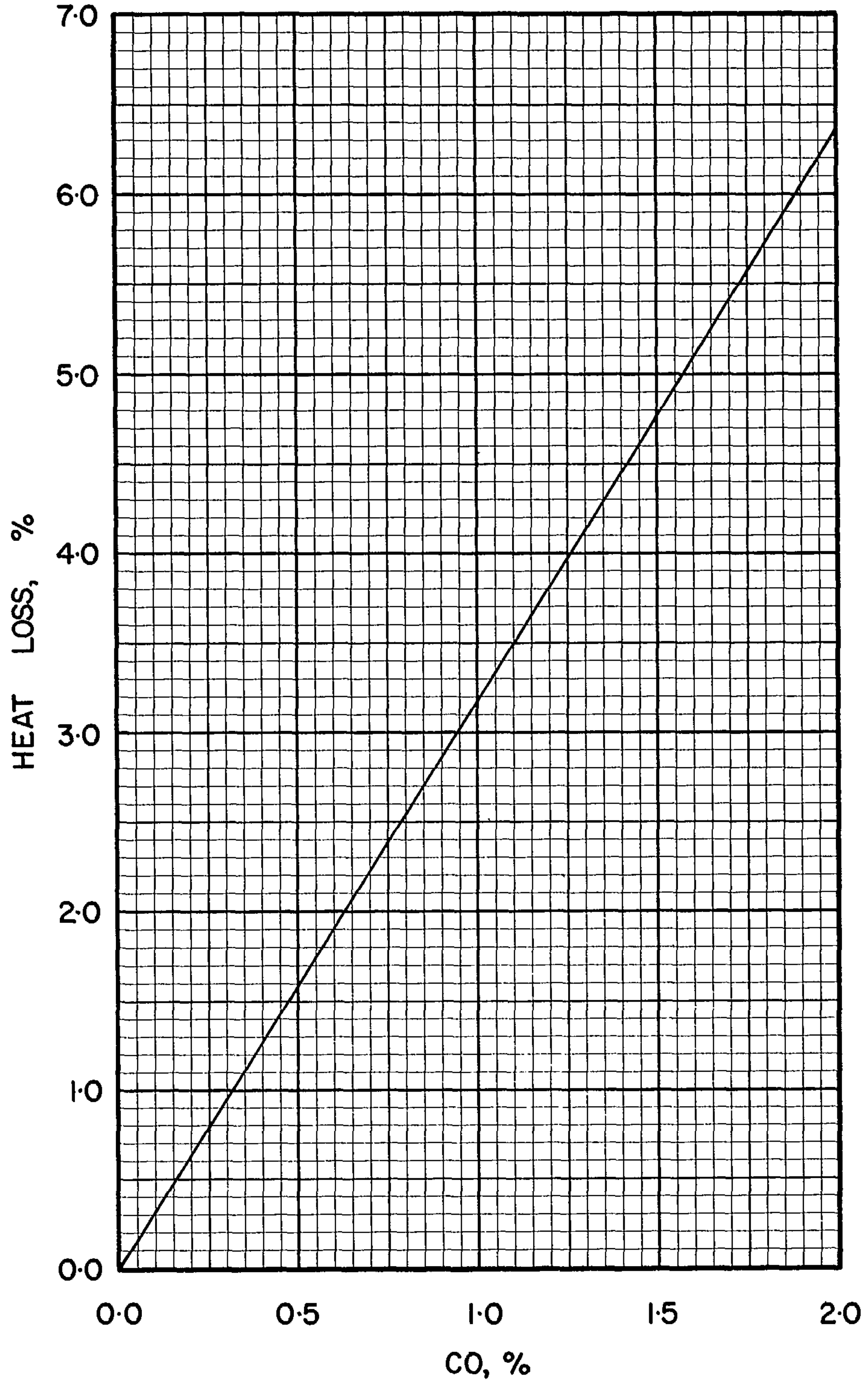


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·1·3

COAL NS 1-4, ACADIA, PICTOU COUNTY, 3/4 in. x 0

Typical Moisture Range: 0 – 6%

Proximate Analysis, (lb/lb dry coal)

Ash	0.1190
Volatile Matter	0.2915
Fixed Carbon	0.5895
Total	1.0000

Ultimate Analysis, (lb/lb dry coal)

Carbon (C)	0.748
Hydrogen (H)	0.047
Sulphur (S)	0.005
Nitrogen (N)	0.014
Oxygen (O)	0.067
Ash	0.119
Total	1.000

Calorific Value

Btu/lb:	13307
Btu/short ton:	26.61×10^6
Btu/long ton:	29.81×10^6
MJ/kg:	30.92

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 75.15 lb
10^6 Btu = 0.03757 short tons
10^6 Btu = 0.03355 long tons

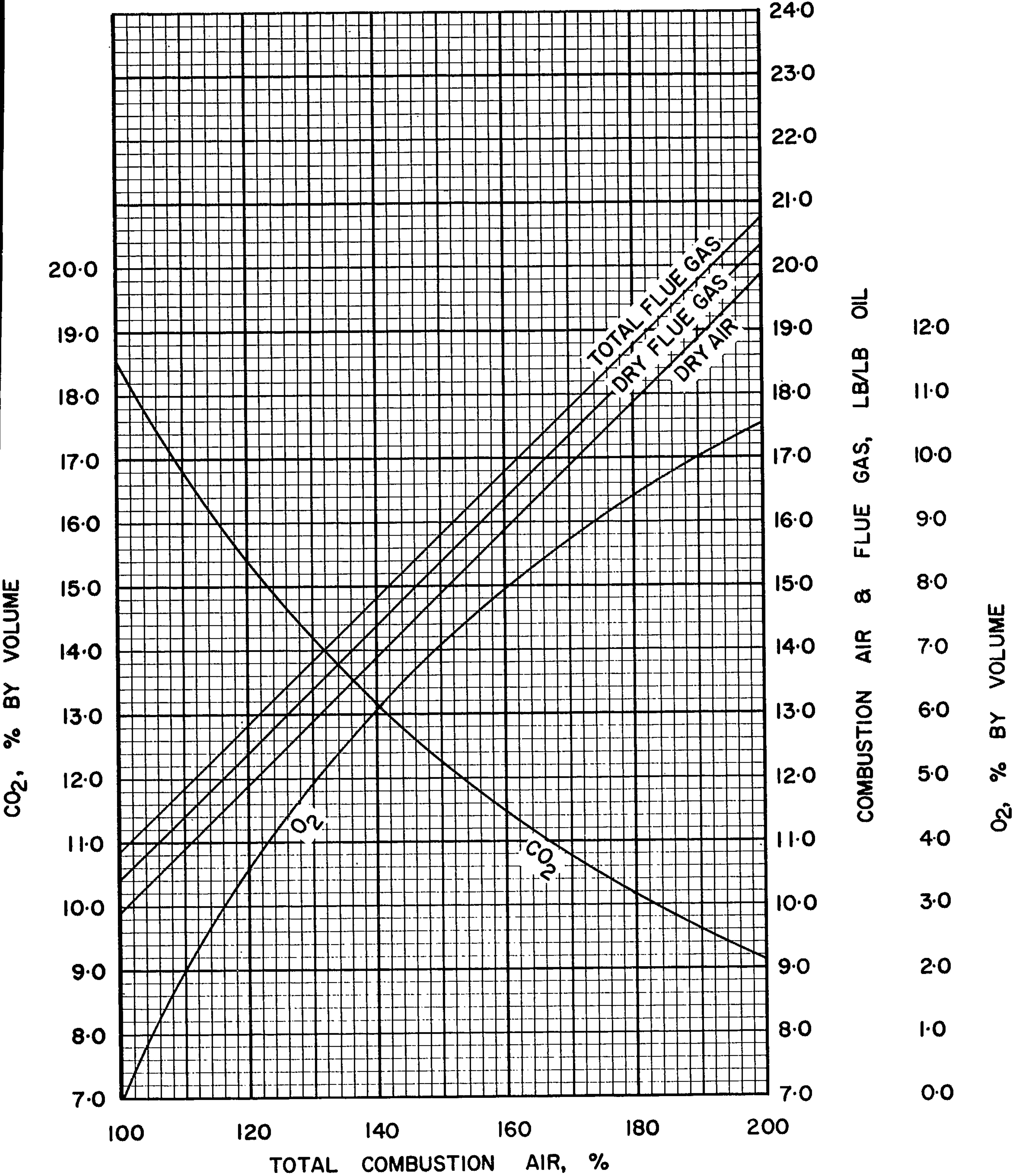


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·1·4

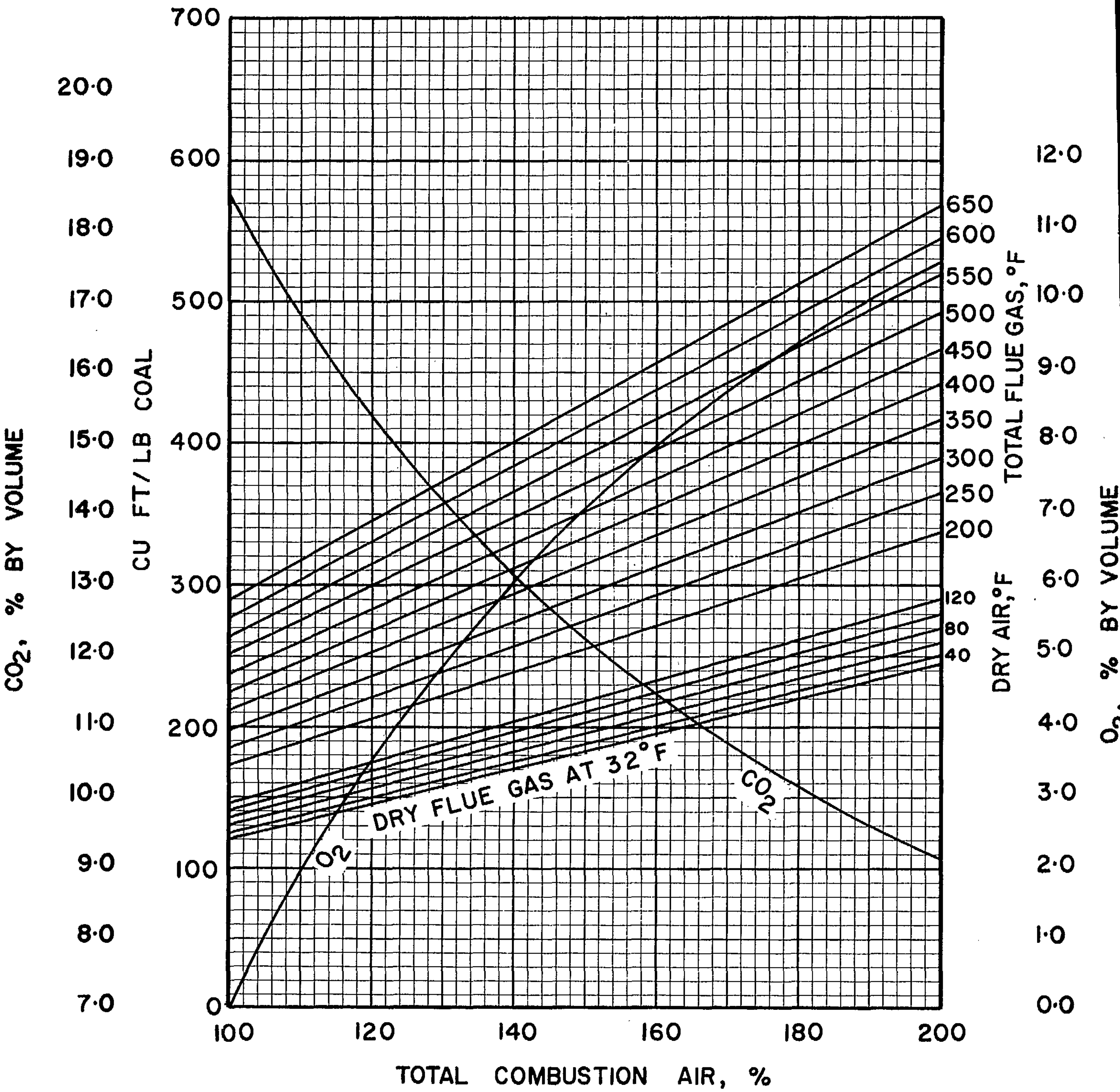


FIGURE 2. COMBUSTION DATA, VOLUME BASIS.

NS·1·4

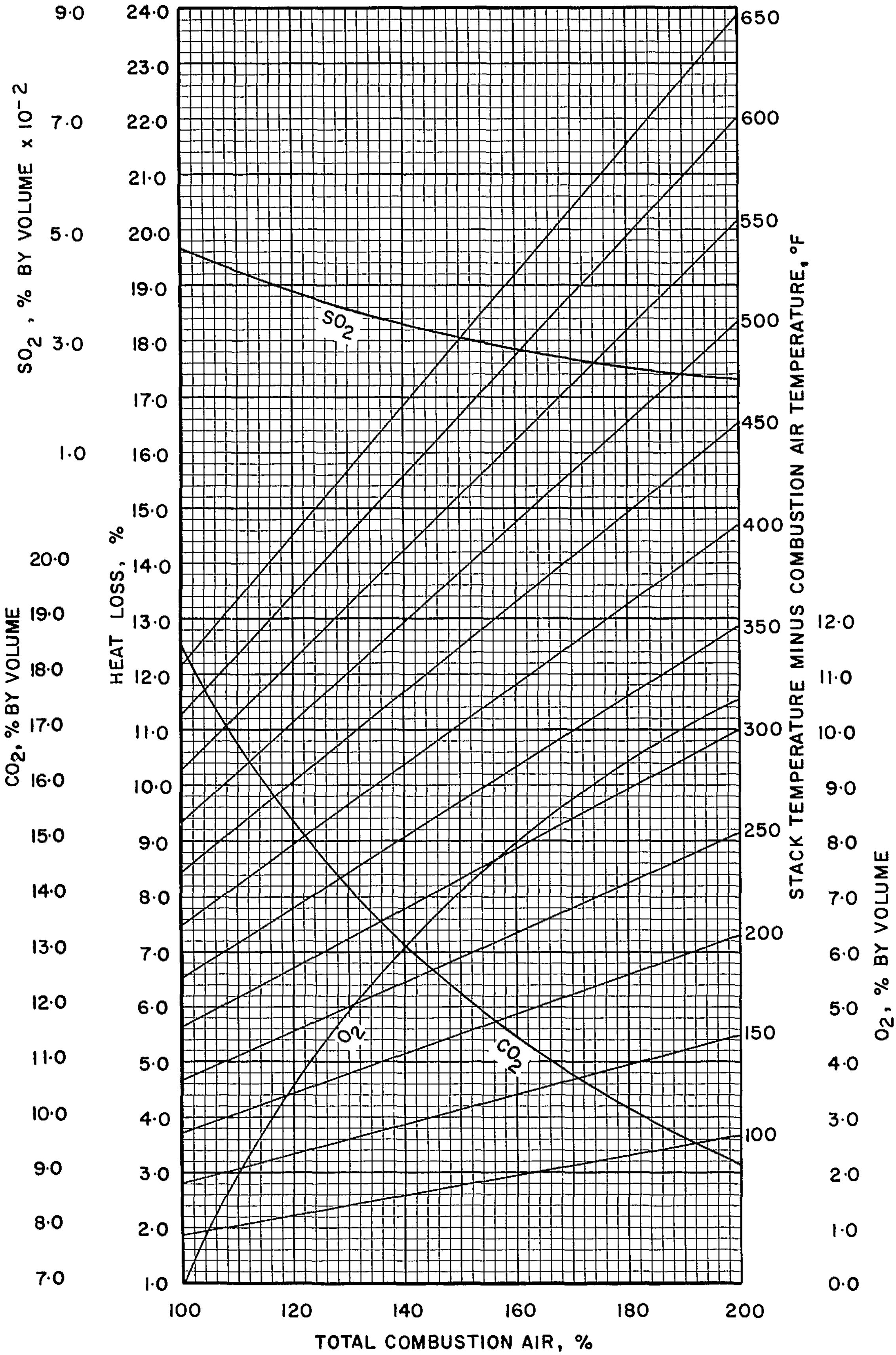


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS·

NS·1·4

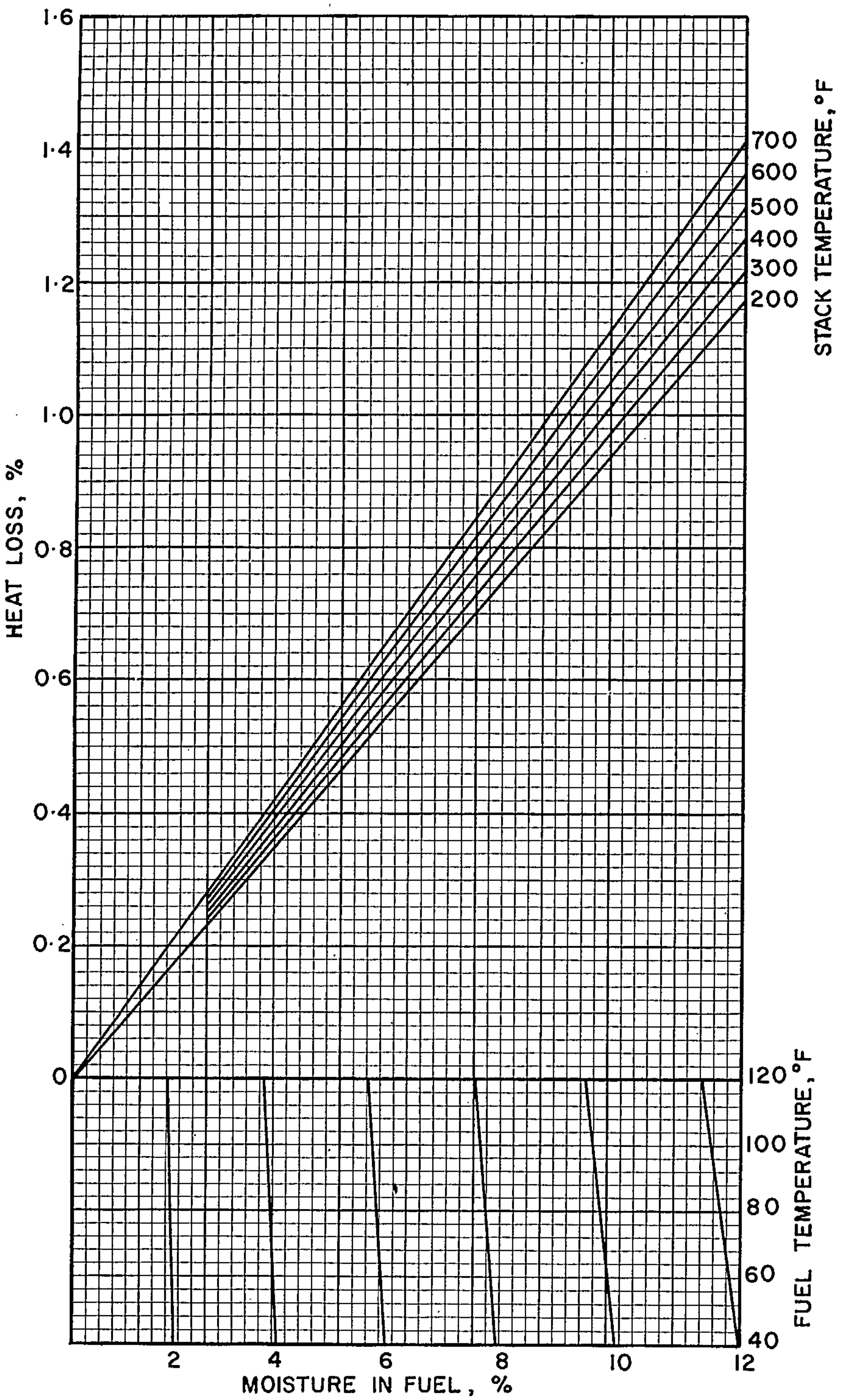


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·1·4

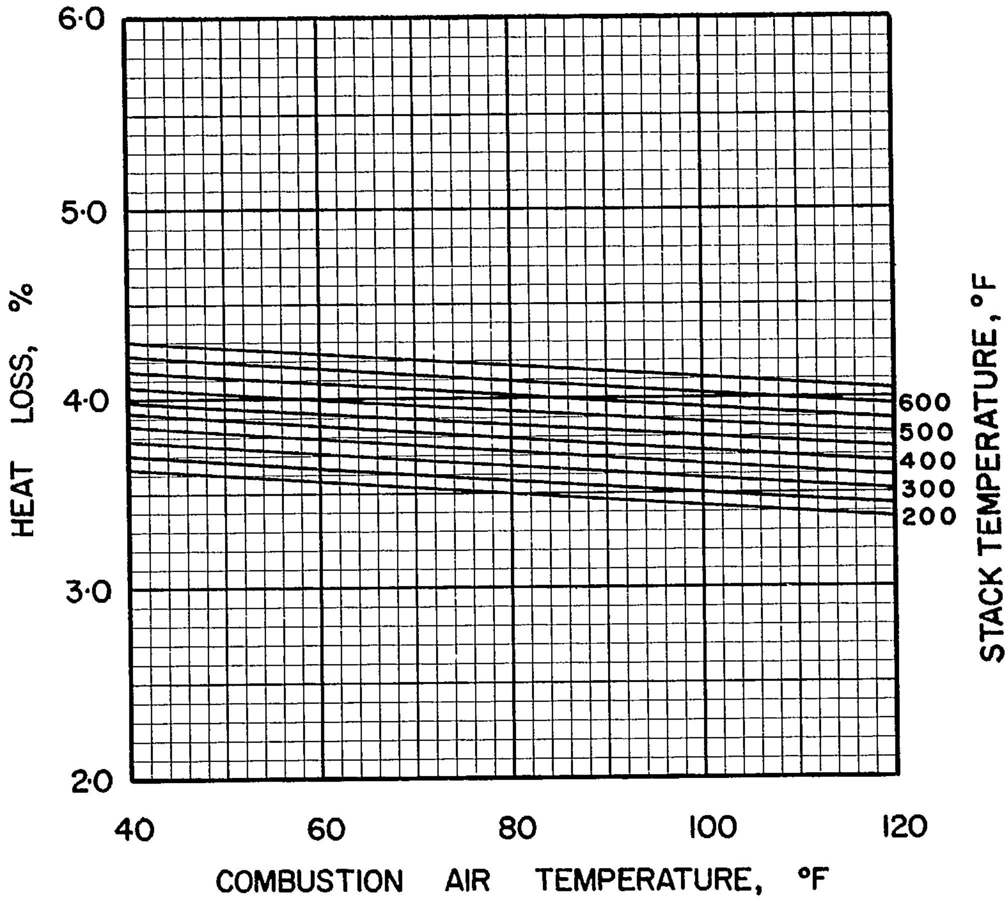


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·1·4

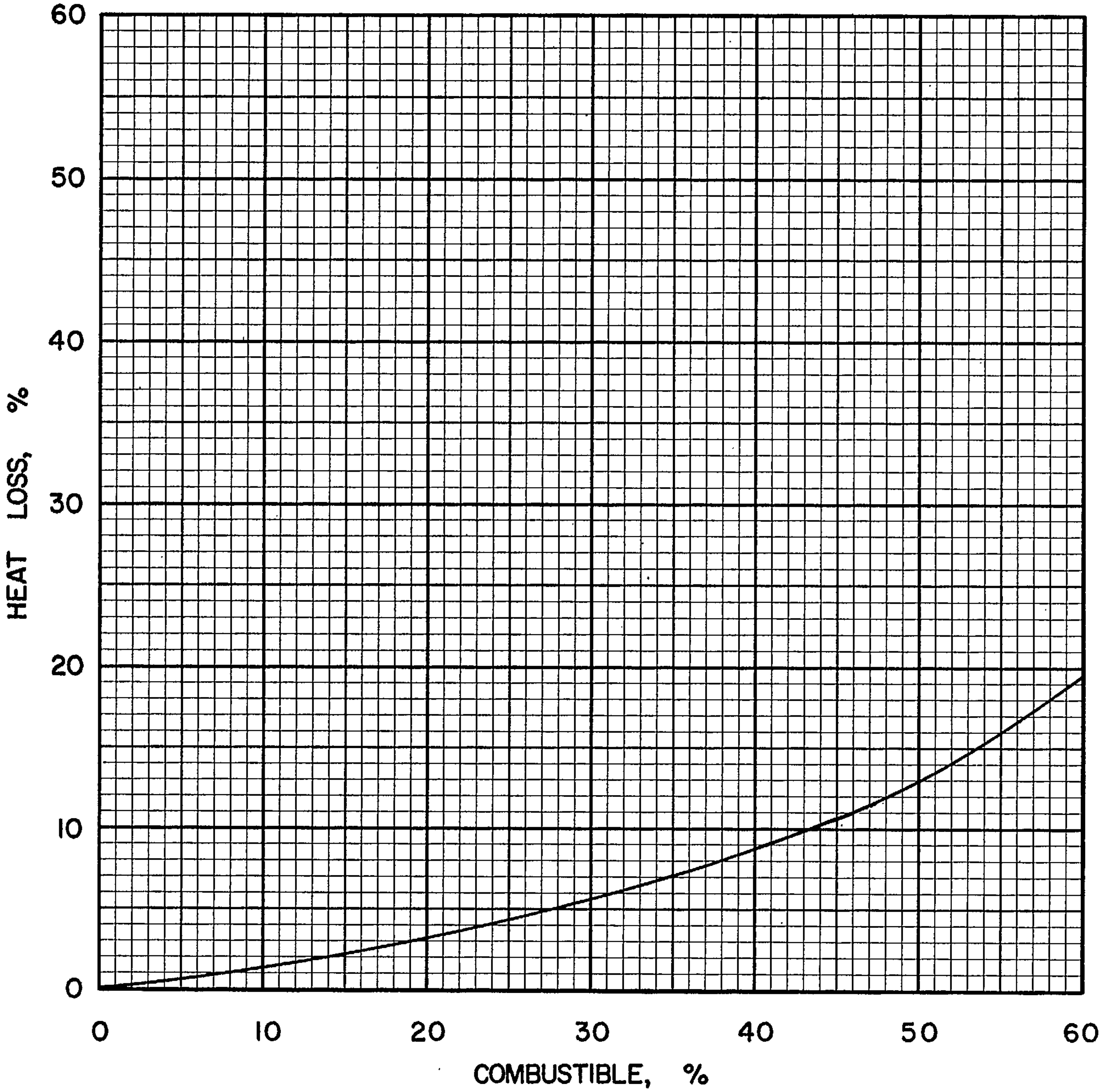


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·1·4

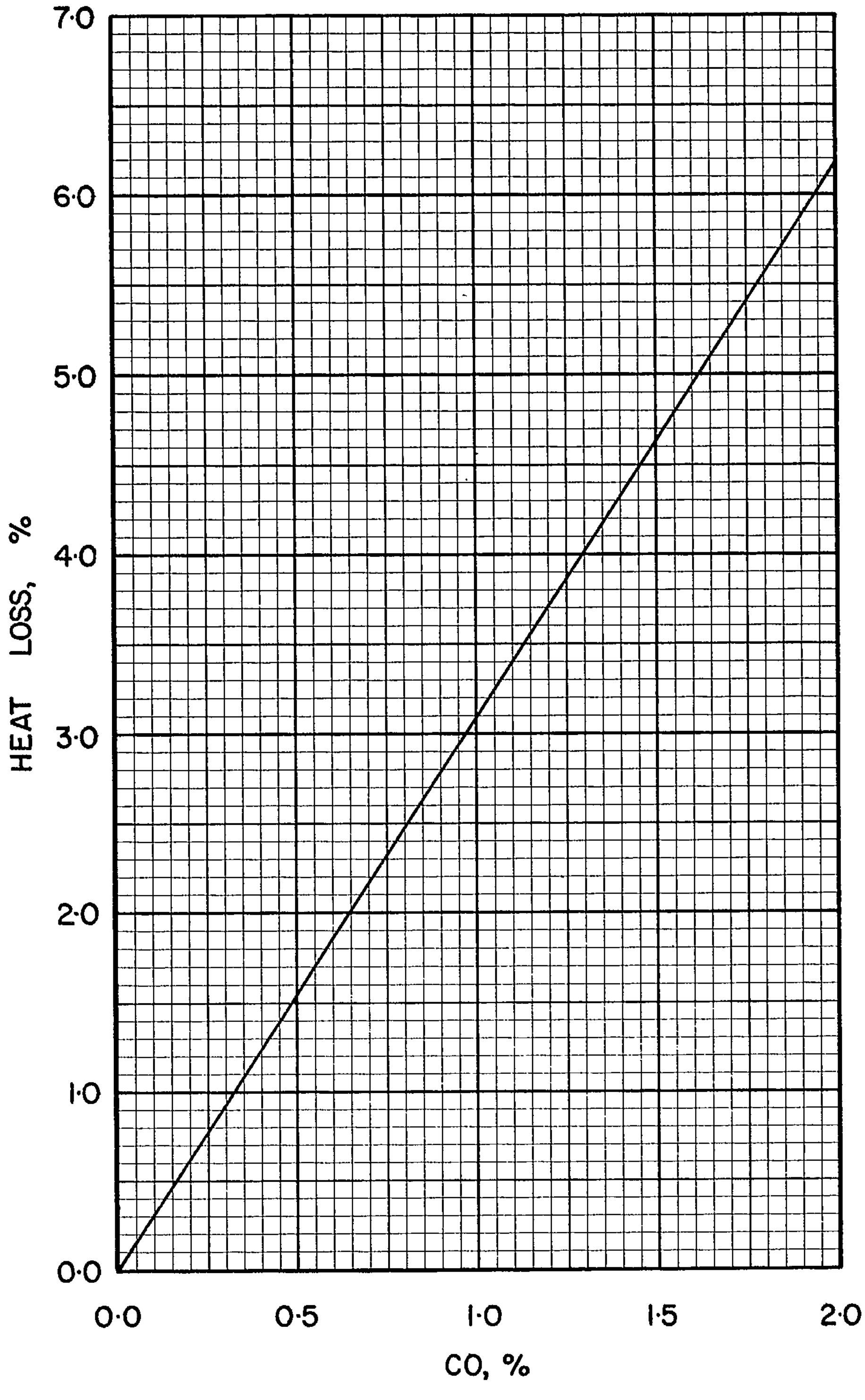


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·1·4

COAL NS 2-1, BRAS D'OR COAL CO. LTD., CAPE BRETON, 3/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1437
Volatile Matter	0.3453
Fixed Carbon	0.5110
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6952
Hydrogen (H)	0.0457
Sulphur (S)	0.0601
Nitrogen (N)	0.0099
Oxygen (O)	0.0454
Ash	0.1437
Total	1.0000

Gross Calorific Value

Btu/lb:	12490
Btu/short ton:	24.98×10^6
Btu/long ton:	27.98×10^6
MJ/kg:	29.04

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 80.06	lb	
10^6 Btu	= 0.04003	short tons	
10^6 Btu	= 0.03574	long tons	

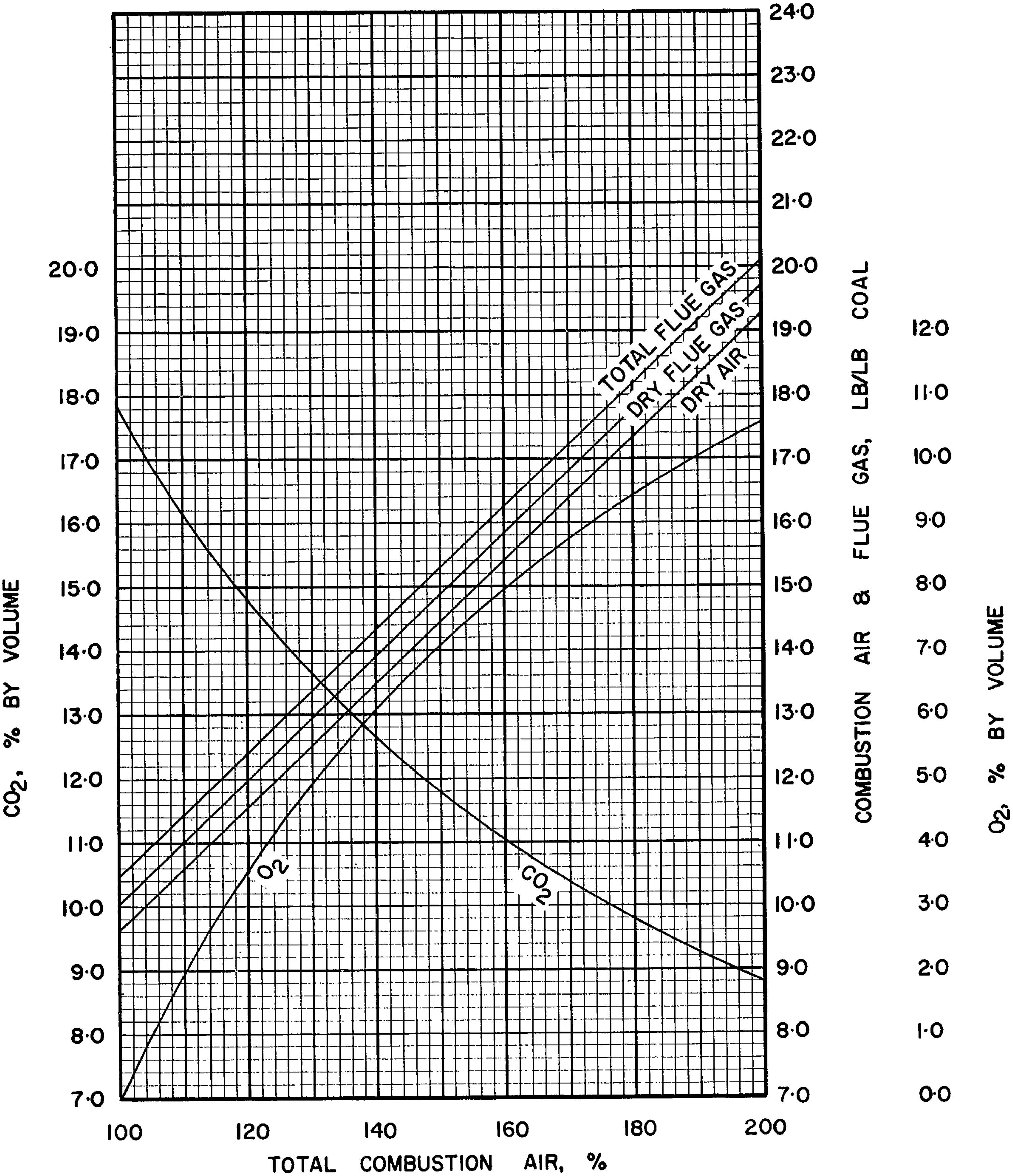


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·2·1

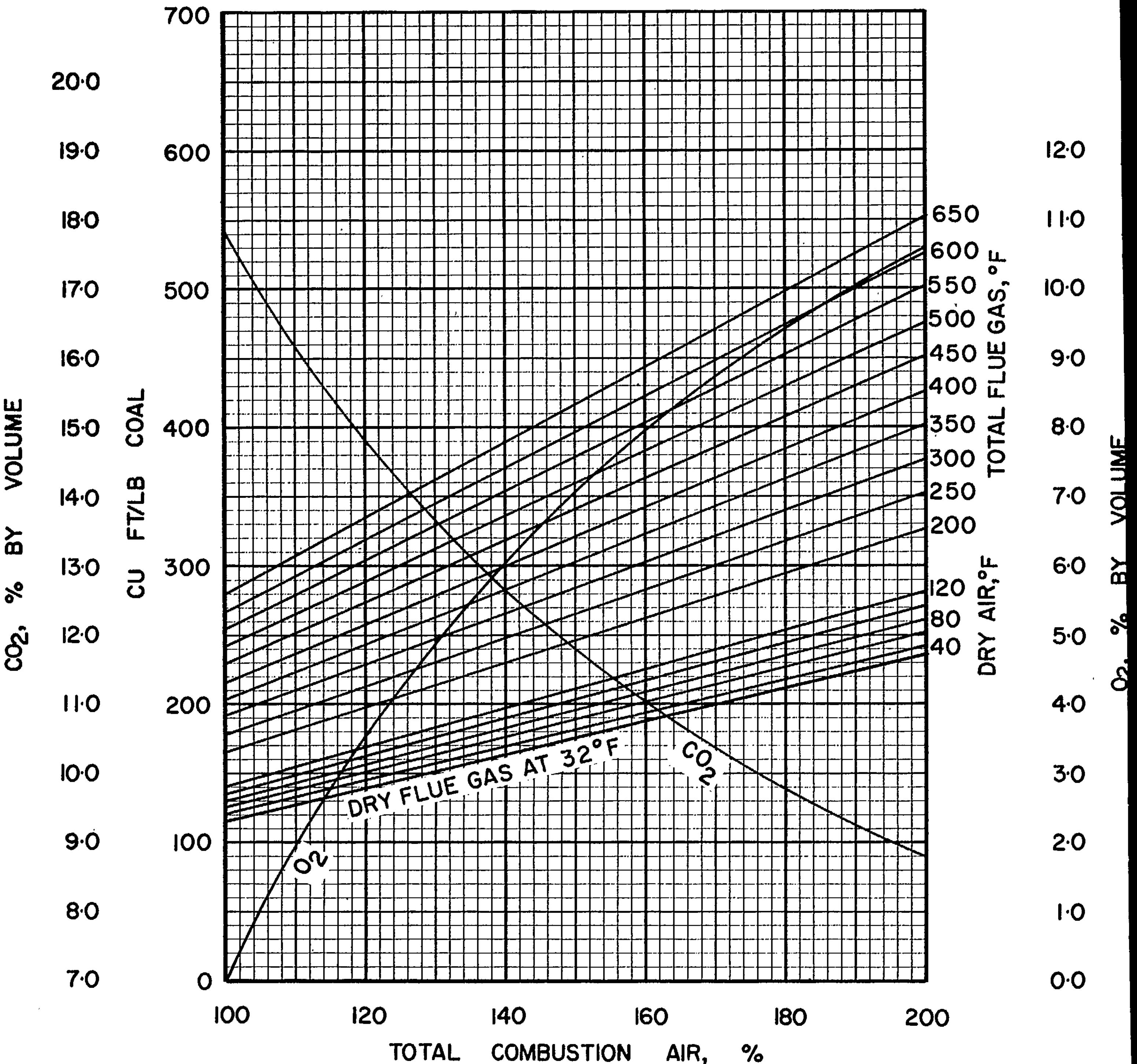


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS · 2 · 1

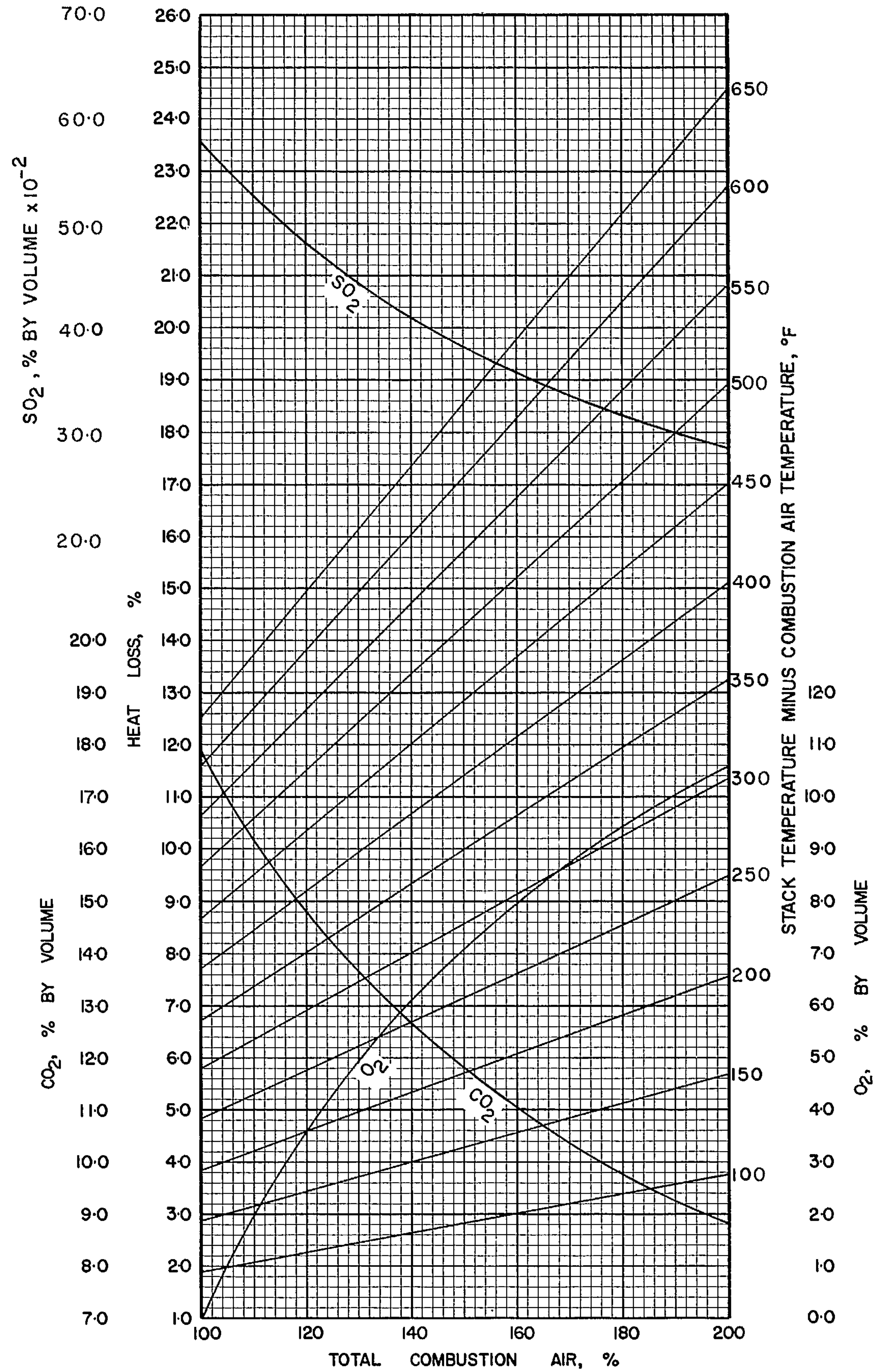


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·2·1

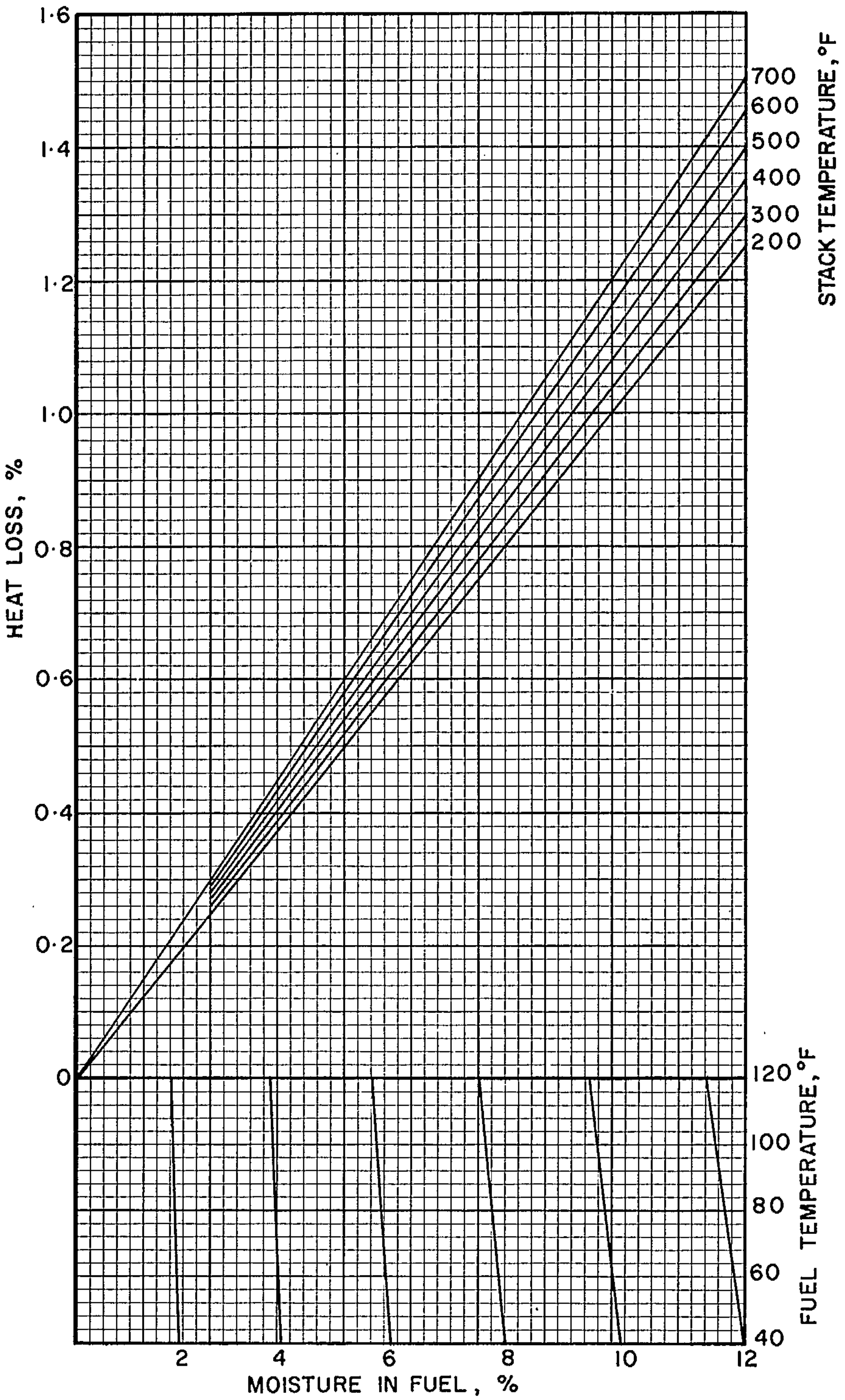


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·2·1

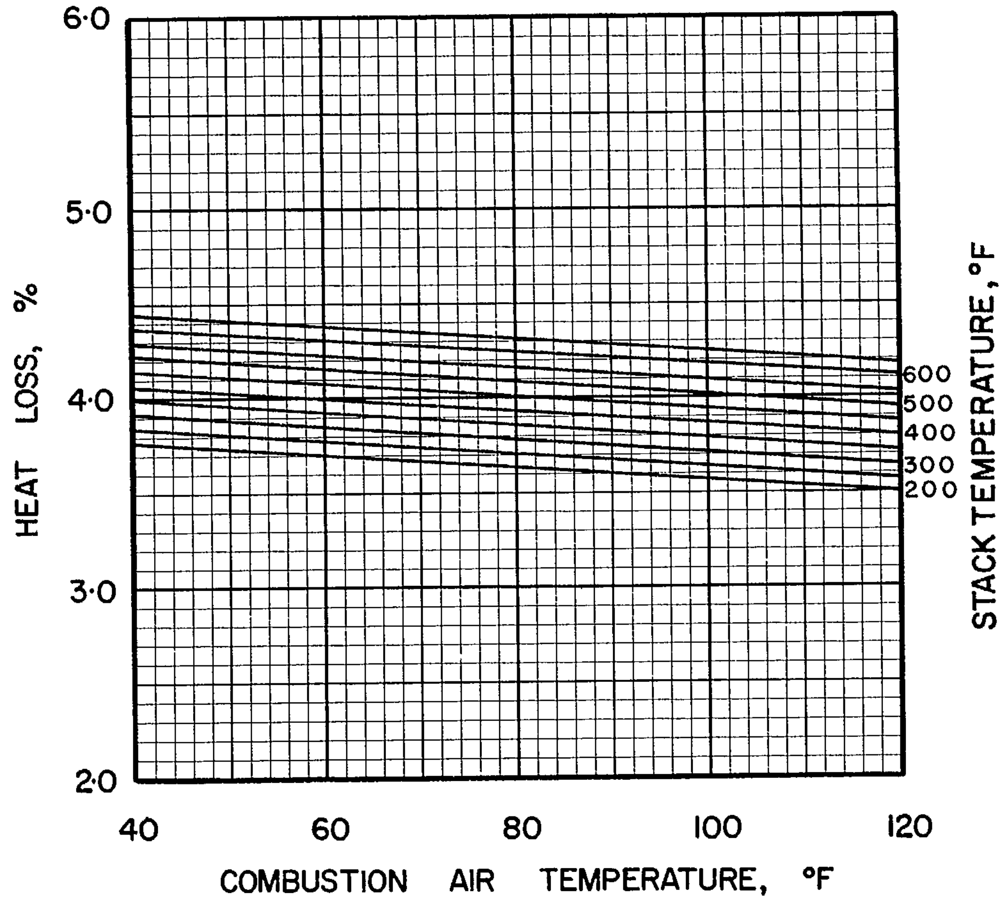


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·2·1

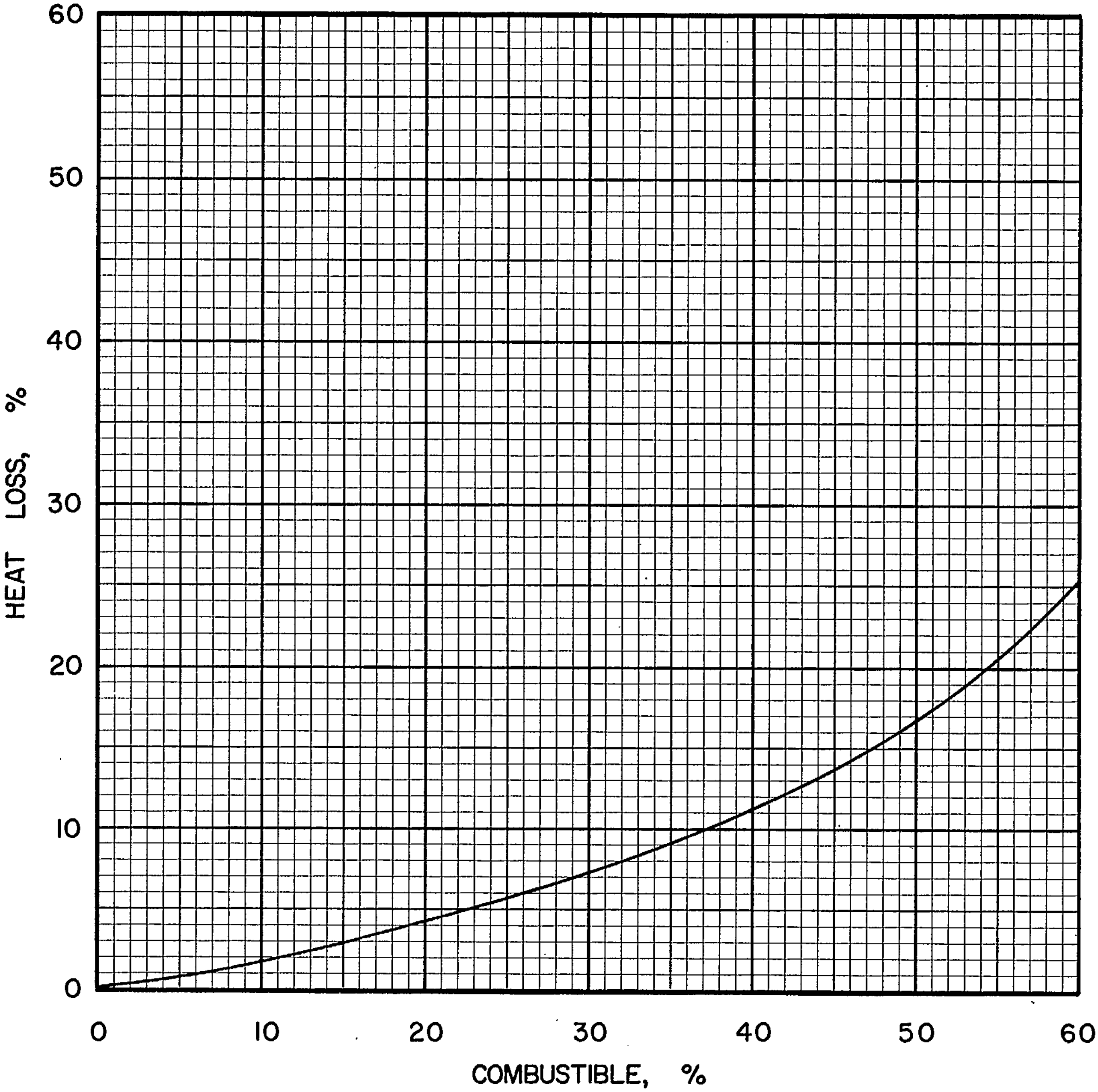


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·2·1

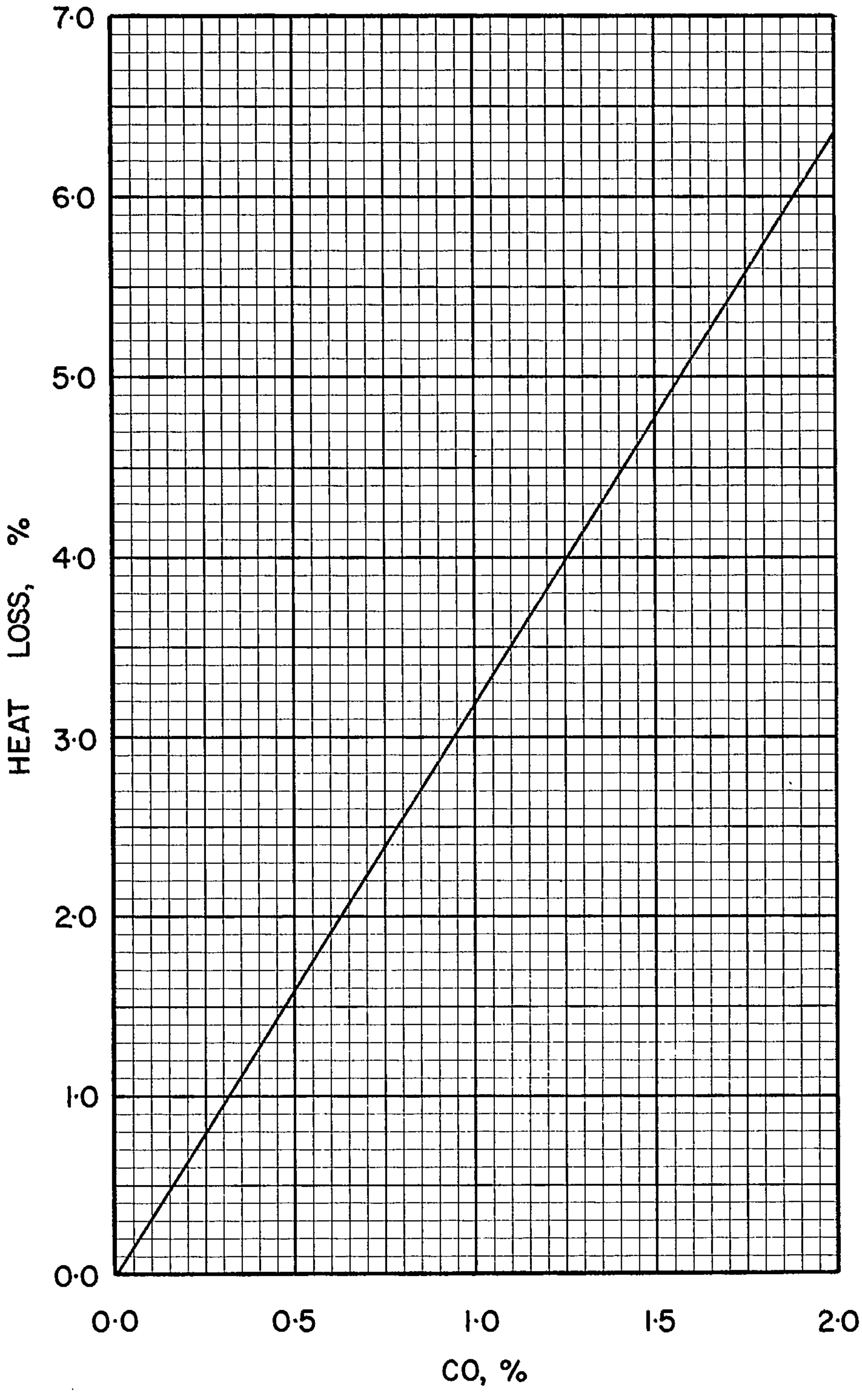


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS · 2 · 1

COAL NS 3-1, DOMINION–ST. LAWRENCE MIX, DEVCO, CAPE BRETON, 1 1/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0847
Volatile Matter	0.3390
Fixed Carbon	0.5763
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7800
Hydrogen (H)	0.0512
Sulphur (S)	0.0177
Nitrogen (N)	0.0141
Oxygen (O)	0.0523
Ash	0.0847
Total	1.0000

Gross Calorific Value

Btu/lb:	14031
Btu/short ton:	28.06×10^6
Btu/long ton:	31.43×10^6
MJ/kg:	32.63

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	71.27	lb	
10^6 Btu	=	0.03563	short tons	
10^6 Btu	=	0.03182	long tons	

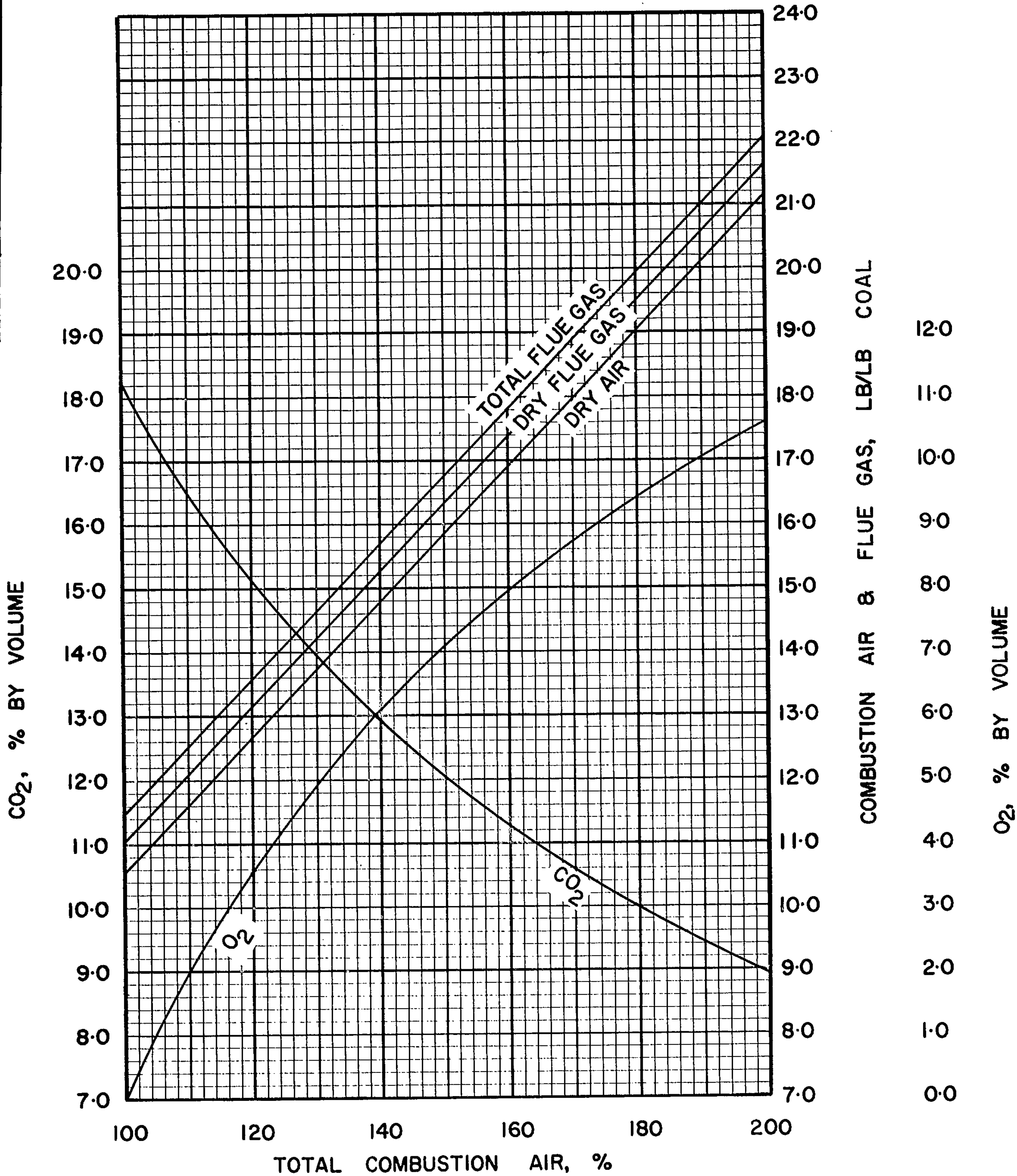


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·3·1

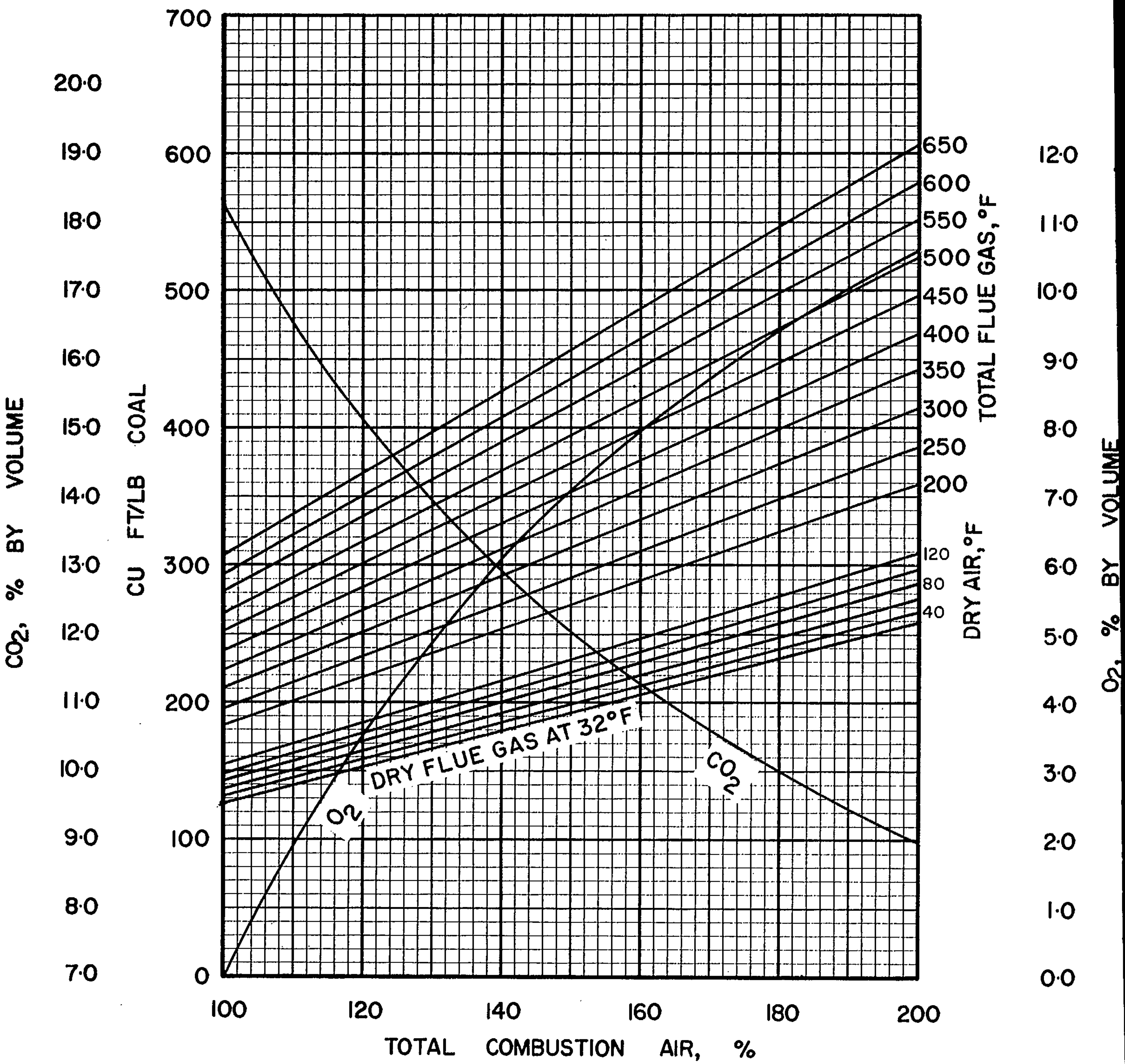


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NS·3·1

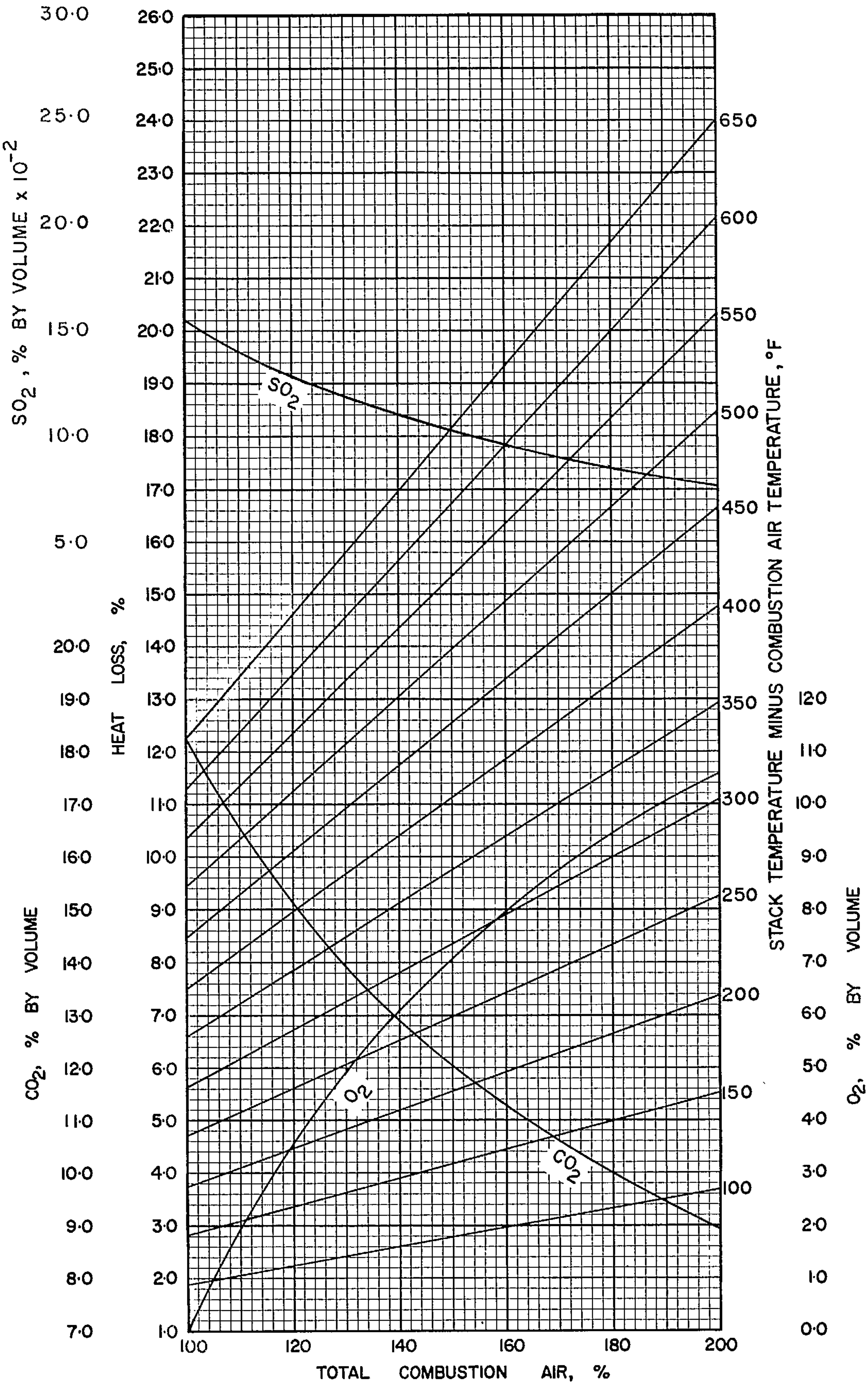


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·3·1

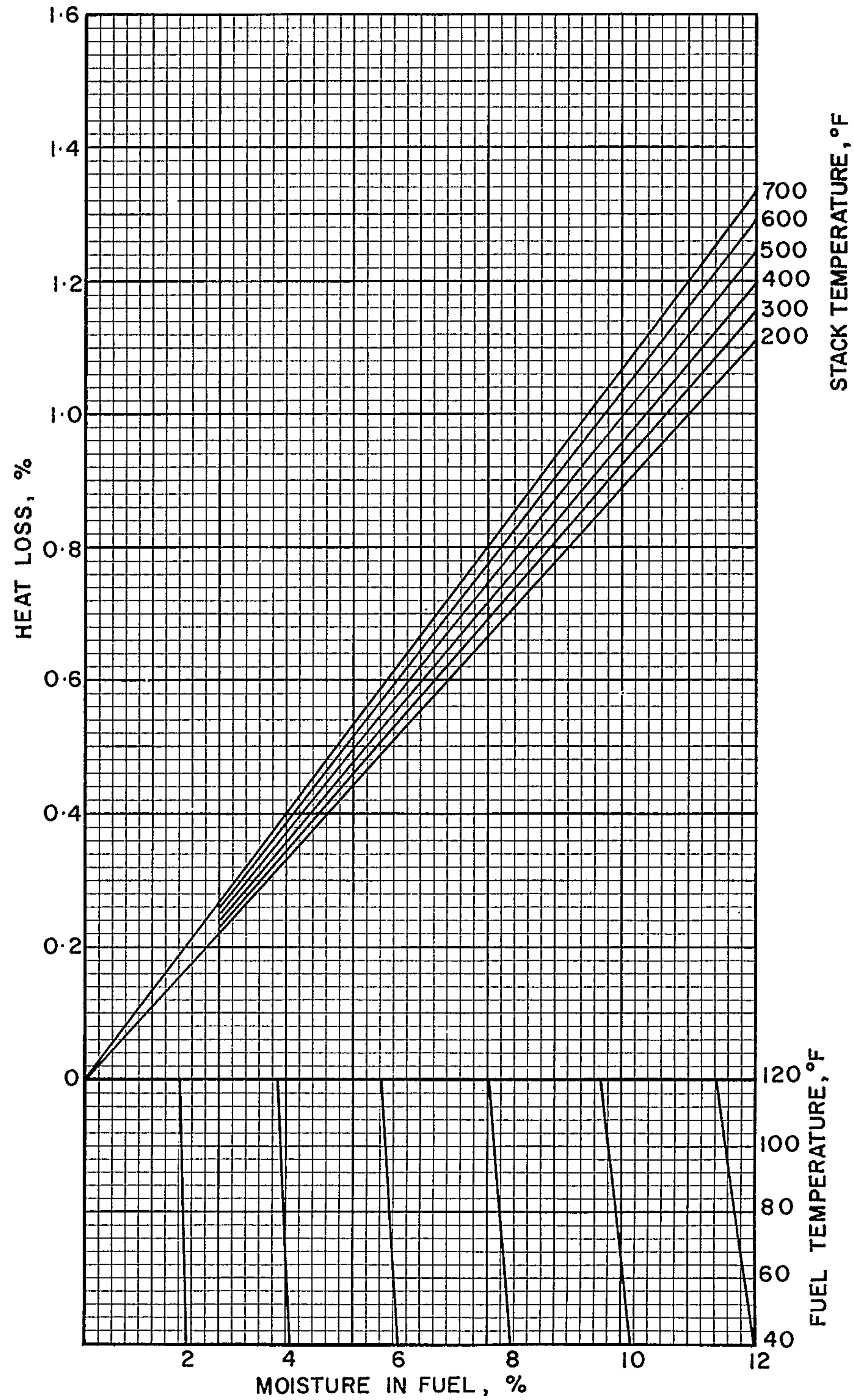


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS· 3·1

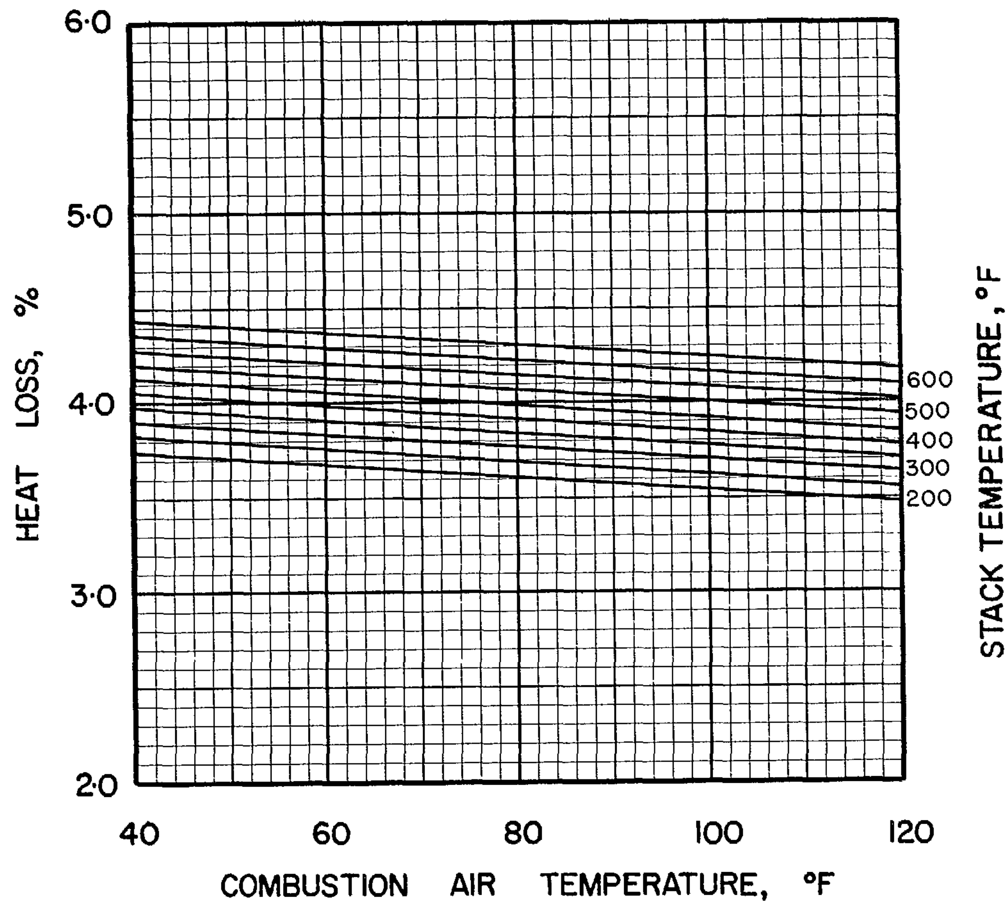


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·1

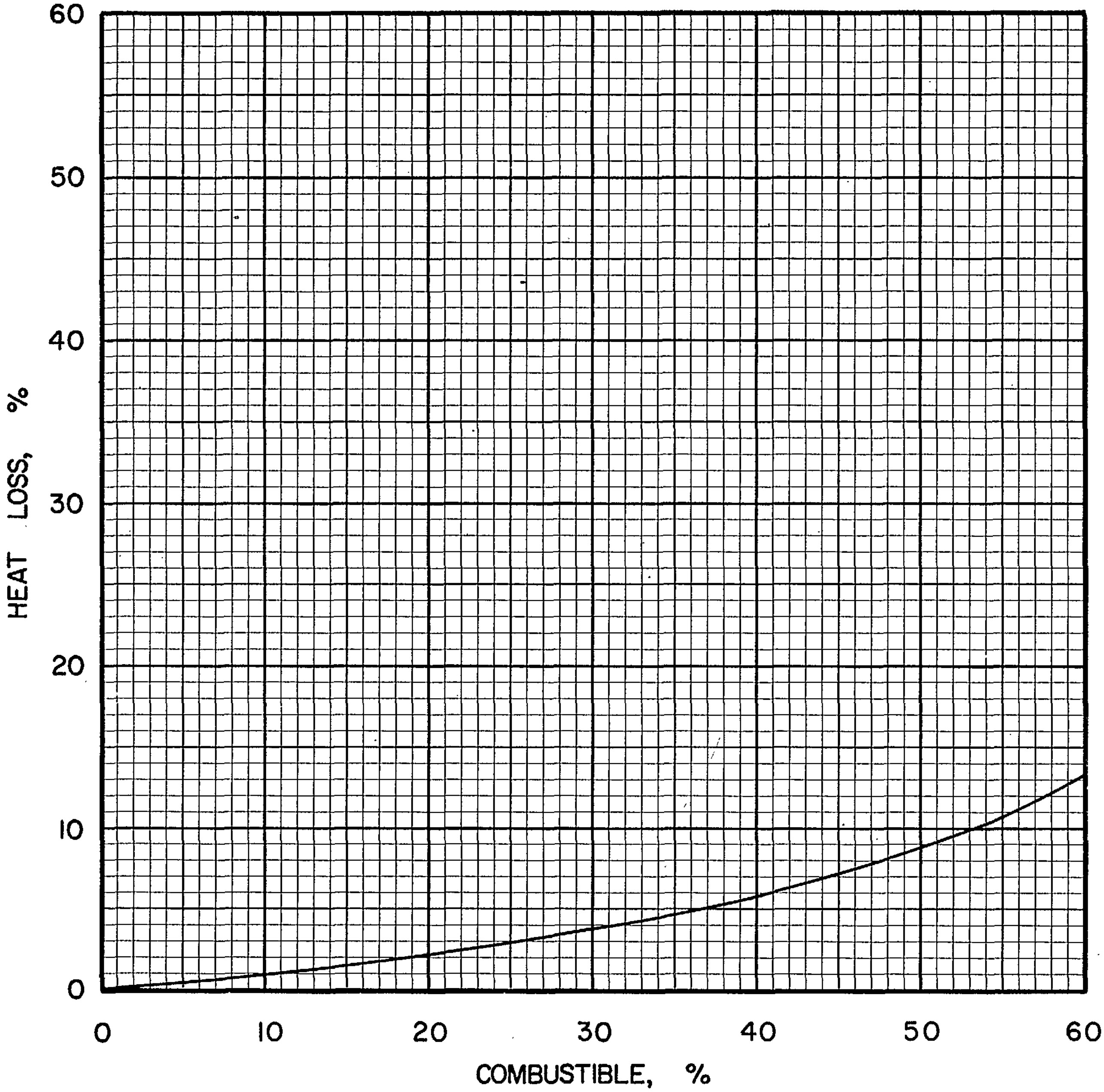


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·3·1

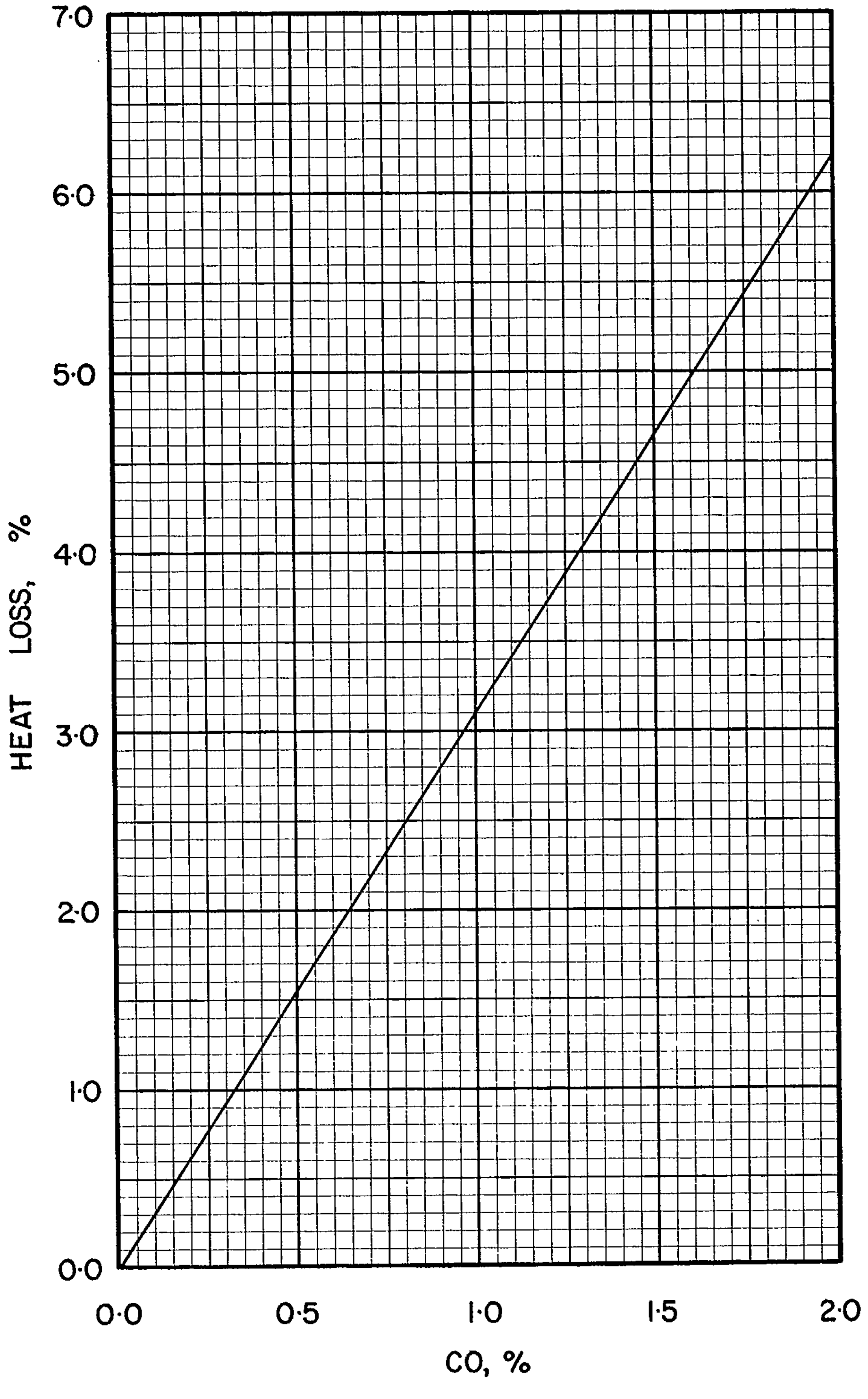


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·3·1

COAL NS 3-2, DOMINION NO. 12, DEVCO, CAPE BRETON, 1 1/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.1040
Volatile Matter	0.3465
Fixed Carbon	0.5495
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7637
Hydrogen (H)	0.0501
Sulphur (S)	0.0152
Nitrogen (N)	0.0135
Oxygen (O)	0.0535
Ash	0.1040
Total	1.0000

Gross Calorific Value

Btu/lb:	13810
Btu/short ton:	27.62×10^6
Btu/long ton:	30.93×10^6
MJ/kg:	32.11

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 72.41	lb	
10^6 Btu	= 0.03621	short tons	
10^6 Btu	= 0.03233	long tons	

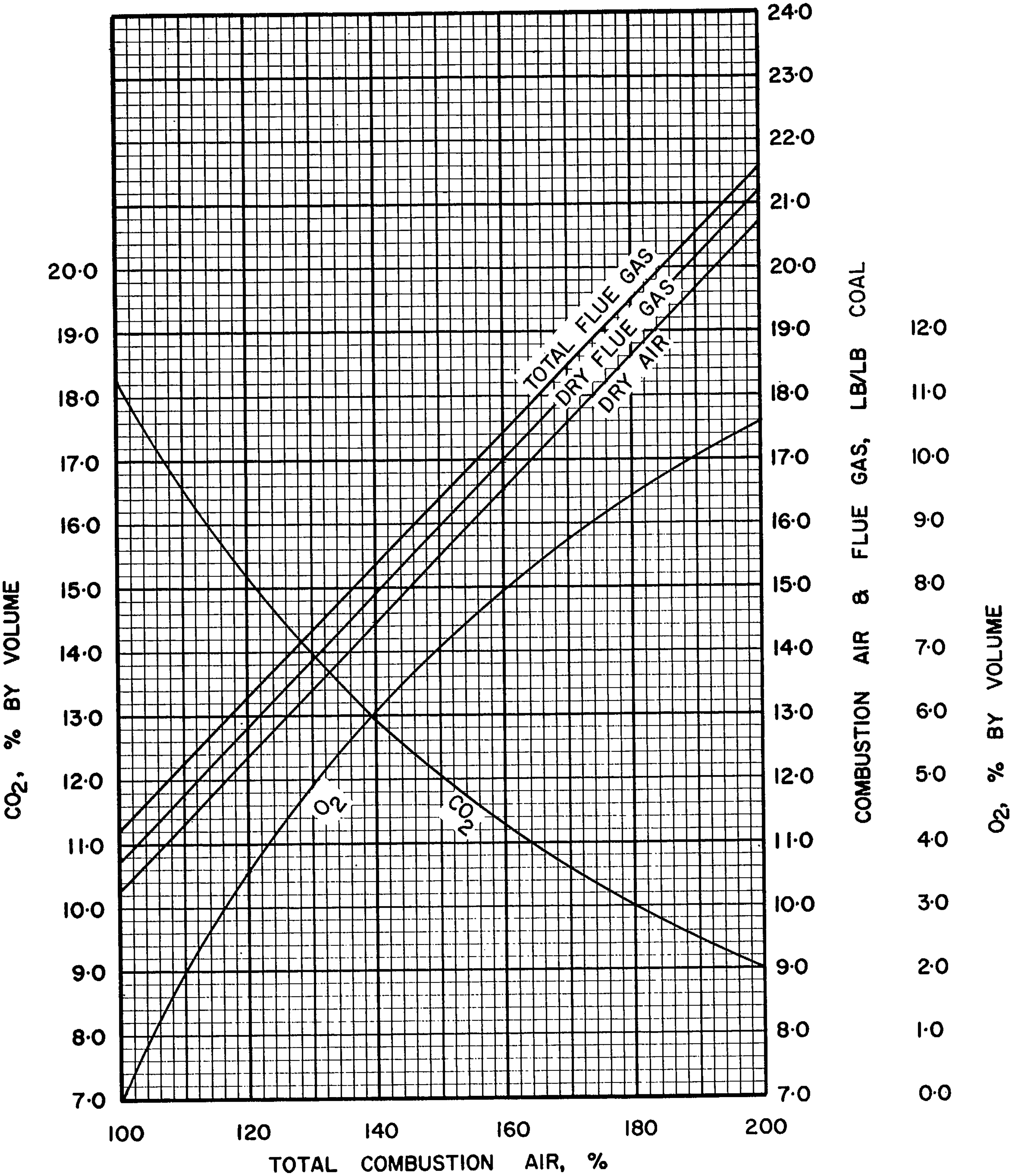


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·3·2

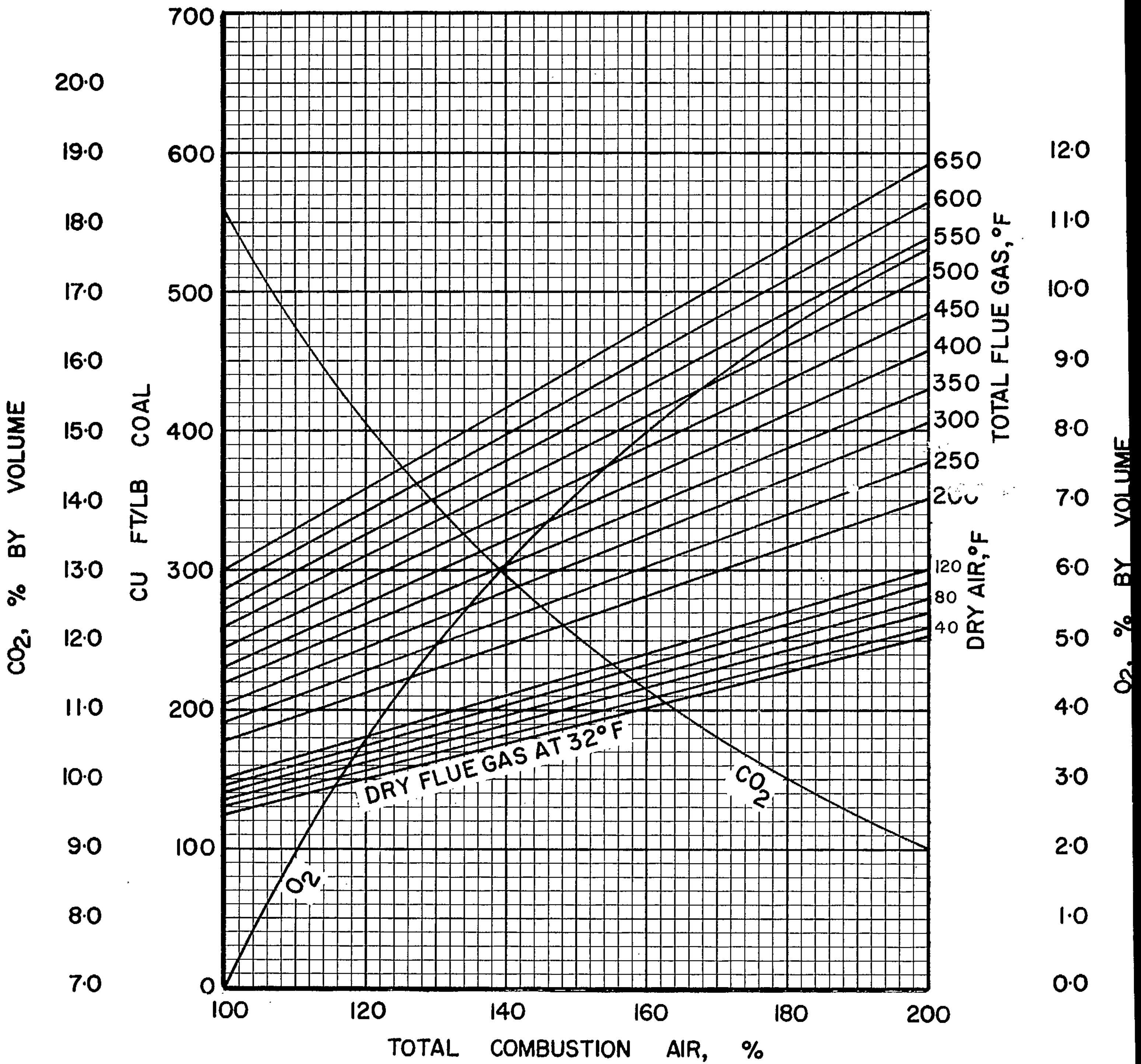


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NS·3·2

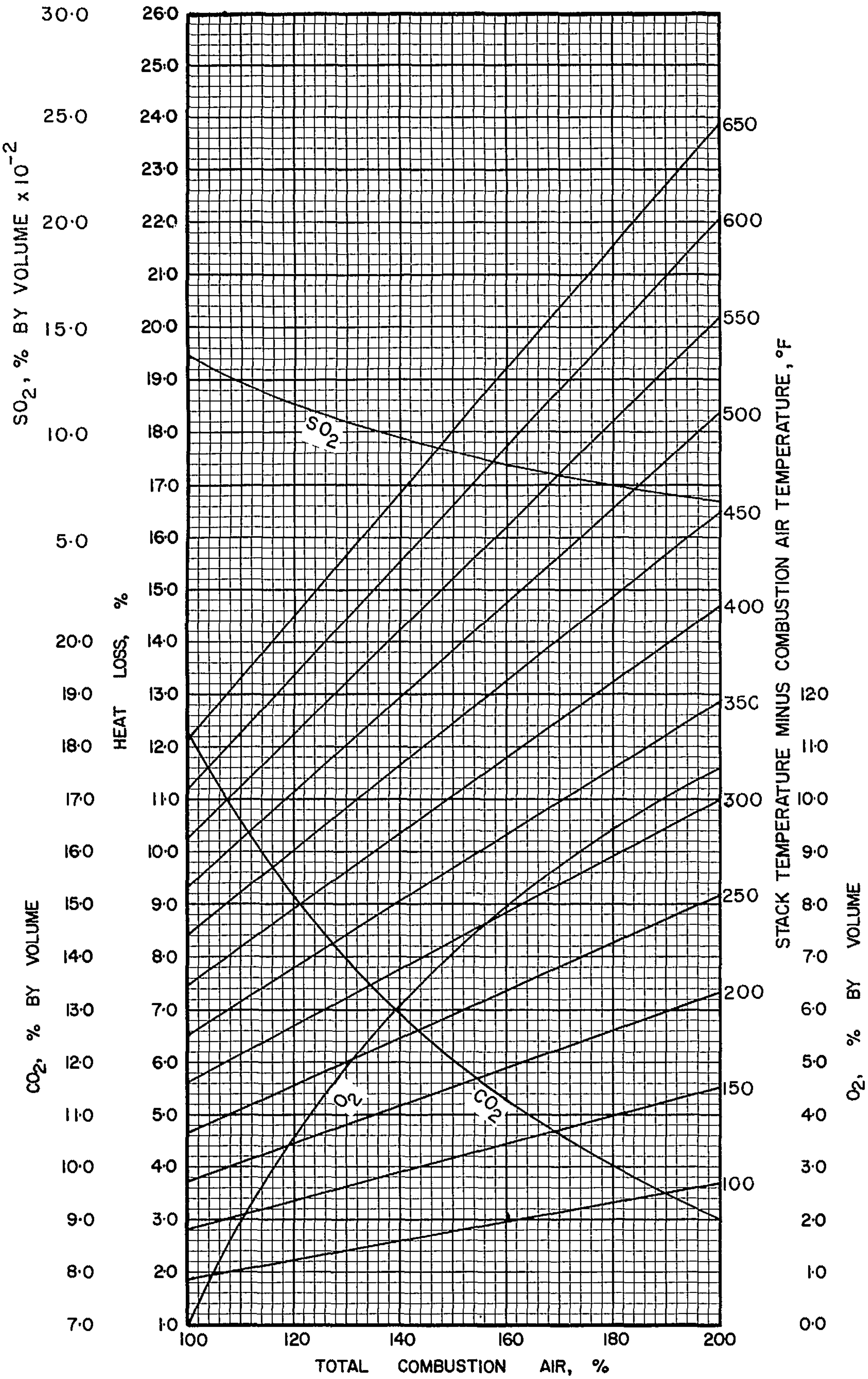


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·3·2

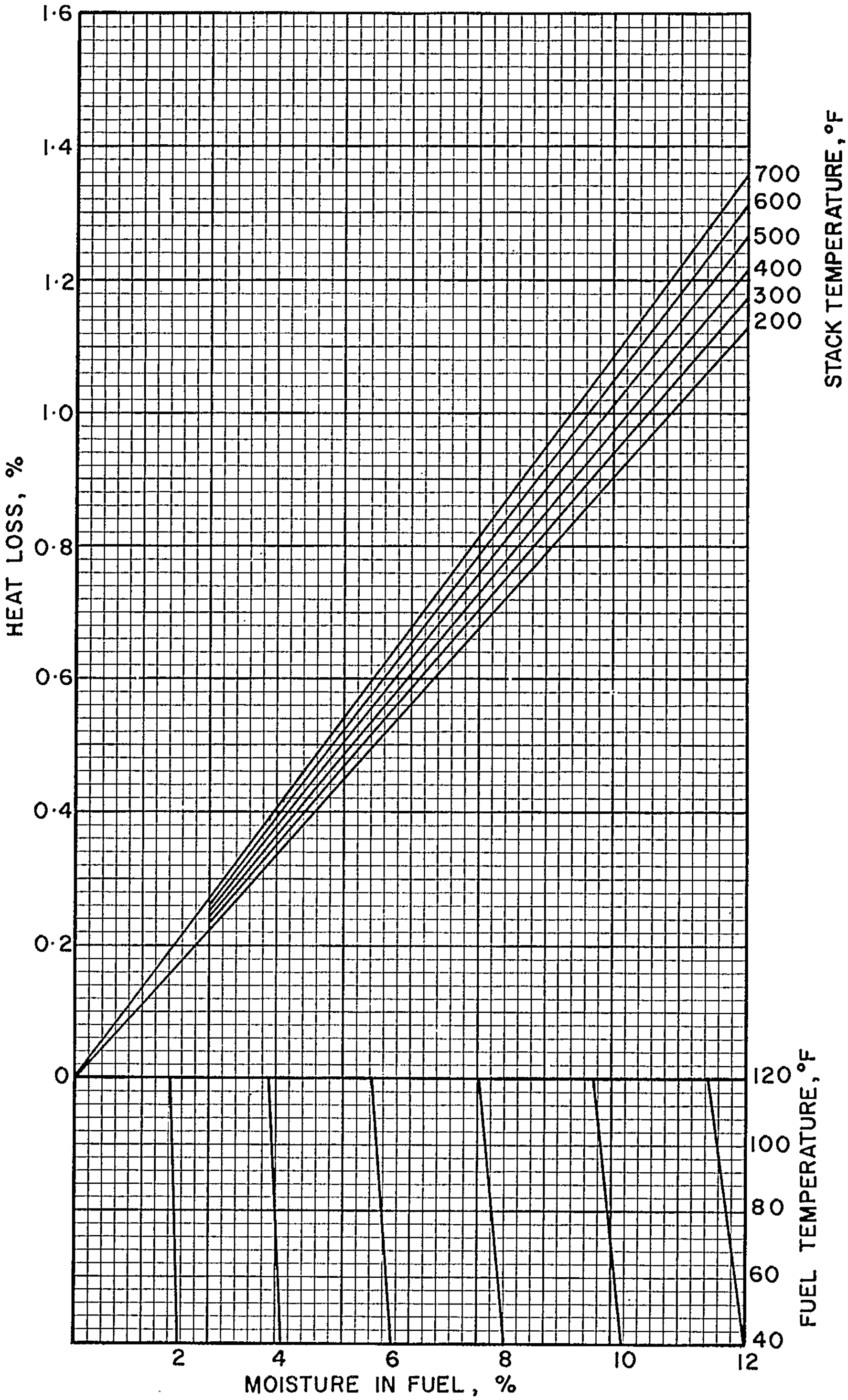


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·3·2

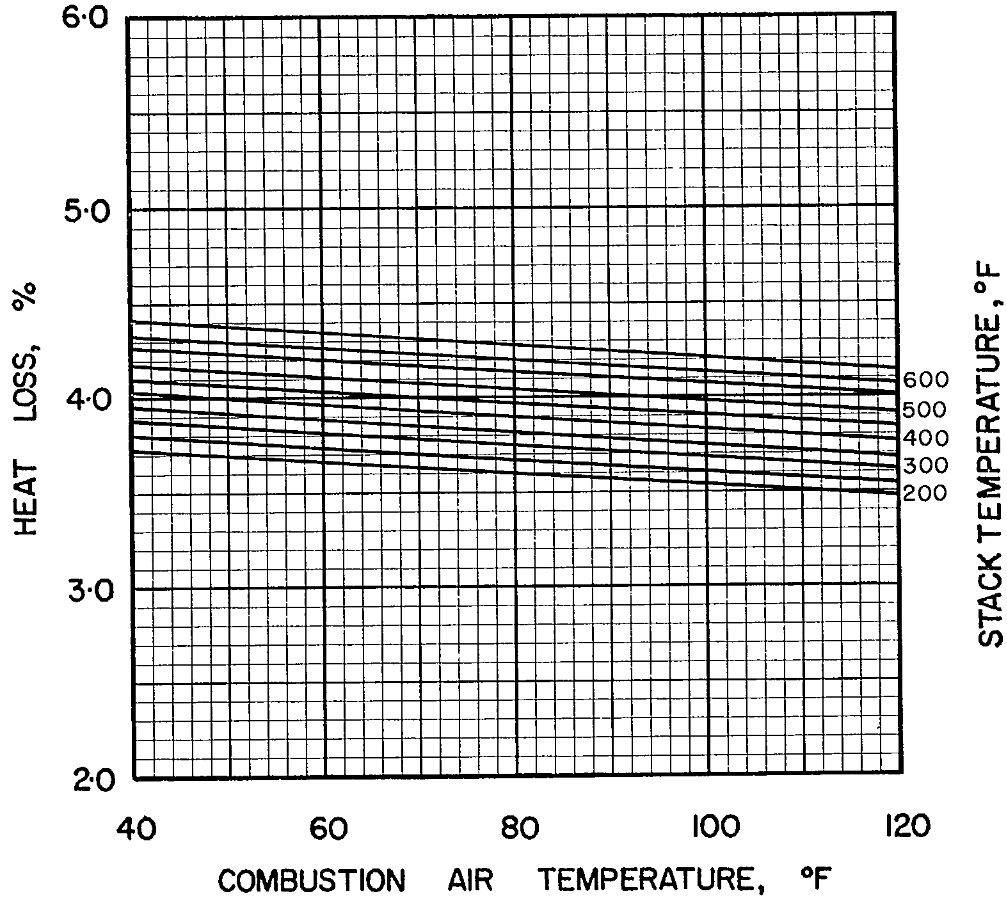


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·2

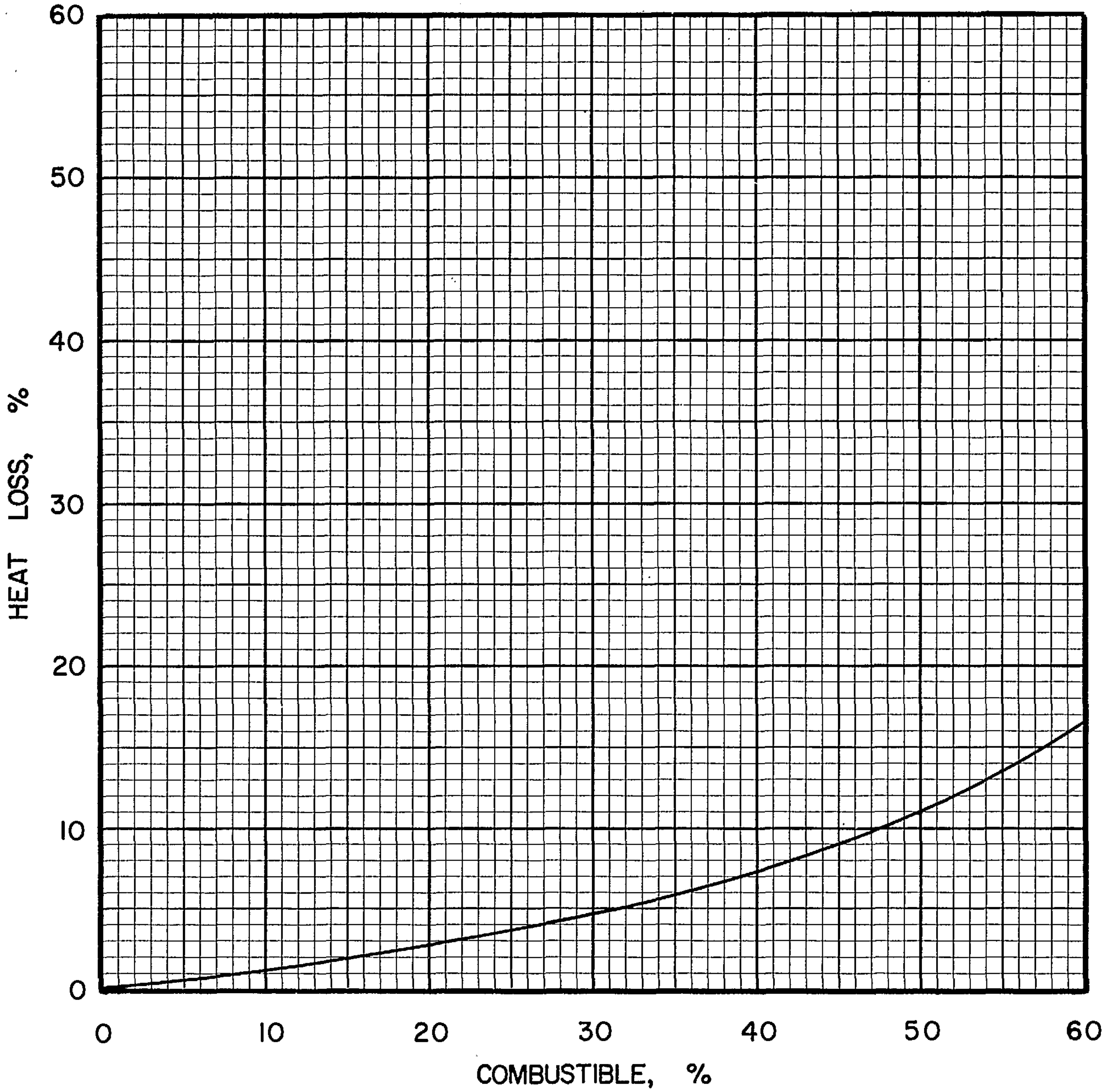


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS-3-2

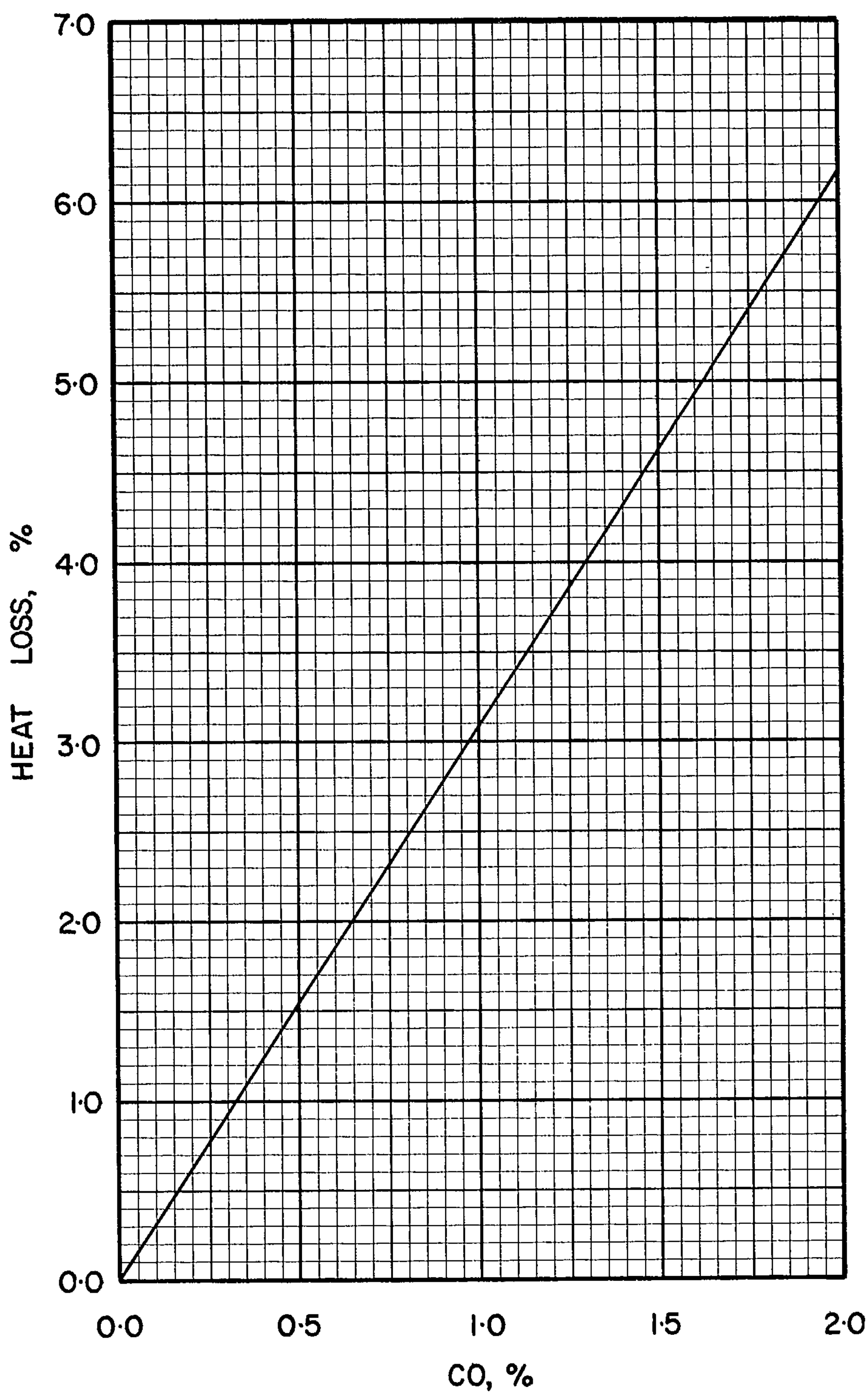


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·3·2

COAL NS 3-3, DOMINION NO. 18, DEVCO, CAPE BRETON, 1 3/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0732
Volatile Matter	0.3795
Fixed Carbon	0.5473
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7811
Hydrogen (H)	0.0516
Sulphur (S)	0.0175
Nitrogen (N)	0.0137
Oxygen (O)	0.0629
Ash	0.0732
Total	1.0000

Gross Calorific Value

Btu/lb:	14110
Btu/short ton:	28.22×10^6
Btu/long ton:	31.61×10^6
MJ/kg:	32.81

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 70.87 lb
10^6 Btu = 0.03544 short tons
10^6 Btu = 0.03164 long tons

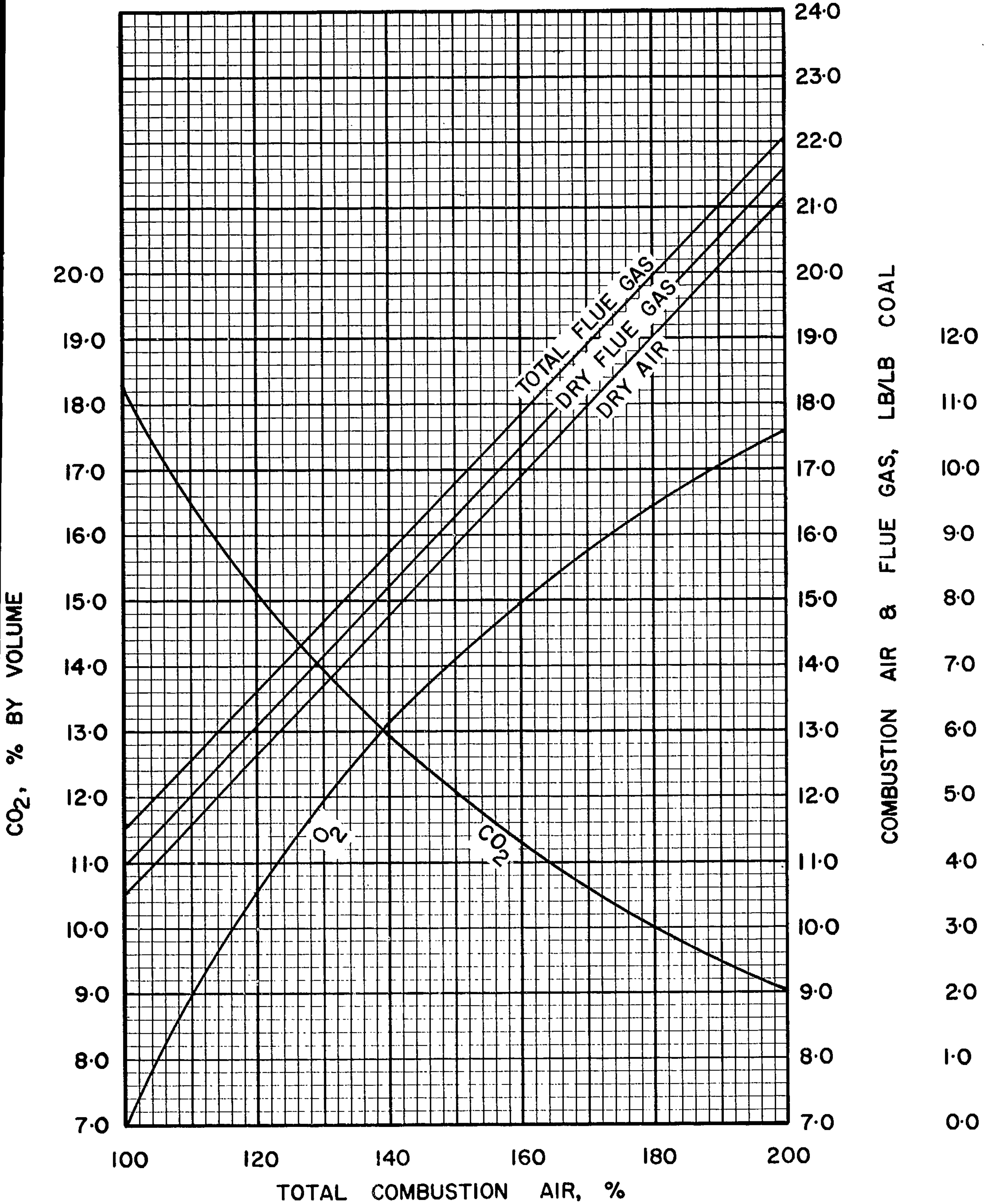


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·3·3

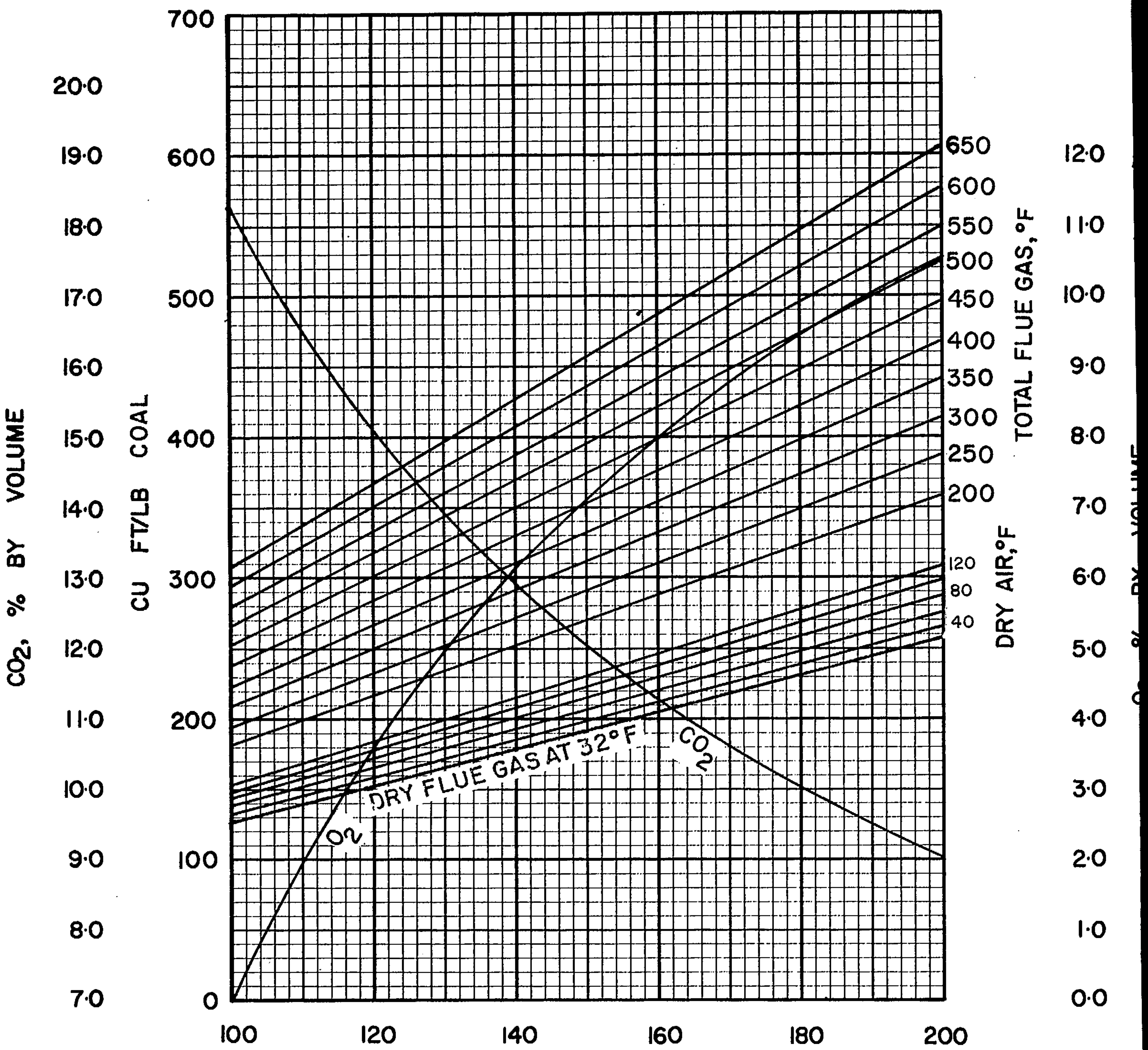


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·3·3

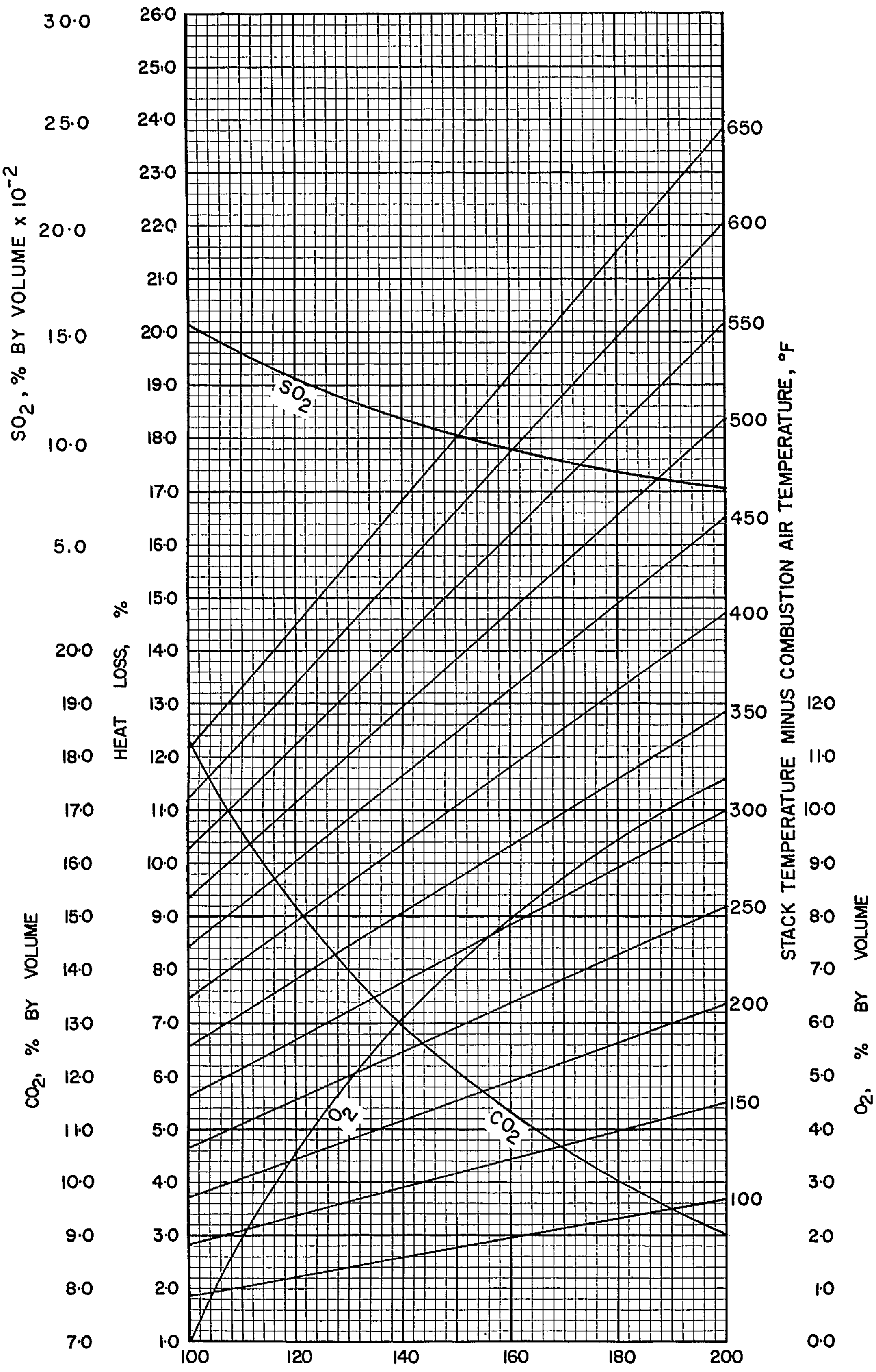


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·3·3

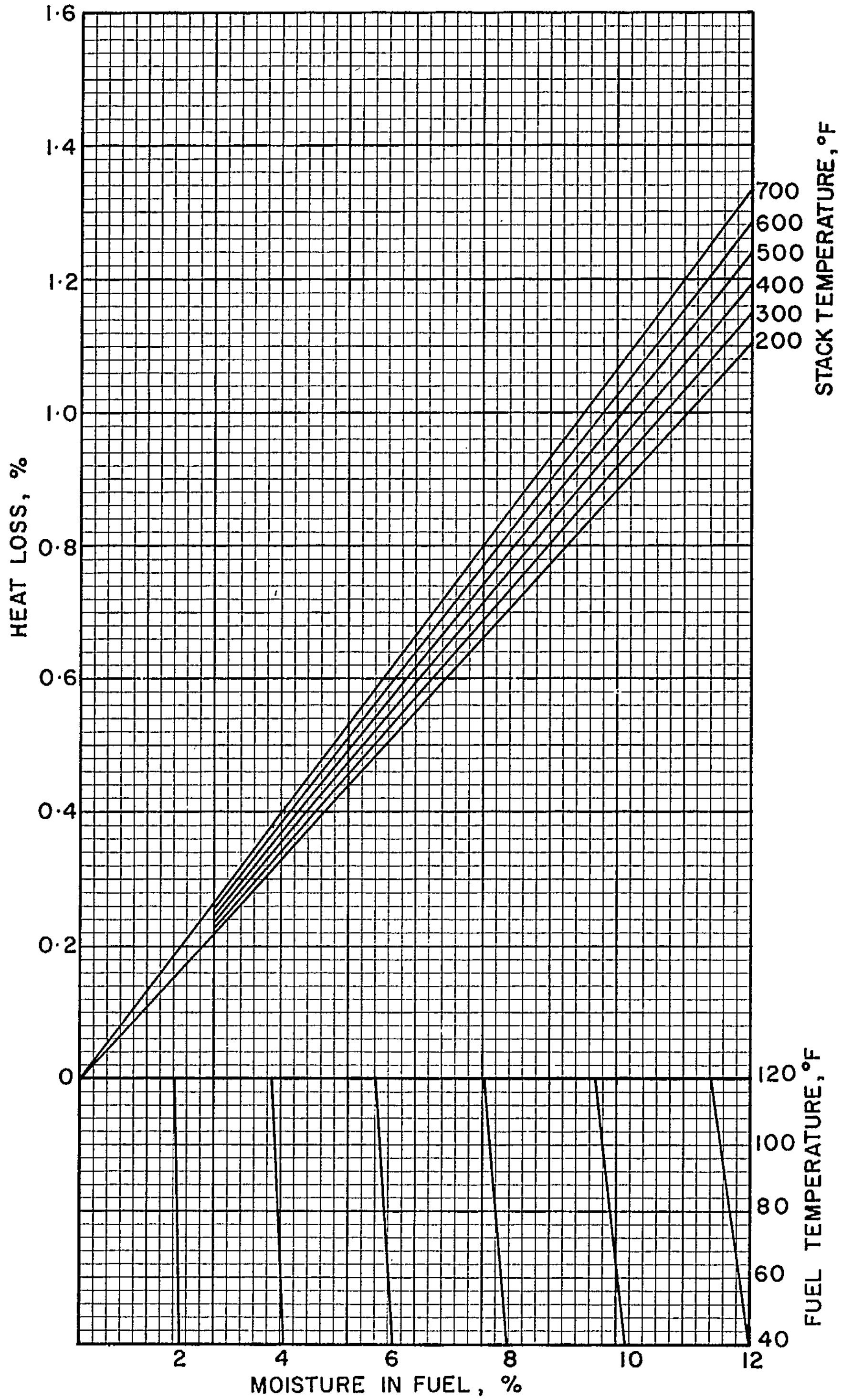


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·3·3

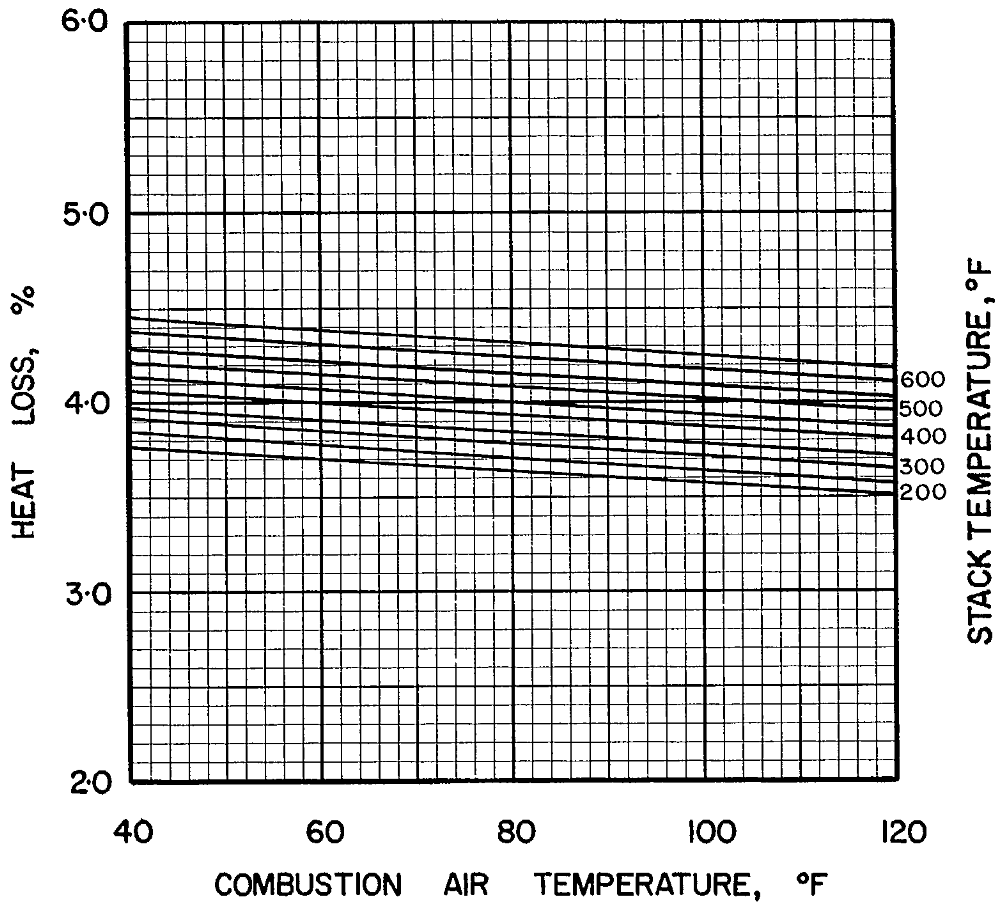


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·3

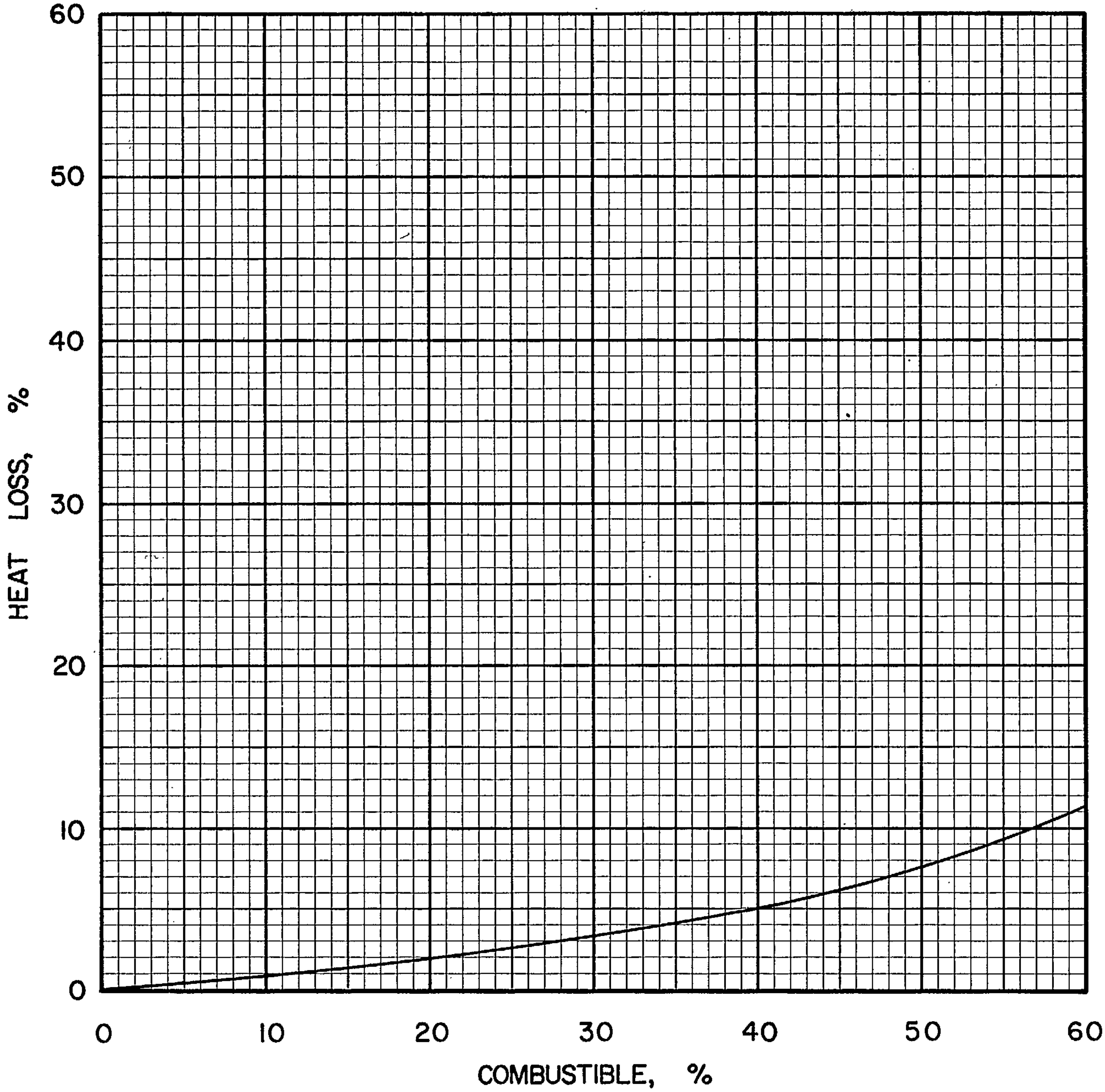


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·3·3

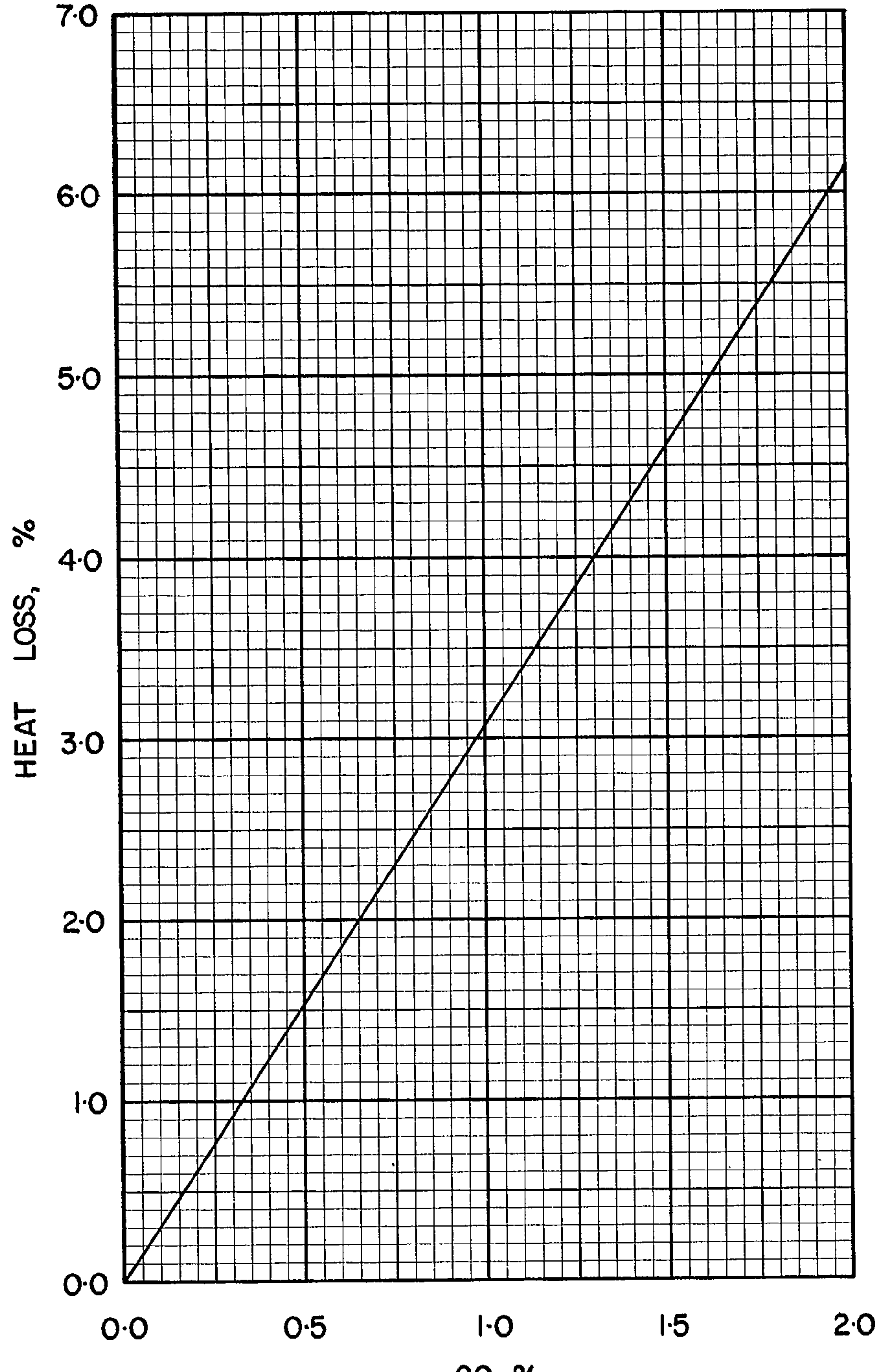


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·3·3

COAL NS 3-4, DOMINION NO. 20, DEVCO, CAPE BRETON, 1 1/2 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0900
Volatile Matter	0.3753
Fixed Carbon	0.5347
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7688
Hydrogen (H)	0.0518
Sulphur (S)	0.0309
Nitrogen (N)	0.0121
Oxygen (O)	0.0464
Ash	0.0900
Total	1.0000

Gross Calorific Value

Btu/lb:	13970
Btu/short ton:	27.94×10^6
Btu/long ton:	31.29×10^6
MJ/kg:	32.49

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	71.58	lb	
10^6 Btu	=	0.03579	short tons	
10^6 Btu	=	0.03196	long tons	

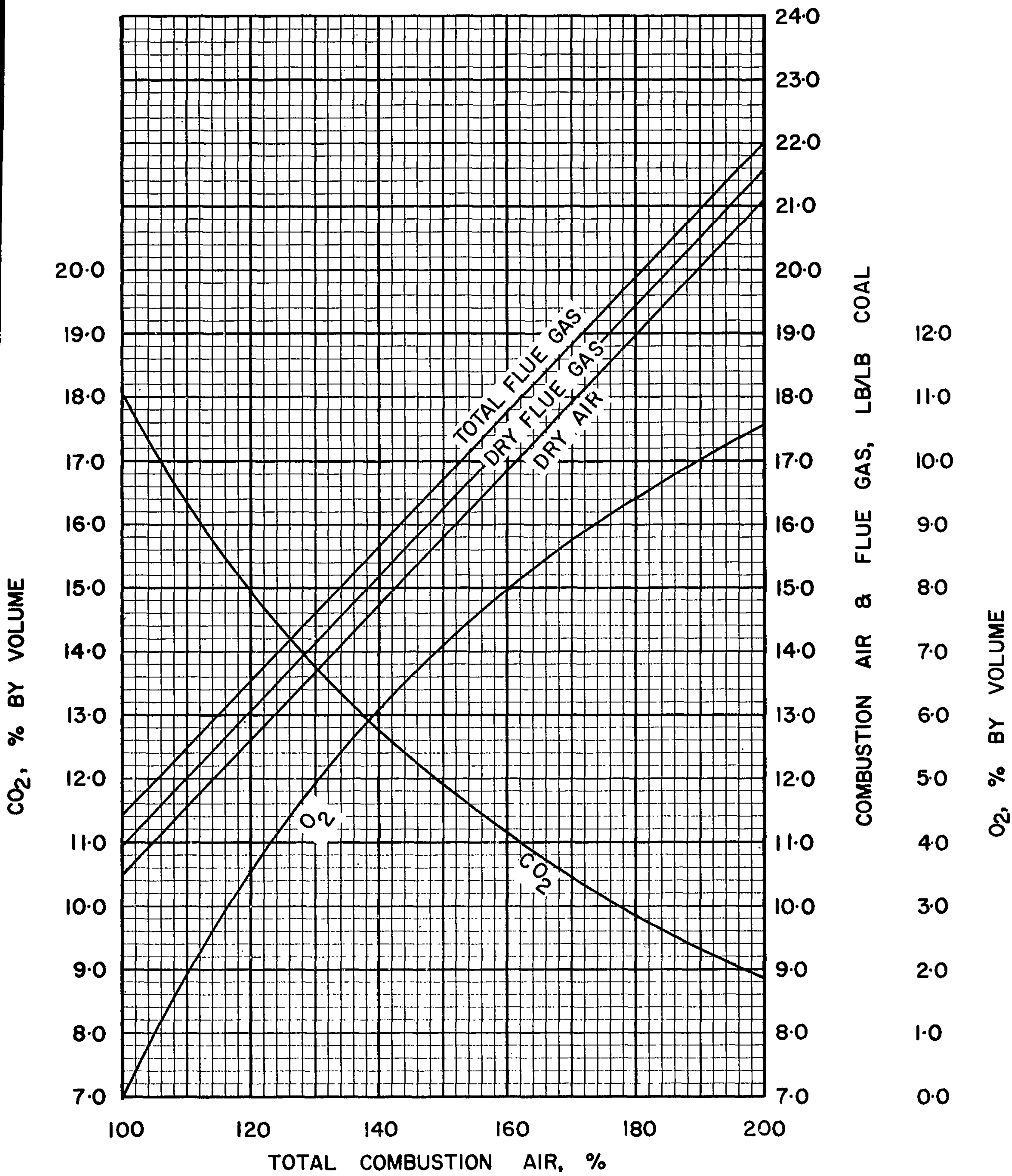


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·3·4

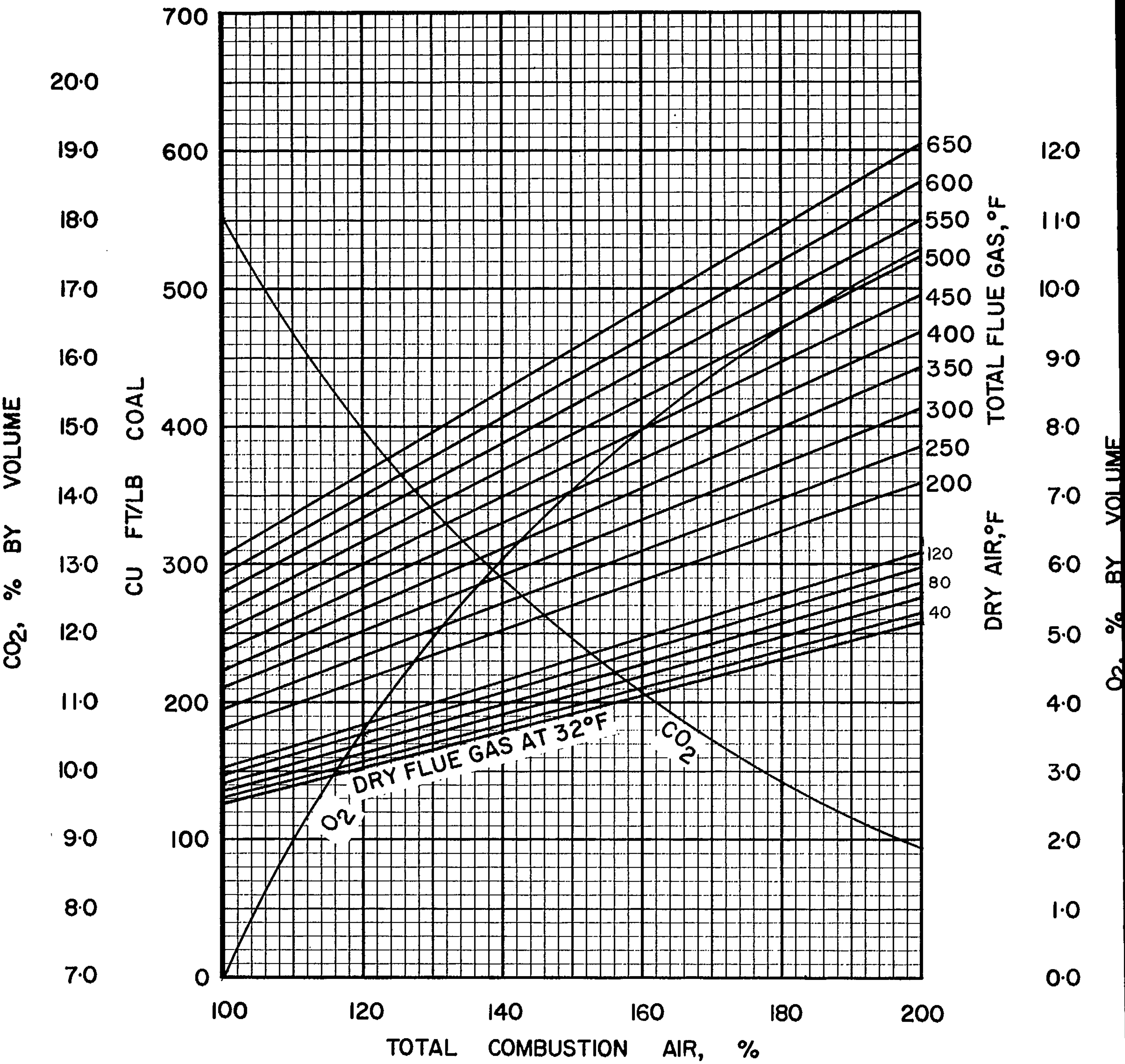


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·3·4

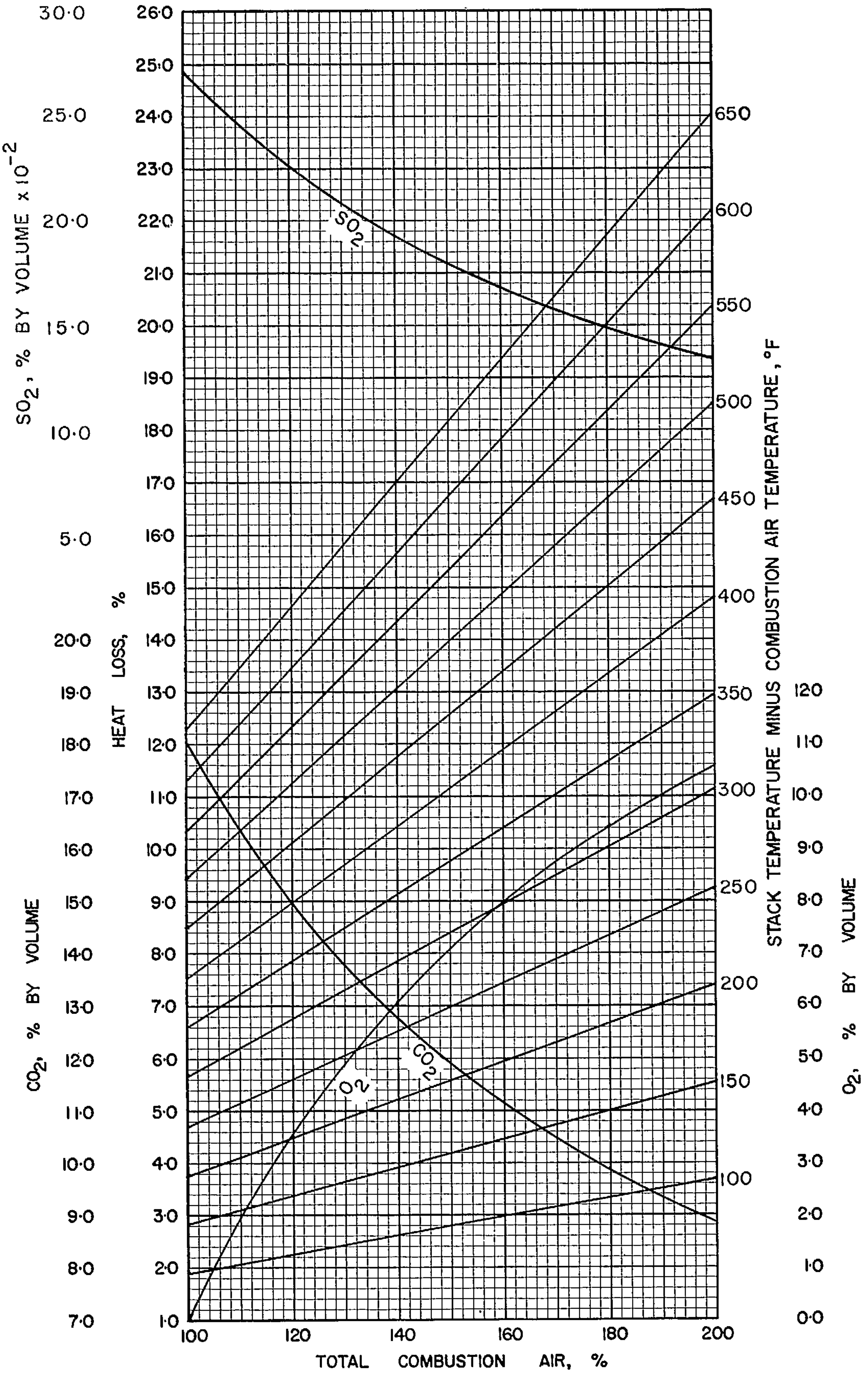


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·3·4

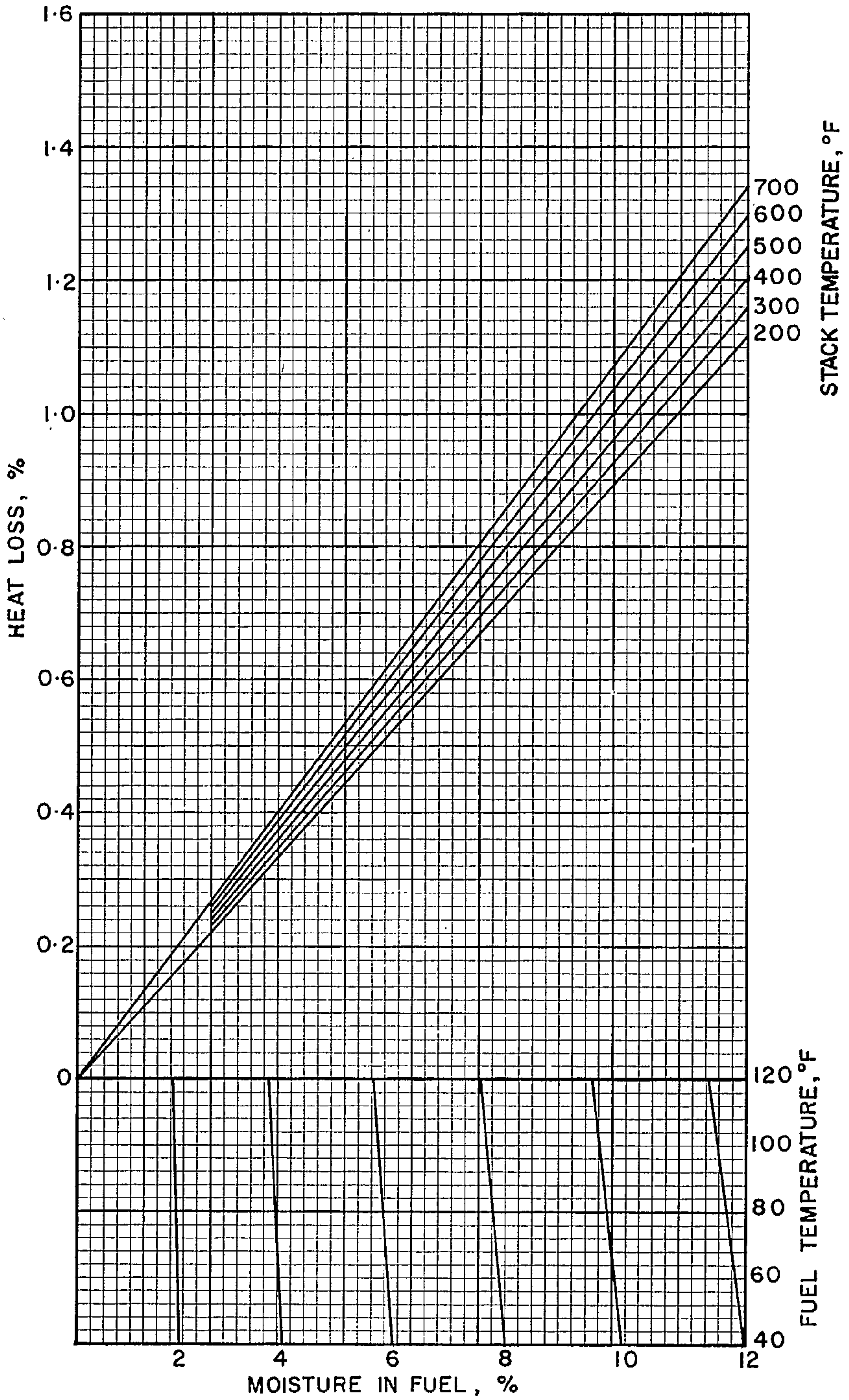


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·3·4

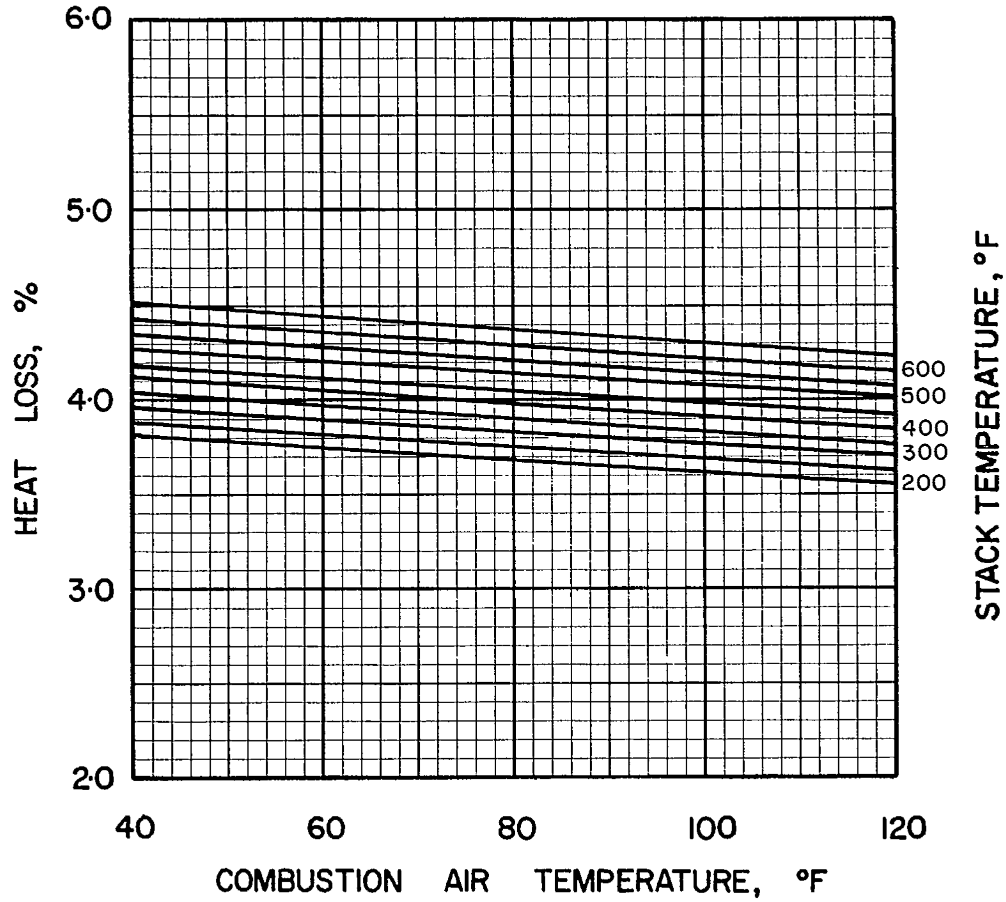


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·4

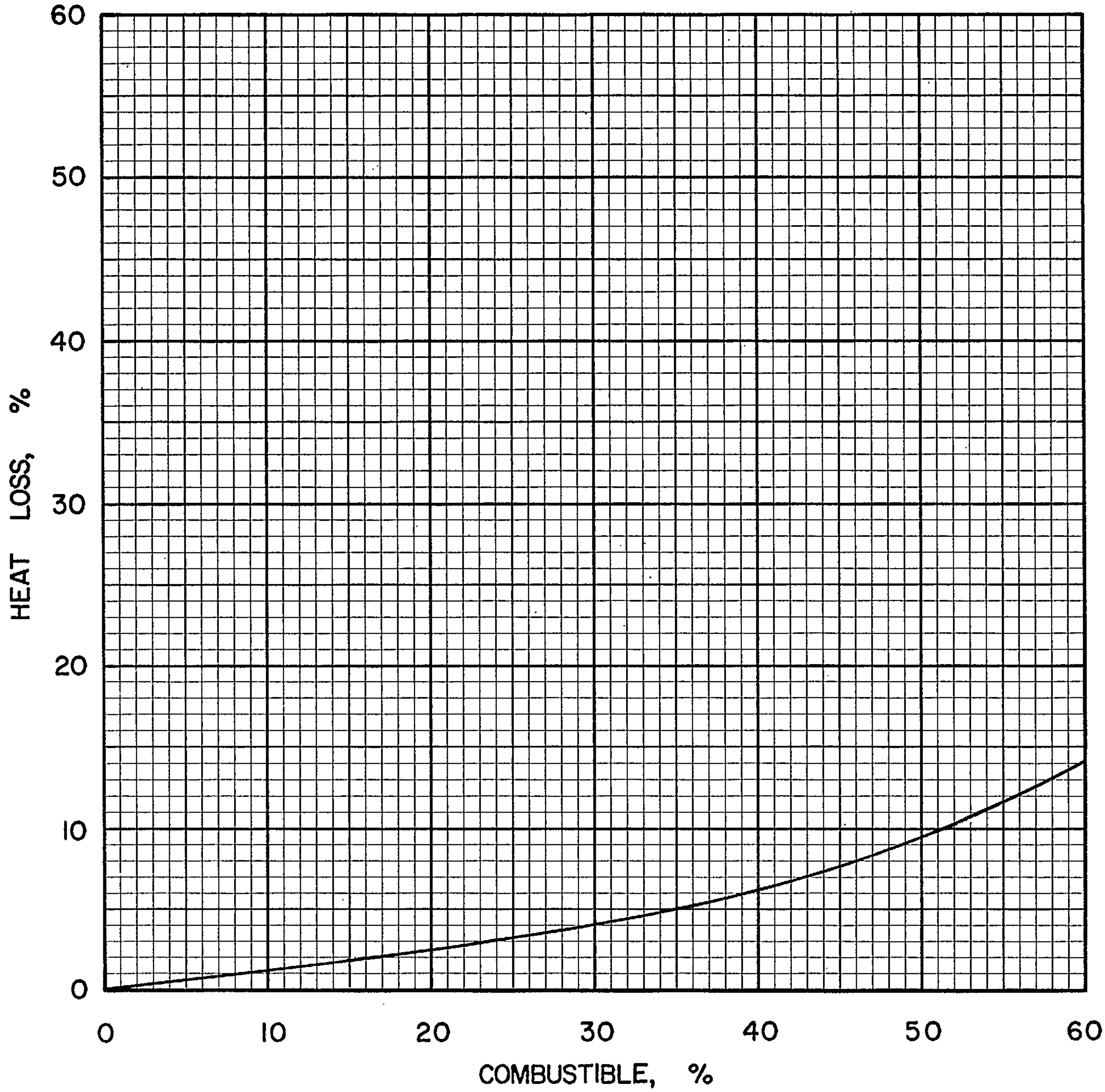


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·3·4

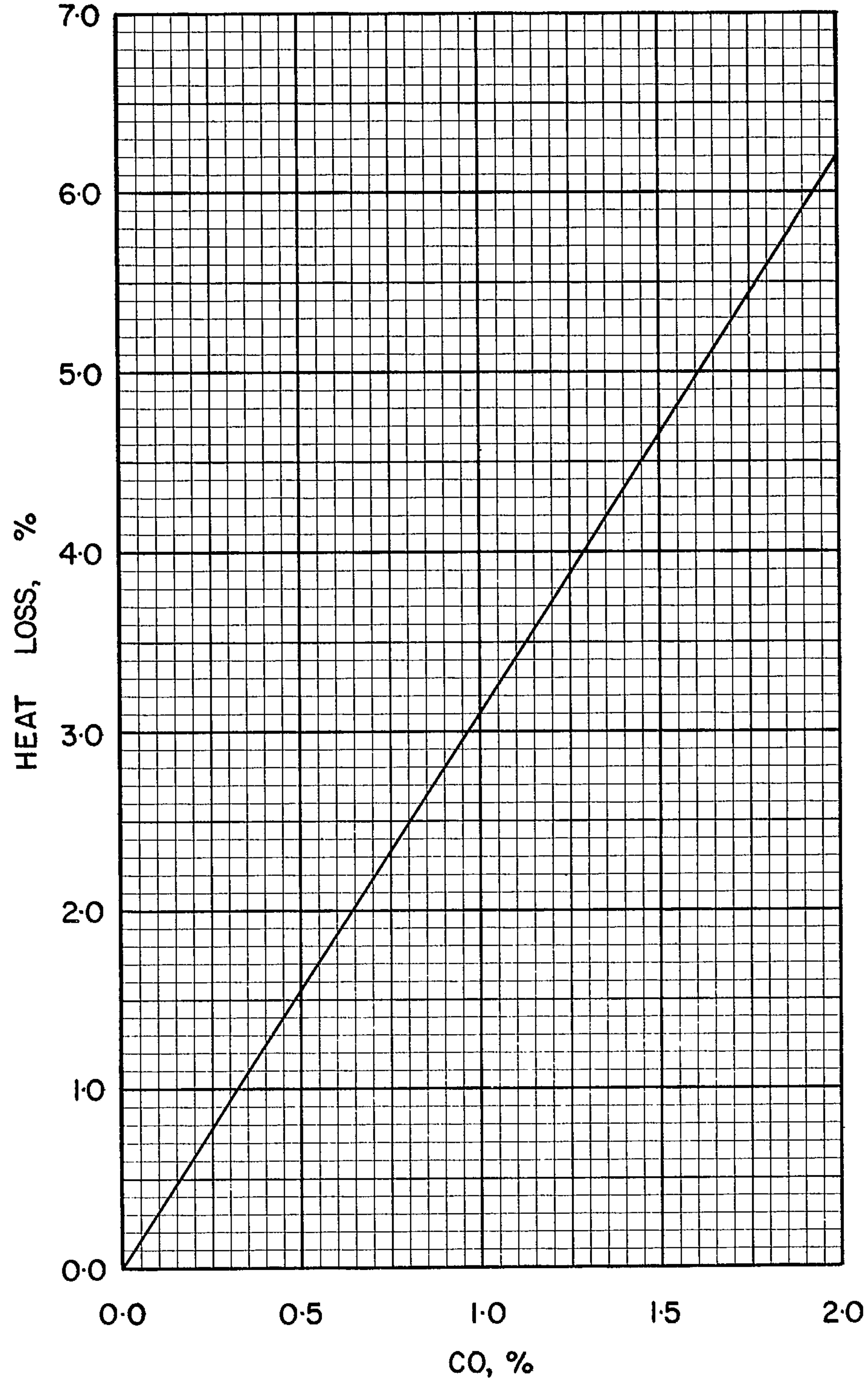


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 3·4

COAL NS 3-5, DOMINION NO. 26, DEVCO, CAPE BRETON, 1 1/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0616
Volatile Matter	0.3465
Fixed Carbon	0.5919
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8069
Hydrogen (H)	0.0524
Sulphur (S)	0.0113
Nitrogen (N)	0.0160
Oxygen (O)	0.0518
Ash	0.0616
Total	1.0000

Calorific Value.

Btu/lb:	14310
Btu/short ton:	28.62×10^6
Btu/long ton:	32.05×10^6
MJ/kg:	33.28

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 69.88	lb	
10^6 Btu	= 0.03494	short tons	
10^6 Btu	= 0.03120	long tons	

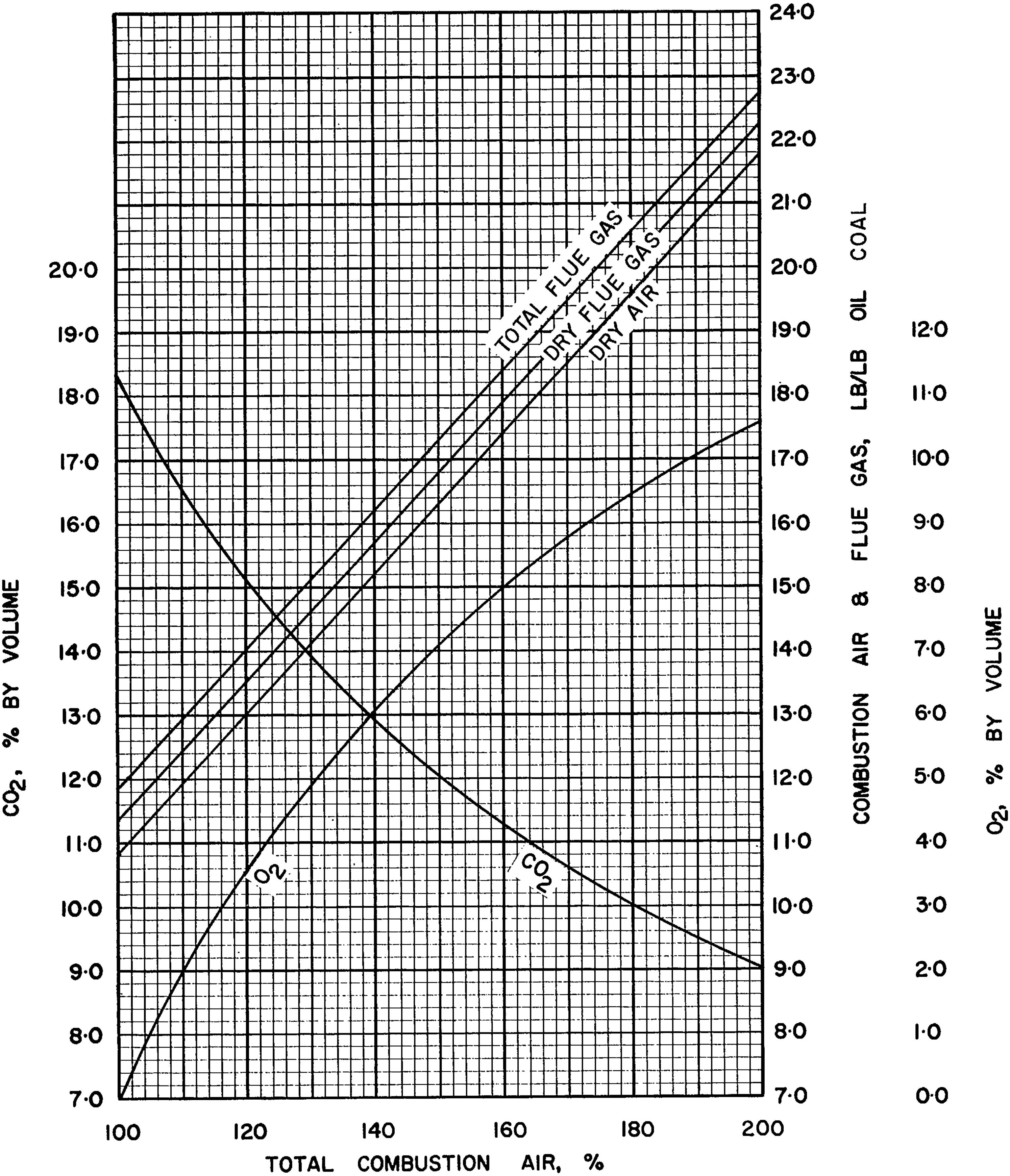


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·3·5

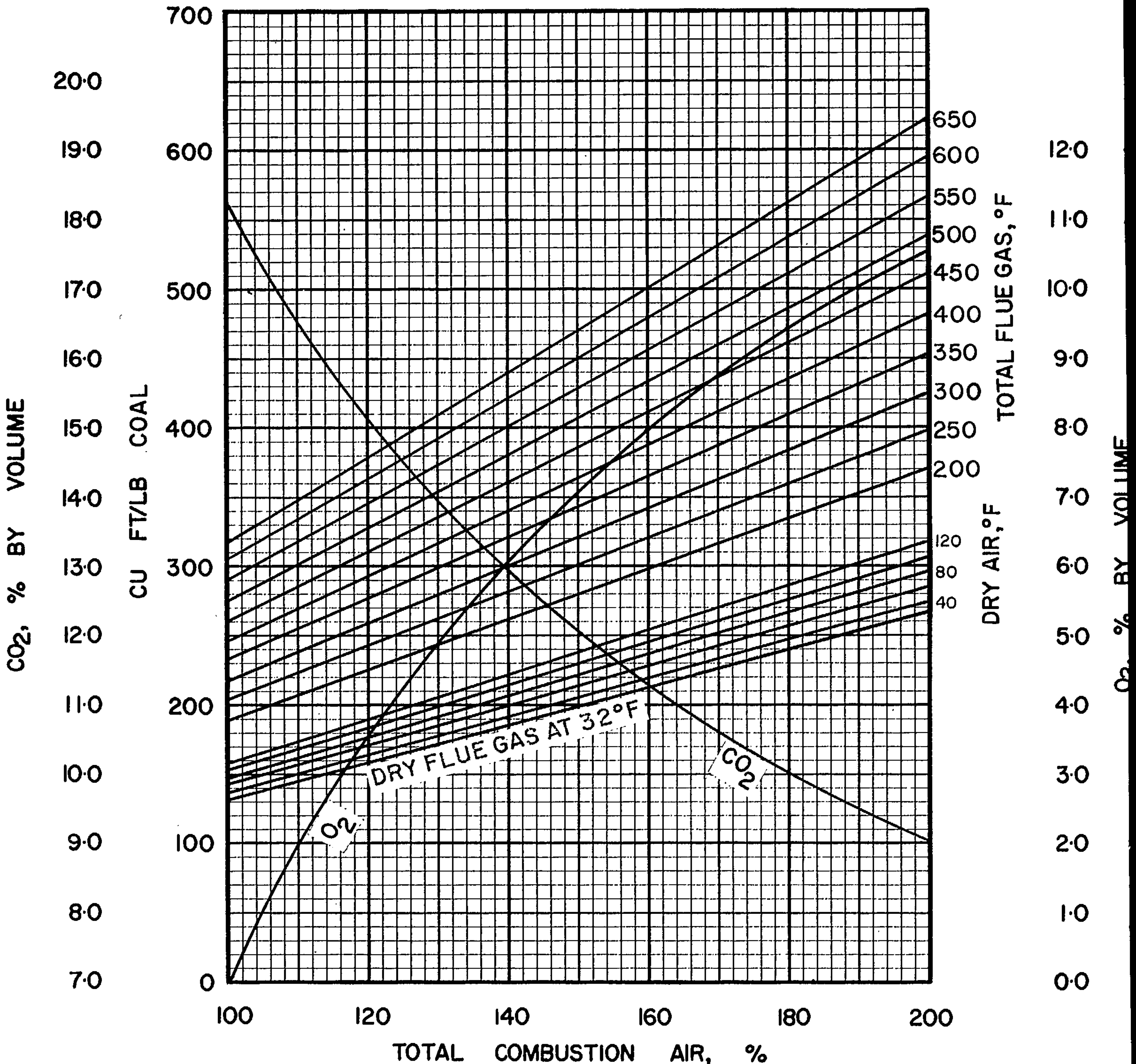


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NS·3·5

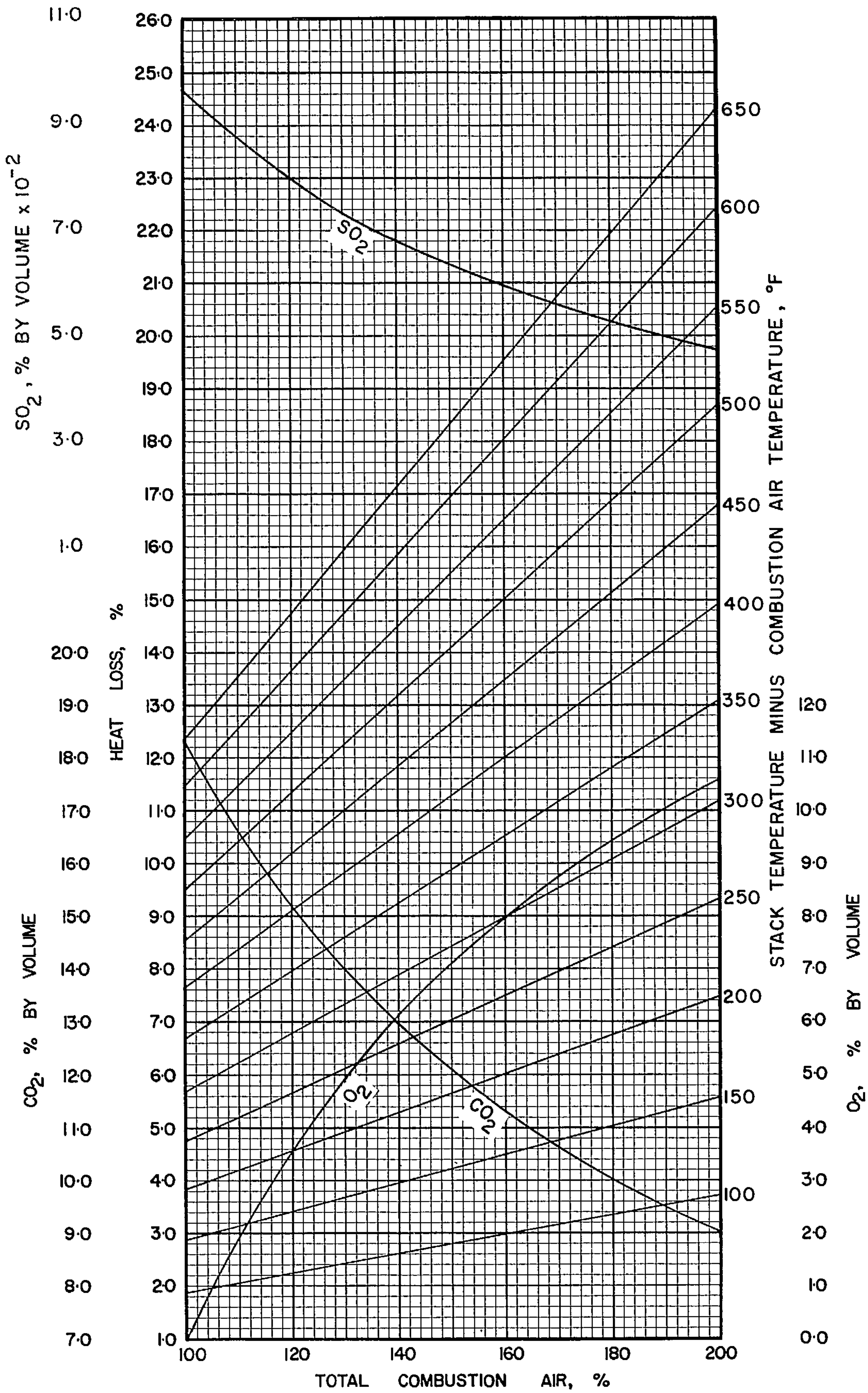


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·3·5

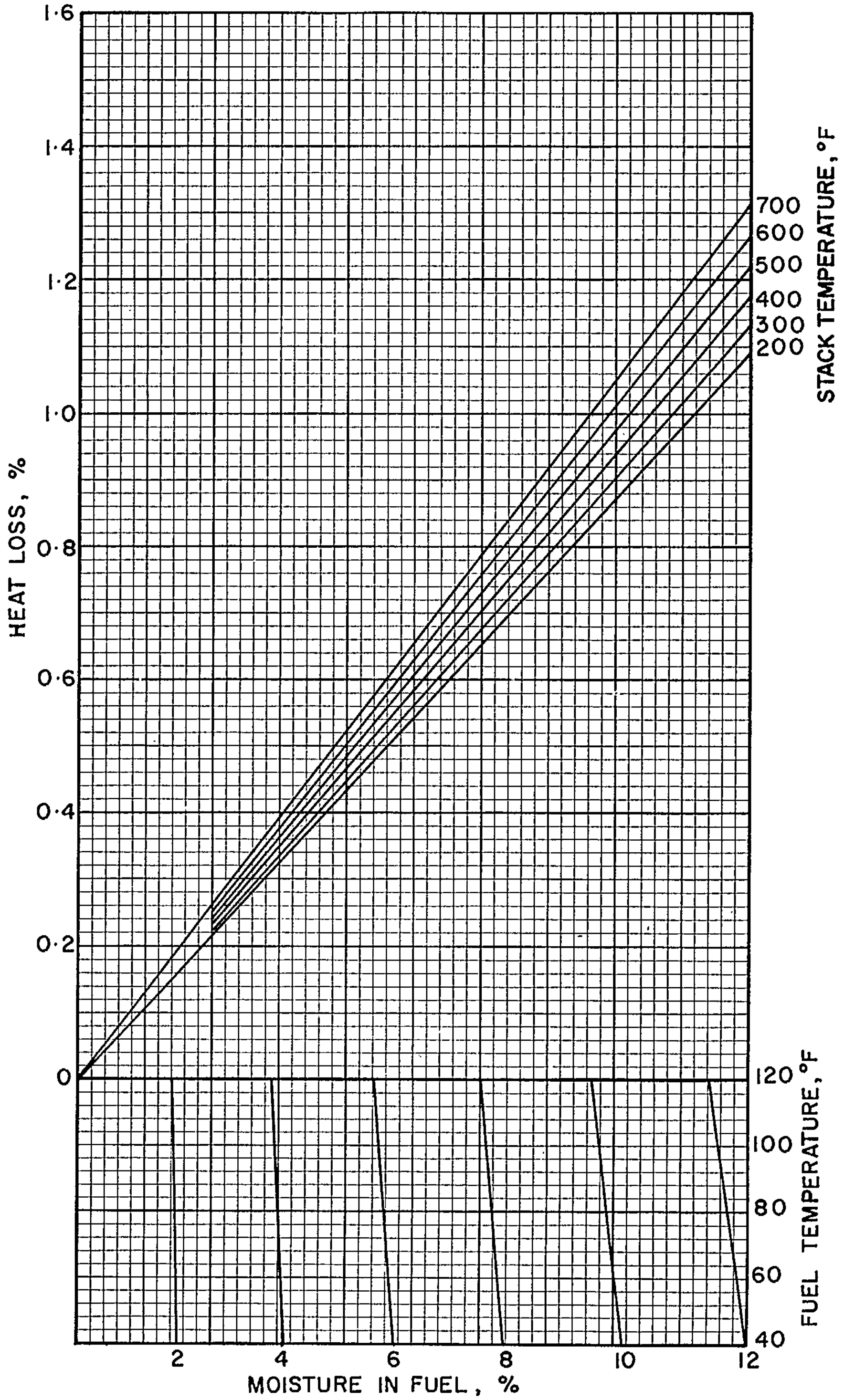


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·3·5

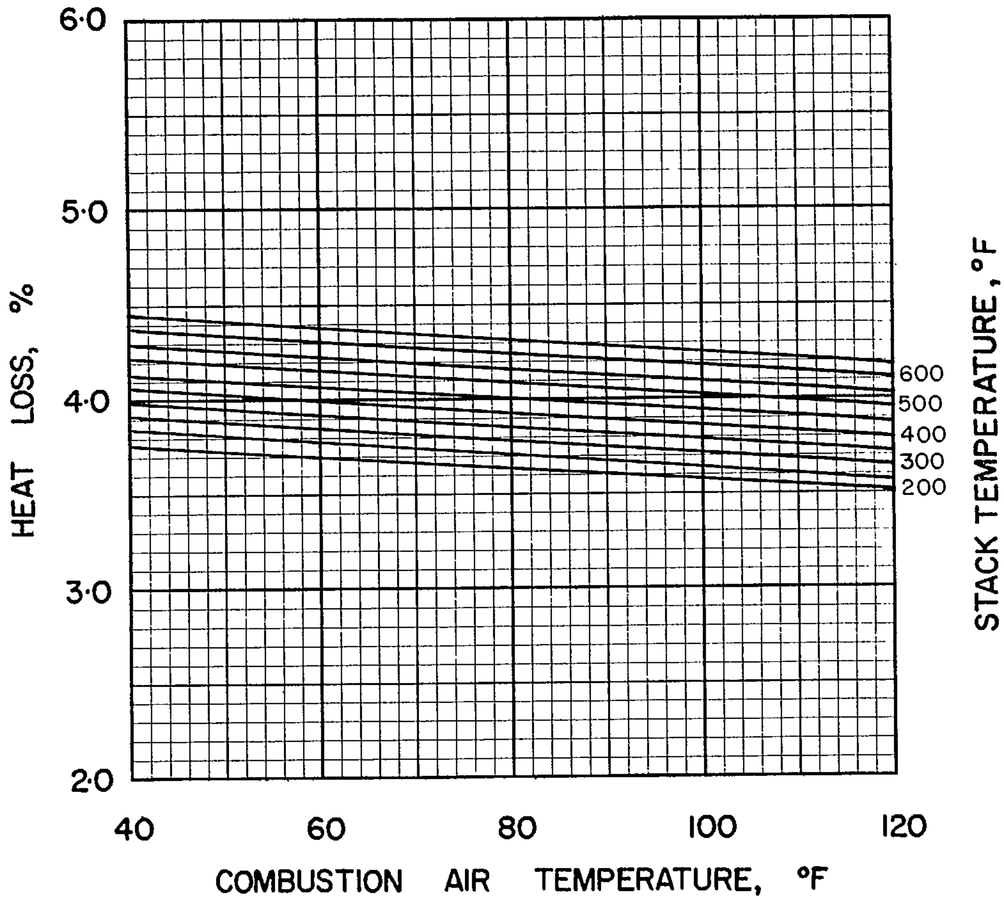


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·5

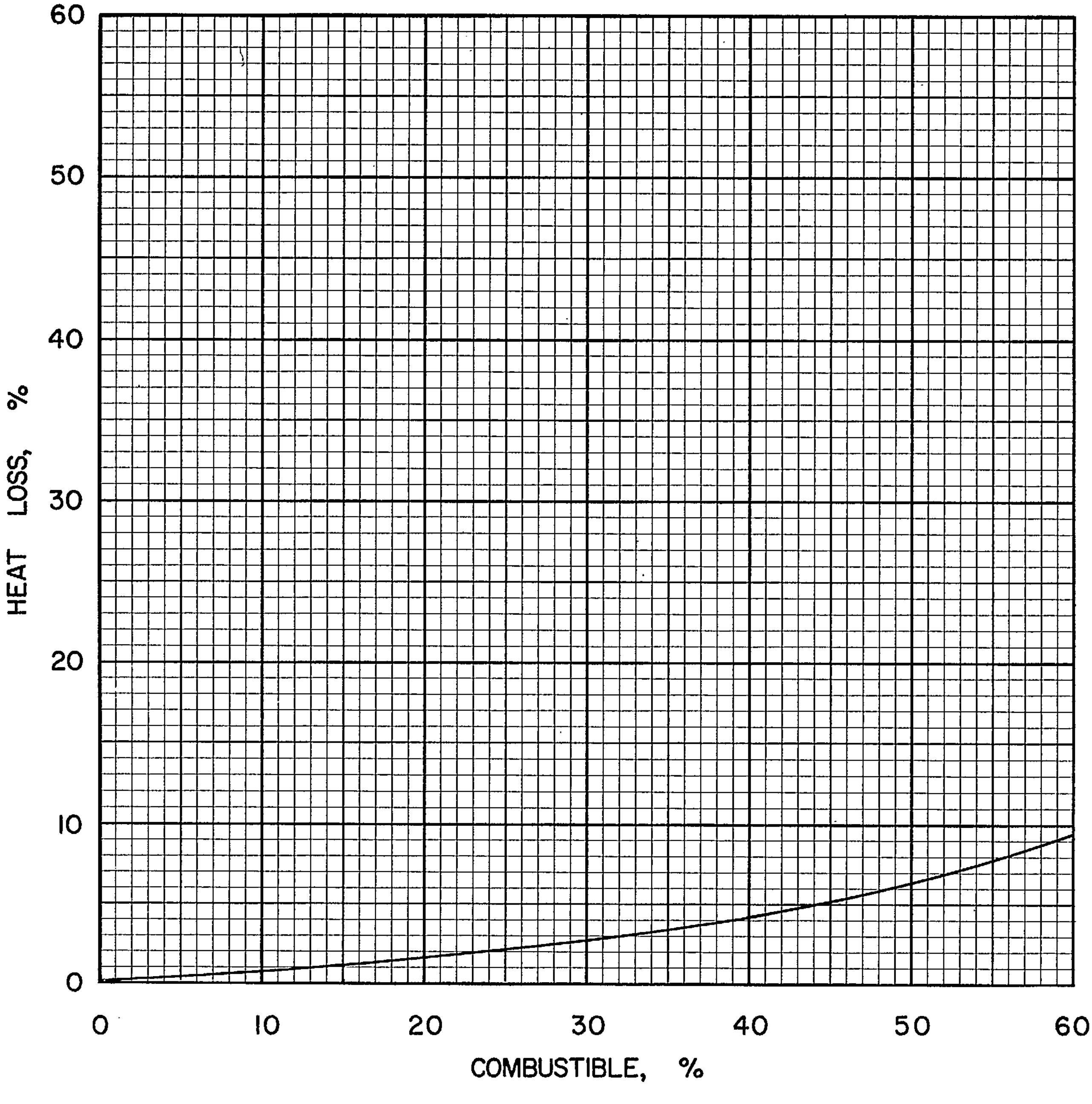


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·3·5

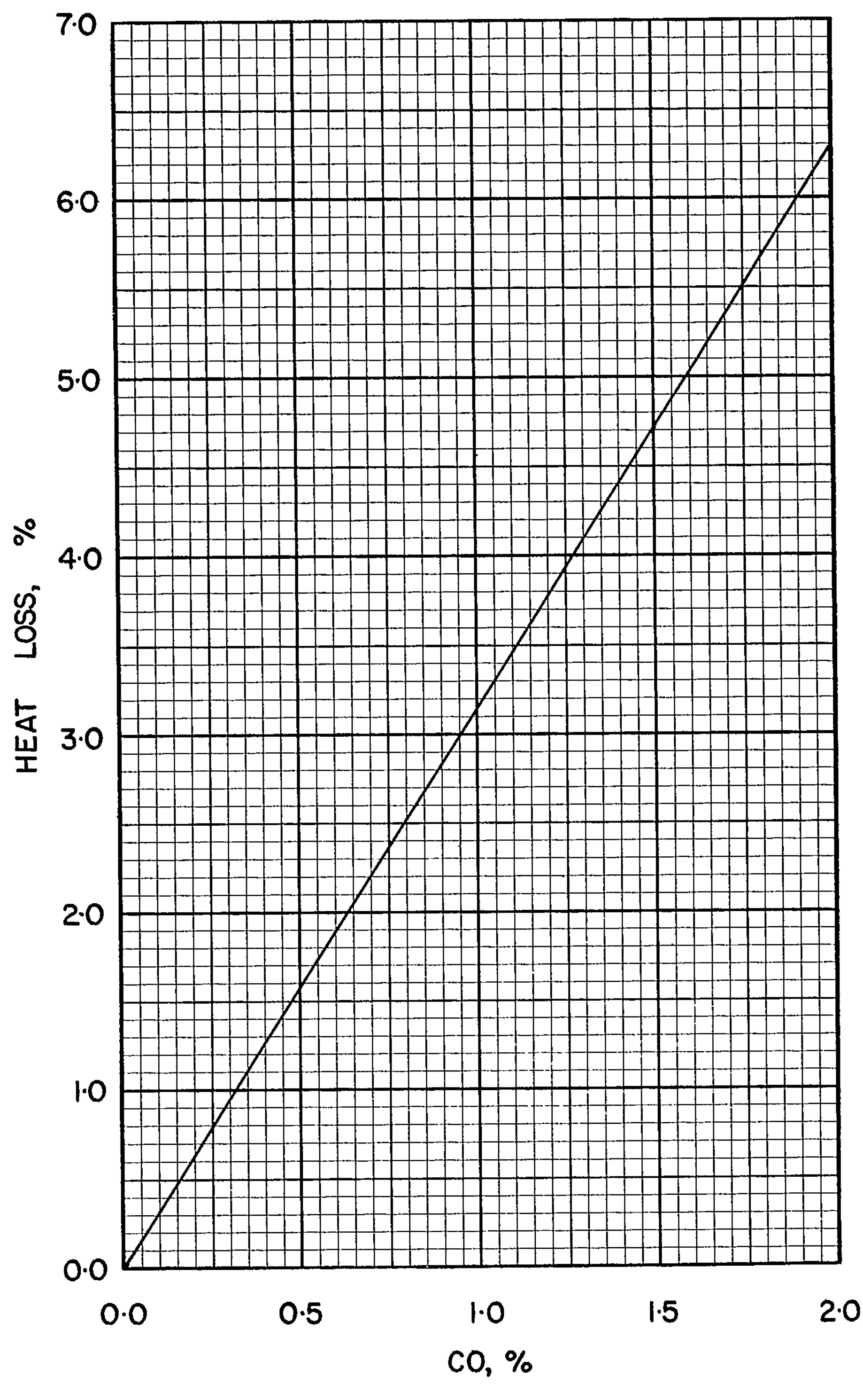


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·3·5

COAL NS 3-6, DOMINION SLACK, DEVCO, CAPE BRETON, 3/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0806
Volatile Matter	0.3484
Fixed Carbon	0.5710
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7781
Hydrogen (H)	0.0506
Sulphur (S)	0.0281
Nitrogen (N)	0.0132
Oxygen (O)	0.0494
Ash	0.0806
Total	1.0000

Gross Calorific Value

Btu/lb:	14070
Btu/short ton:	28.14×10^6
Btu/long ton:	31.52×10^6
MJ/kg:	32.72

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 71.07 lb
10^6 Btu = 0.03554 short tons
10^6 Btu = 0.03173 long tons

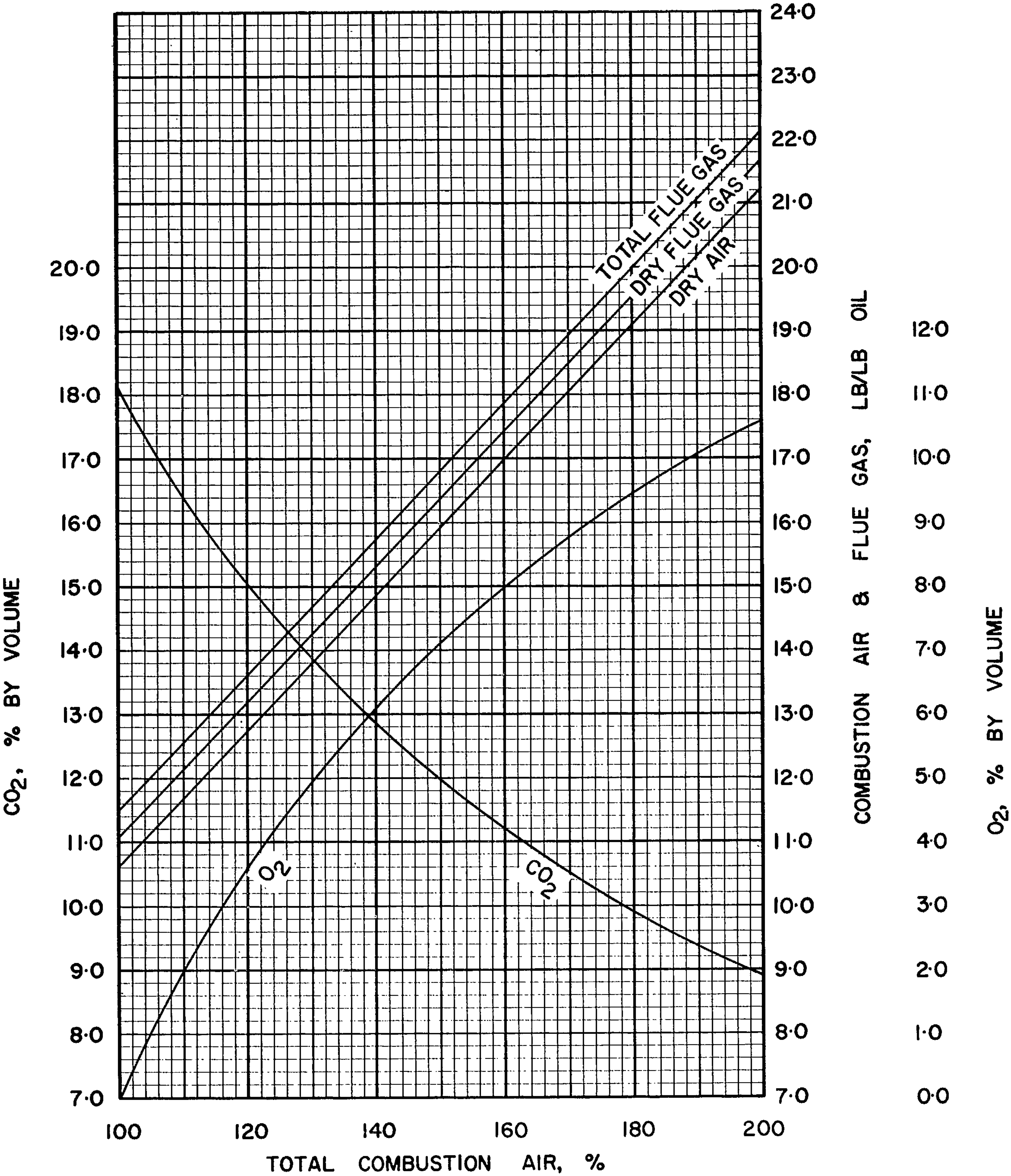


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·3·6

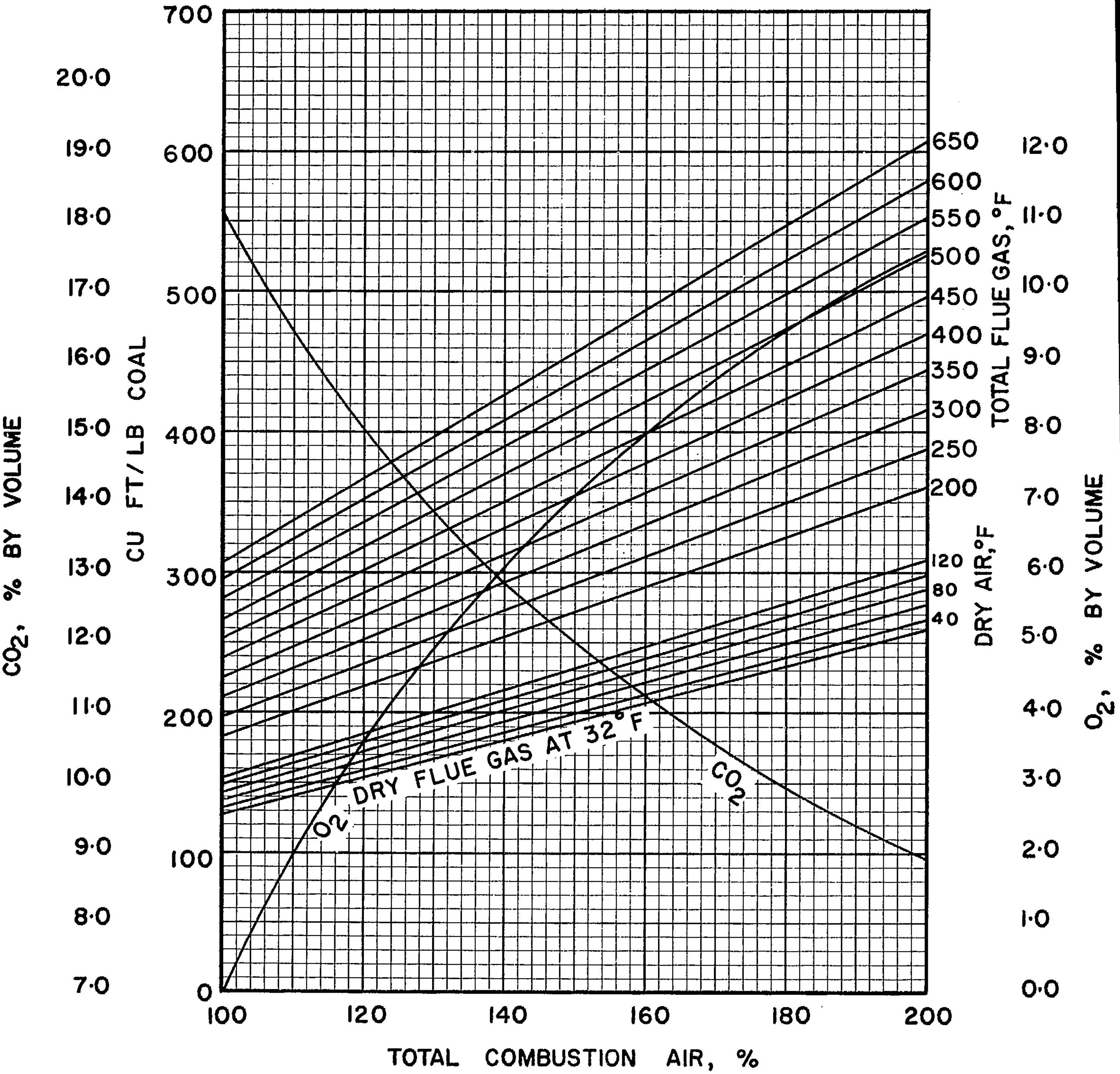


FIGURE 2. COMBUSTION DATA, VOLUME BASIS.

NS·3·6

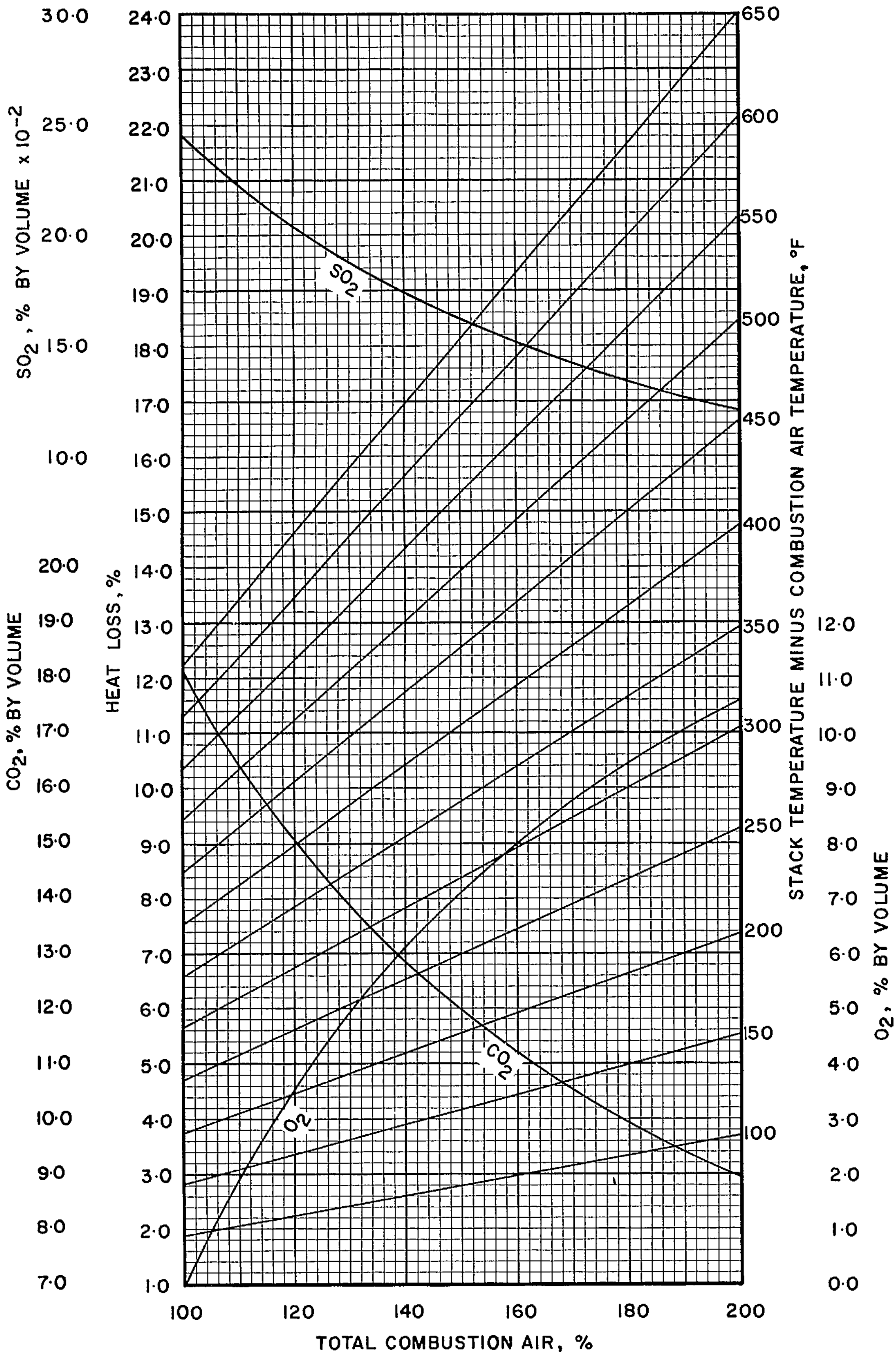


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS.

NS·3·6

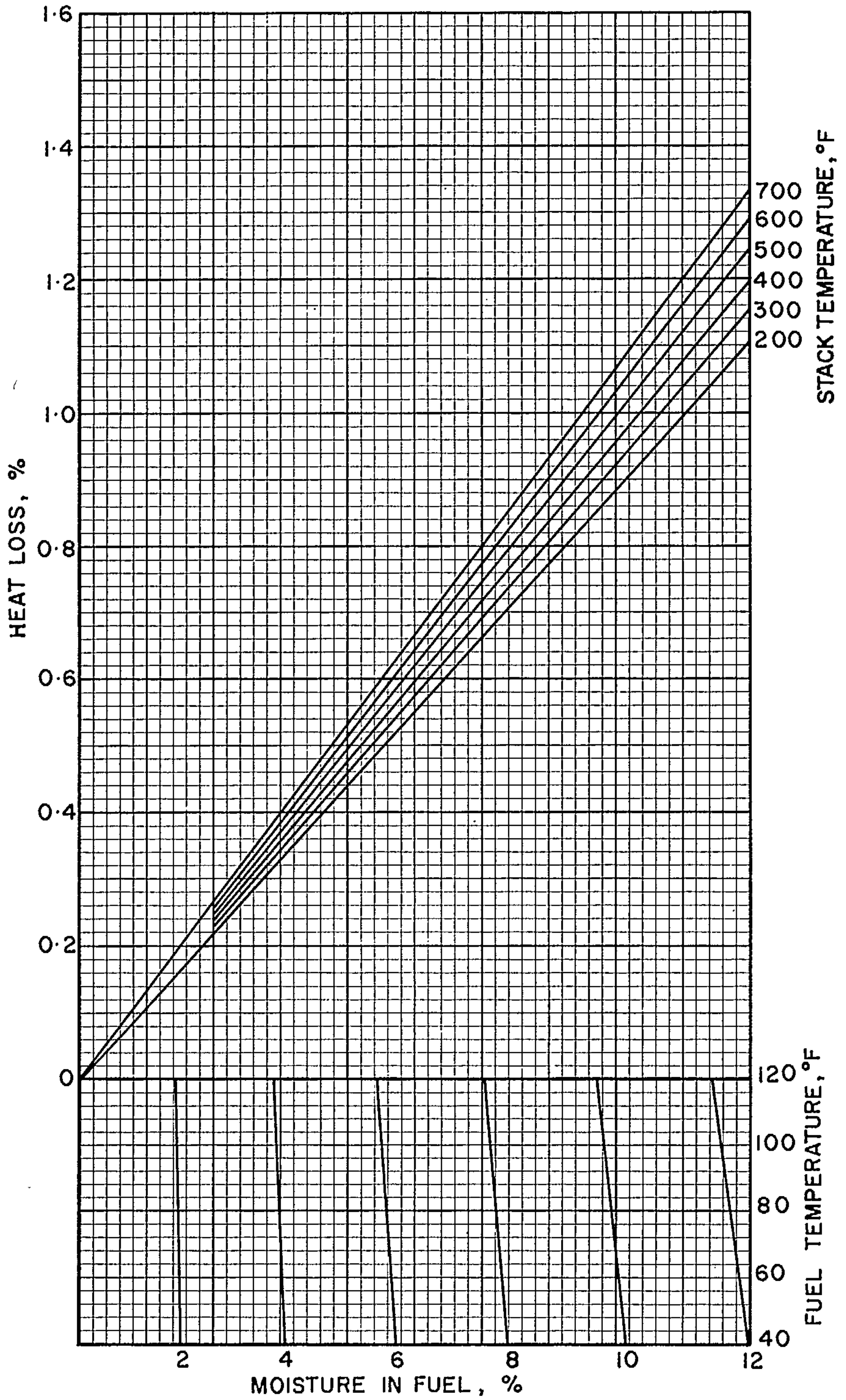


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·3·6

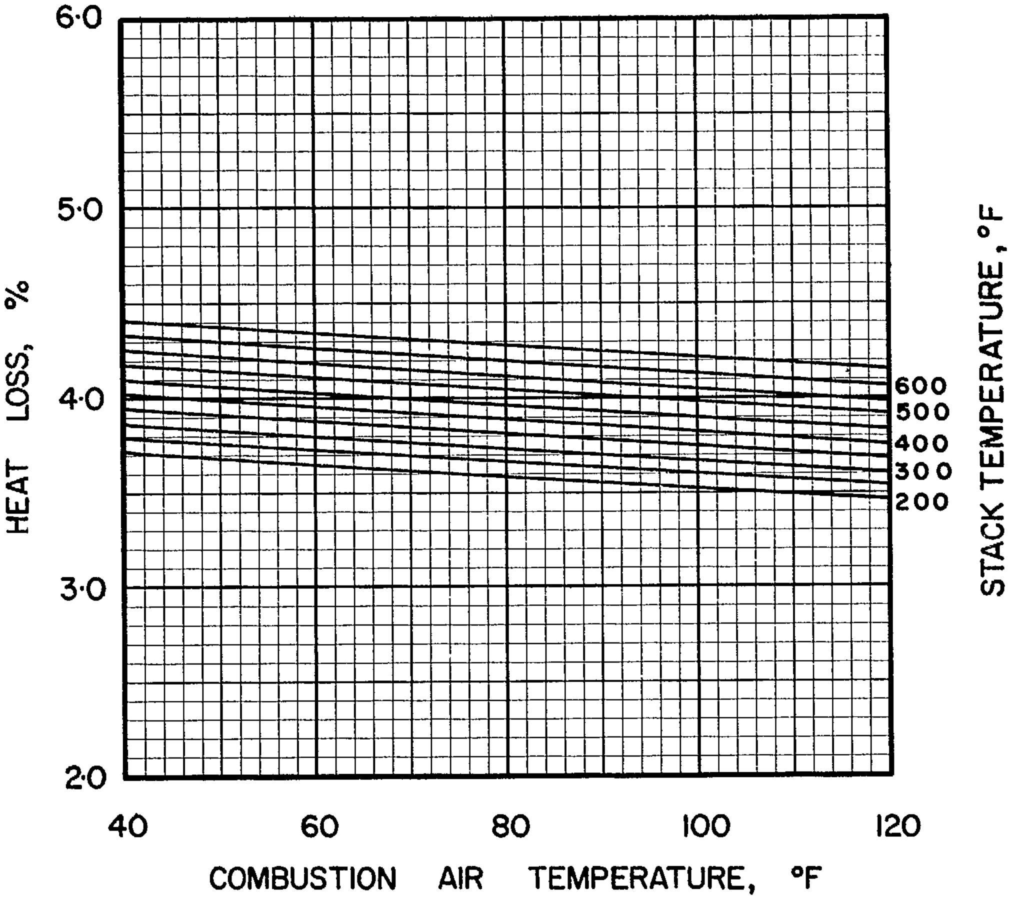


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·3·6

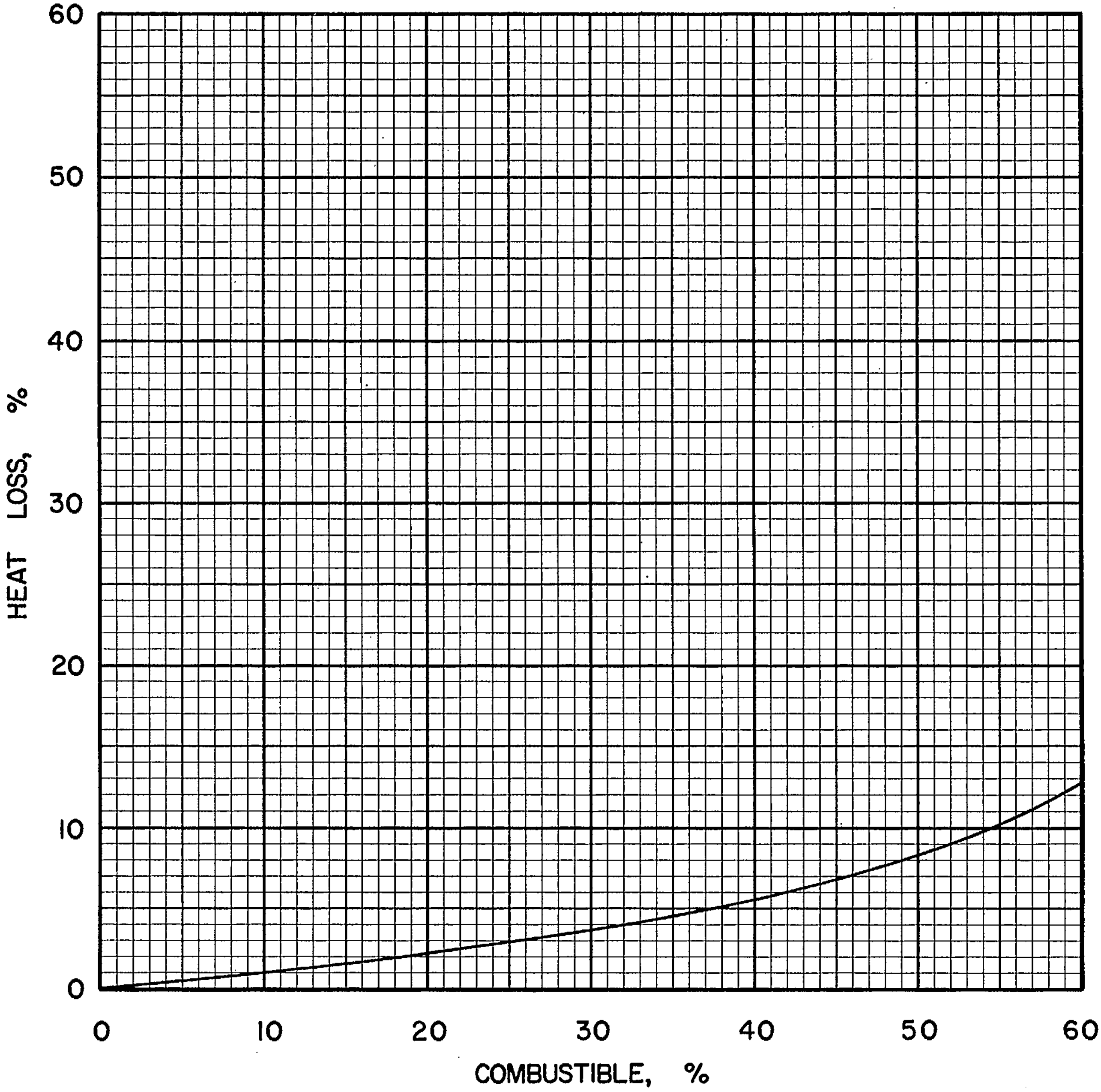


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·3·6

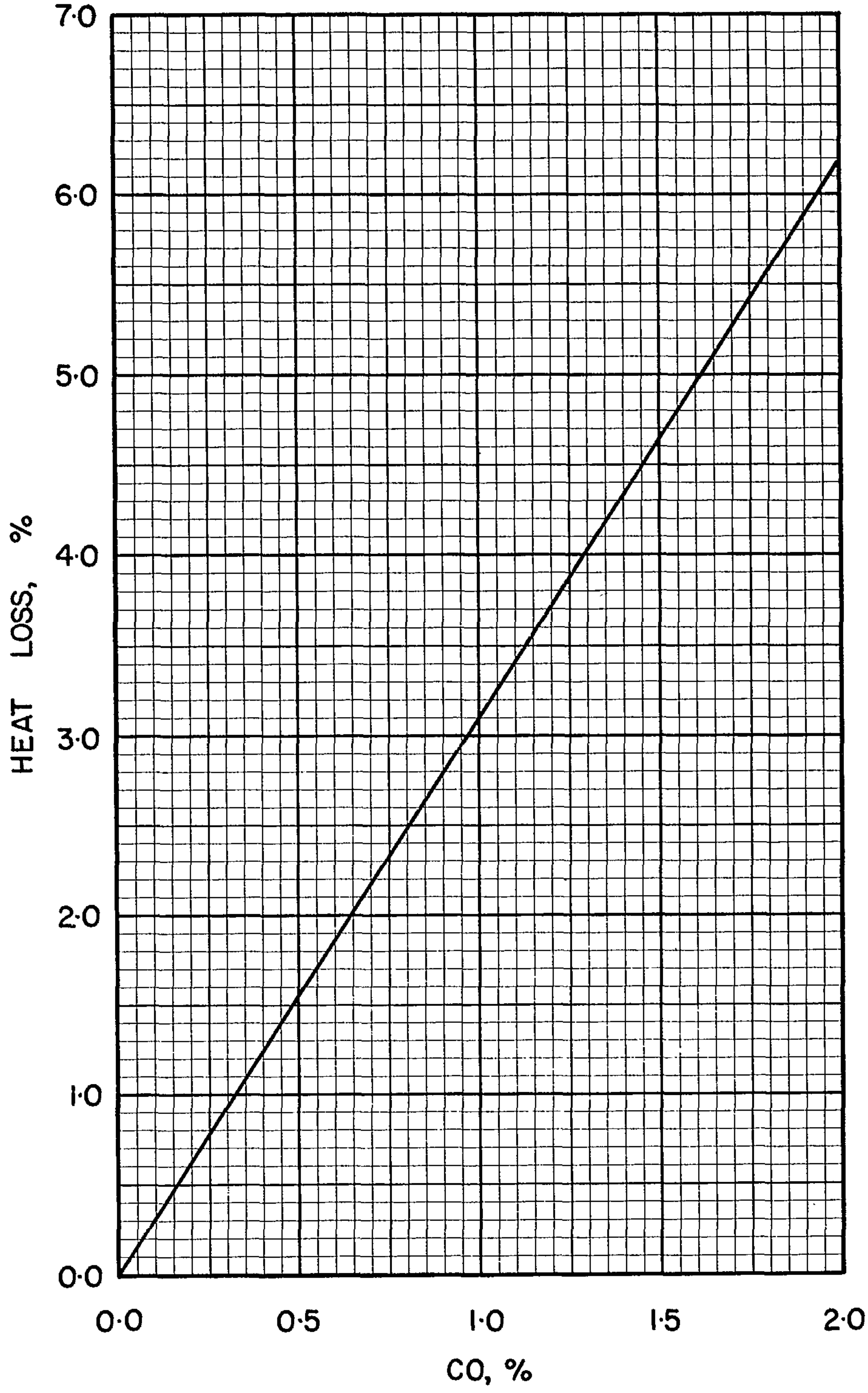


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·3·6

COAL NS 4-1, DRUMMOND NO. 1, PICTOU COUNTY, 3/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.2251
Volatile Matter	0.2389
Fixed Carbon	0.5360
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6497
Hydrogen (H)	0.0428
Sulphur (S)	0.0076
Nitrogen (N)	0.0171
Oxygen (O)	0.0577
Ash	0.2251
Total	1.0000

Gross Calorific Value

Btu/lb:	10994
Btu/short ton:	21.99×10^6
Btu/long ton:	24.63×10^6
MJ/kg:	25.57

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 90.96 lb
10^6 Btu = 0.04548 short tons
10^6 Btu = 0.04060 long tons

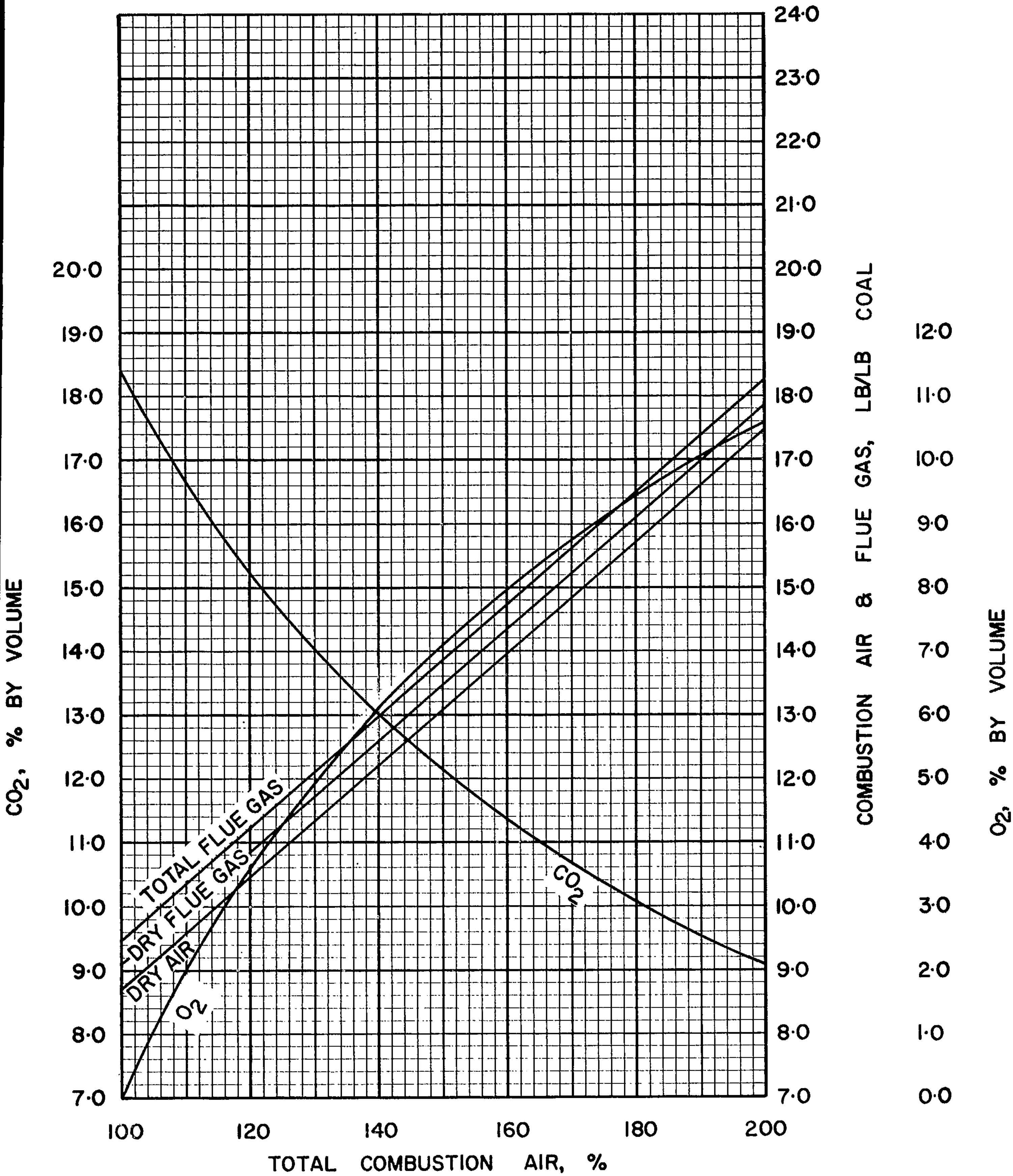


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·4·1

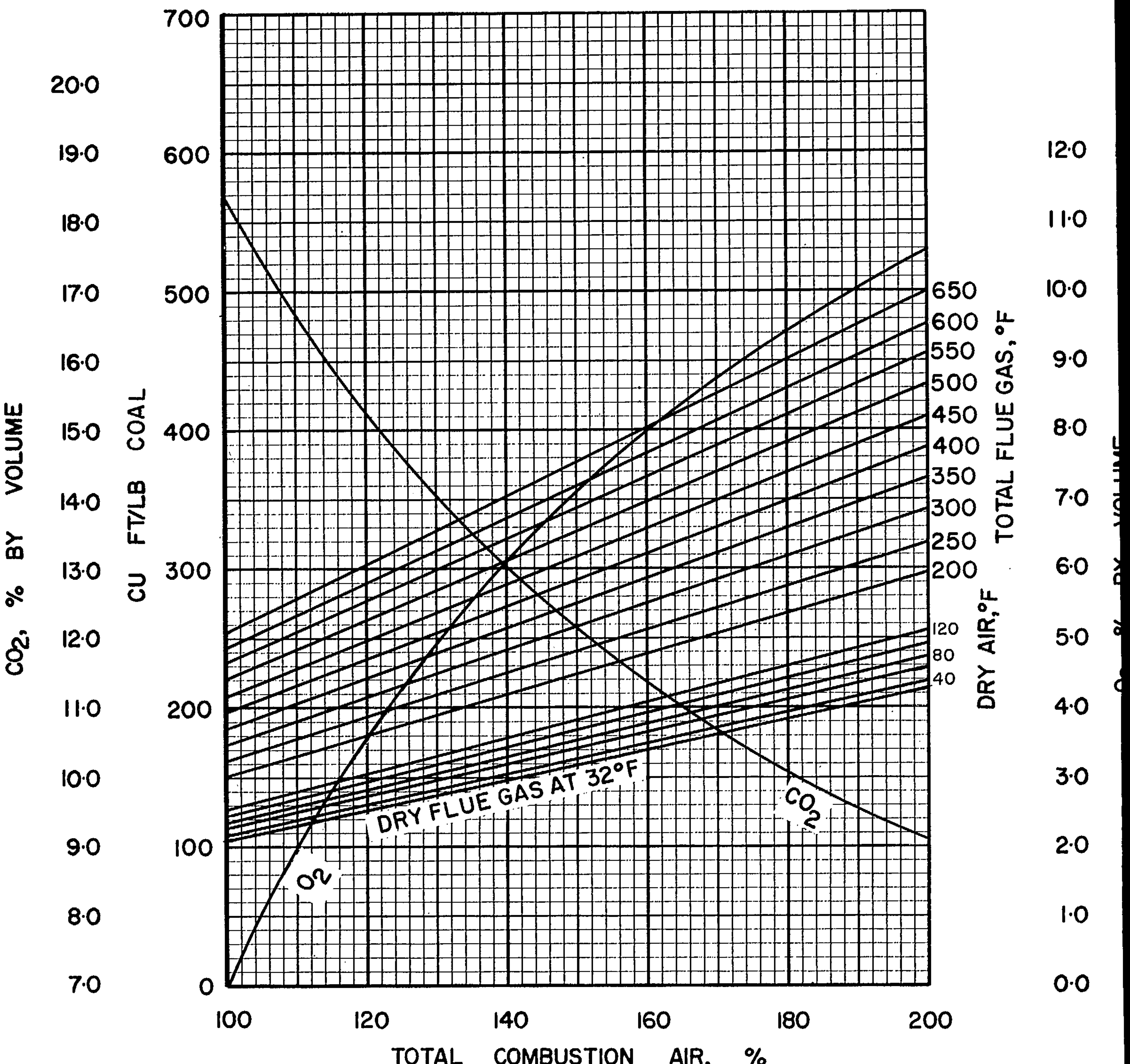


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS · 4 · 1

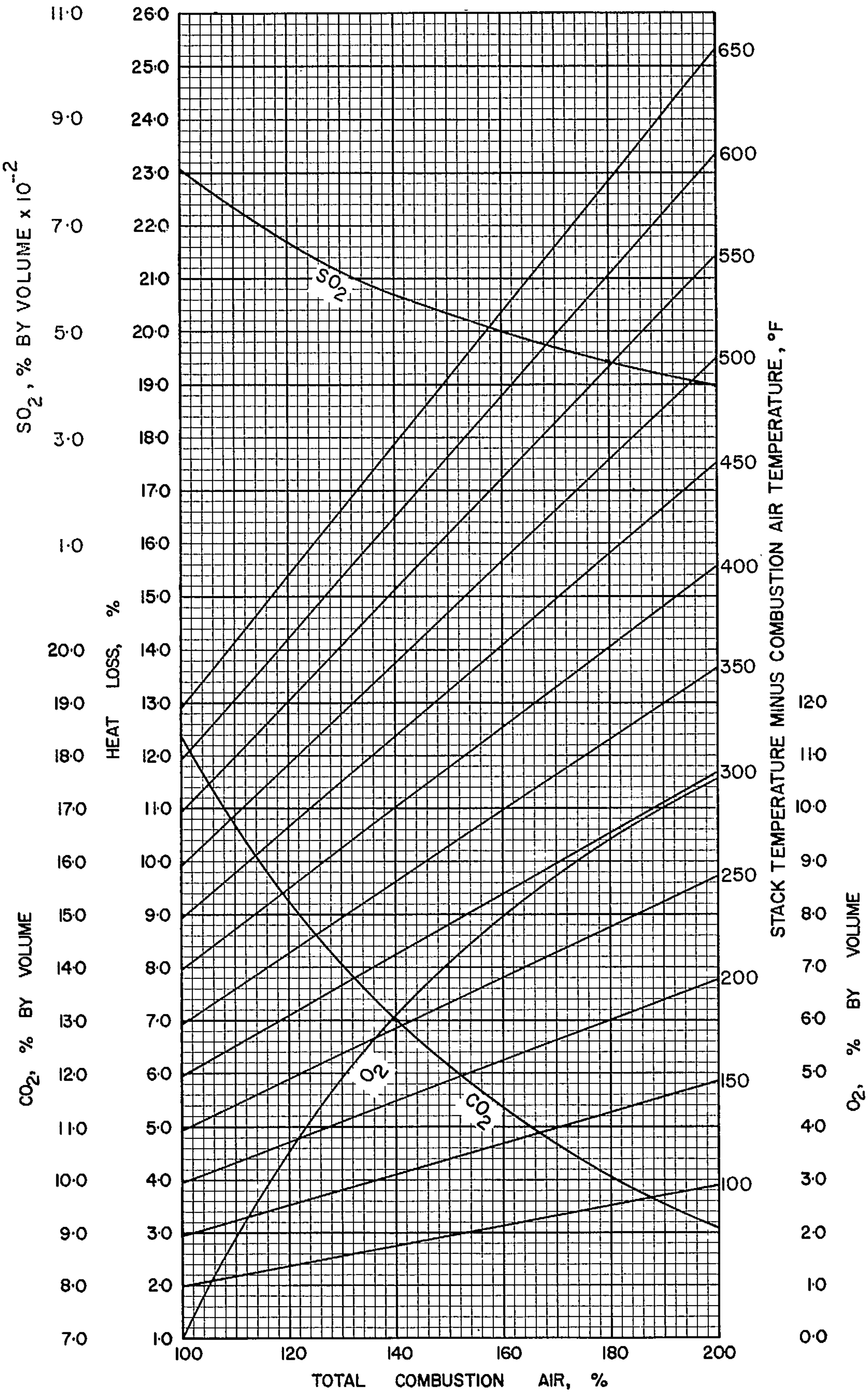


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·4·1

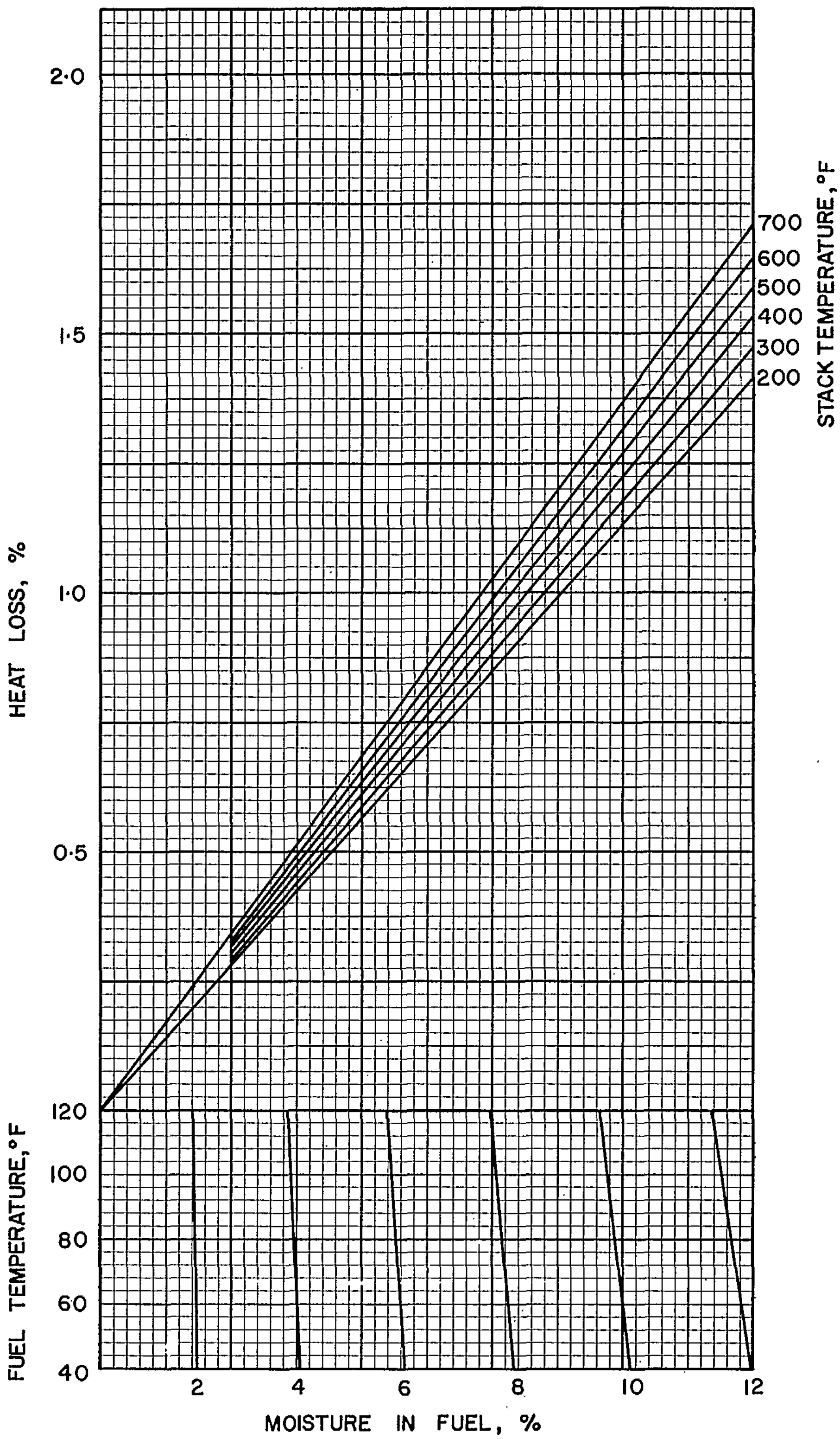


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·4·1

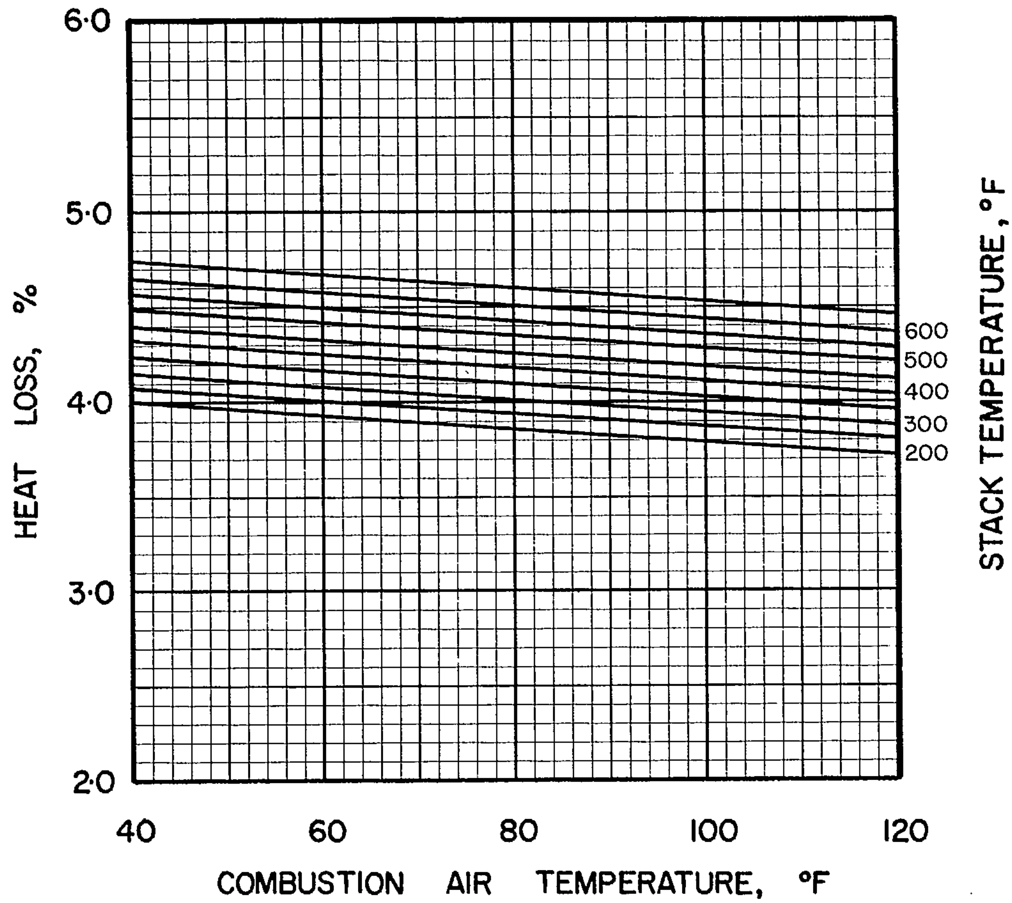


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·4·1

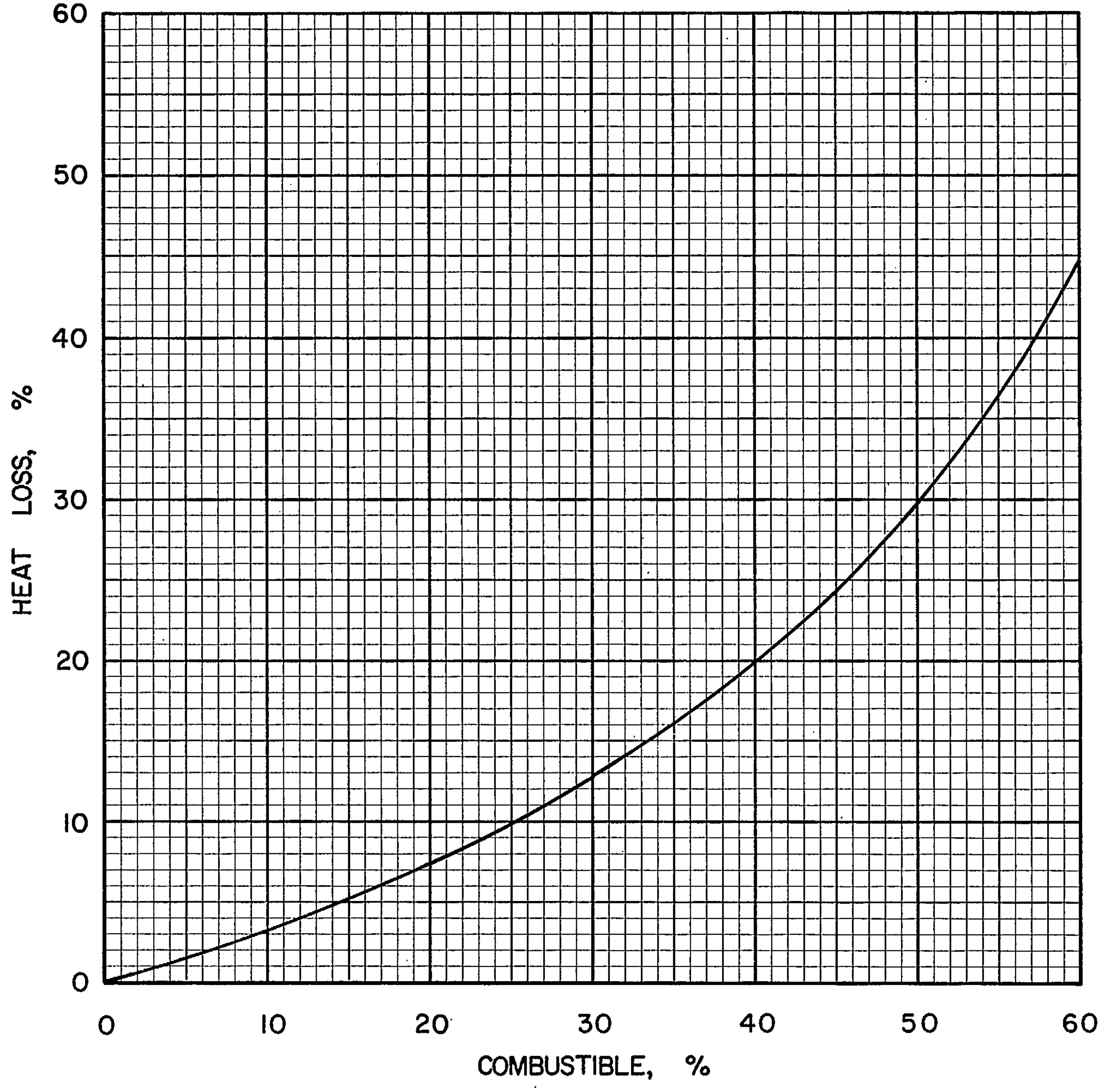


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·4·1

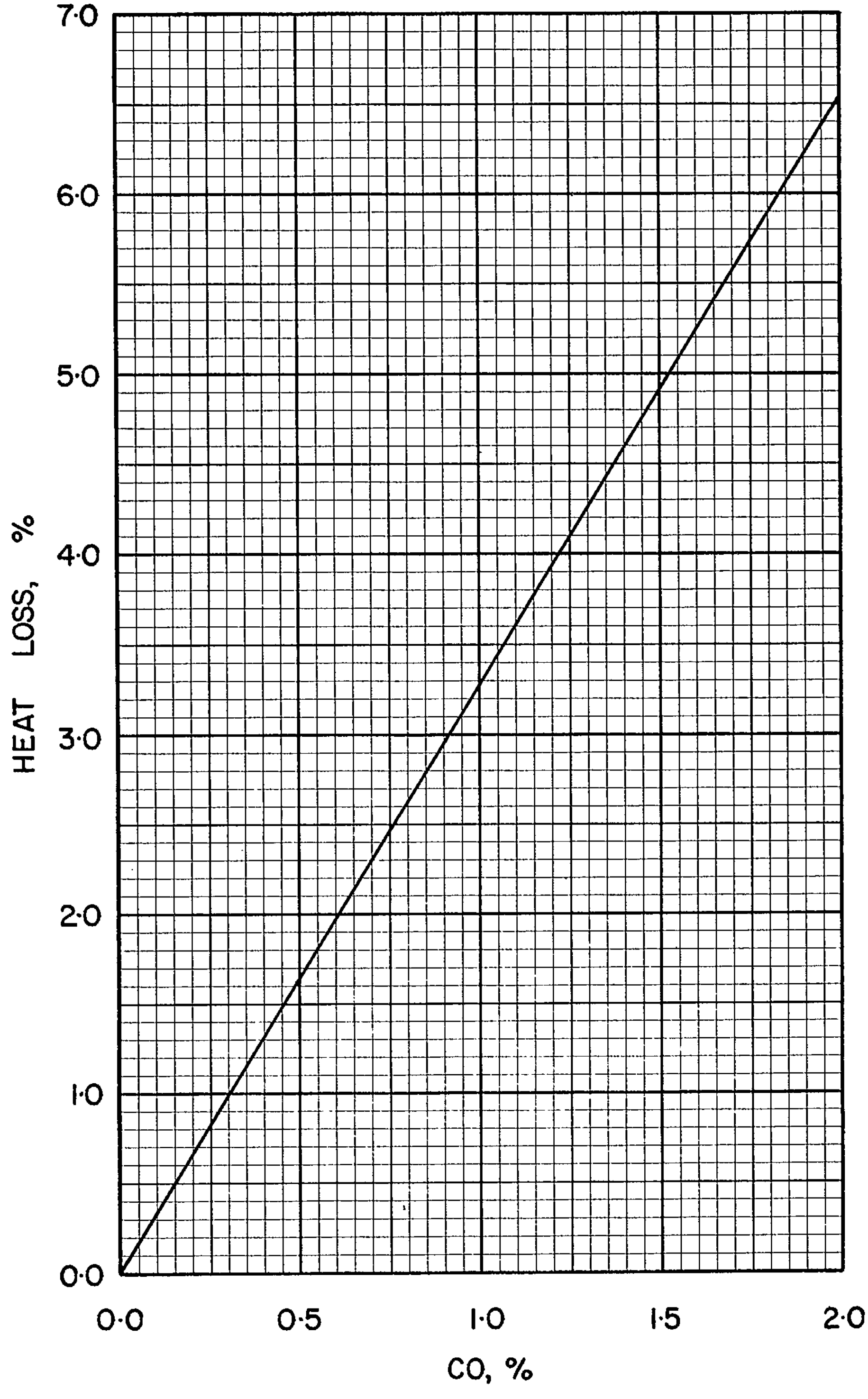


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS · 4 · 1

COAL NS 4-2, DRUMMOND NO. 2, PICTOU COUNTY, 3/4 in. x 0

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.2103
Volatile Matter	0.2457
Fixed Carbon	0.5440
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6577
Hydrogen (H)	0.0426
Sulphur (S)	0.0146
Nitrogen (N)	0.0161
Oxygen (O)	0.0587
Ash	0.2103
Total	1.0000

Gross Calorific Value

Btu/lb:	11173
Btu/short ton:	22.35×10^6
Btu/long ton:	25.03×10^6
MJ/kg:	25.98

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 89.50 lb
10^6 Btu = 0.04475 short tons
10^6 Btu = 0.03996 long tons

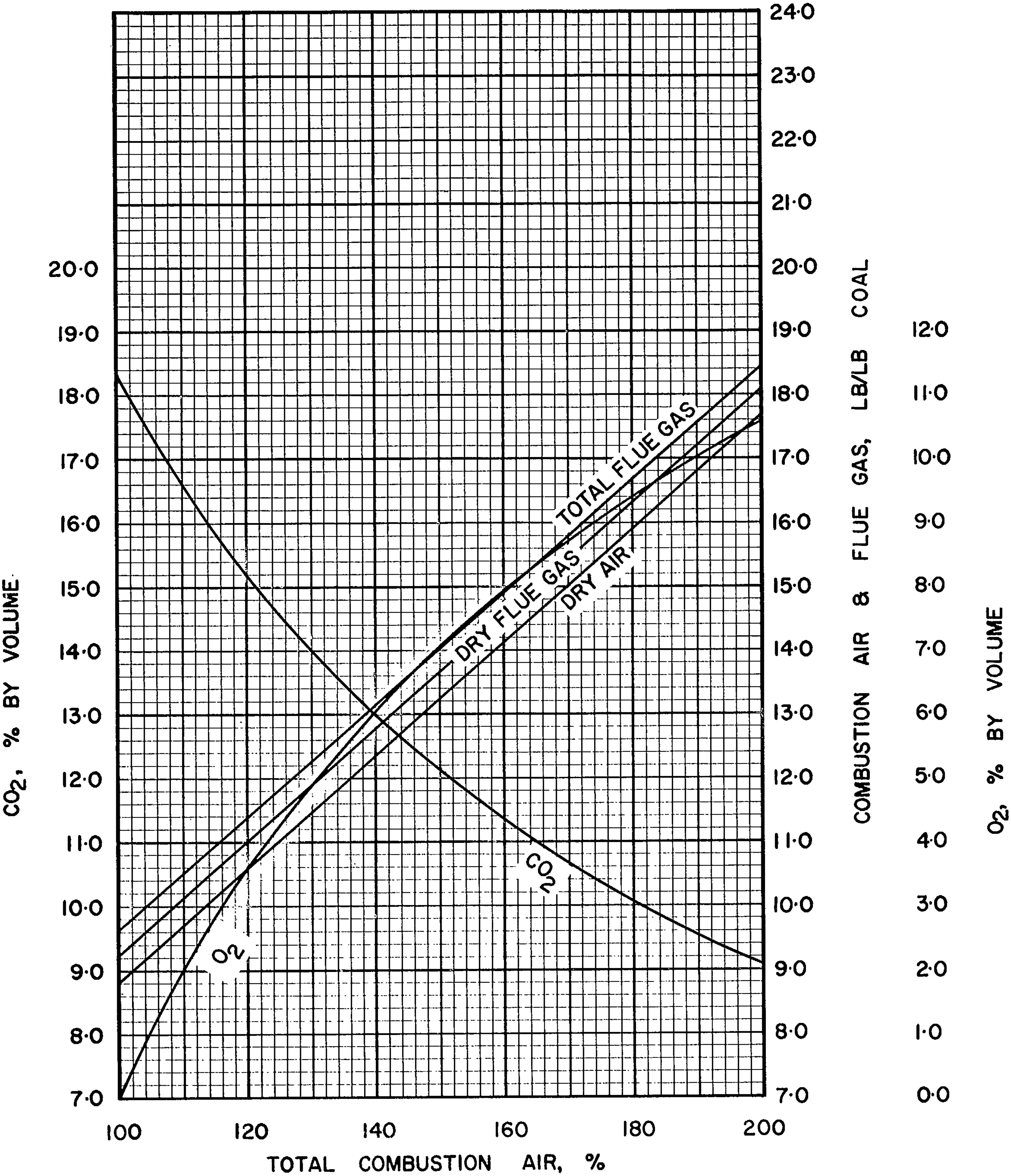


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·4·2

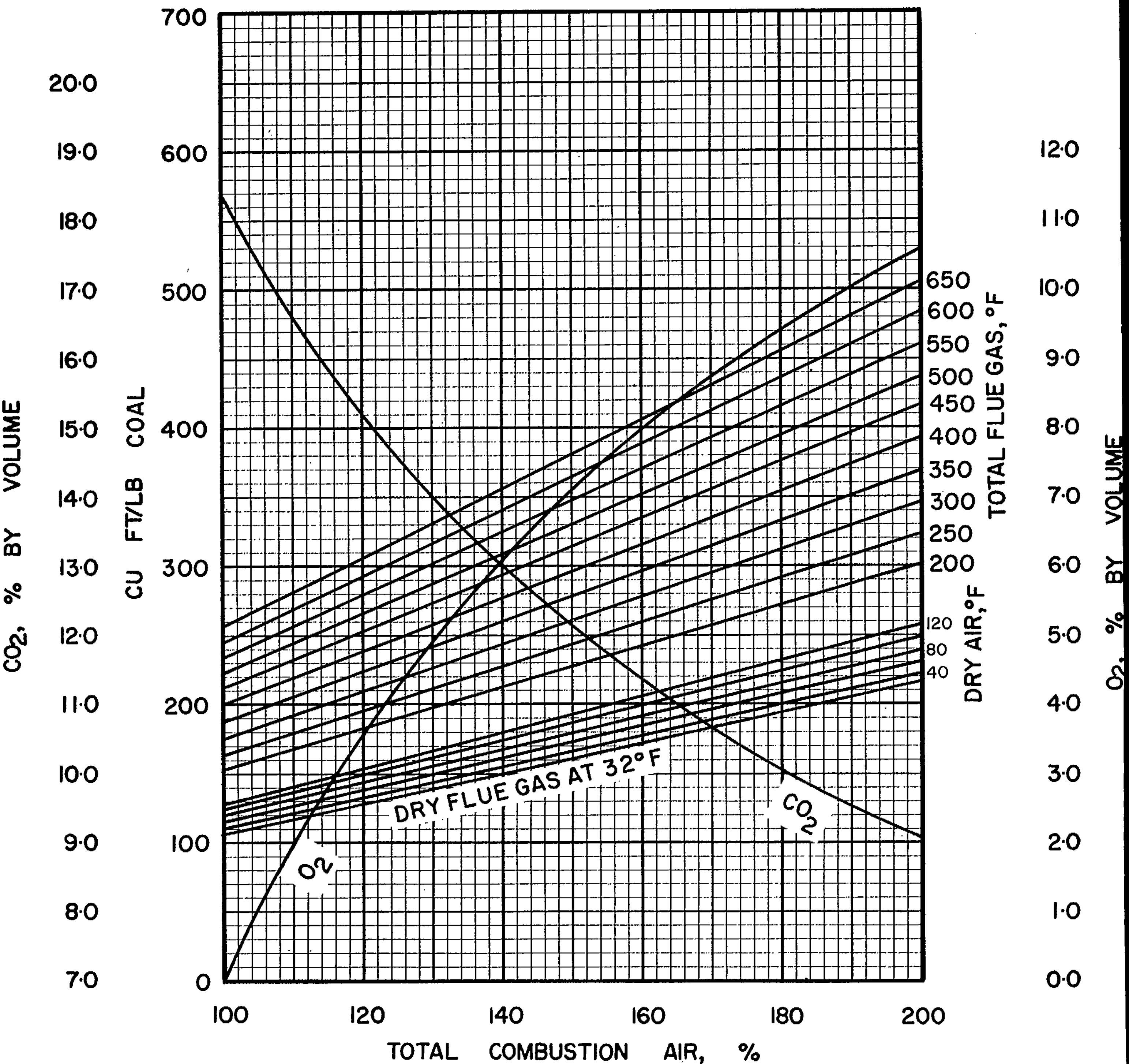


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NS·4·2

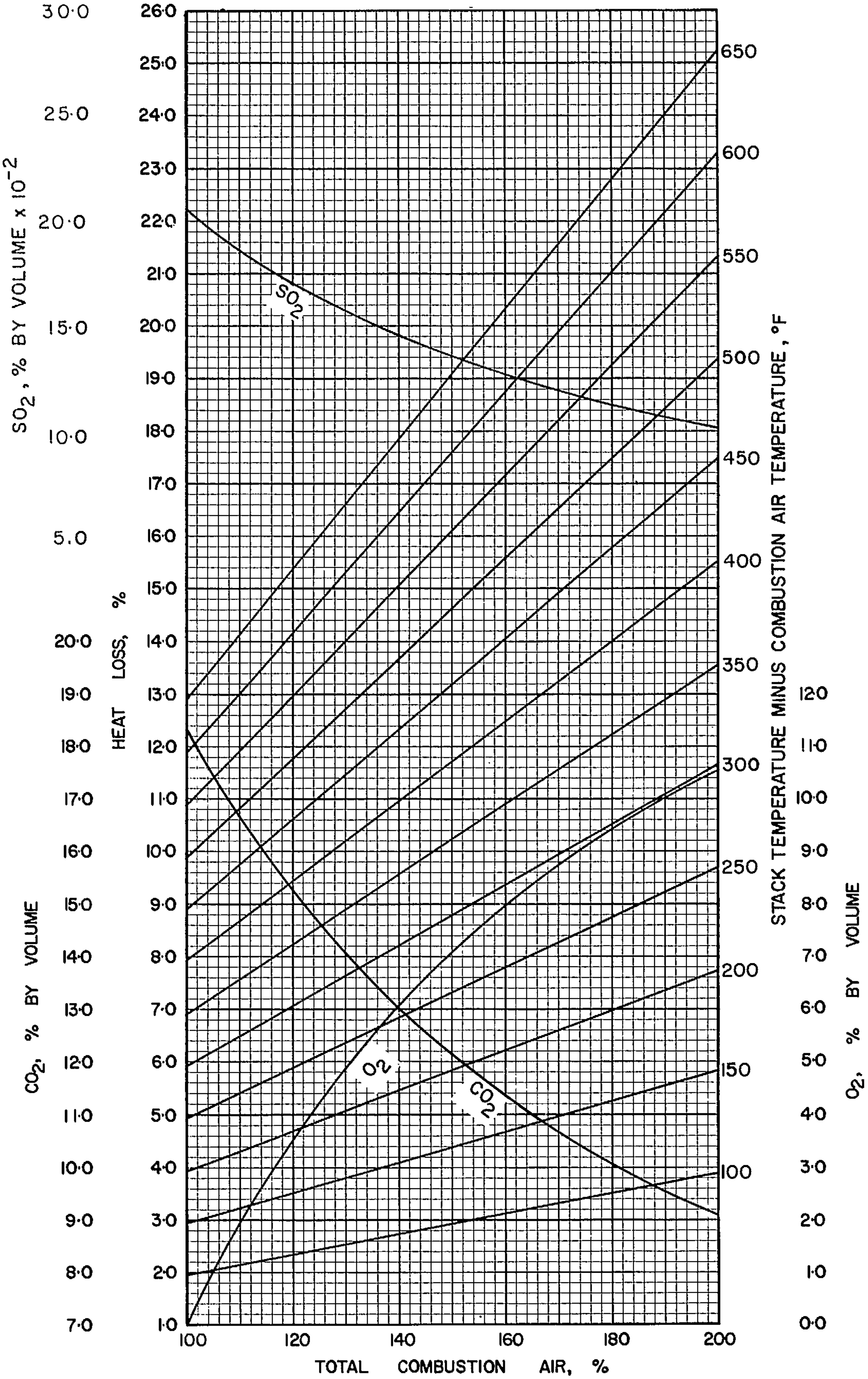


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·4·2

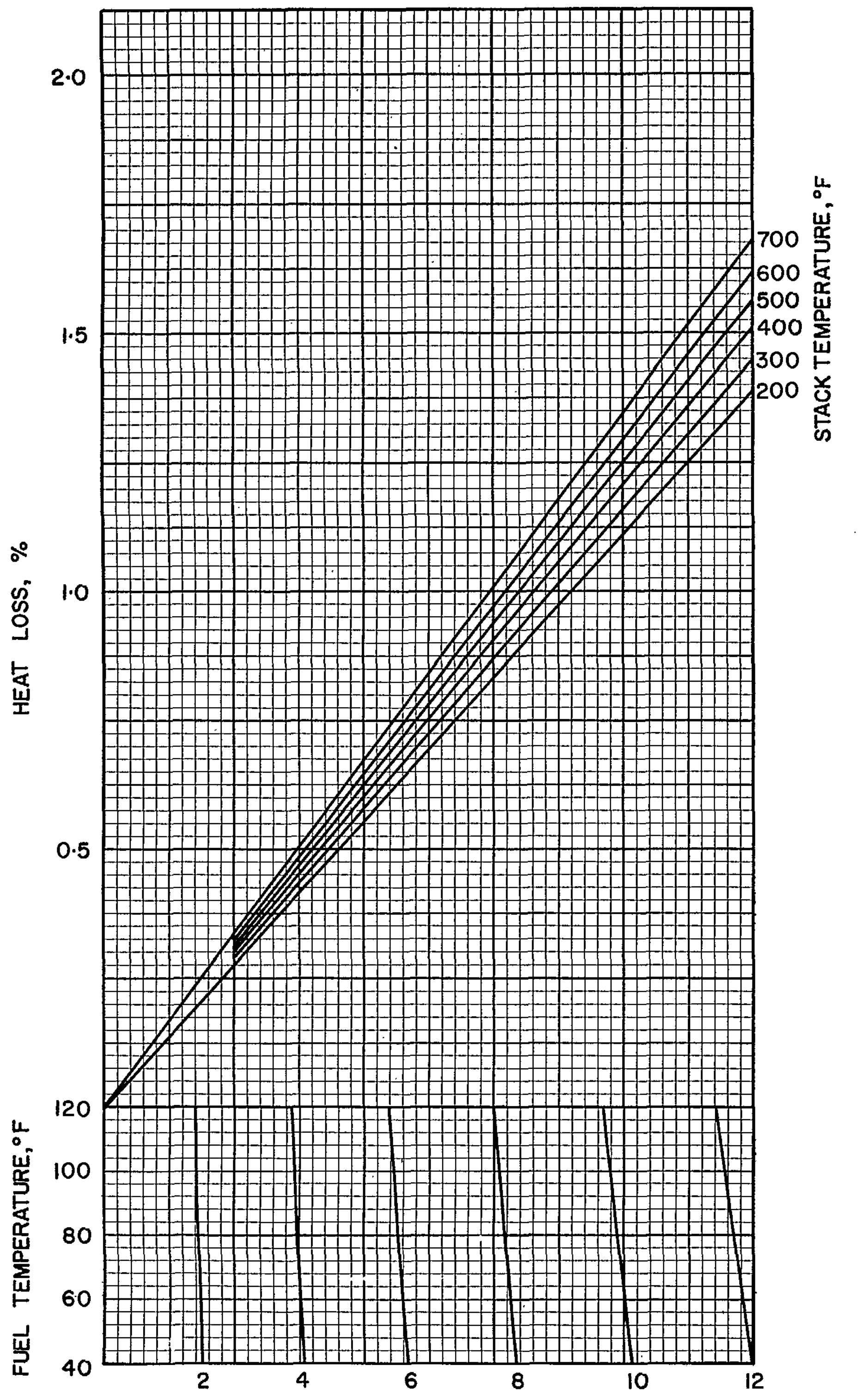


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·4·2

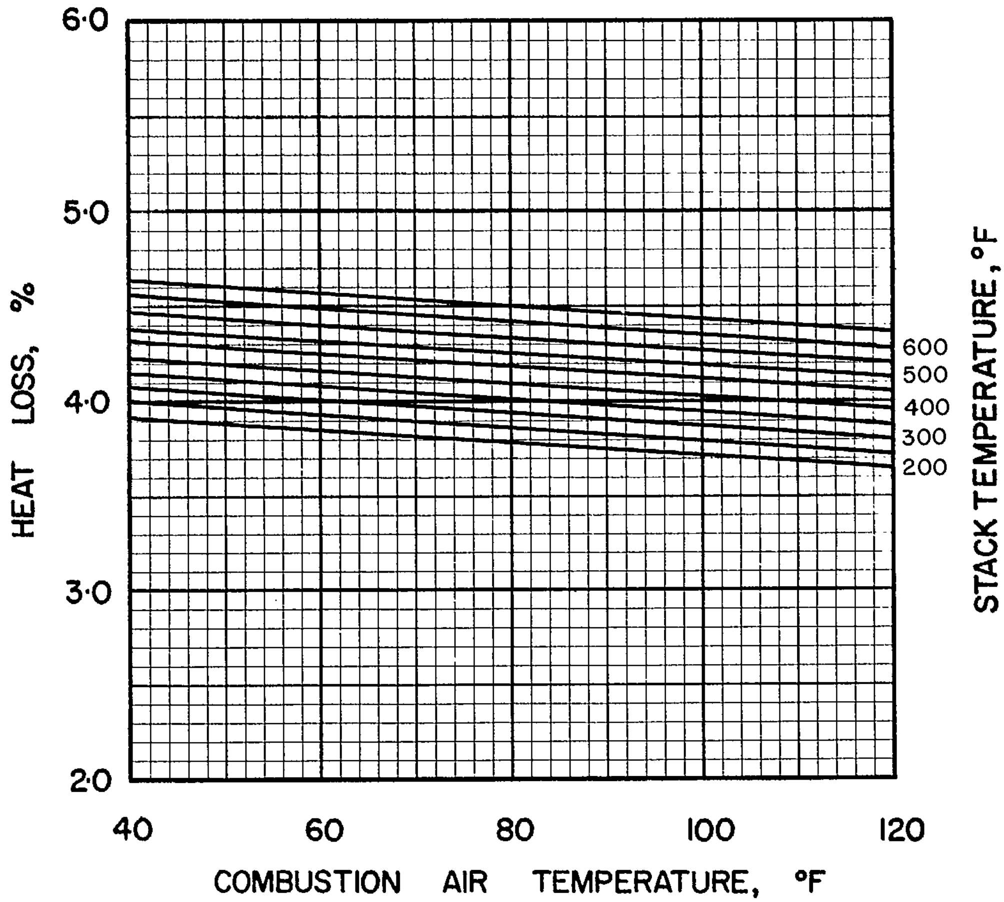


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·4·2

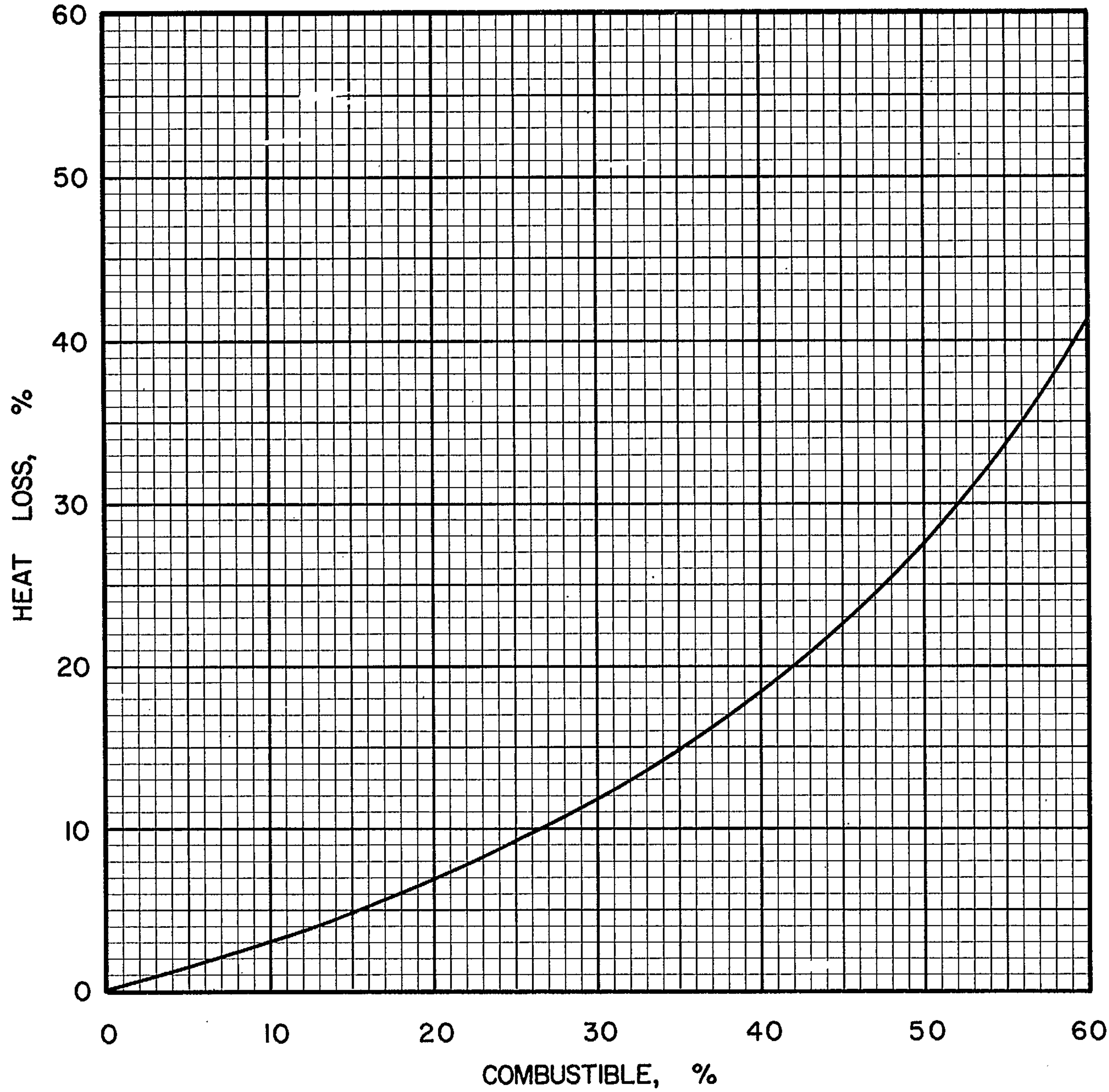


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·4·2

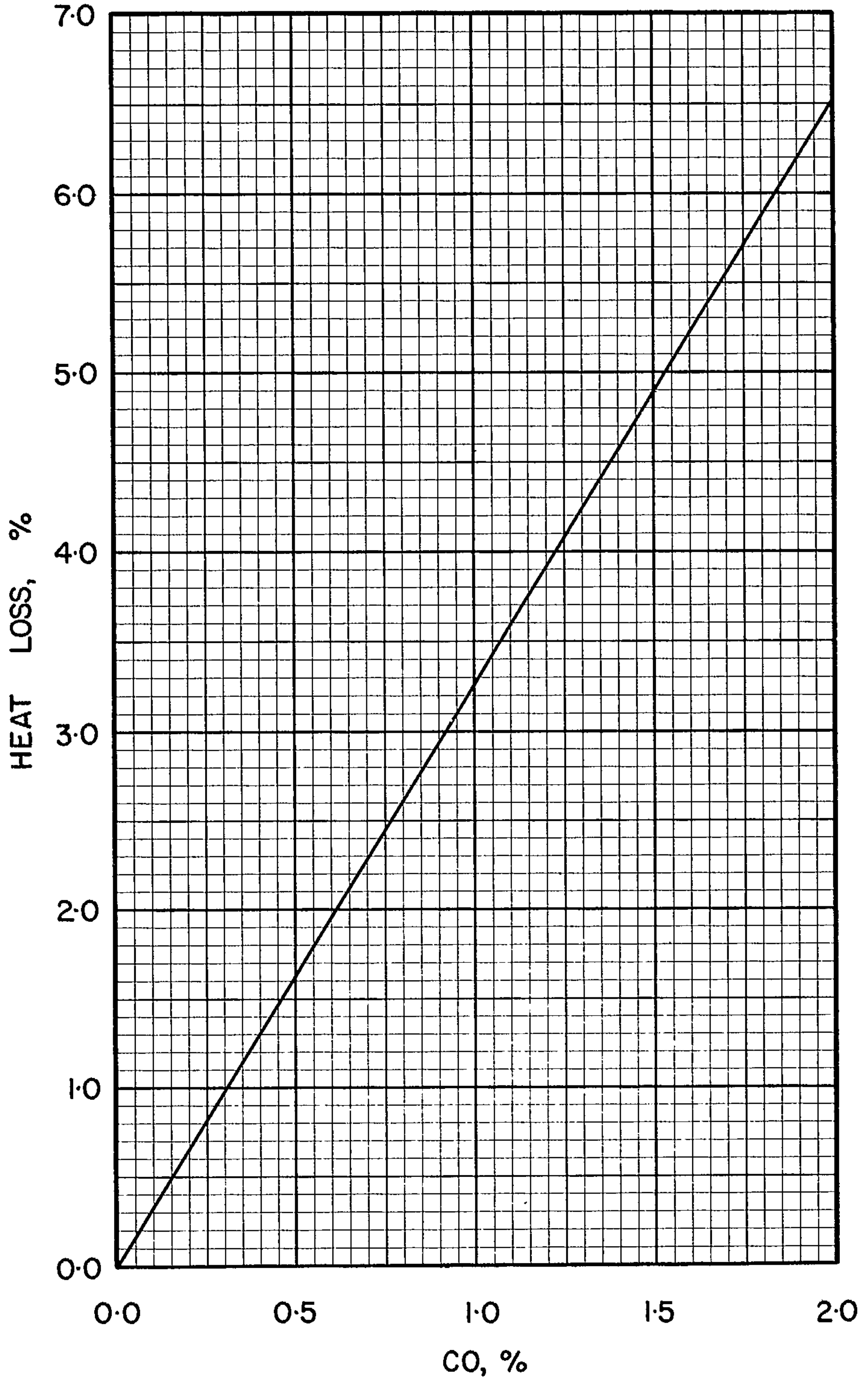


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·4·2

COAL NS 5-1, EVANS COAL MINES LTD., CAPE BRETON, 1 in. x 3/4 in.

Typical Moisture Range: 4–10%

Proximate Analysis (lb/lb dry coal)

Ash	0.0920
Volatile Matter	0.3768
Fixed Carbon	0.5312
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7190
Hydrogen (H)	0.0459
Sulphur (S)	0.0649
Nitrogen (N)	0.0123
Oxygen (O)	0.0659
Ash	0.0920
Total	1.0000

Gross Calorific Value

Btu/lb:	12910
Btu/short ton:	25.82×10^6
Btu/long ton:	28.92×10^6
MJ/kg:	30.02

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 77.46	lb	
10^6 Btu	= 0.03873	short tons	
10^6 Btu	= 0.03458	long tons	

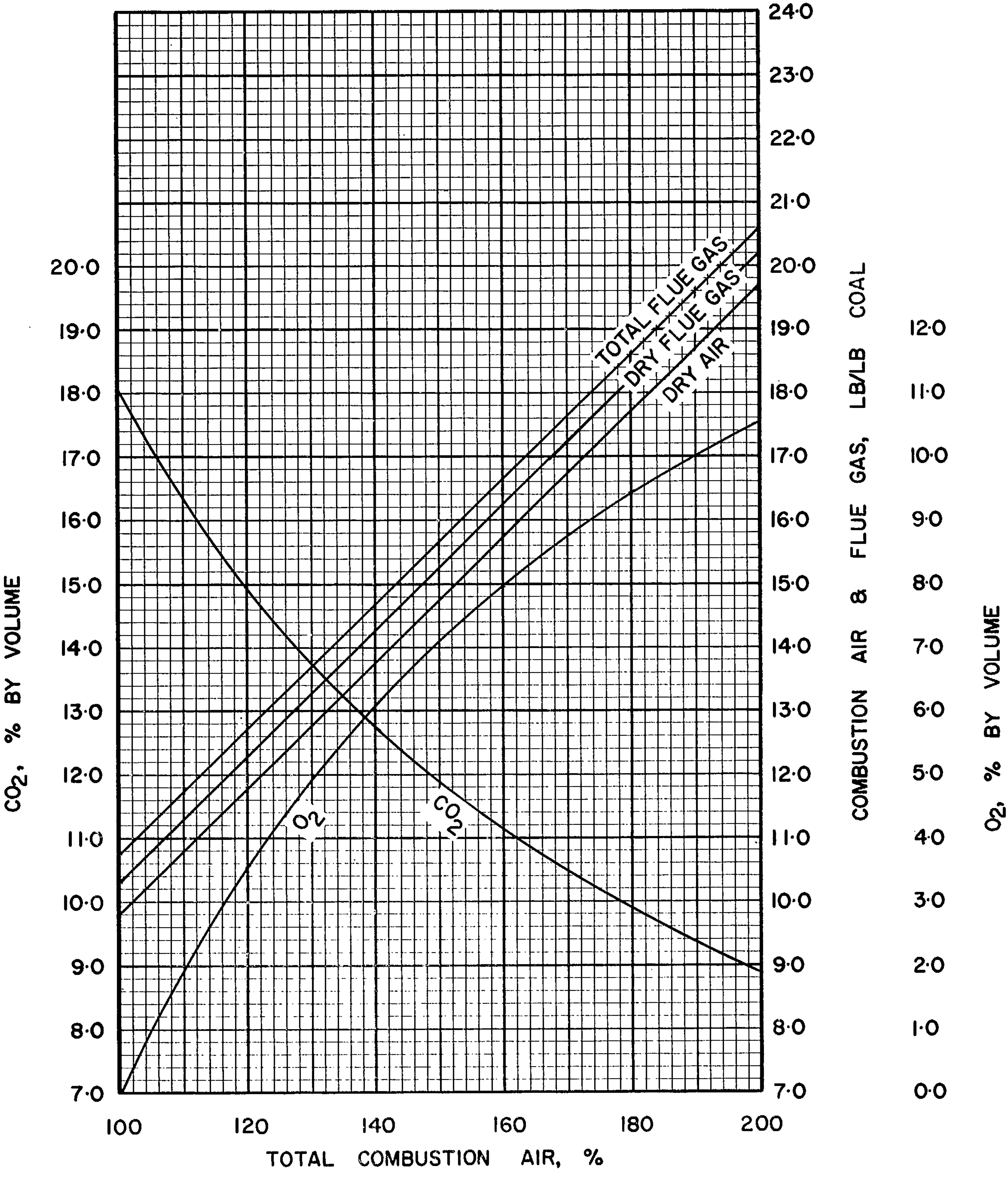


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·5·1

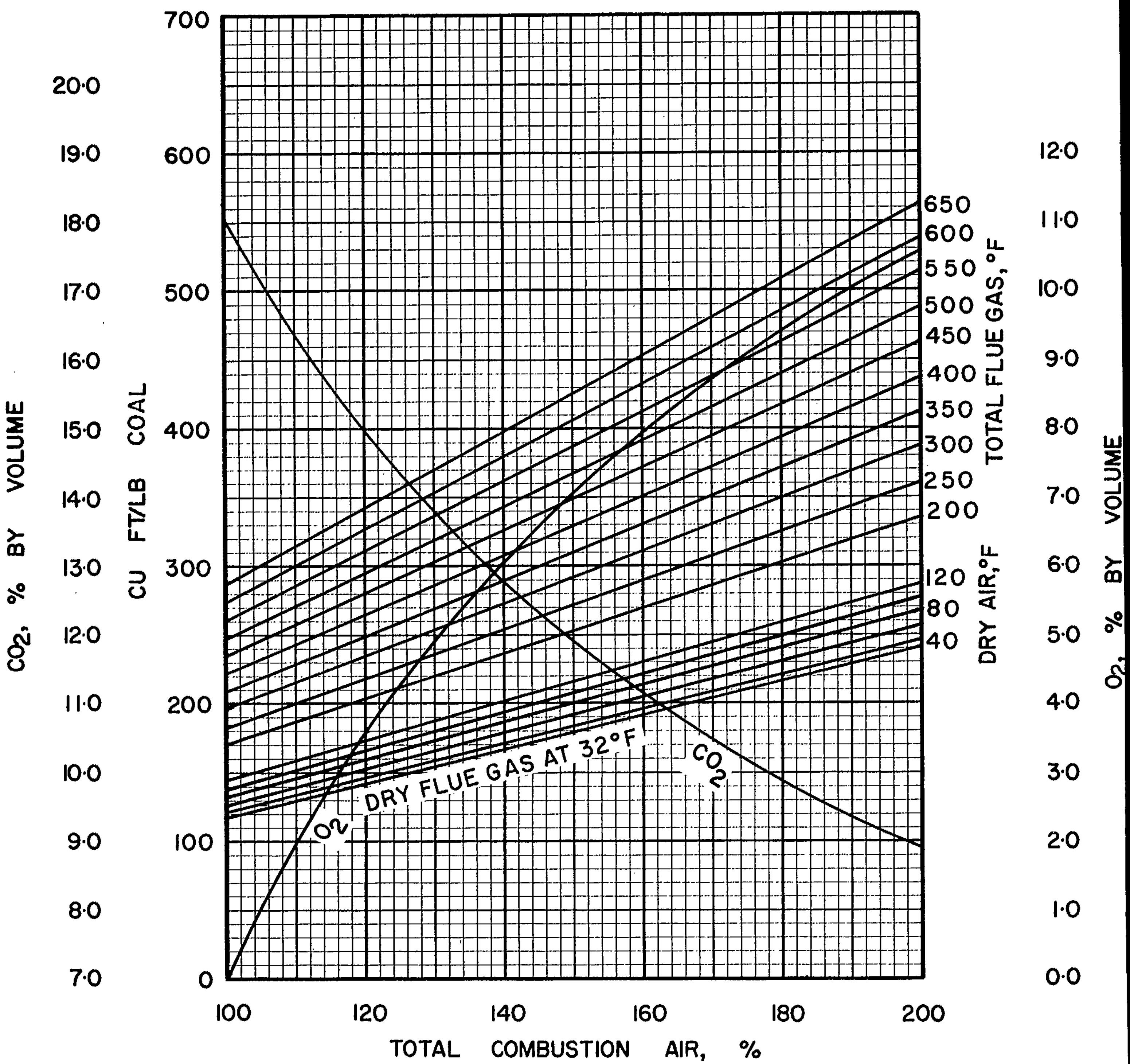


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·5·1

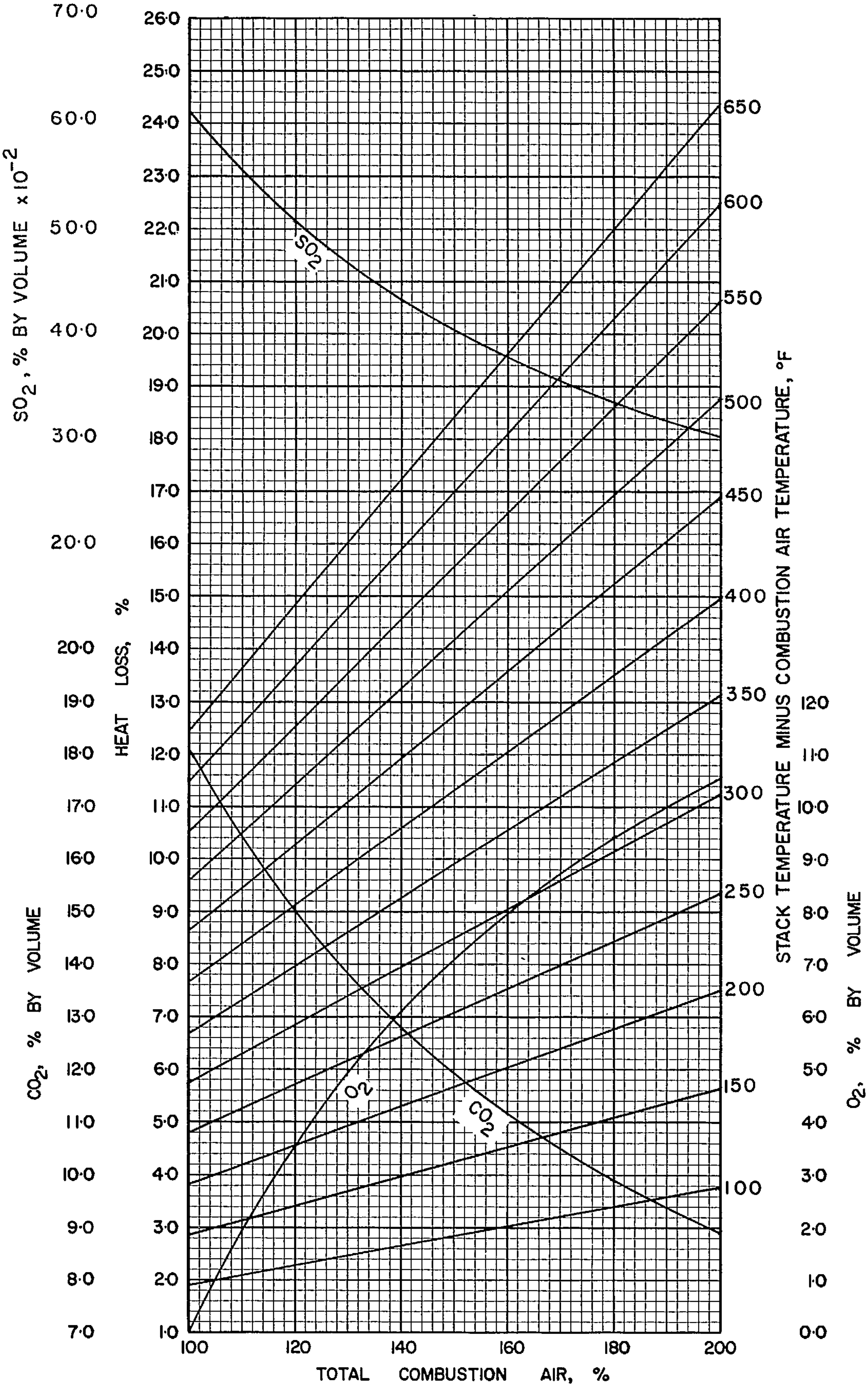


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·5·1

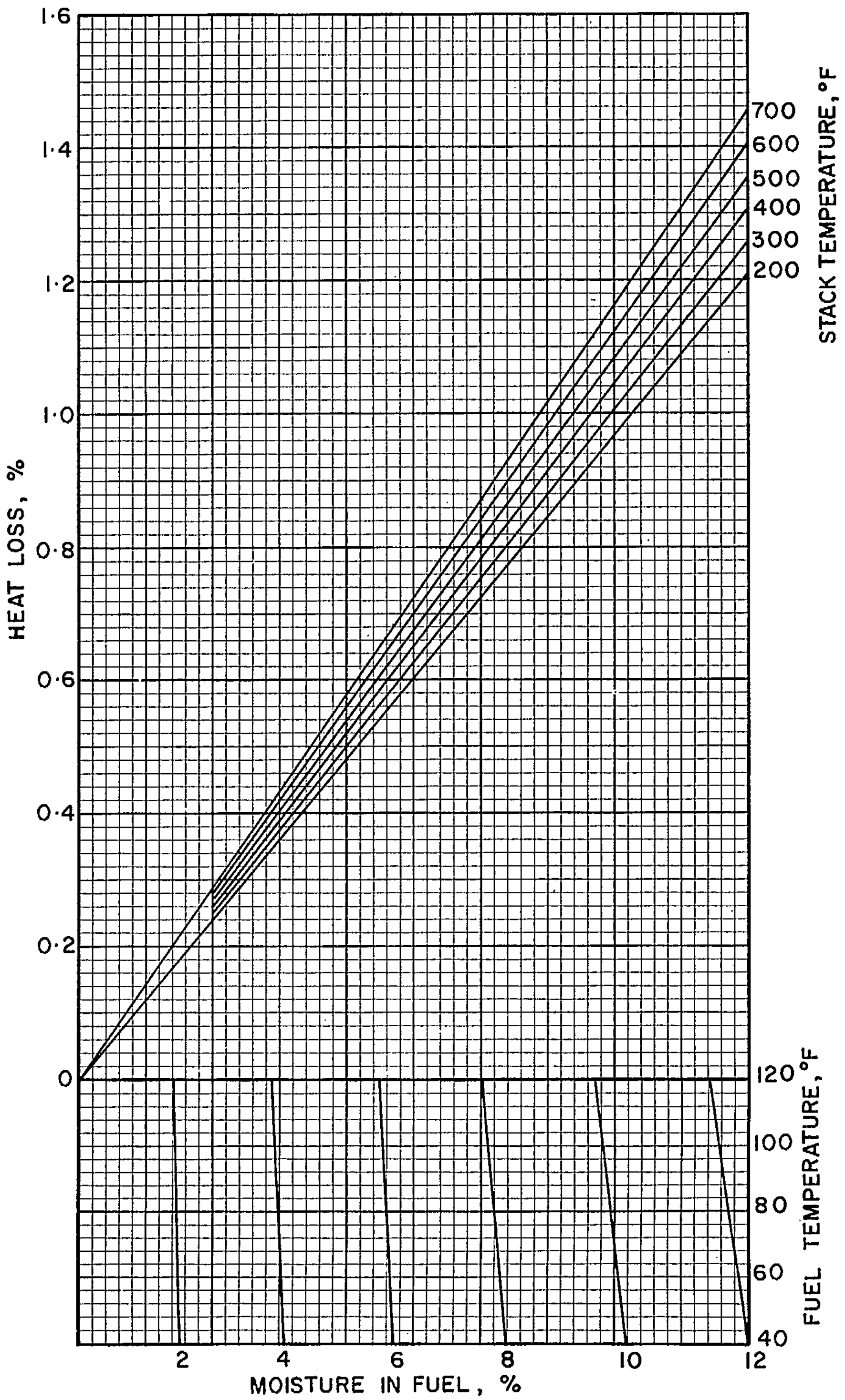


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·5·1

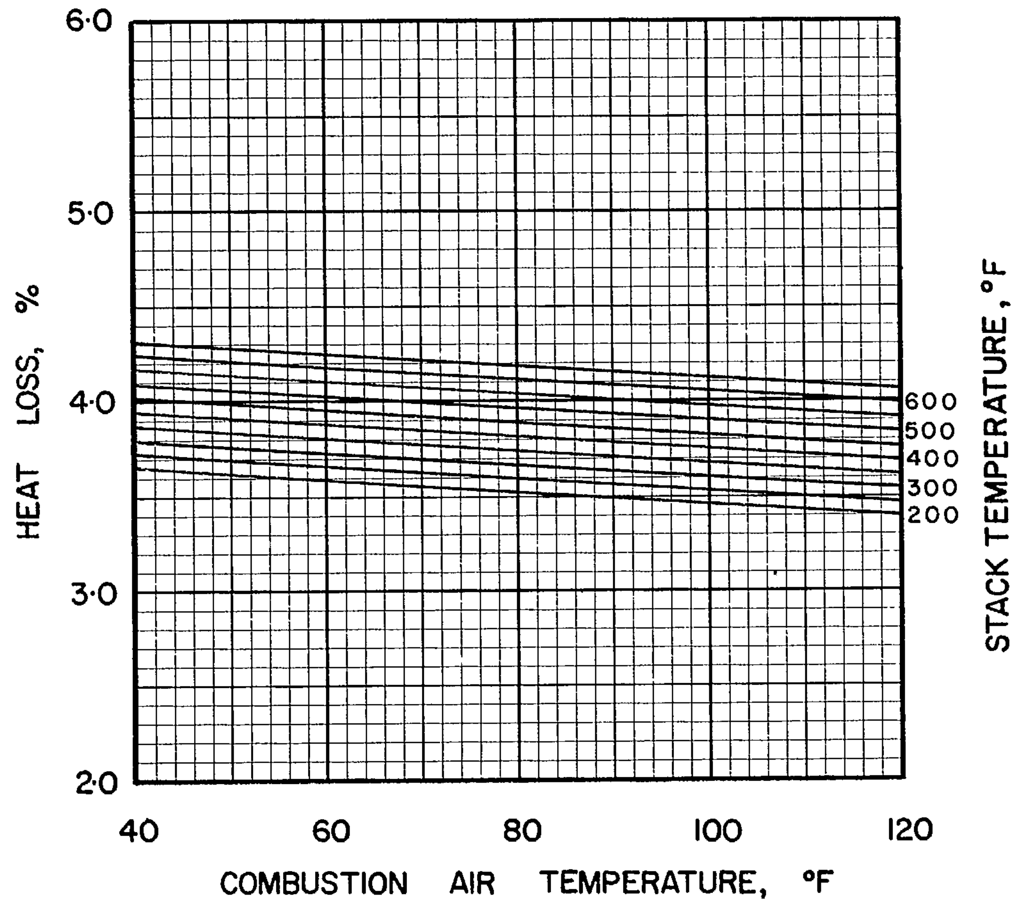


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·5·1

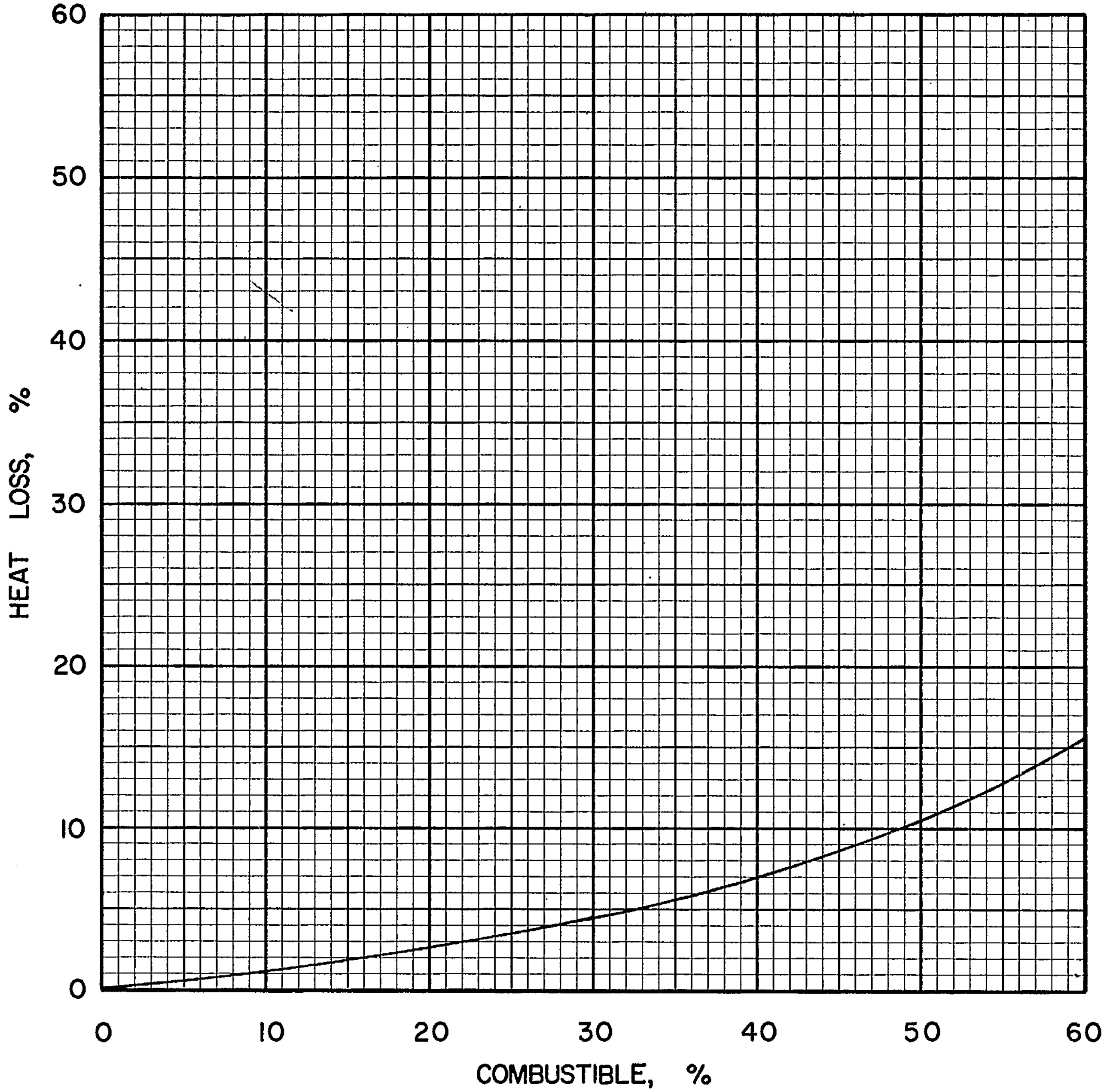


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS-5-1

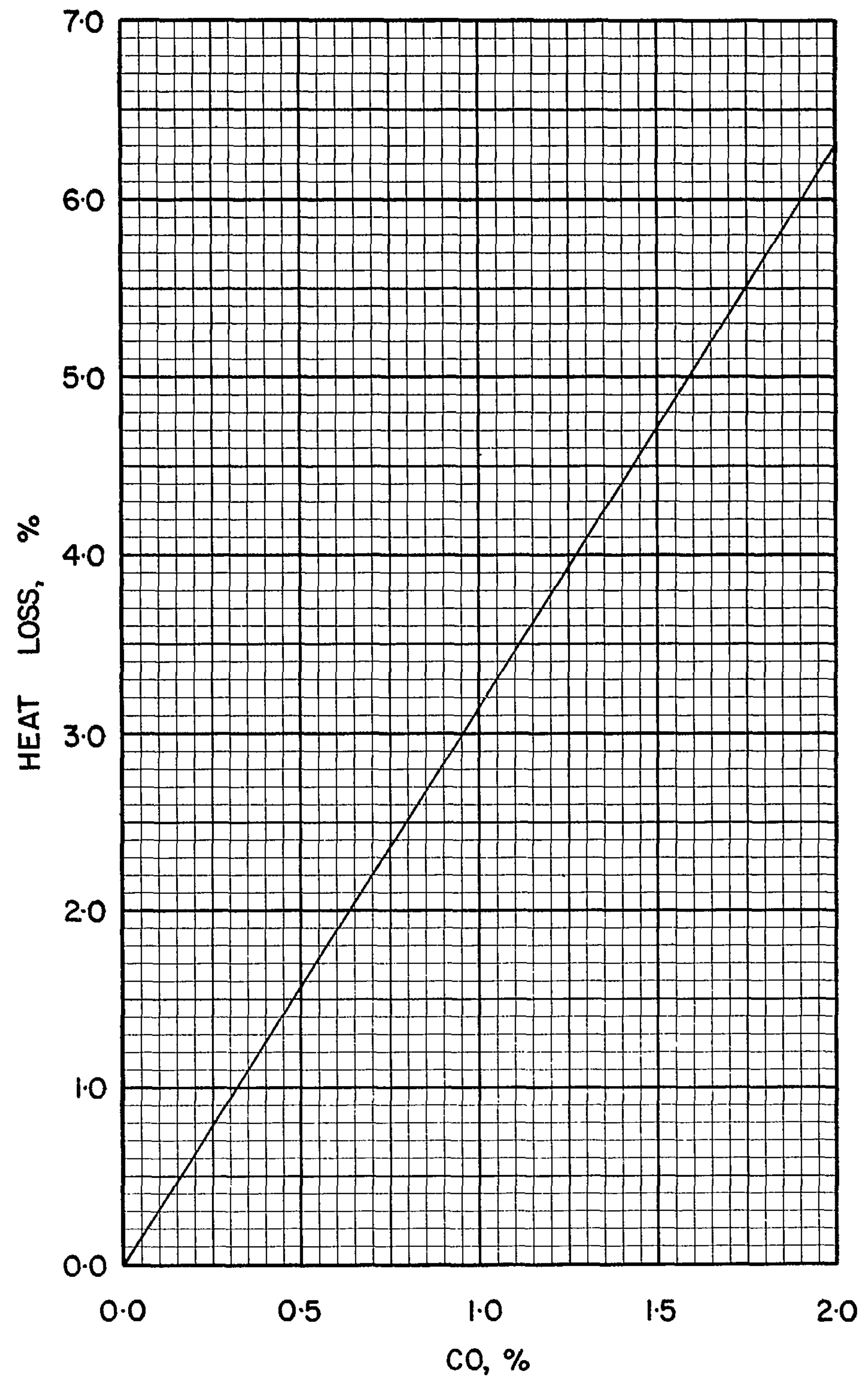


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·5·1

COAL NS 5-2, EVANS COAL MINES LTD., CAPE BRETON, 3/4 in. x 1/2 in.

Typical Moisture Range: 4–10%

Proximate Analysis (lb/lb dry coal)

Ash	0.0900
Volatile Matter	0.3787
Fixed Carbon	0.5313
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7148
Hydrogen (H)	0.0464
Sulphur (S)	0.0673
Nitrogen (N)	0.0136
Oxygen (O)	0.0679
Ash	0.0900
Total	1.0000

Gross Calorific Value

Btu/lb:	12900
Btu/short ton:	25.80×10^6
Btu/long ton:	23.04×10^6
MJ/kg:	30.00

Conversion Factors

1 short ton	=	0.8929	long tons	=	2000 lb
10^6 Btu	=	77.52	lb		
10^6 Btu	=	0.03876	short tons		
10^6 Btu	=	0.03461	long tons		

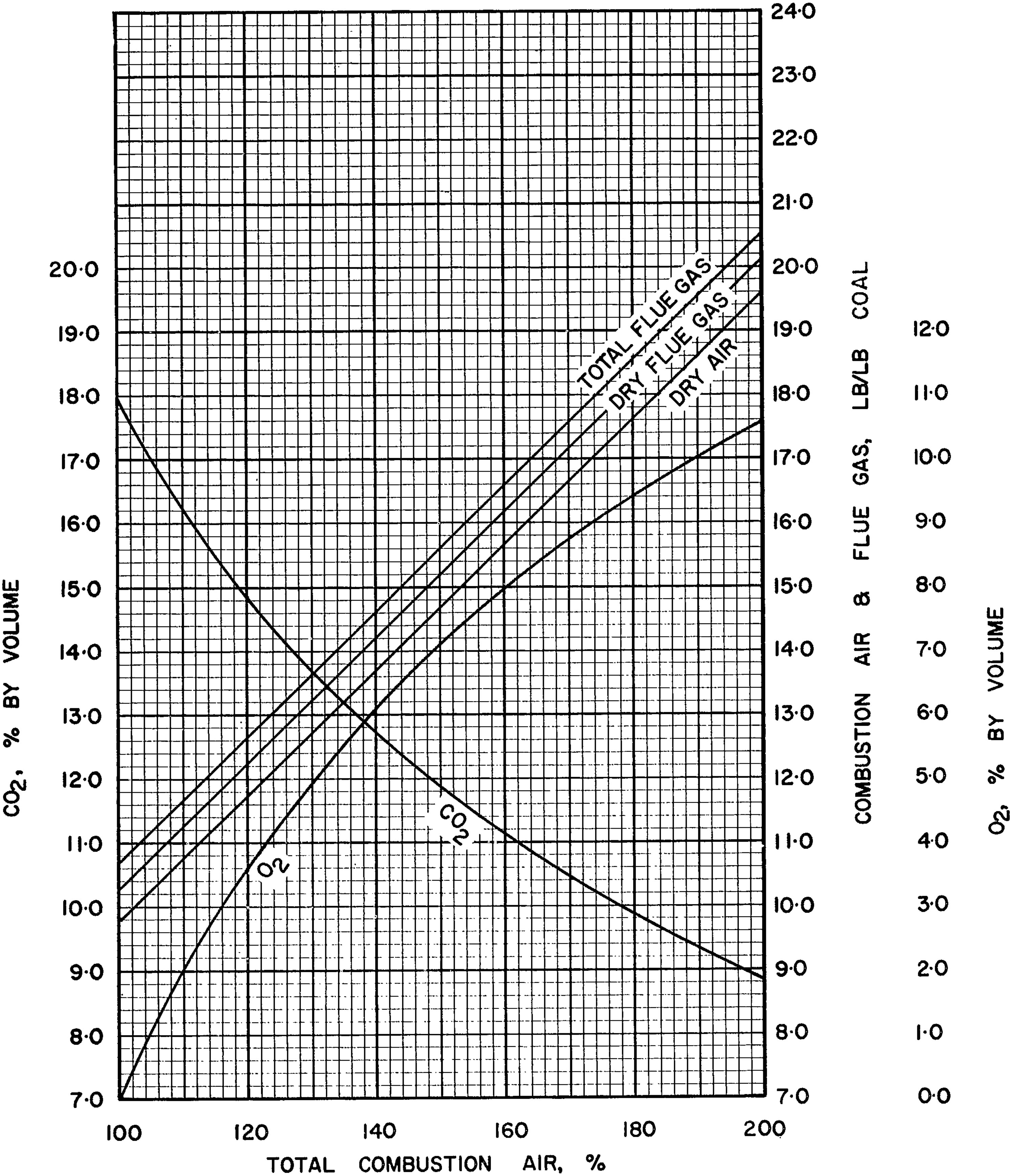


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·5·2

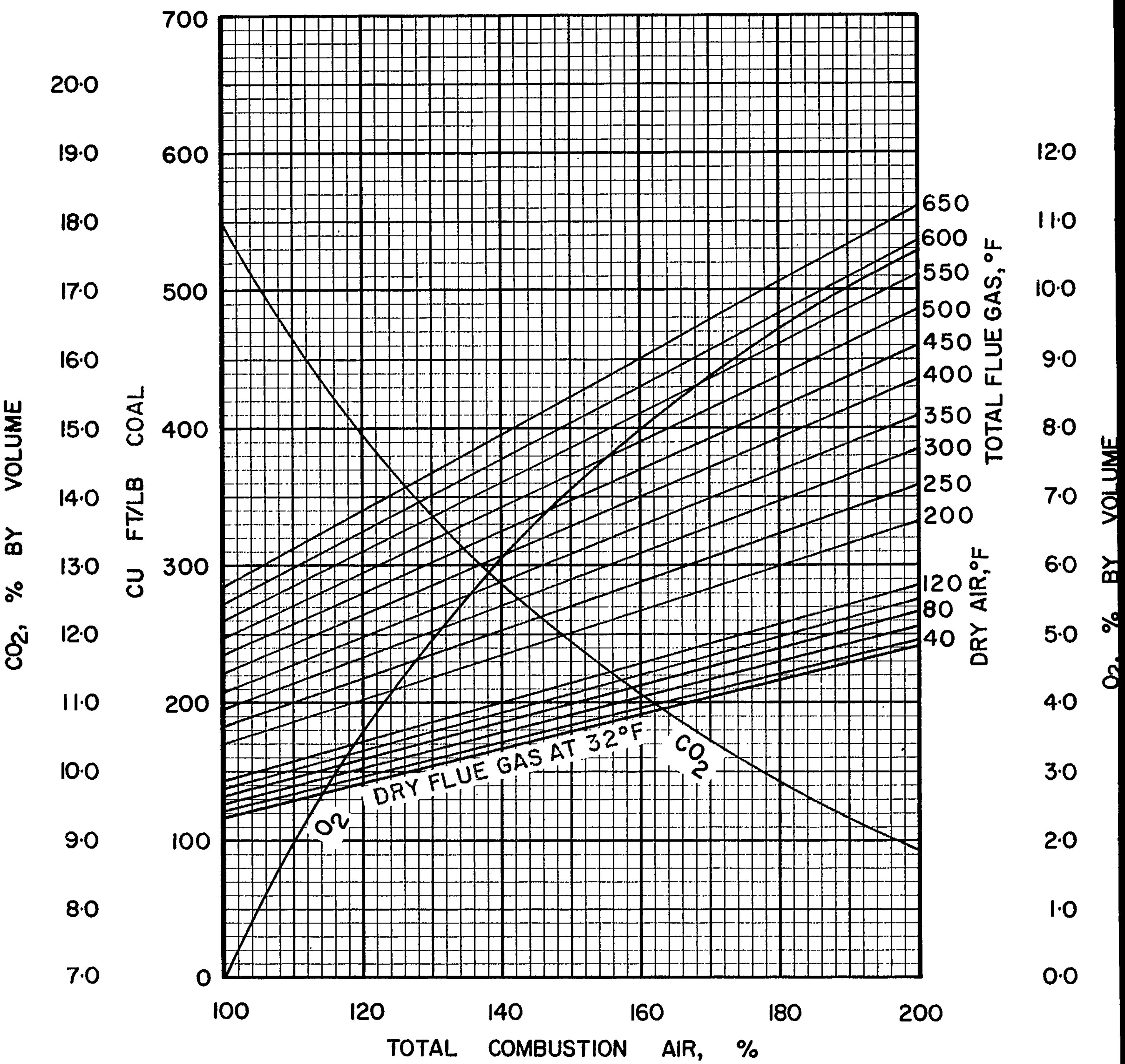


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NS· 5· 2

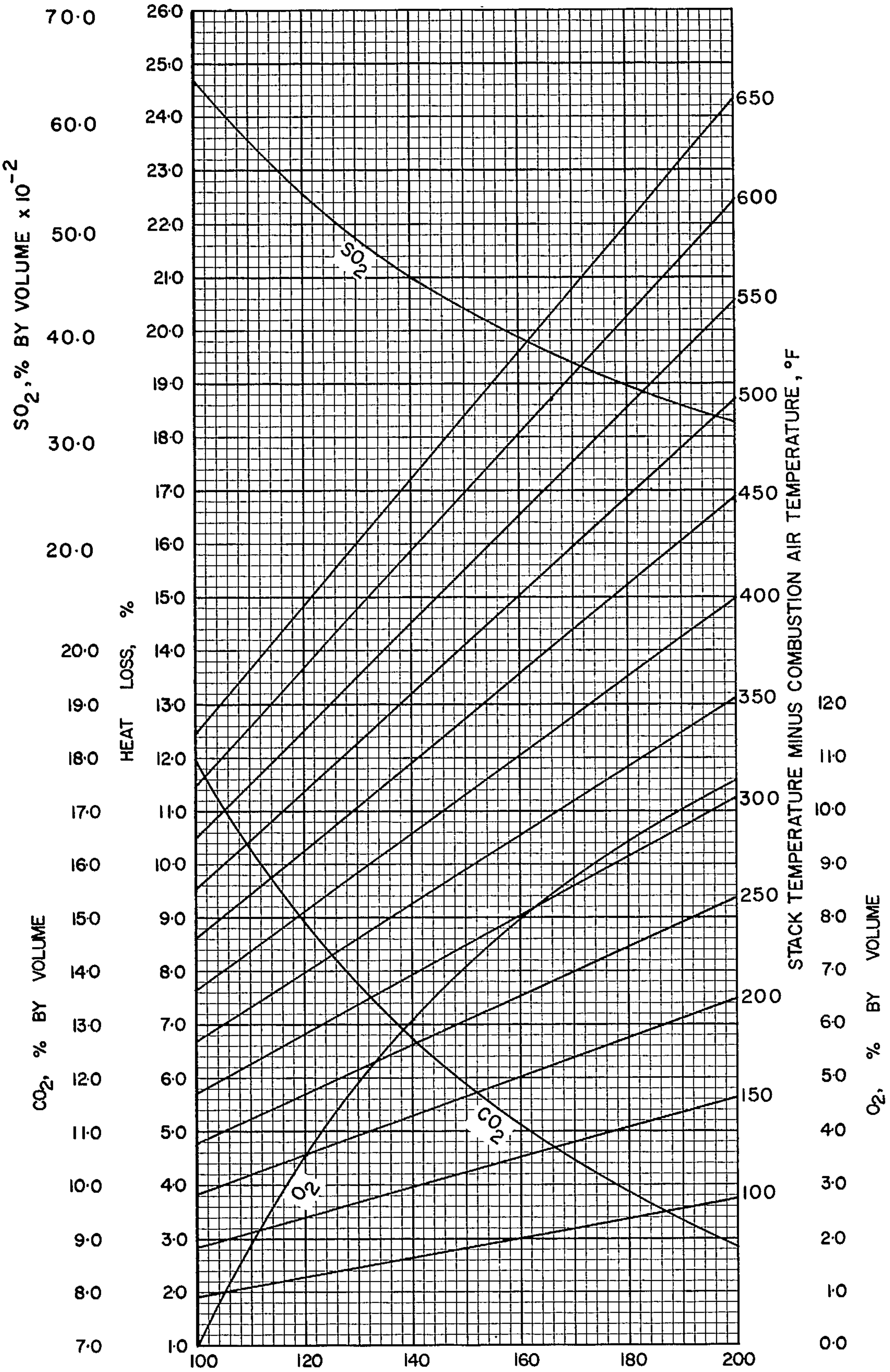


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS· 5·2

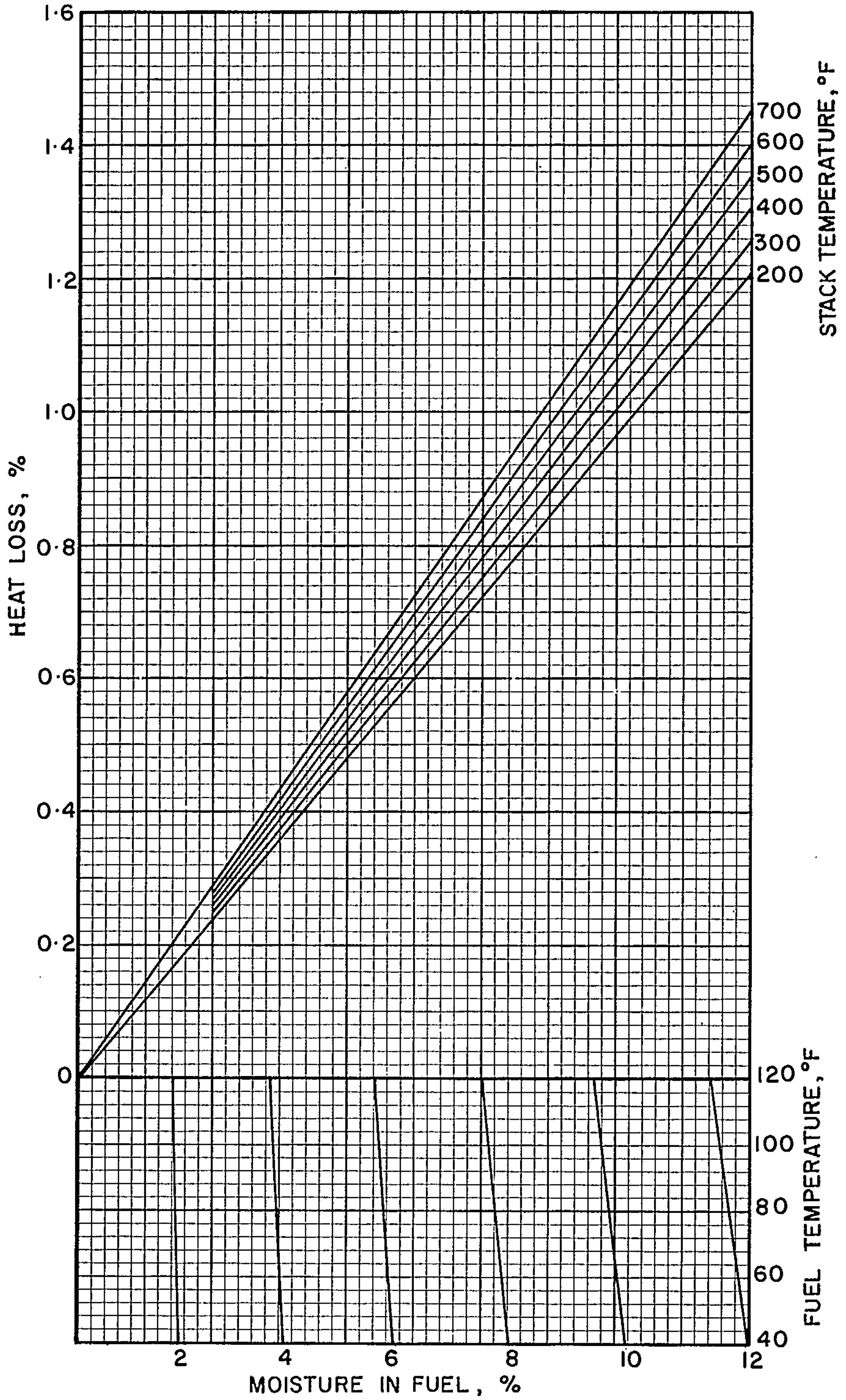


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS· 5·2

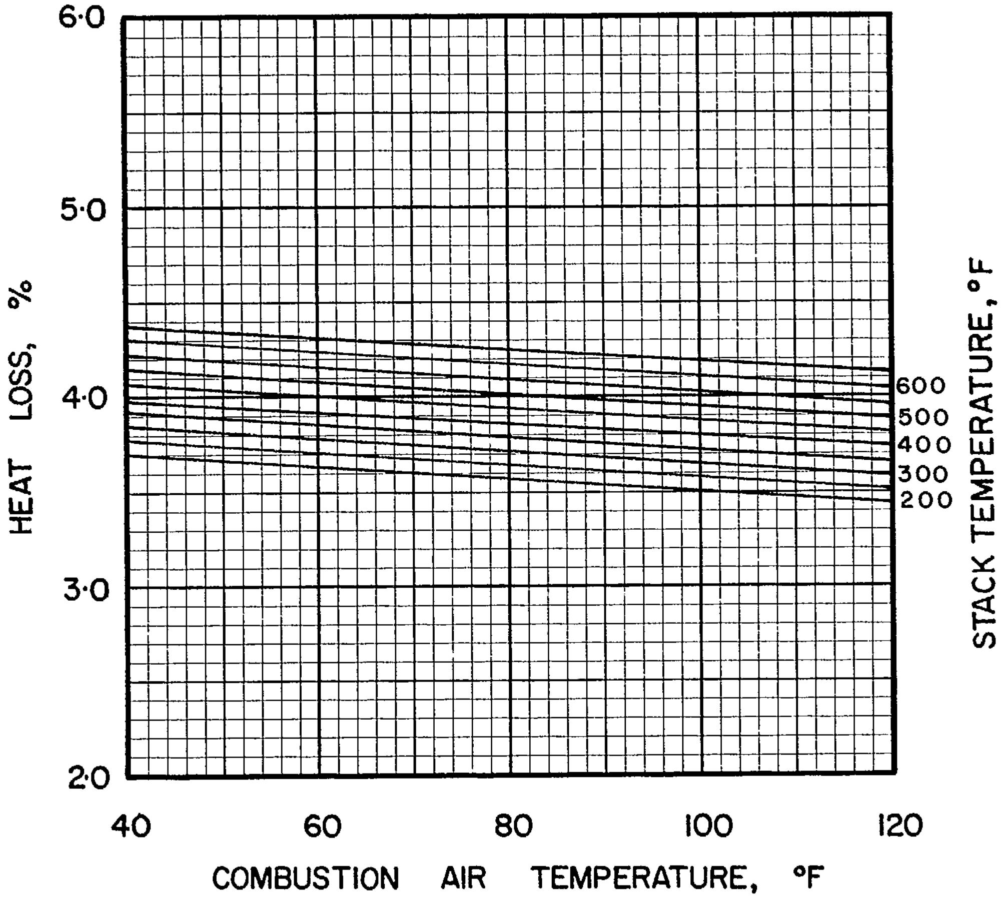


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS · 5·2

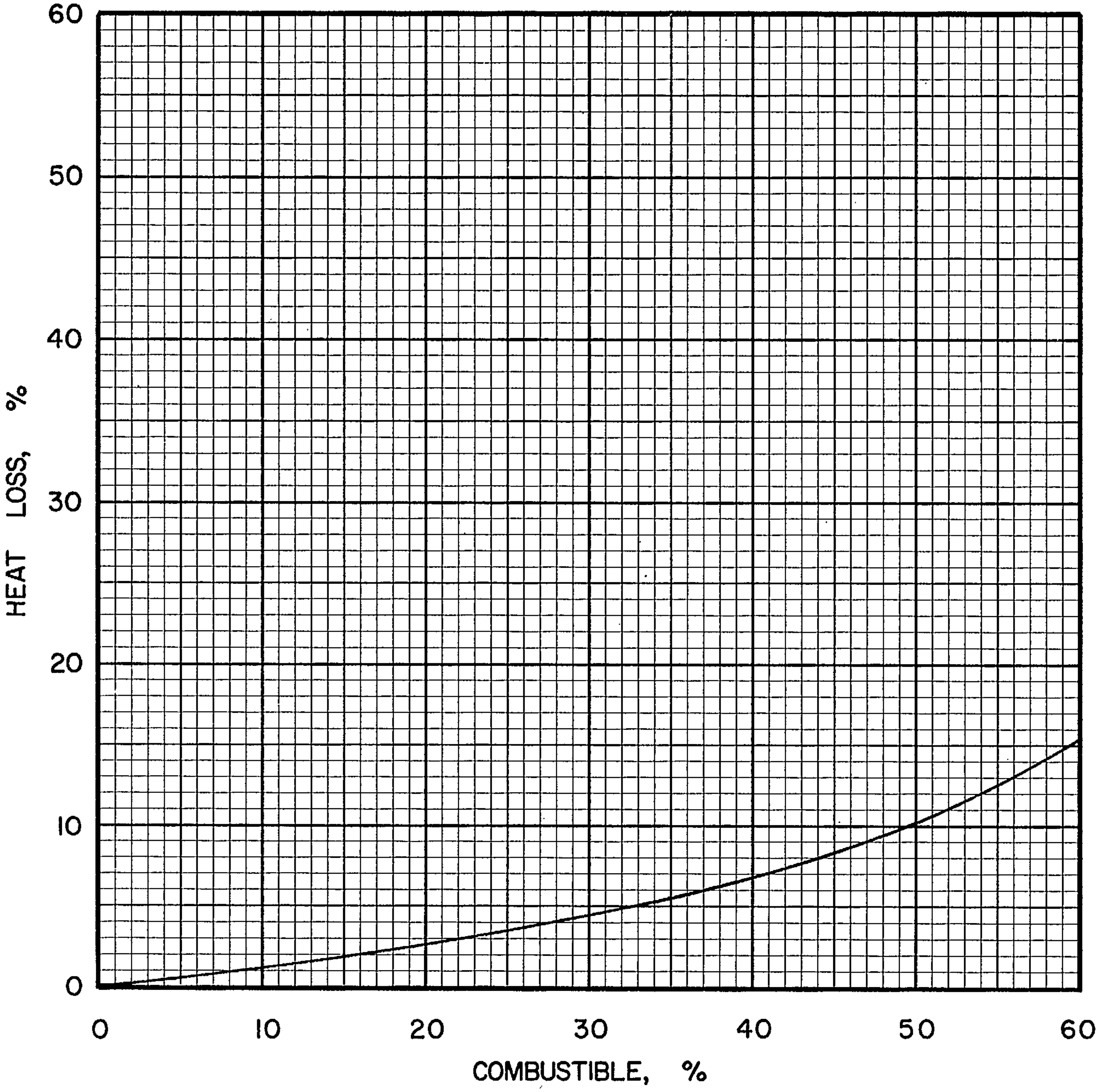


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS-5-2

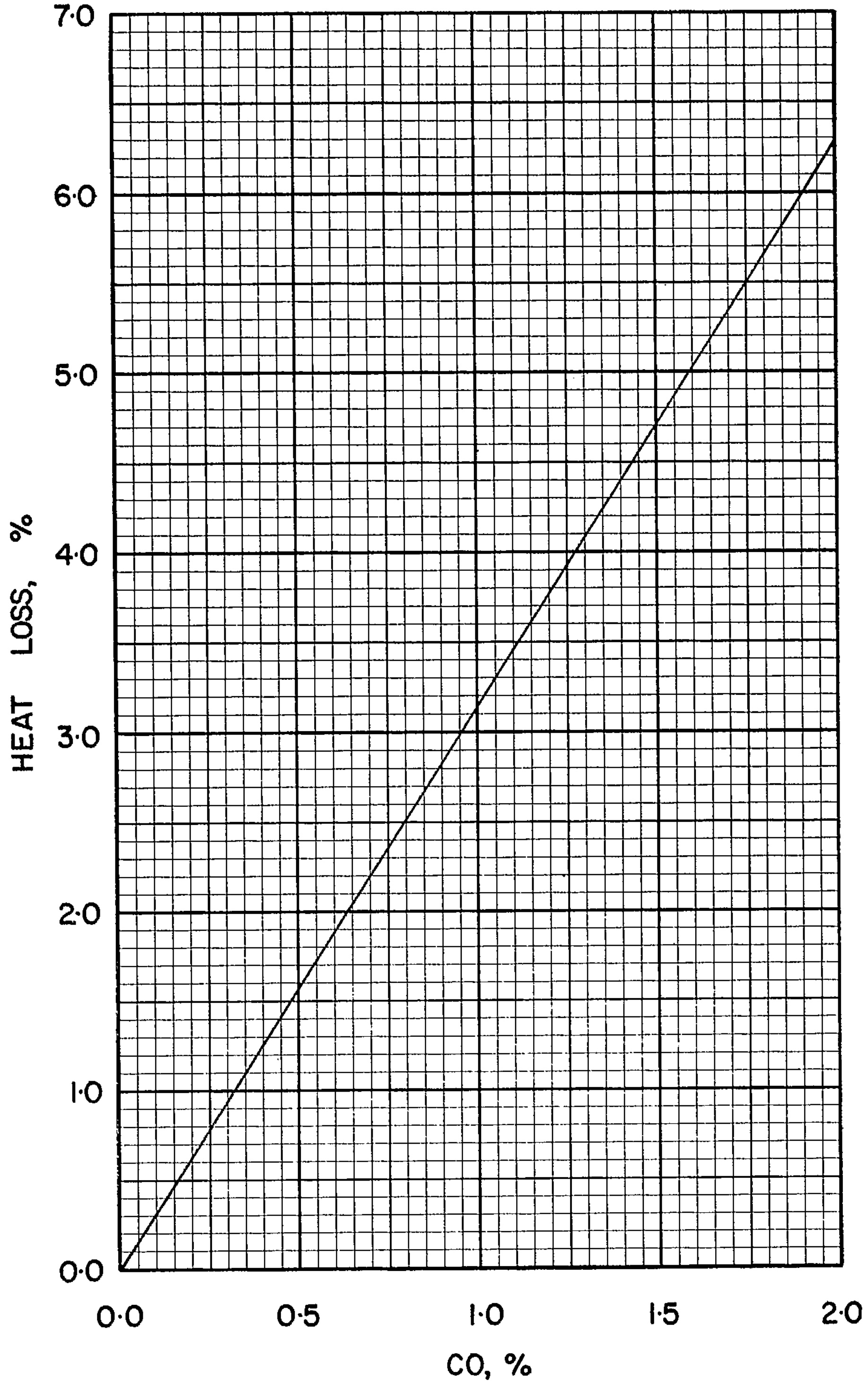


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 5· 2

COAL NS 5-3, EVANS COAL MINES LTD., CAPE BRETON, 1/2 in. x 0

Typical Moisture Range: 4–10%

Proximate Analysis (lb/lb dry coal)

Ash	0.1204
Volatile Matter	0.3799
Fixed Carbon	0.4997
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6853
Hydrogen (H)	0.0434
Sulphur (S)	0.0670
Nitrogen (N)	0.0127
Oxygen (O)	0.0712
Ash	0.1204
Total	1.0000

Gross Calorific Value

Btu/lb:	12227
Btu/short ton:	24.45×10^6
Btu/long ton:	27.39×10^6
MJ/kg:	28.43

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 81.79	lb	
10^6 Btu	= 0.04089	short tons	
10^6 Btu	= 0.03651	long tons	

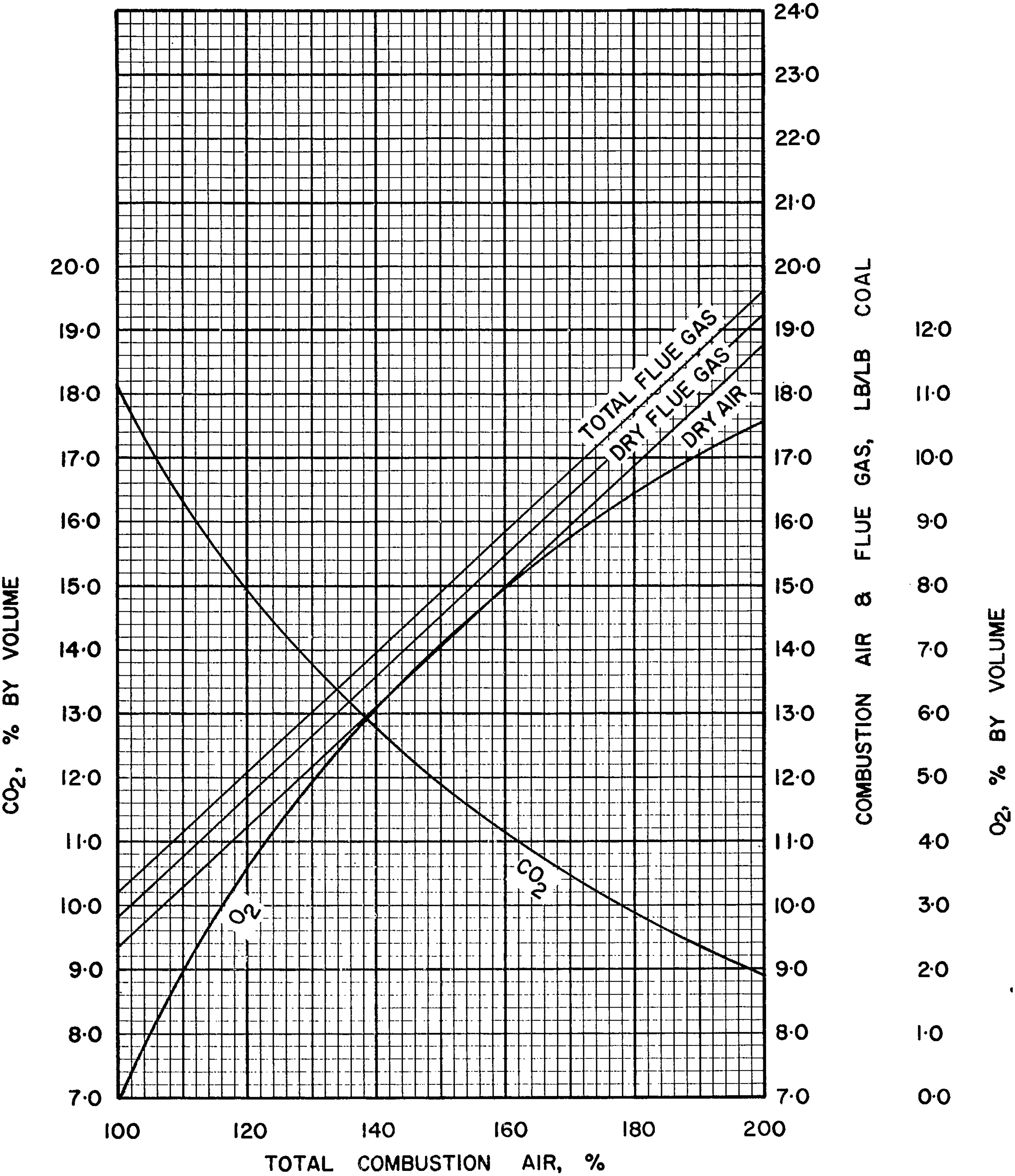


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS· 5· 3

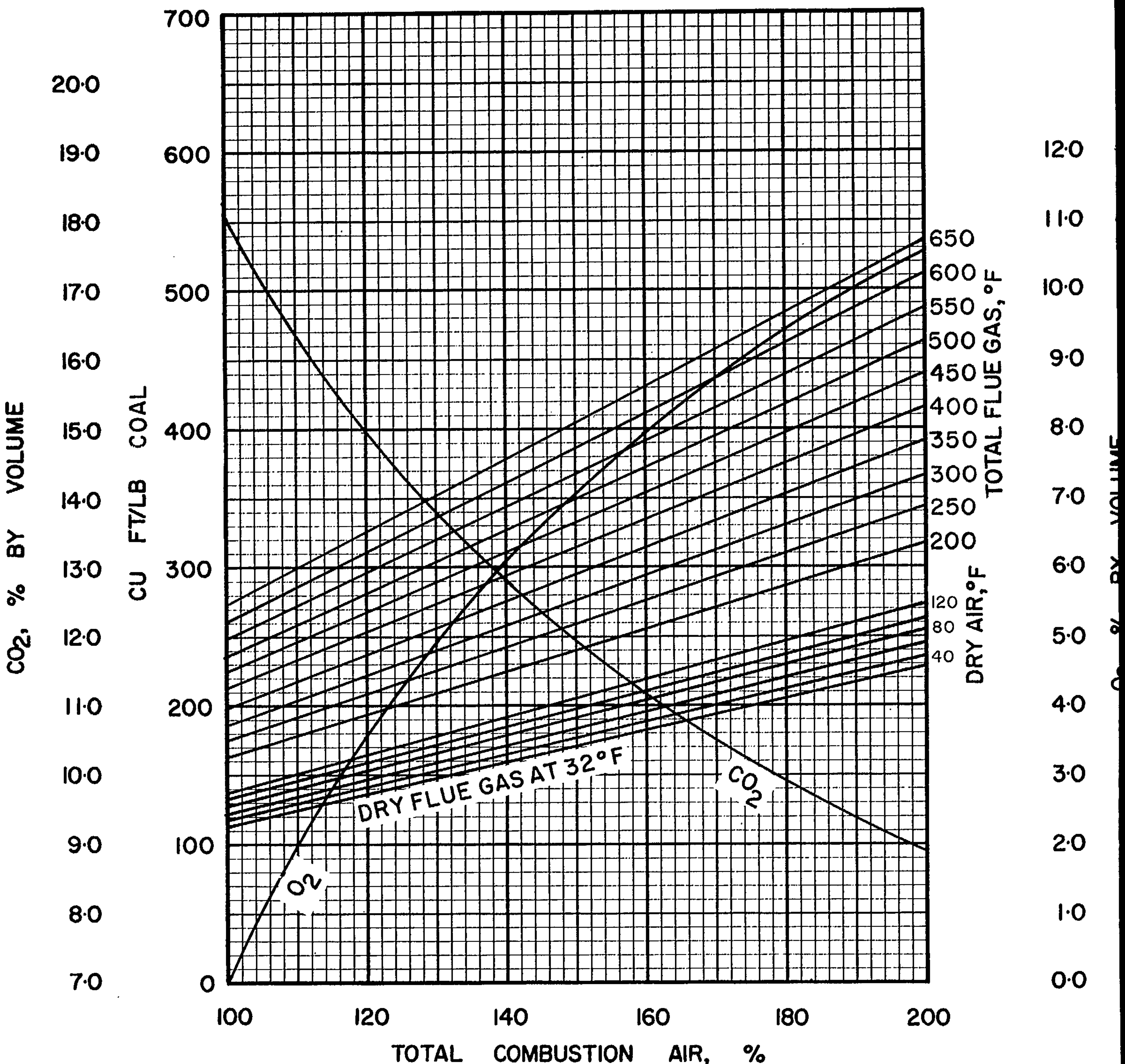


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS · 5·3

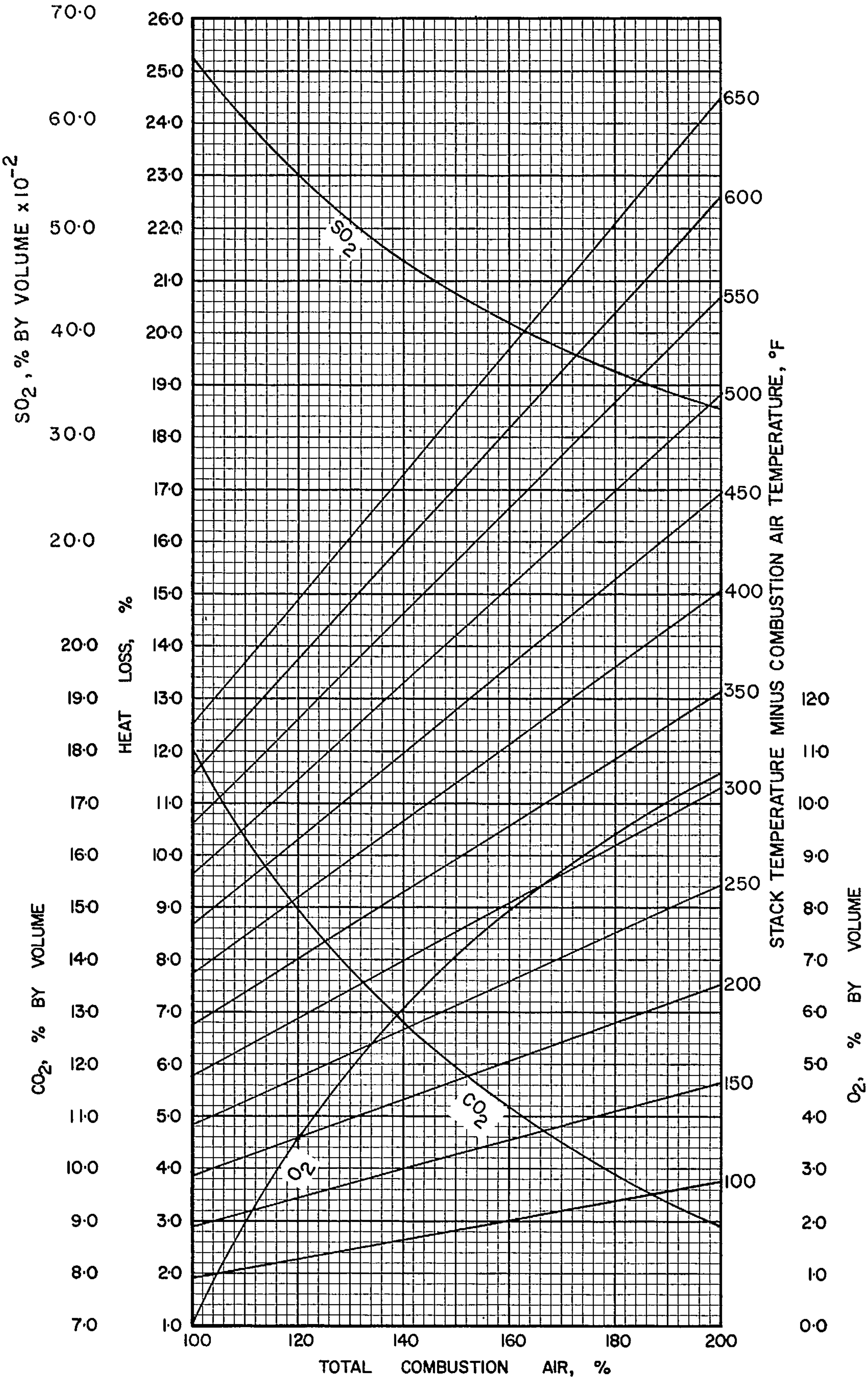


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS· 5·3

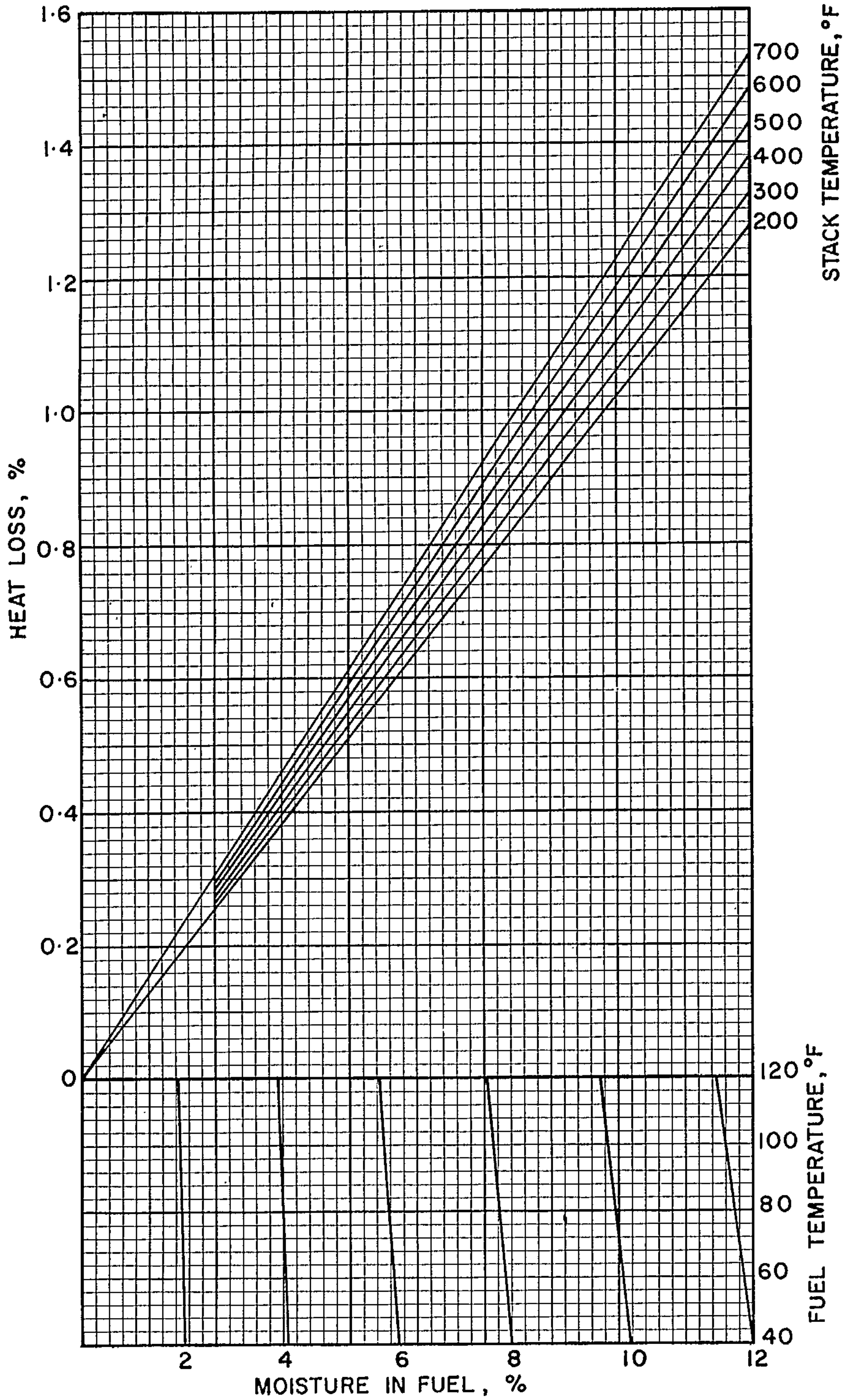


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS· 5·3

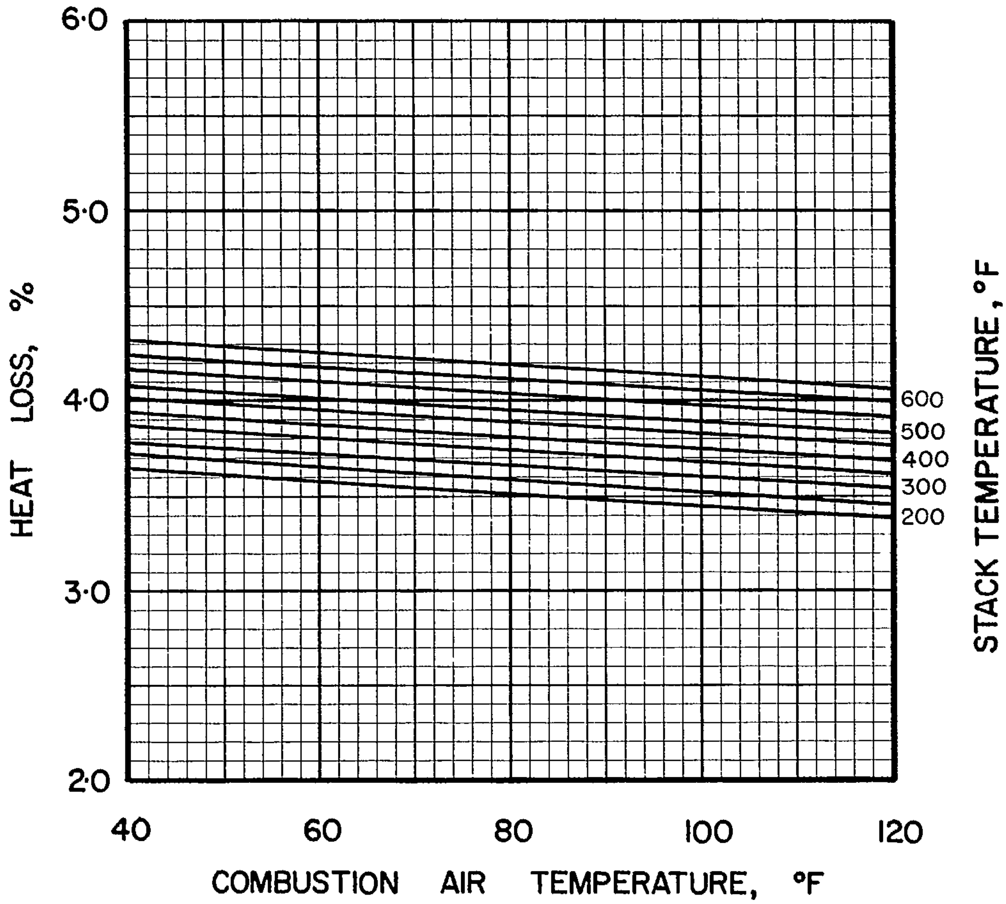


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS · 5·3

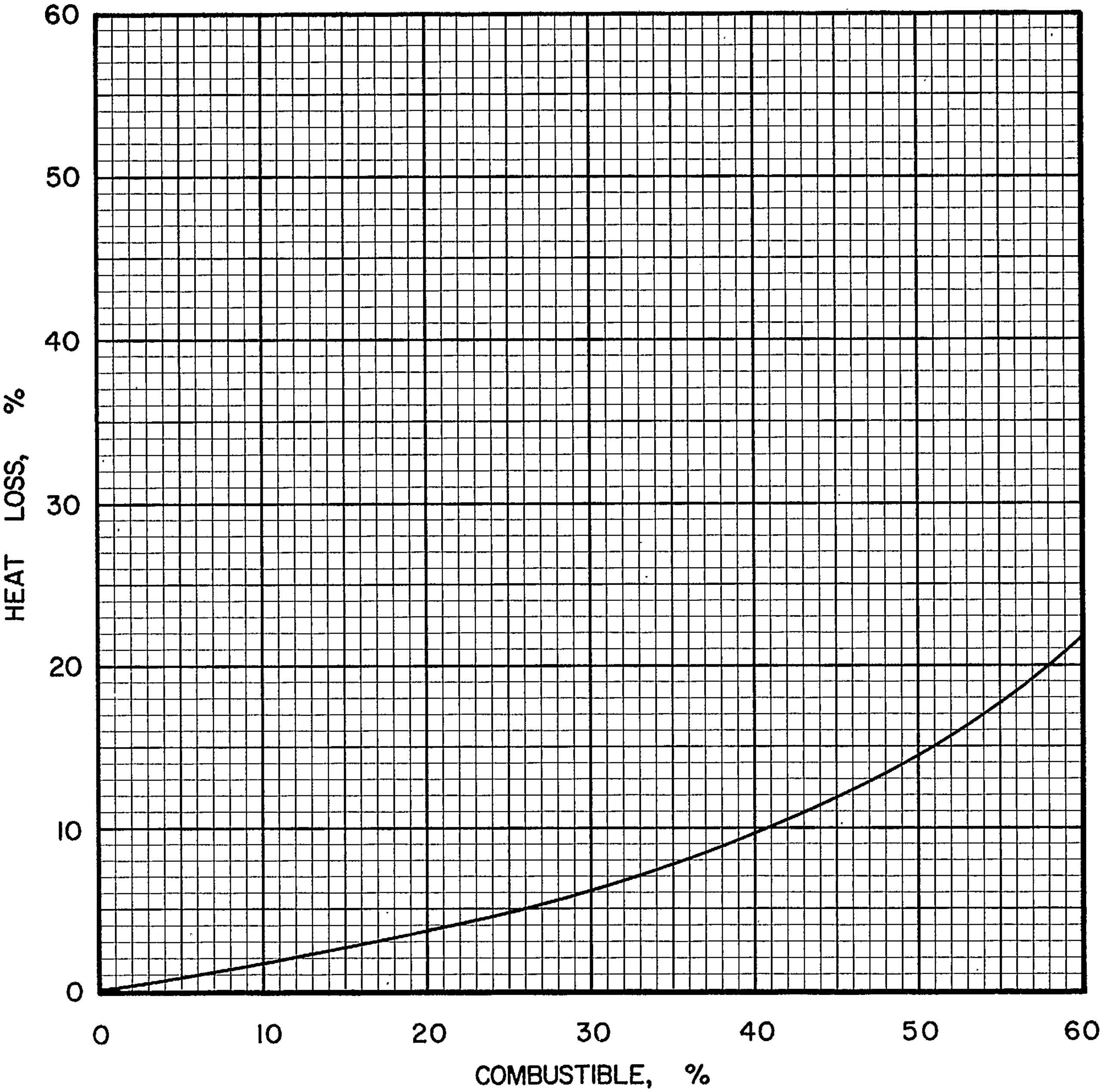


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS· 5·3

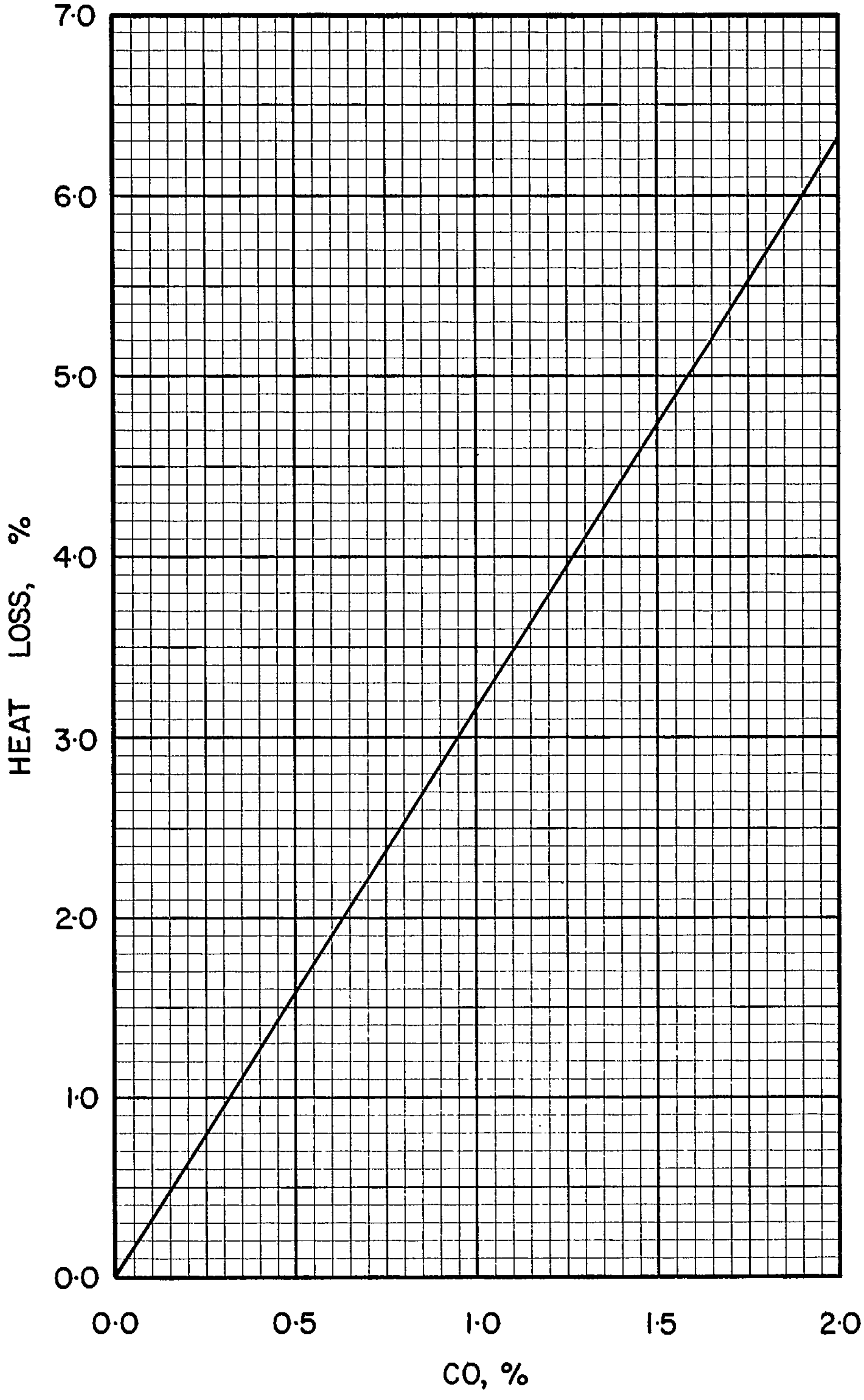


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 5·3

COAL NS 5-4, EVANS COAL MINES LTD., CAPE BRETON, 4 in. x 2 in.

Typical Moisture Range: 4–10%

Proximate Analysis (lb/lb dry coal)

Ash	0.0877
Volatile Matter	0.3783
Fixed Carbon	0.5340
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7197
Hydrogen (H)	0.0458
Sulphur (S)	0.0670
Nitrogen (N)	0.0124
Oxygen (O)	0.0674
Ash	0.0877
Total	1.0000

Gross Calorific Value

Btu/lb:	12990
Btu/short ton:	25.98×10^6
Btu/long ton:	29.10×10^6
MJ/kg:	30.21

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 76.98 lb
10^6 Btu = 0.03849 short tons
10^6 Btu = 0.03437 long tons

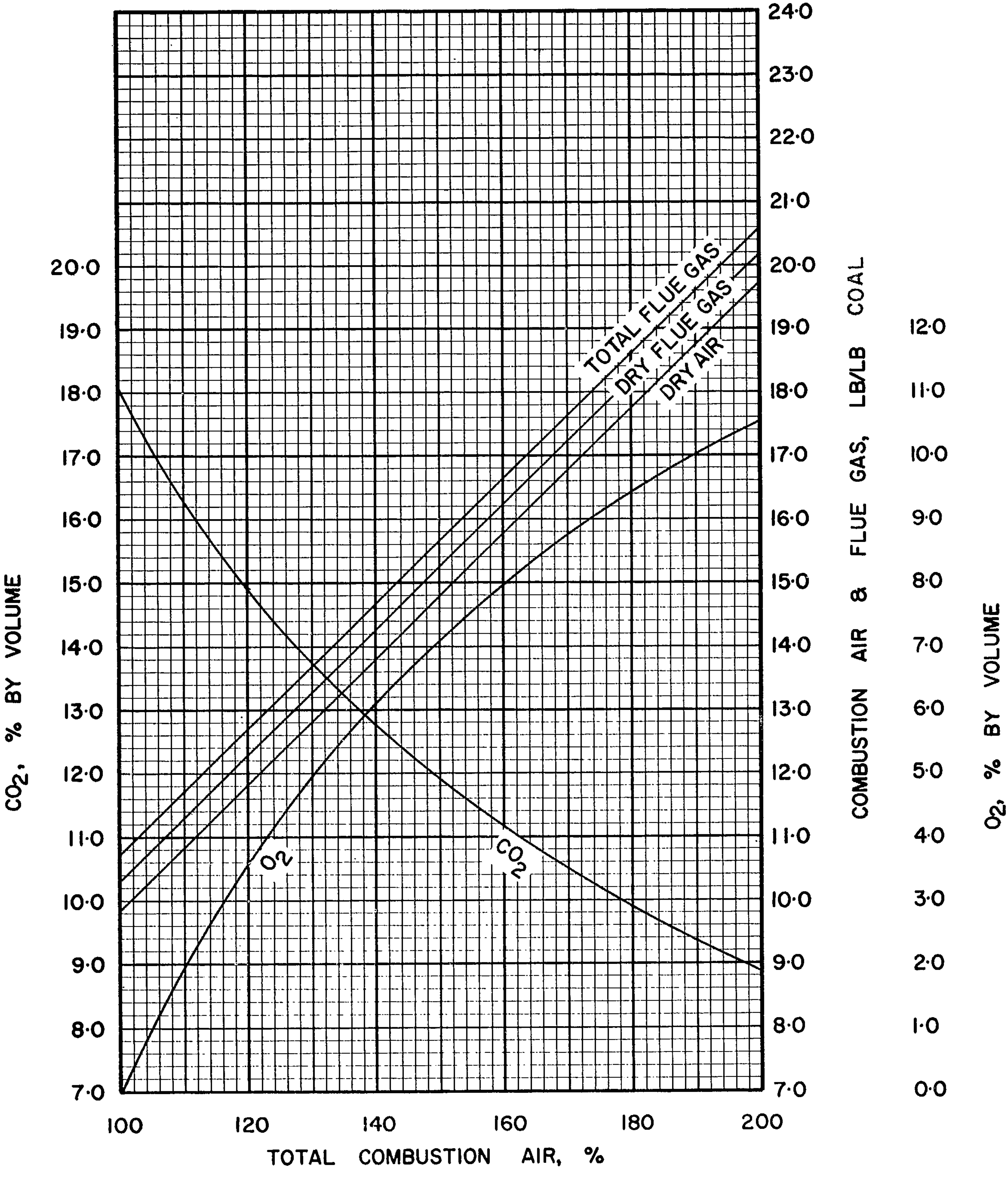


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·5·4

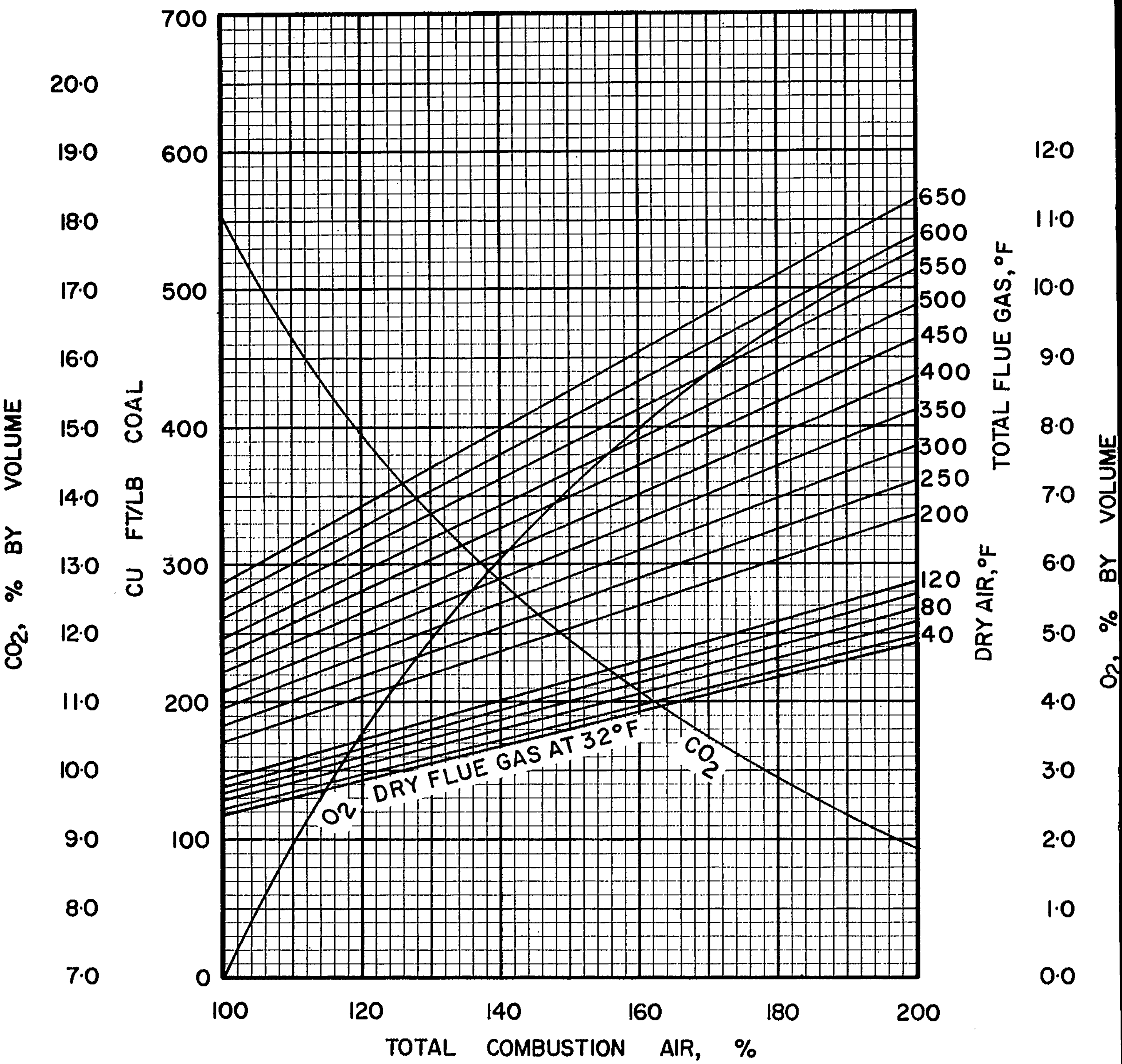


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS · 5 · 4

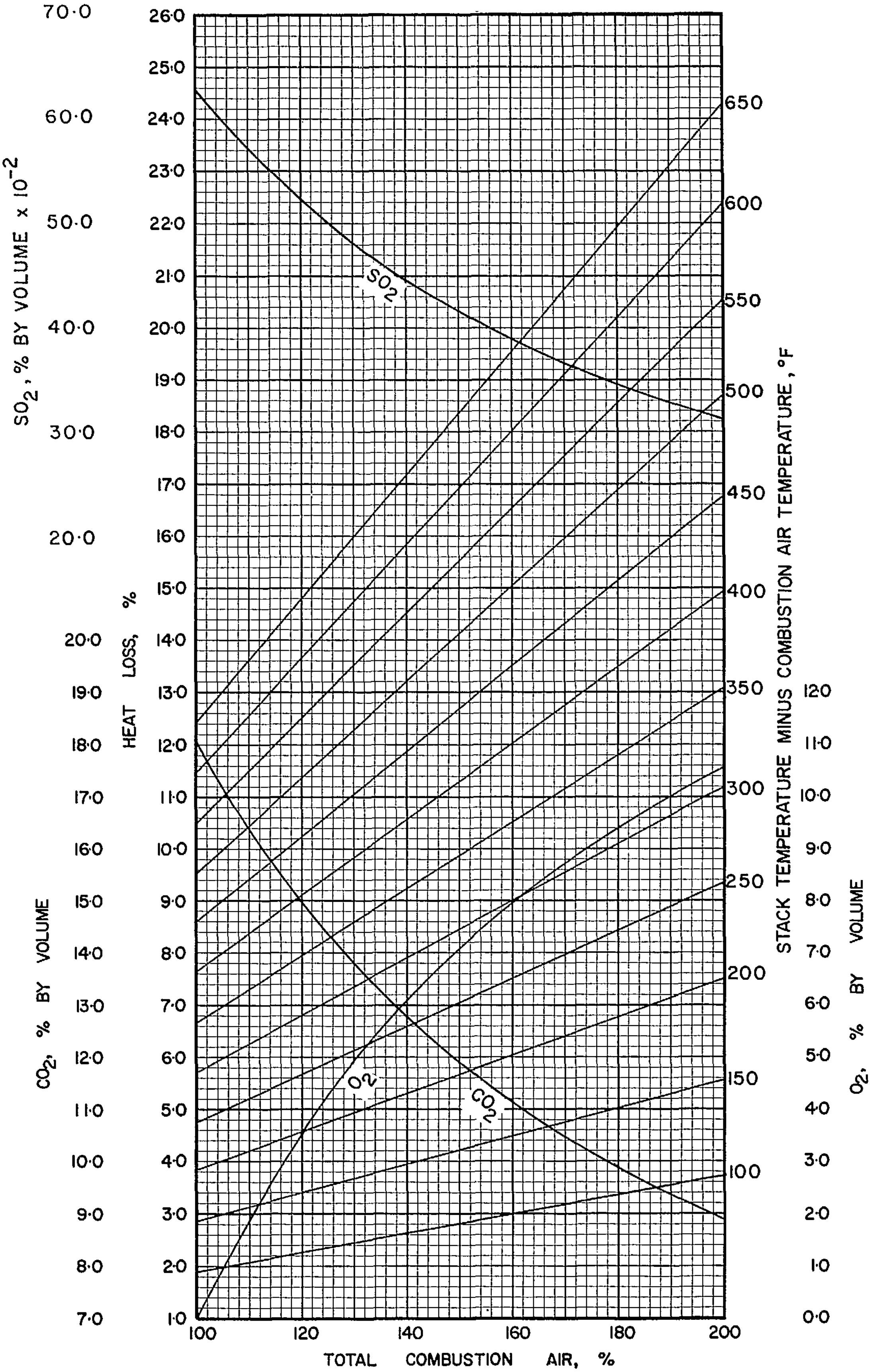


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·5·4

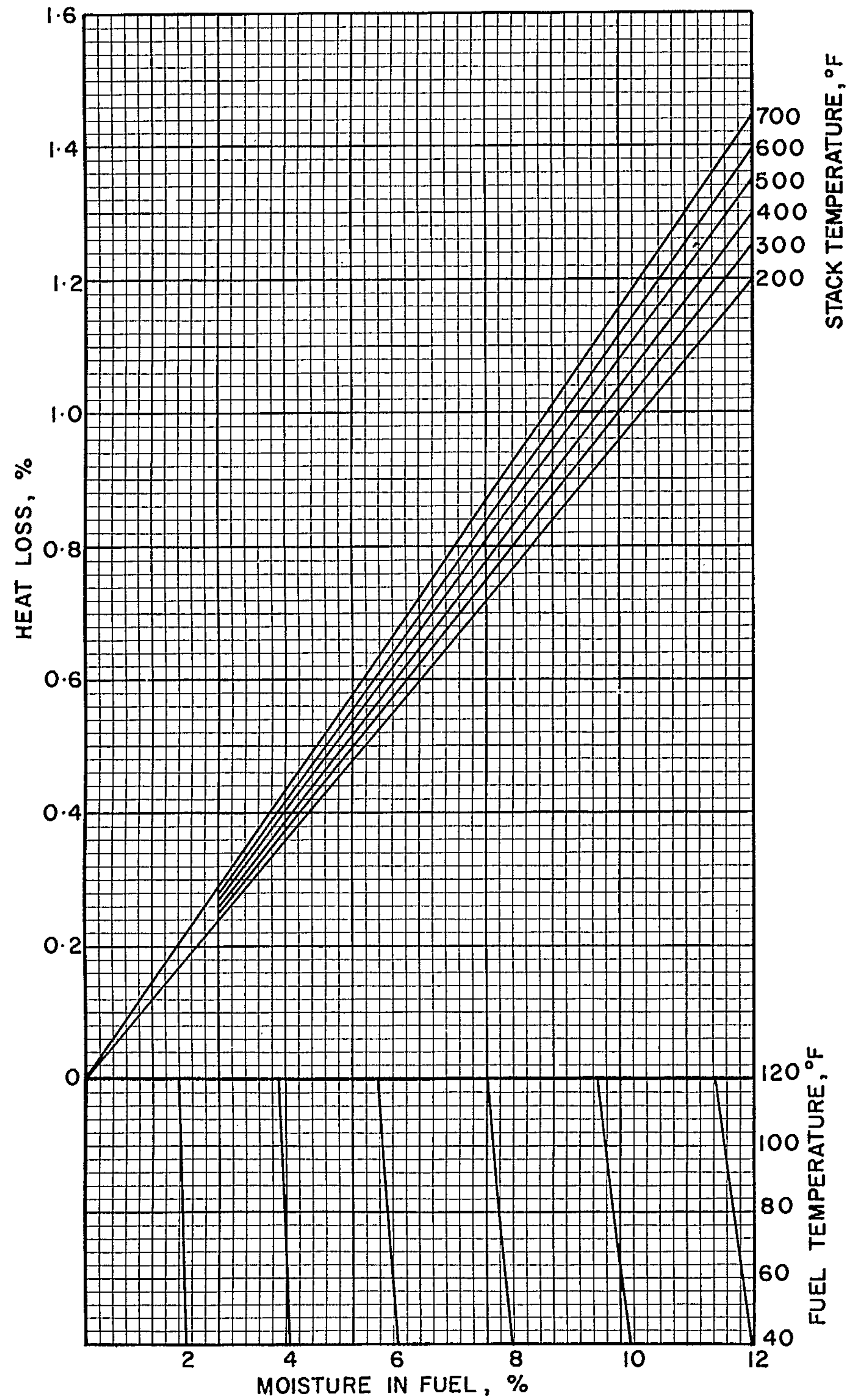


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·5·4

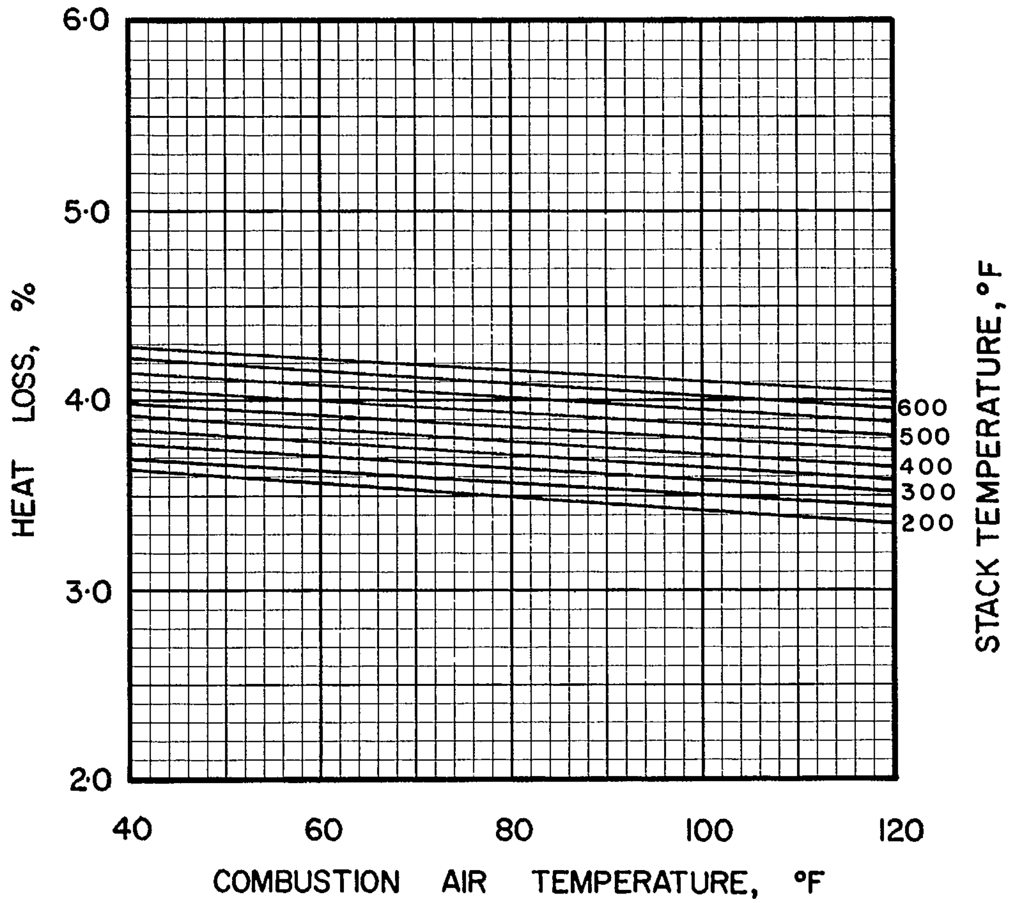


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·5·4

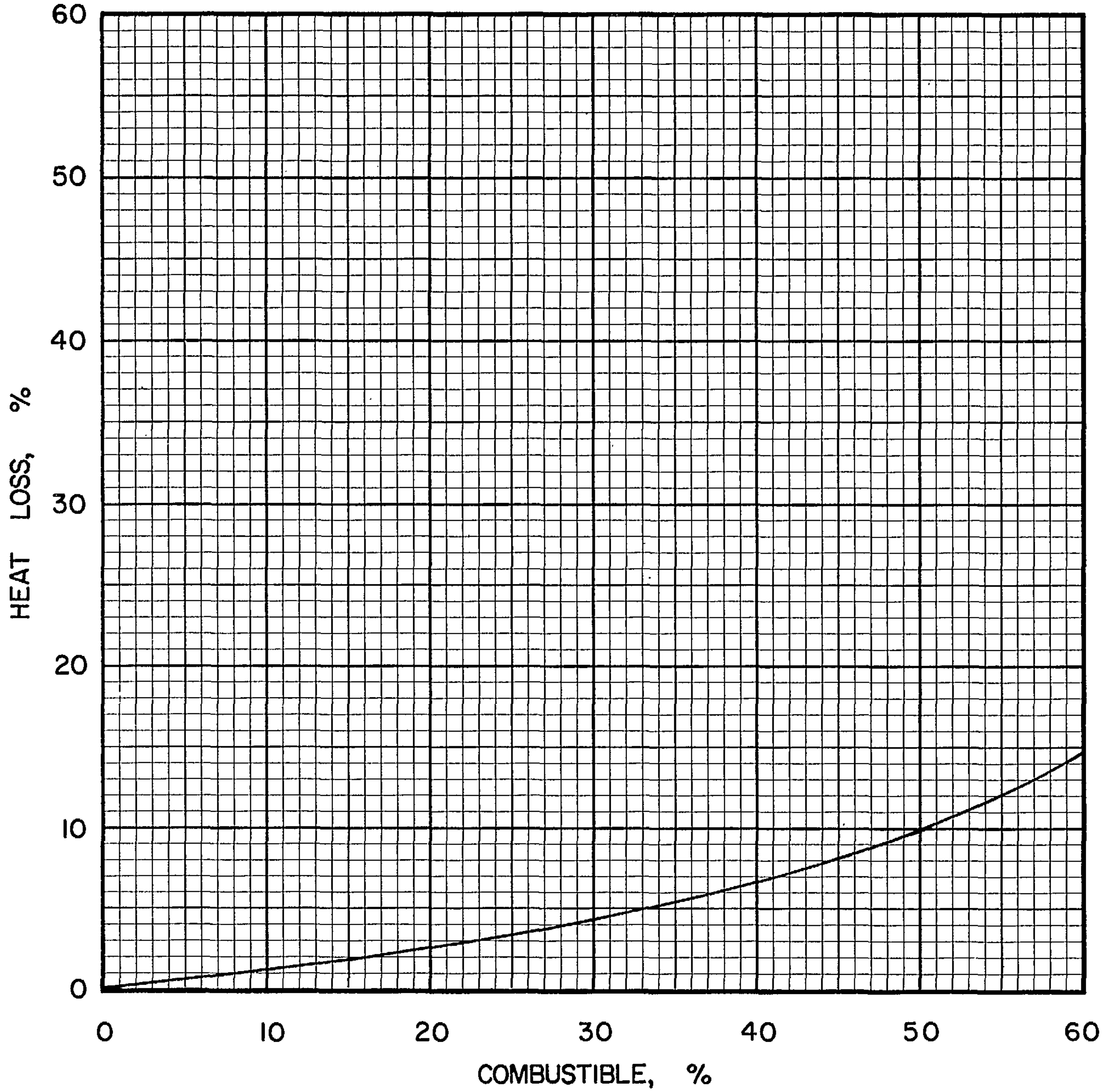


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS· 5·4

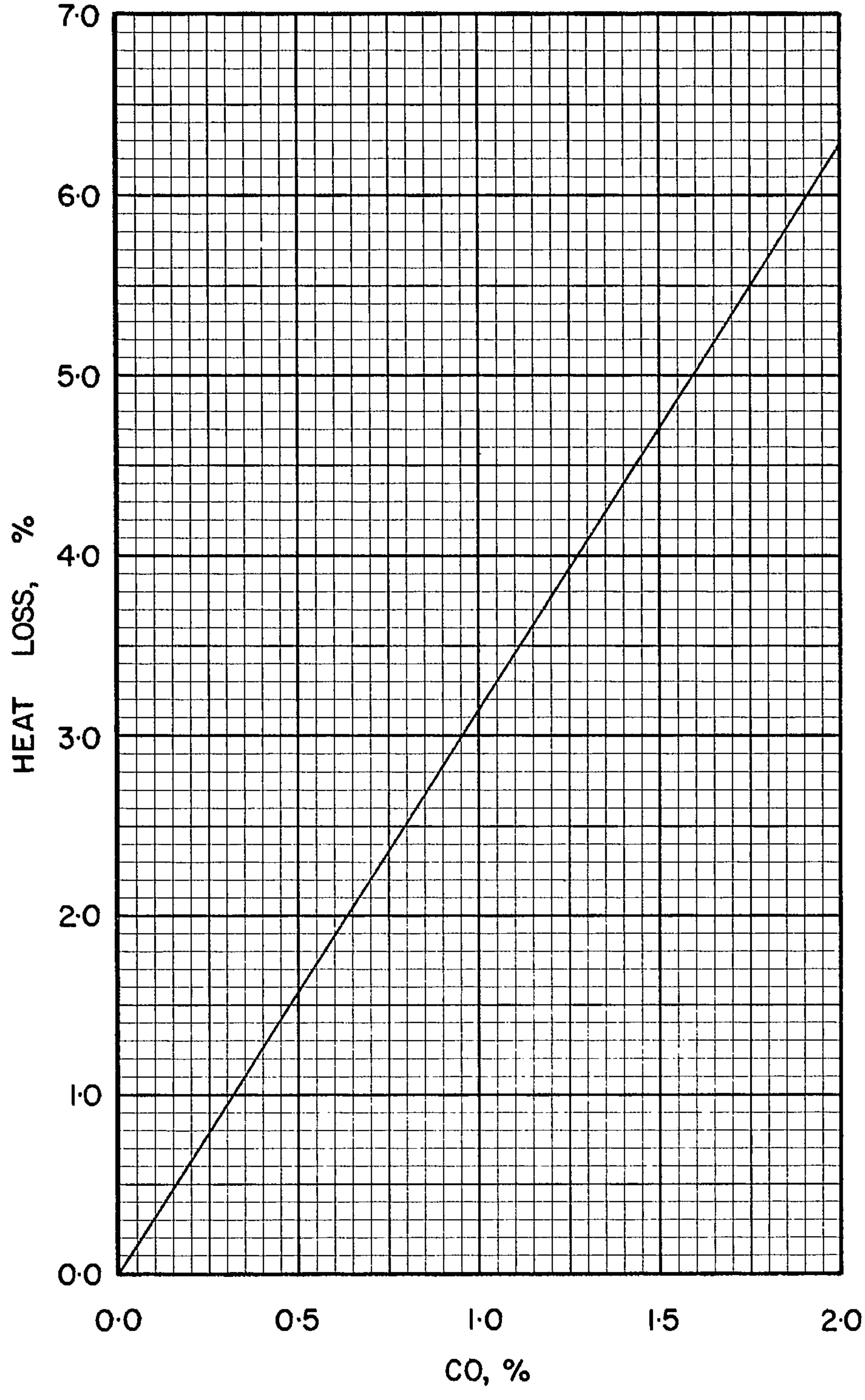


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS · 5·4

COAL NS 5-5, EVANS COAL MINES LTD.
CAPE BRETON, 2 in. x 1 in.

Typical Moisture Range: 4–10%

Proximate Analysis (lb/lb dry coal)

Ash	0.0911
Volatile Matter	0.3851
Fixed Carbon	0.5238
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7099
Hydrogen (H)	0.0463
Sulphur (S)	0.0691
Nitrogen (N)	0.0124
Oxygen (O)	0.0712
Ash	0.0911
Total	1.0000

Gross Calorific Value

Btu/lb:	12836
Btu/short ton:	25.67×10^6
Btu/long ton:	28.75×10^6
MJ/kg:	29.85

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 77.91 lb
10^6 Btu = 0.03895 short tons
10^6 Btu = 0.03478 long tons

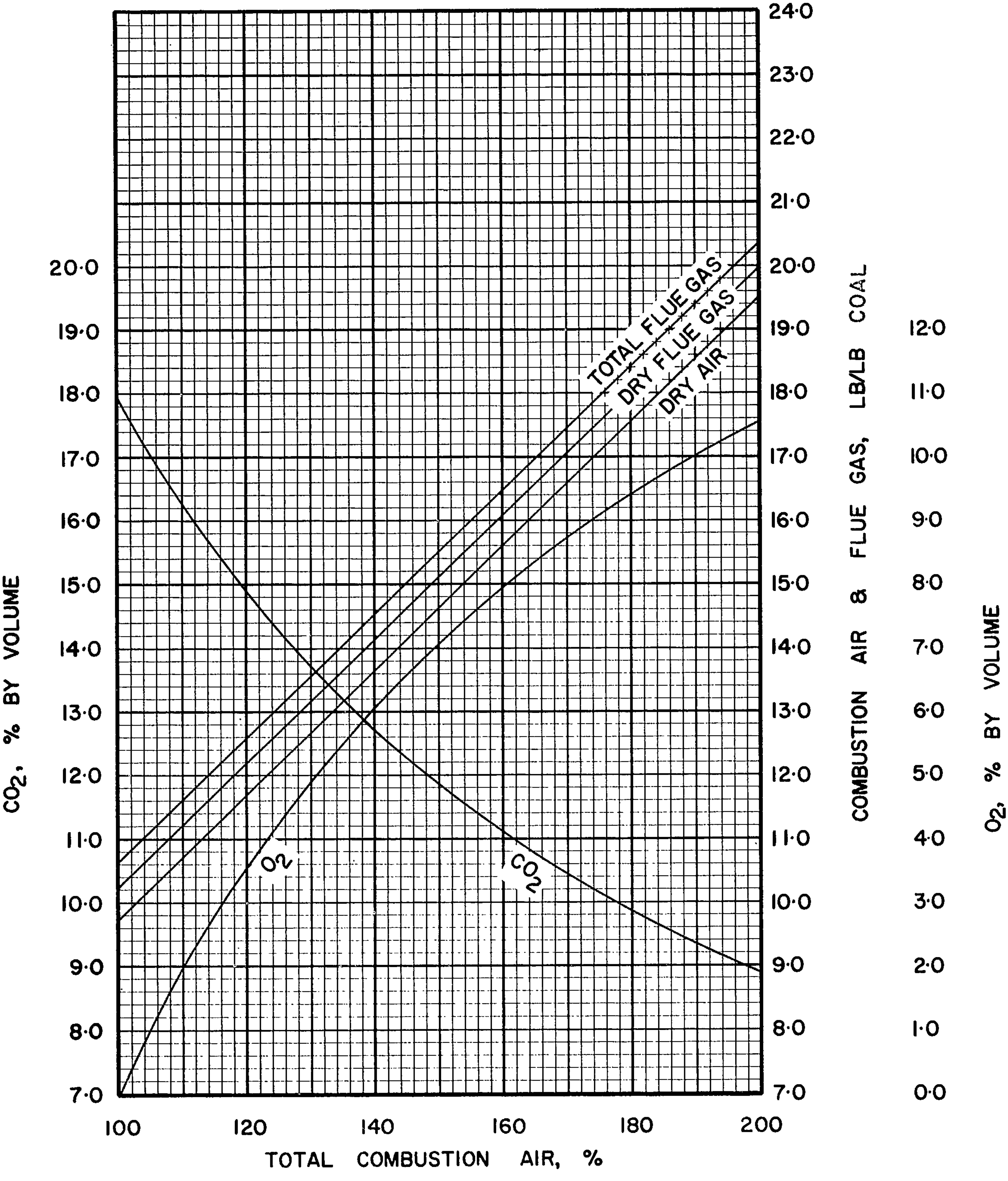


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS· 5·5

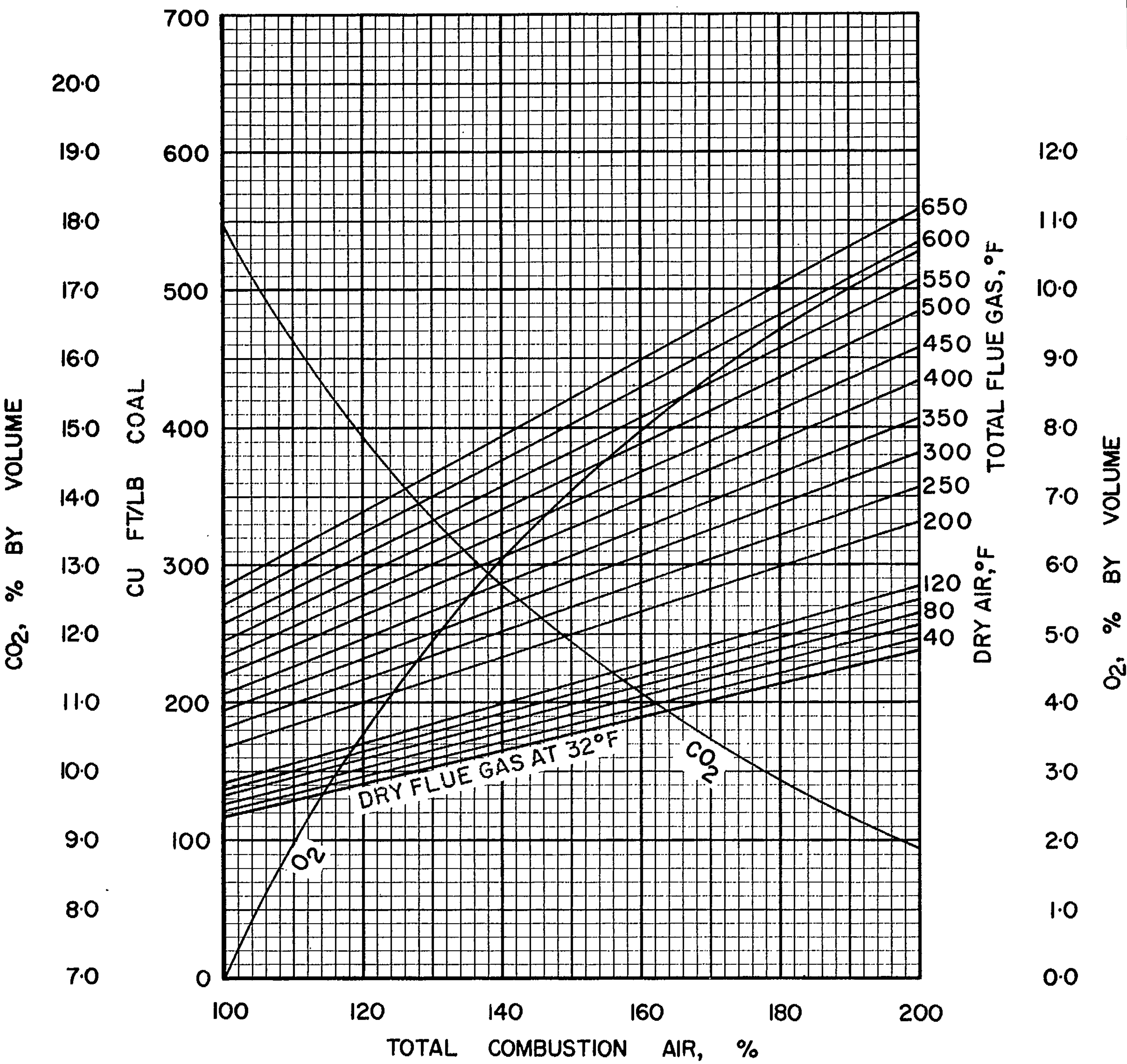


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS· 5·5

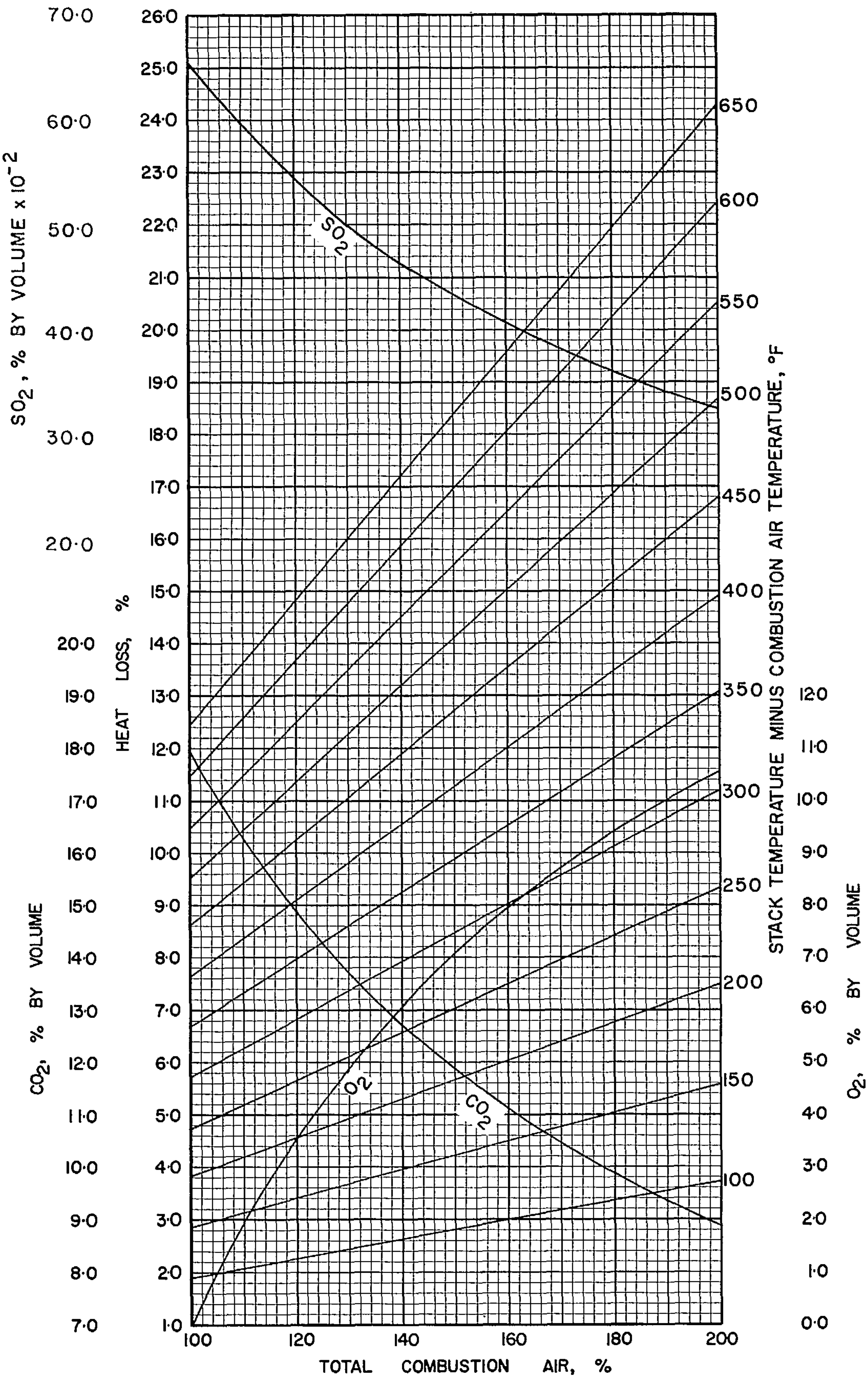


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·5·5

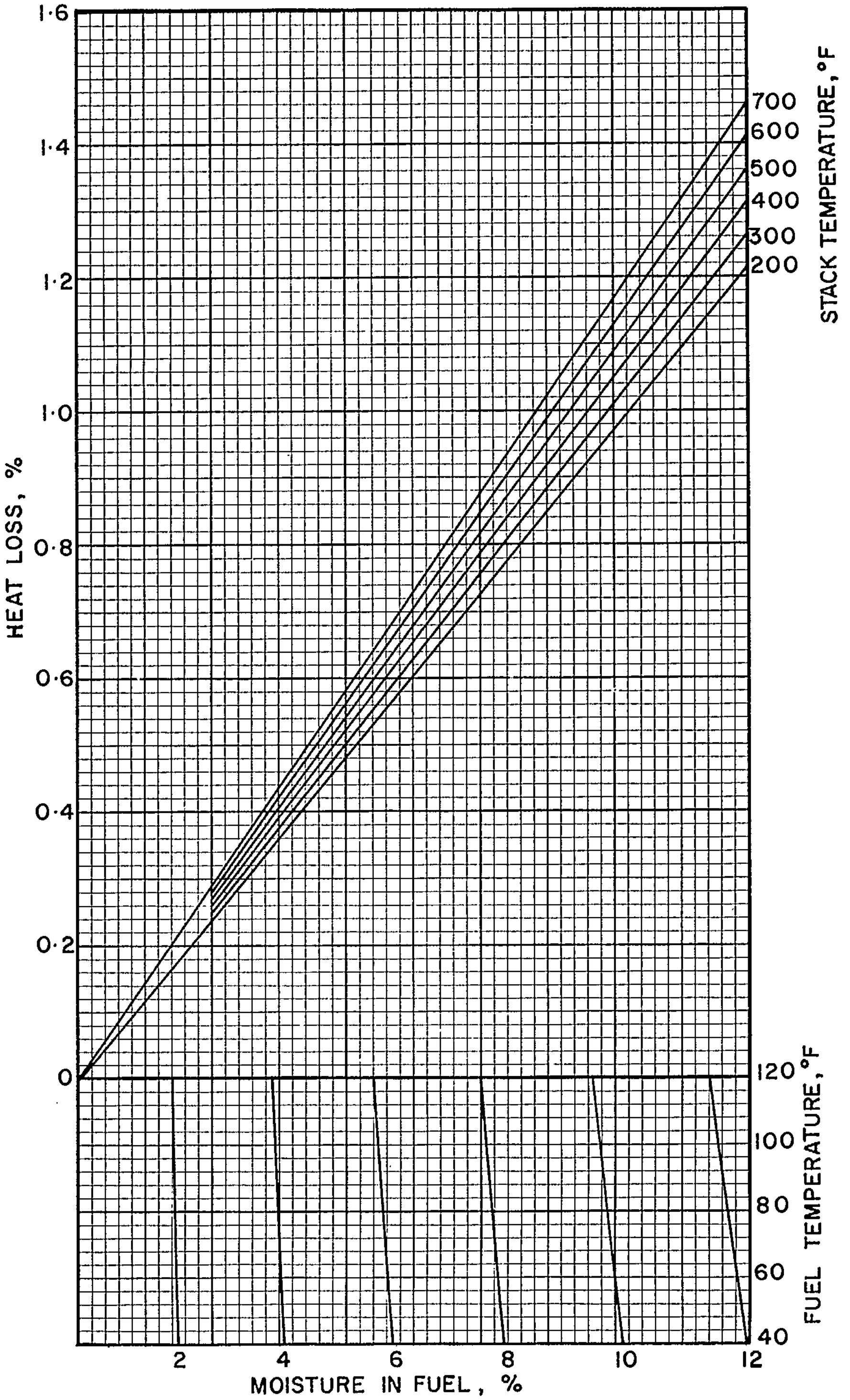


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·5·5

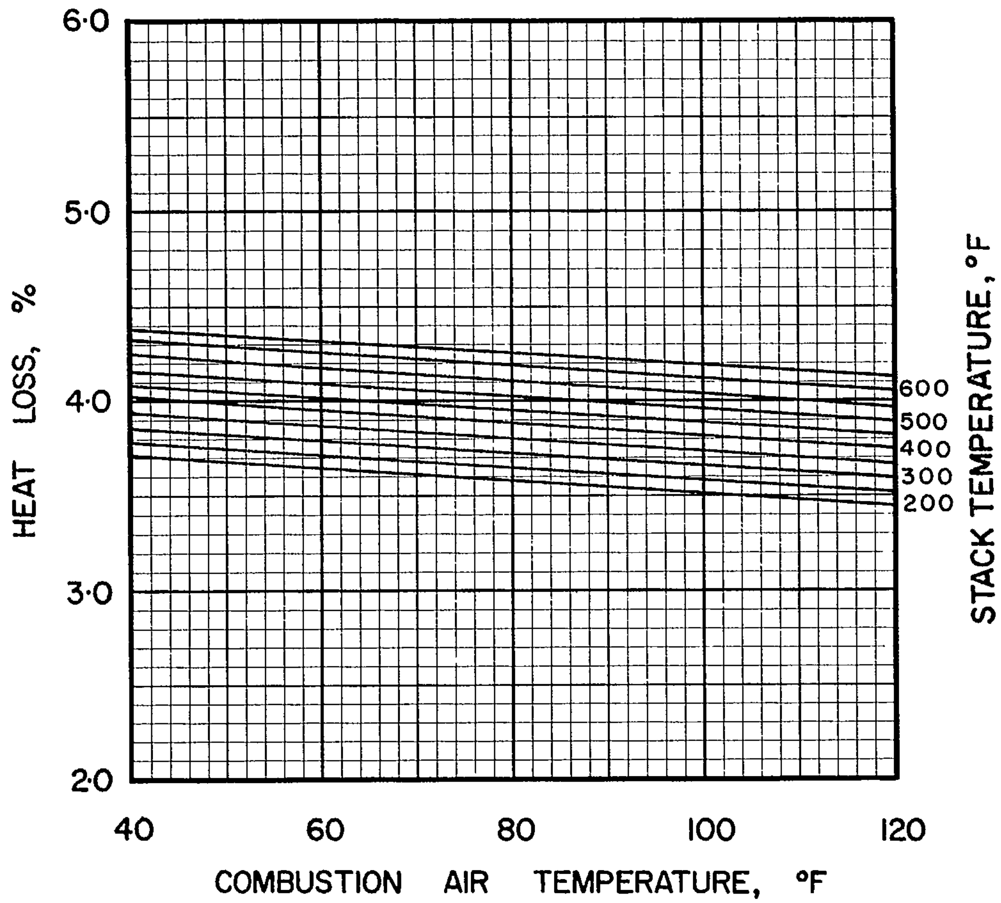


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS· 5·5

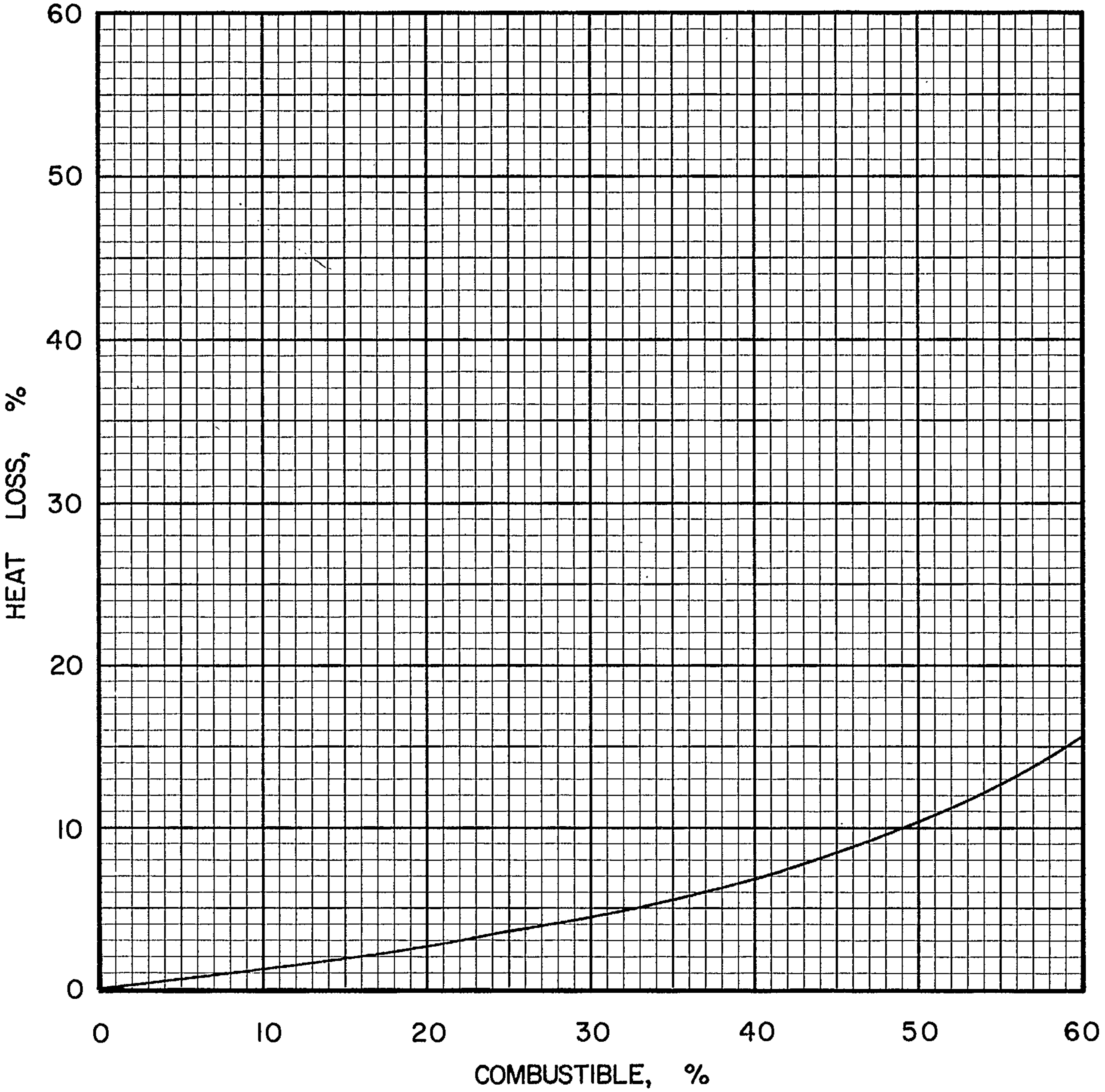


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·5·5

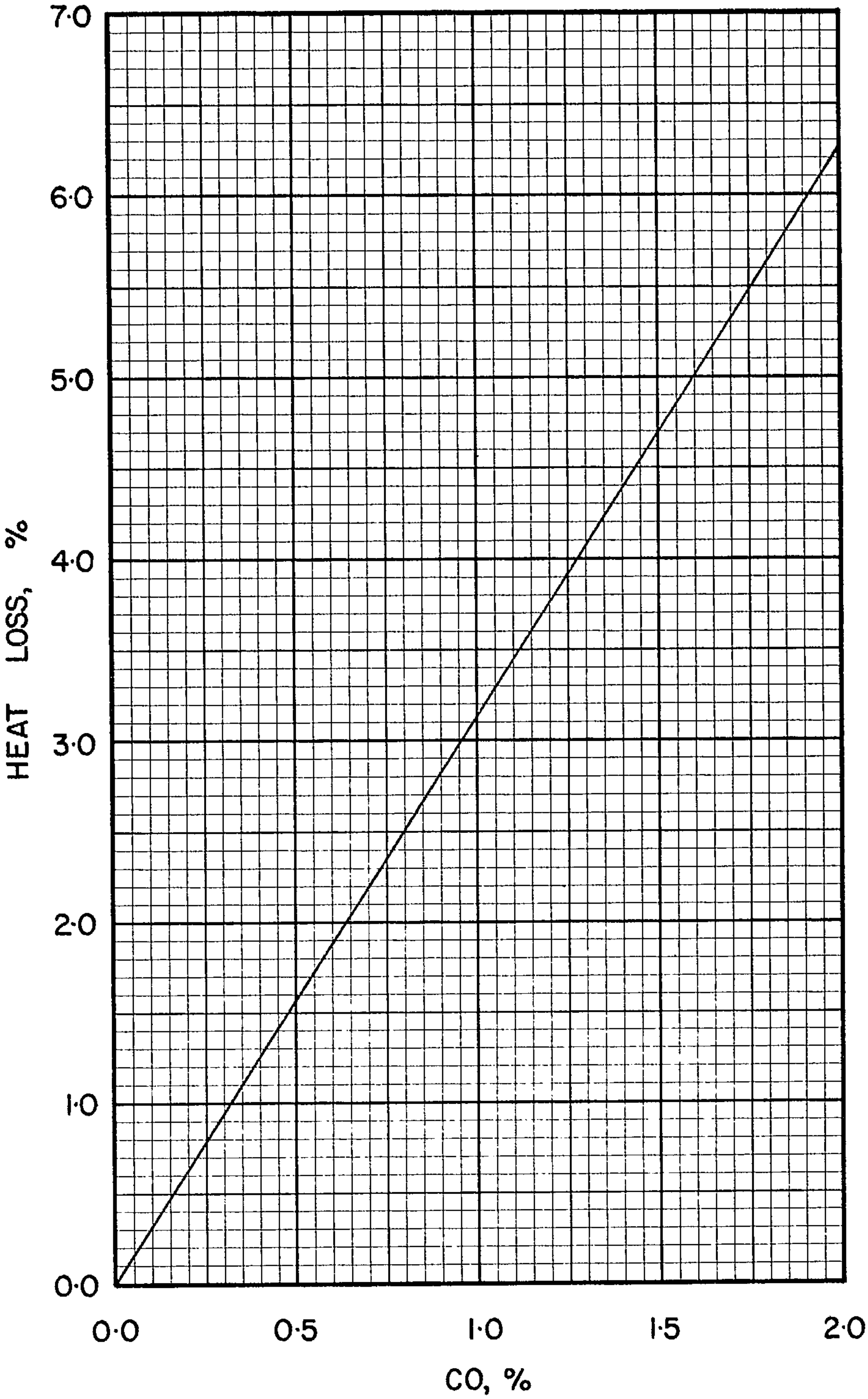


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 5·5

COAL NS 6-1, OLD SYDNEY, DEVCO, CAPE BRETON, 1 3/4 in. x 3/4 in.

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0322
Volatile Matter	0.3924
Fixed Carbon	0.5754
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8247
Hydrogen (H)	0.0550
Sulphur (S)	0.0151
Nitrogen (N)	0.0162
Oxygen (O)	0.0568
Ash	0.0322
Total	1.0000

Gross Calorific Value

Btu/lb:	14890
Btu/short ton:	29.78×10^6
Btu/long ton:	33.35×10^6
MJ/kg:	34.63

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 67.16	lb	
10^6 Btu	= 0.03358	short tons	
10^6 Btu	= 0.02998	long tons	

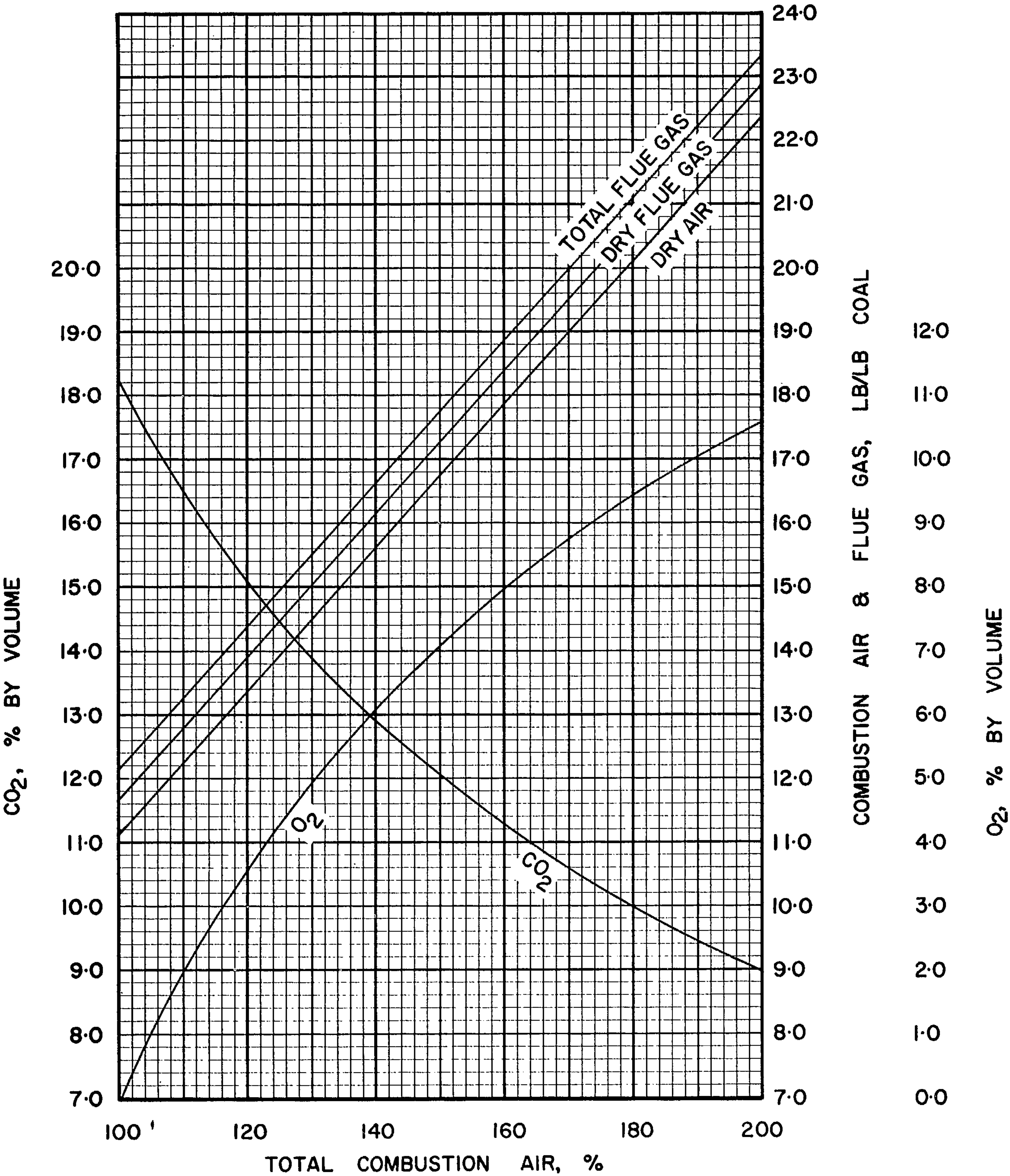


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS·6·1

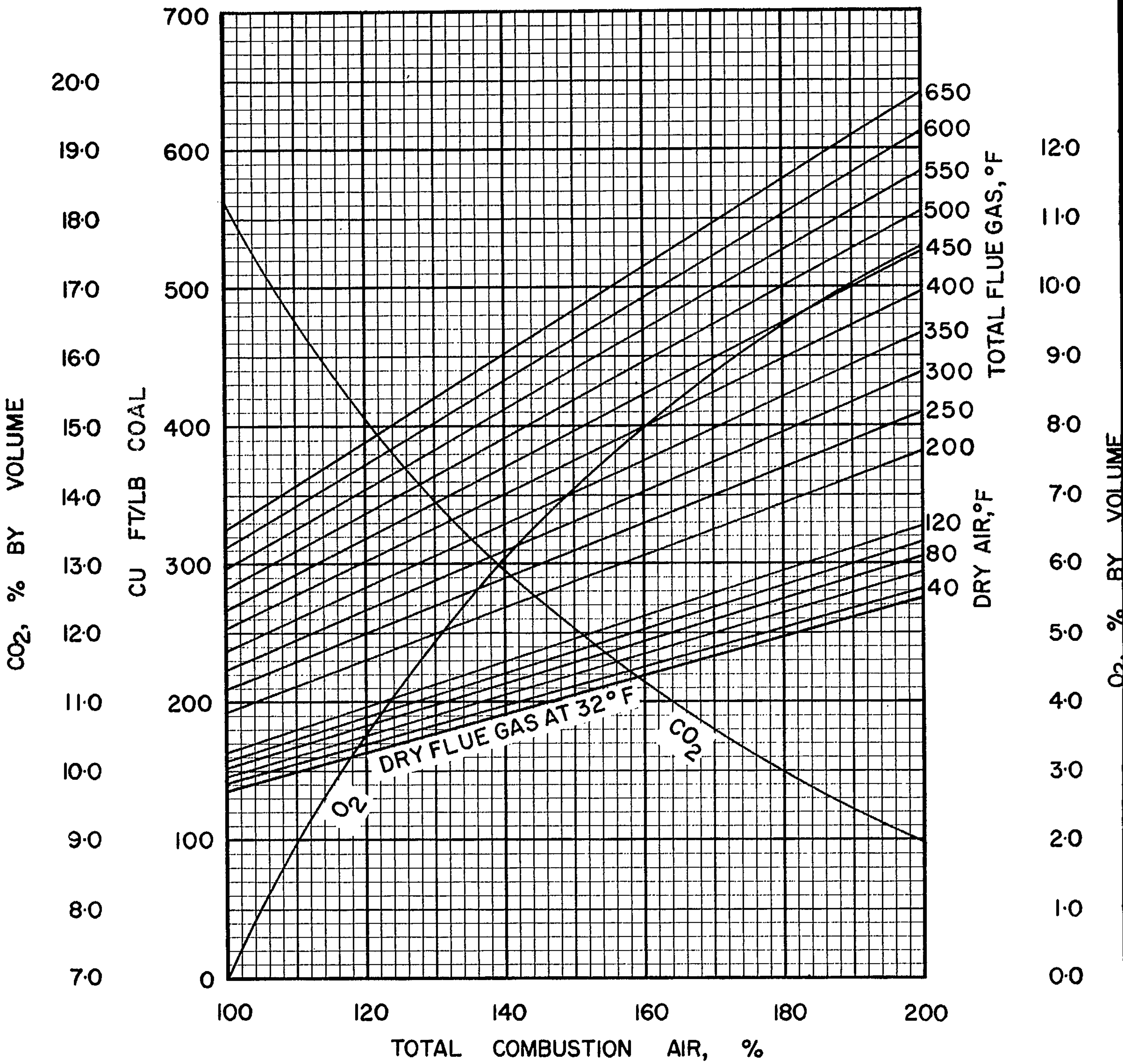


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·6·1

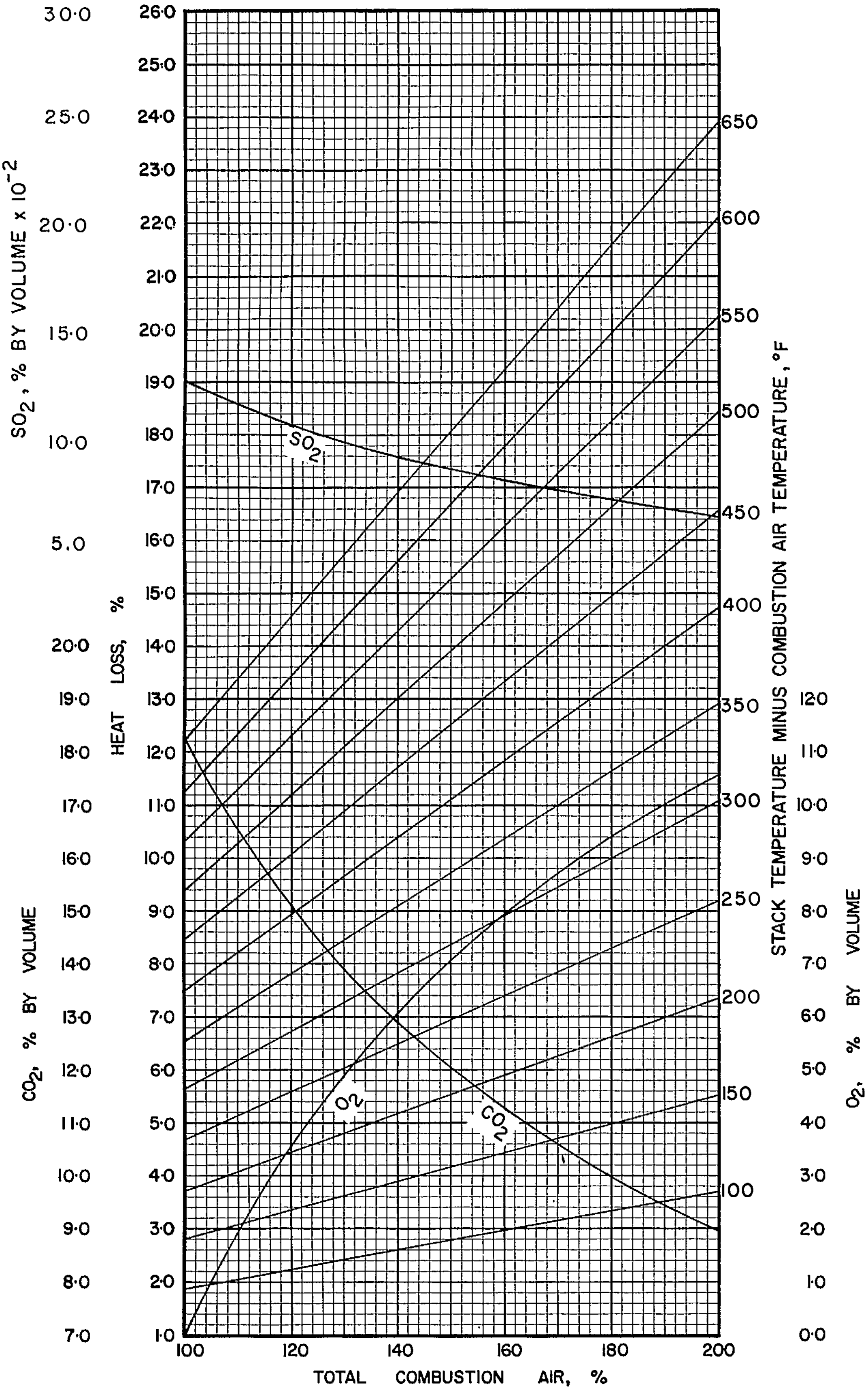


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS· 6·1

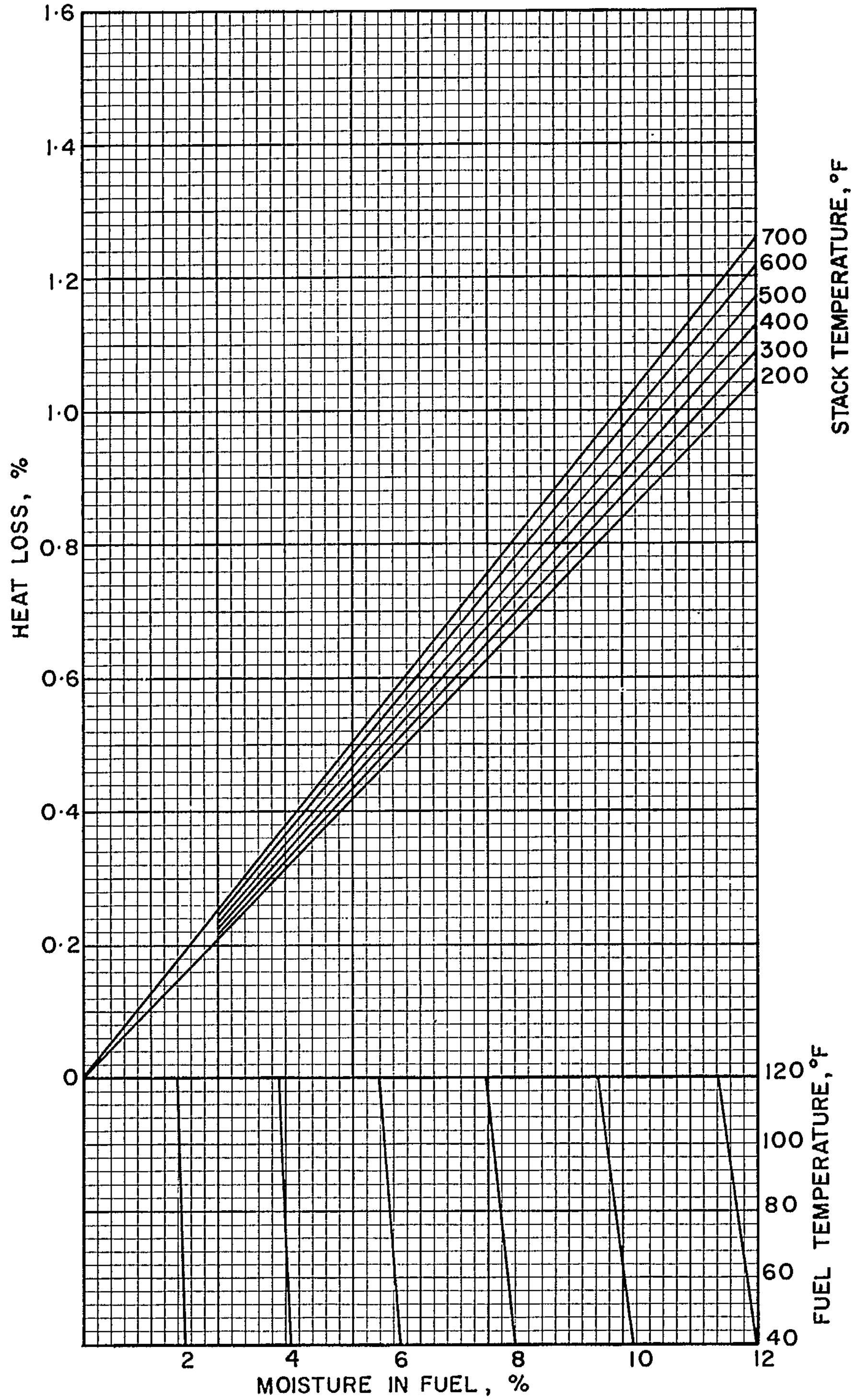


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·6·1

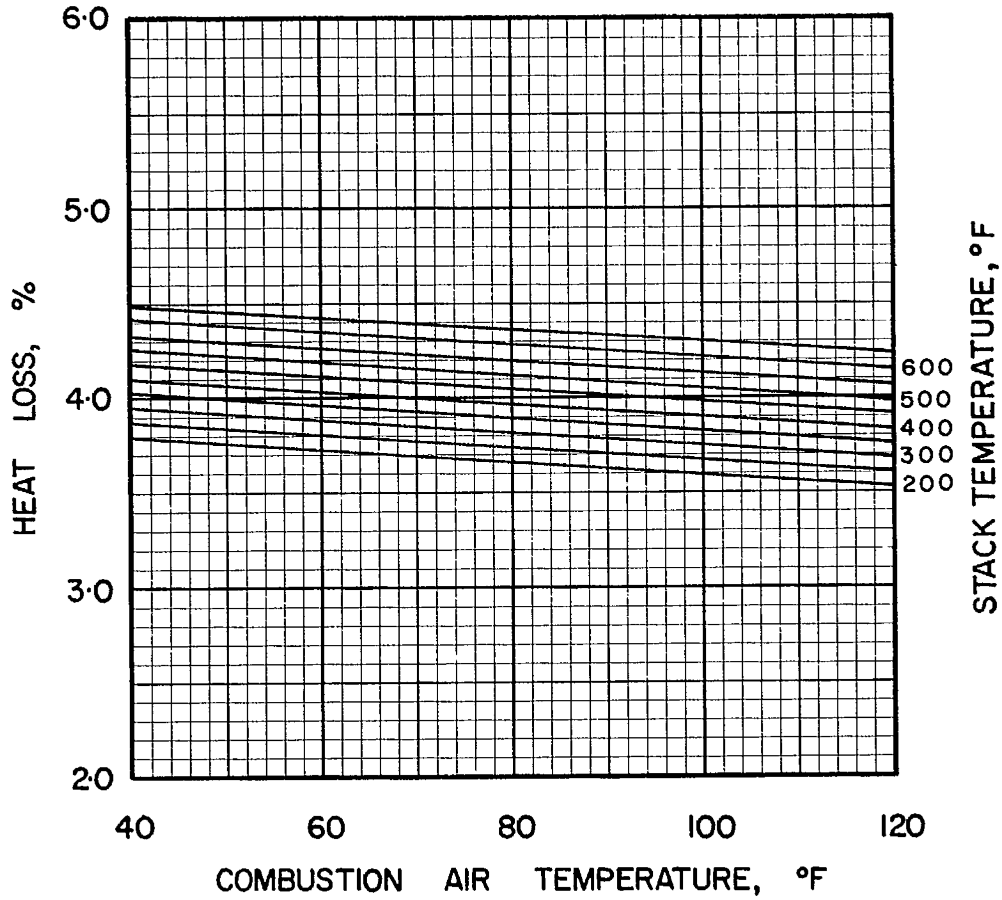


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·6·1

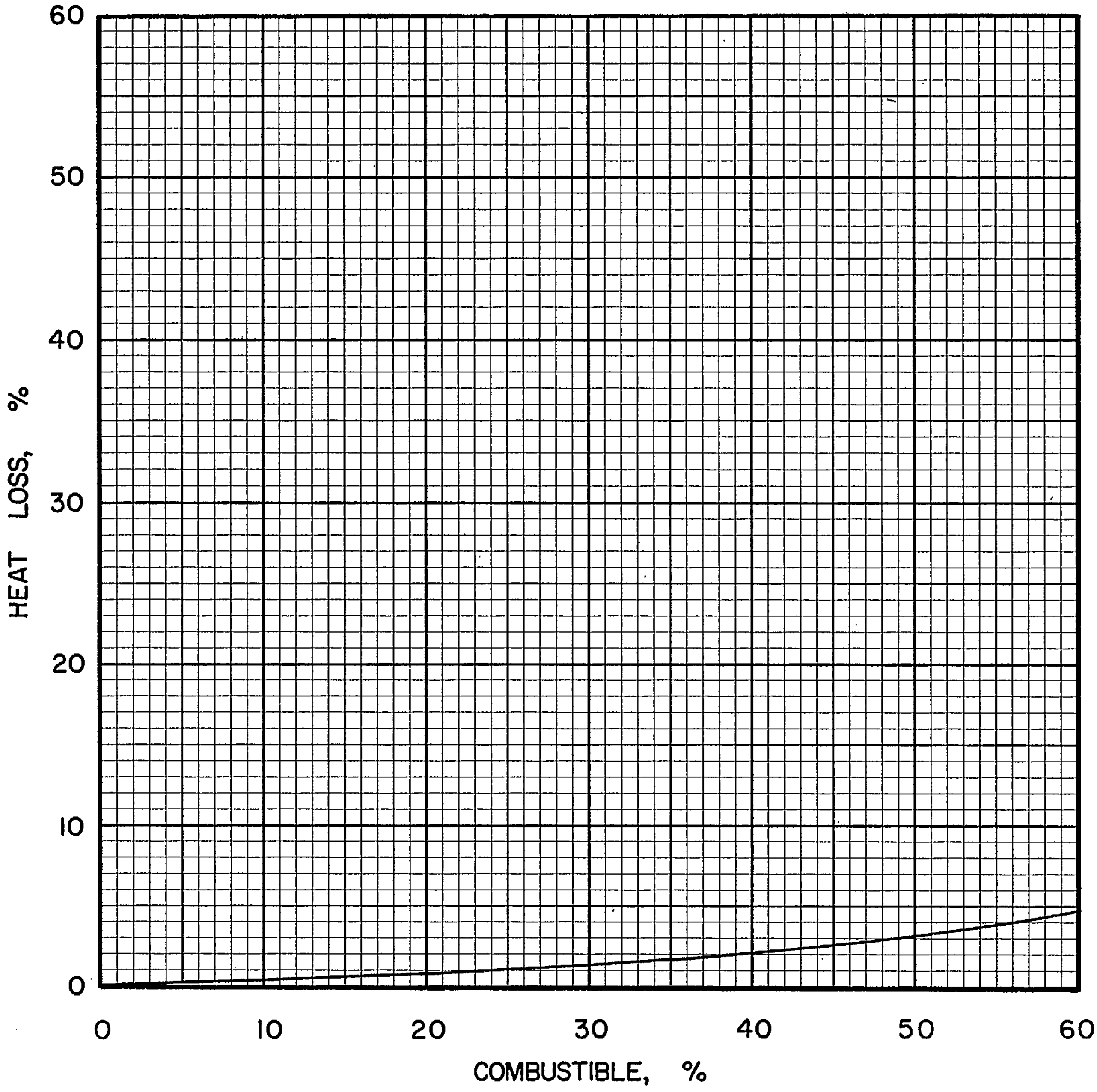


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·6·1

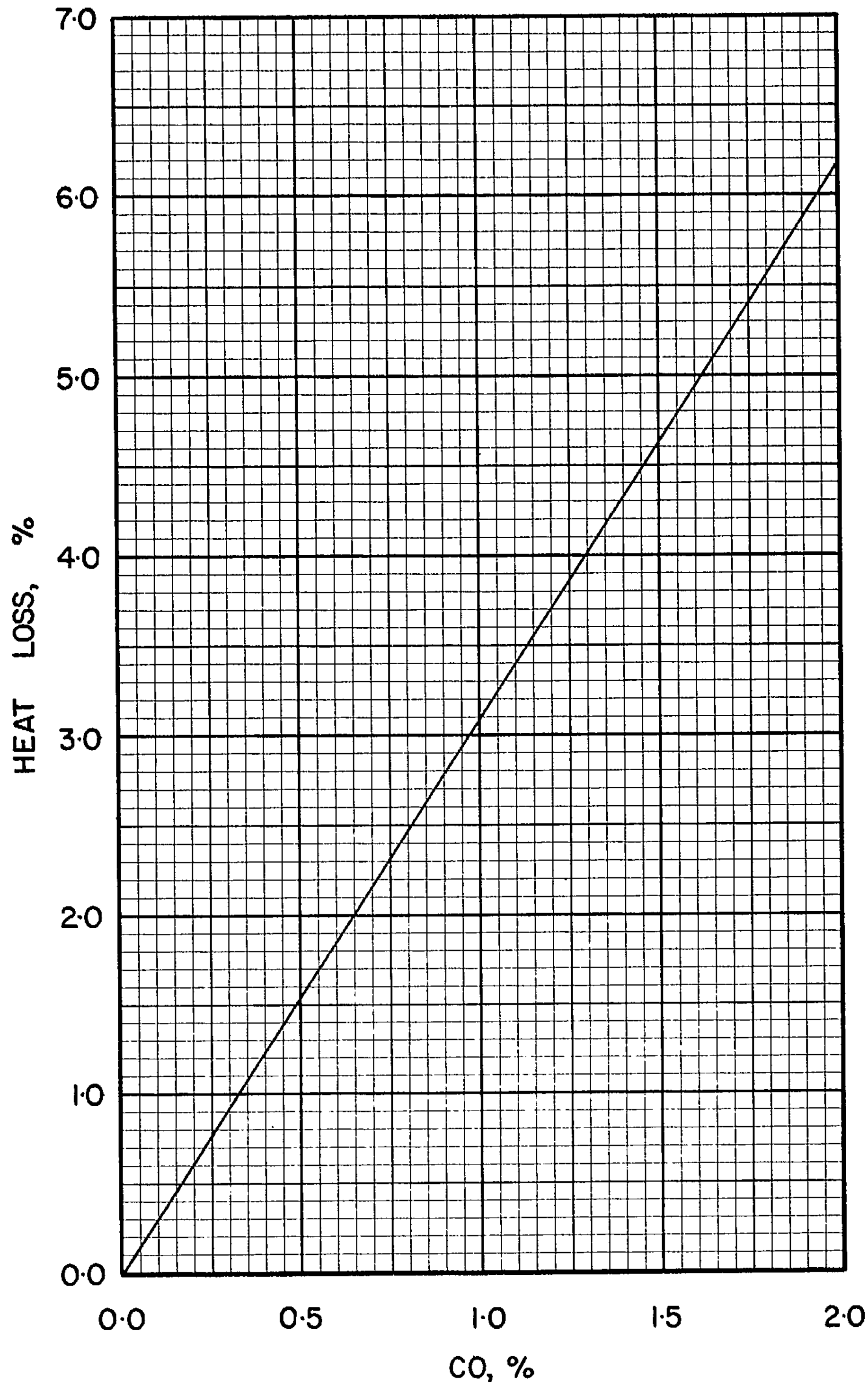


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·6·1

COAL NS 6-2, OLD SYDNEY, DEVCO, CAPE BRETON, 3/4 in. x 1/4 in.

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0387
Volatile Matter	0.3903
Fixed Carbon	0.5710
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8184
Hydrogen (H)	0.0544
Sulphur (S)	0.0225
Nitrogen (N)	0.0140
Oxygen (O)	0.0520
Ash	0.0387
Total	1.0000

Gross Calorific Value

Btu/lb:	14640
Btu/short ton:	29.28×10^6
Btu/long ton:	32.79×10^6
MJ/kg:	34.04

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 68.31	lb	
10^6 Btu	= 0.03415	short tons	
10^6 Btu	= 0.03049	long tons	

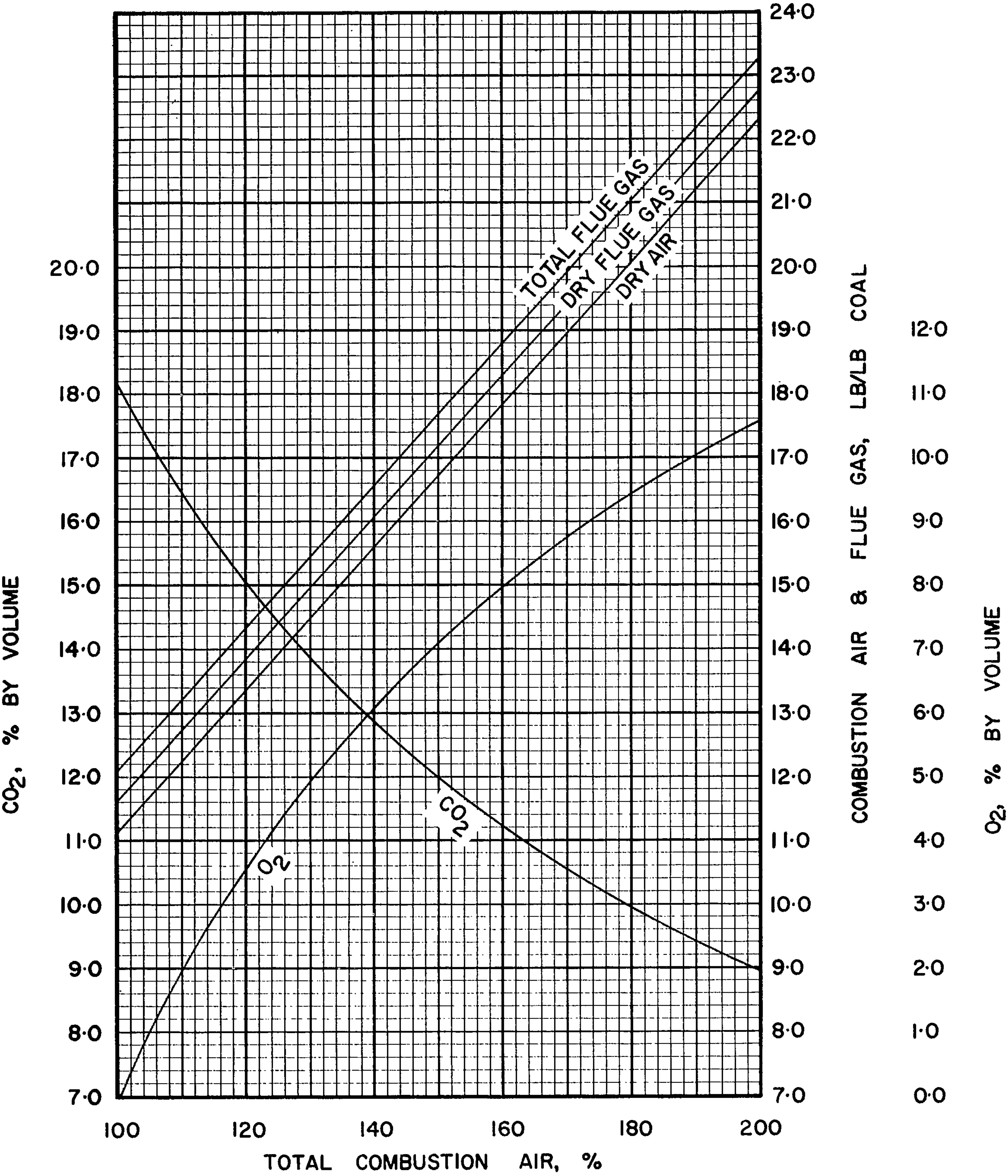


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

NS· 6·2

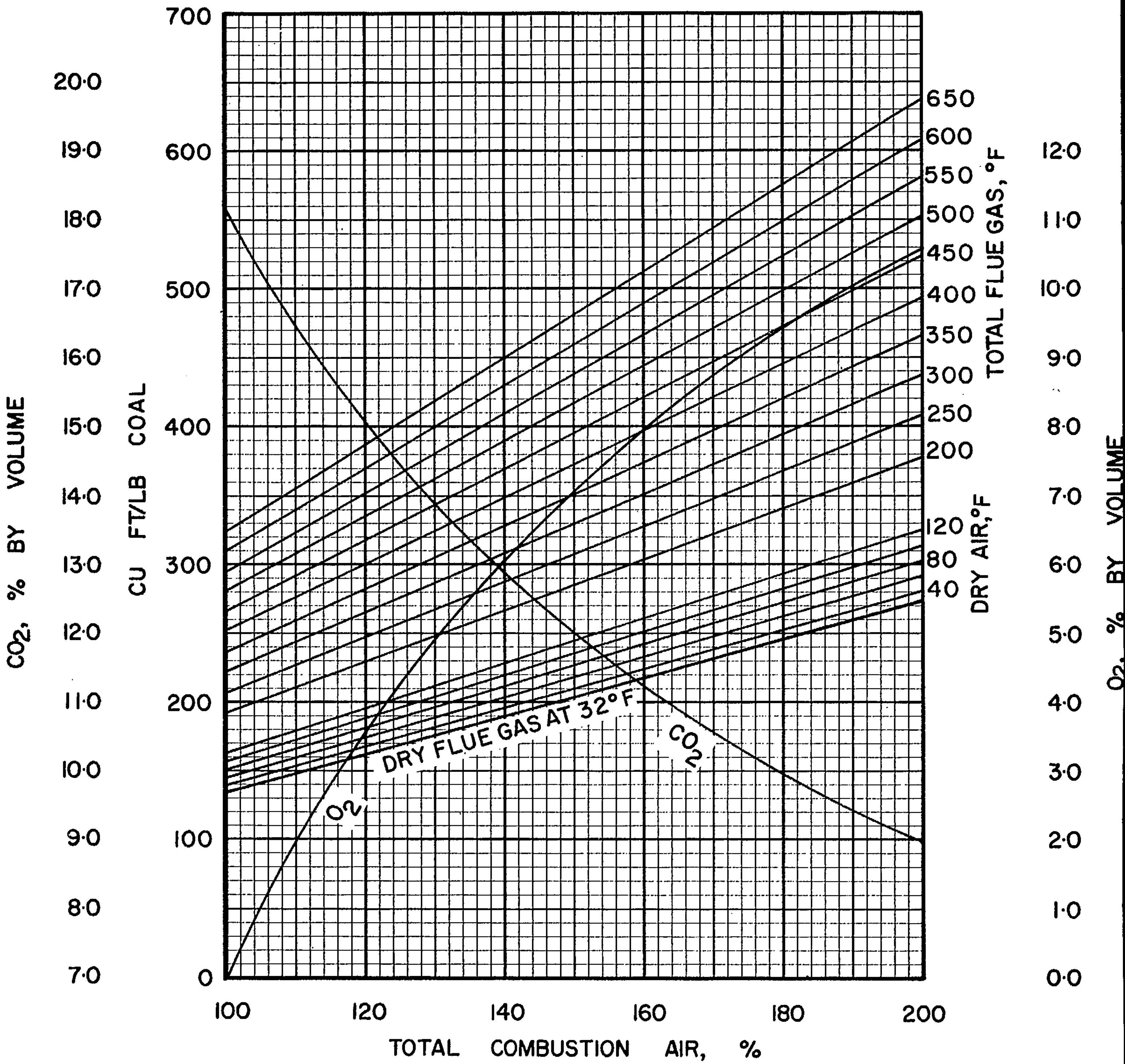


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS· 6·2

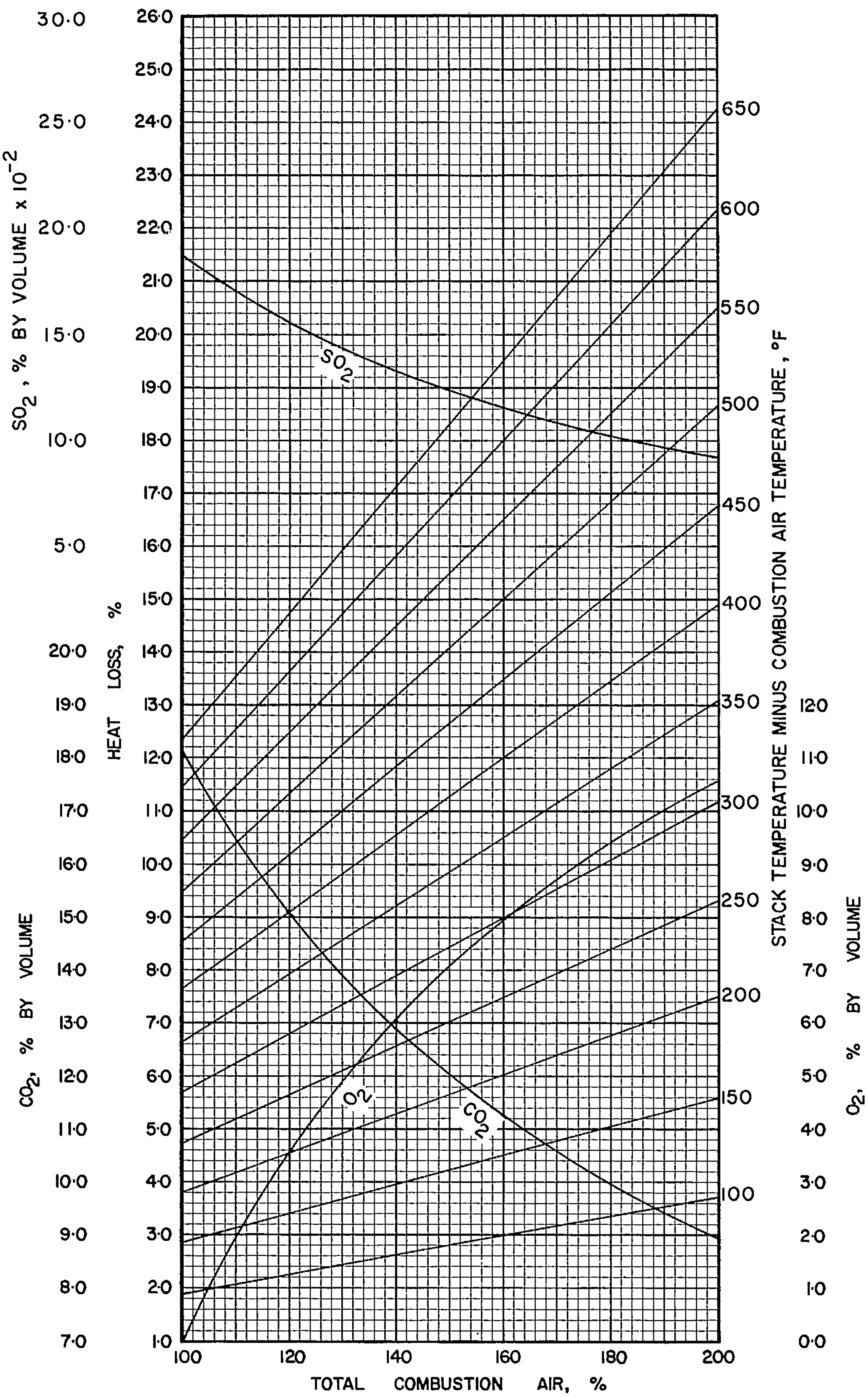


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·6·2

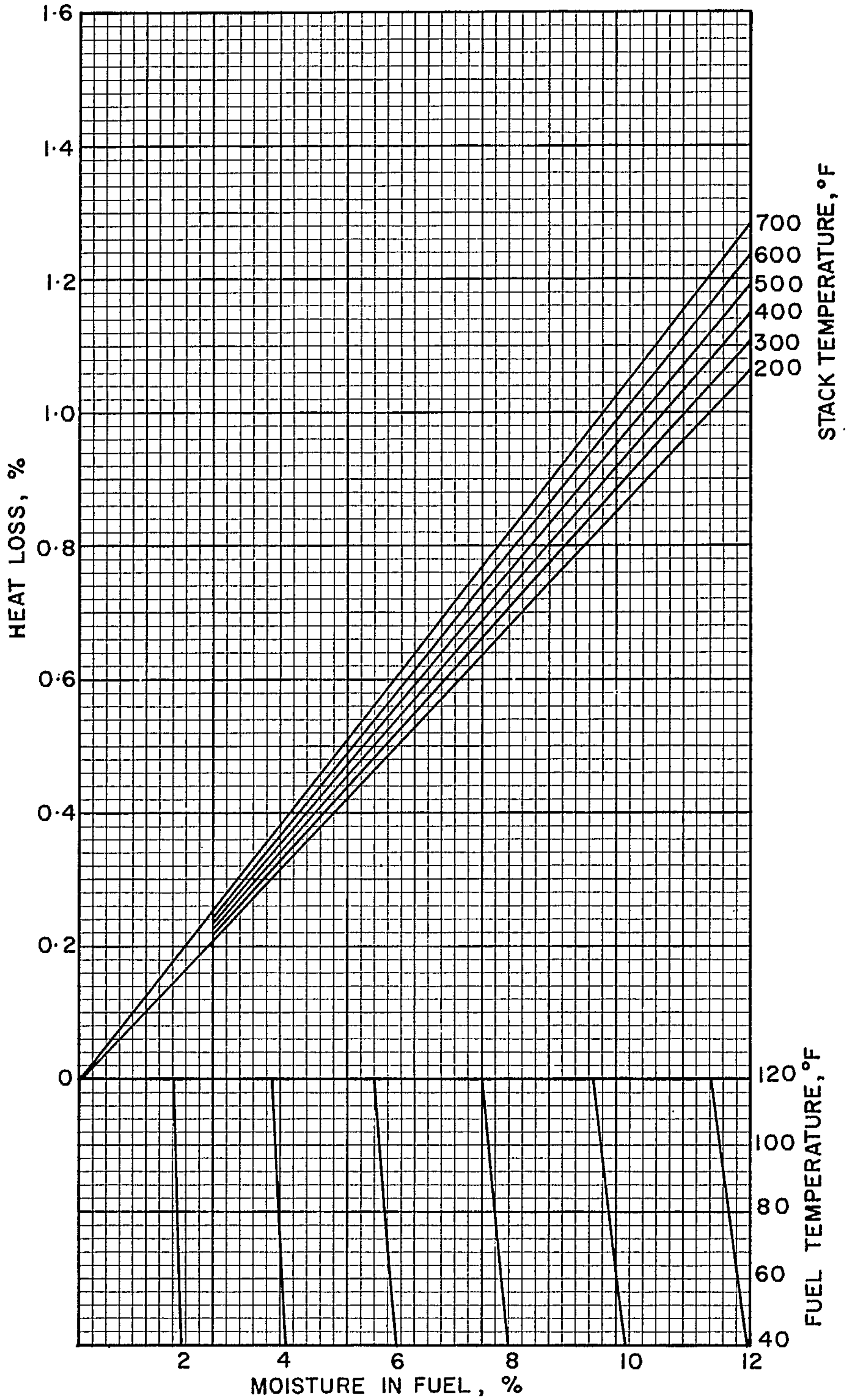


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS· 6·2

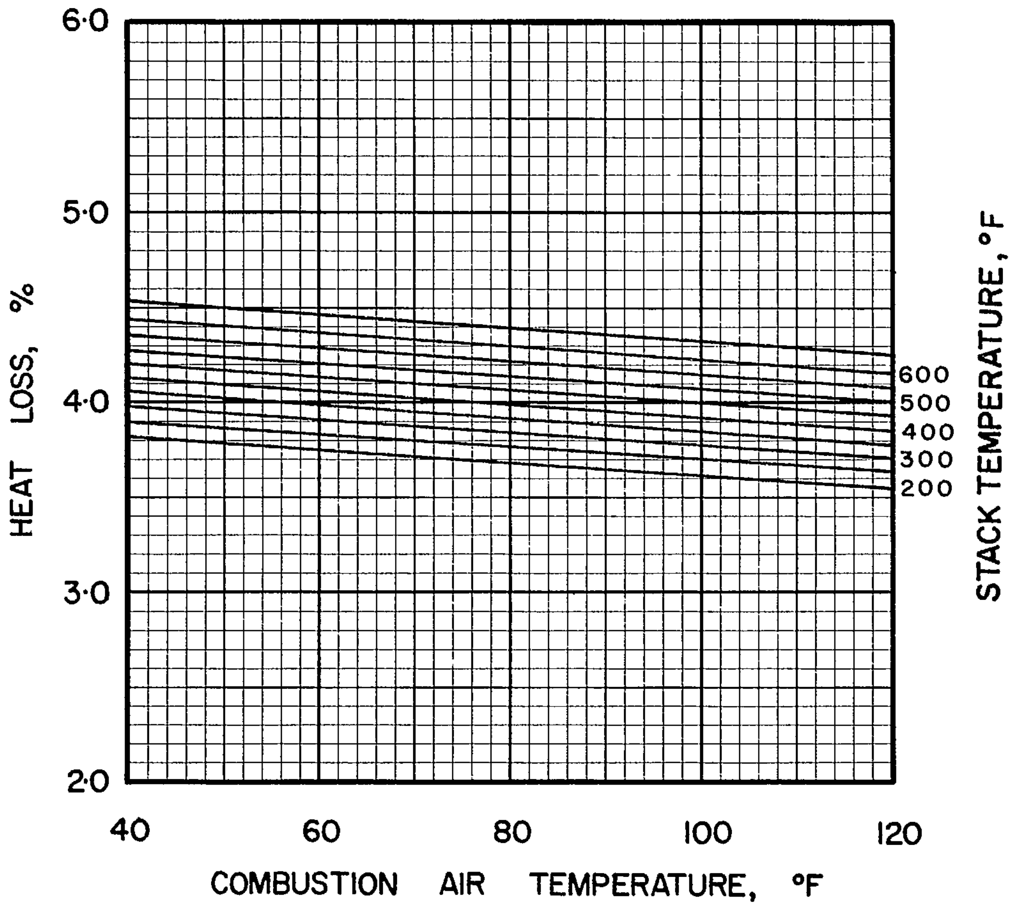


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS · 6 · 2

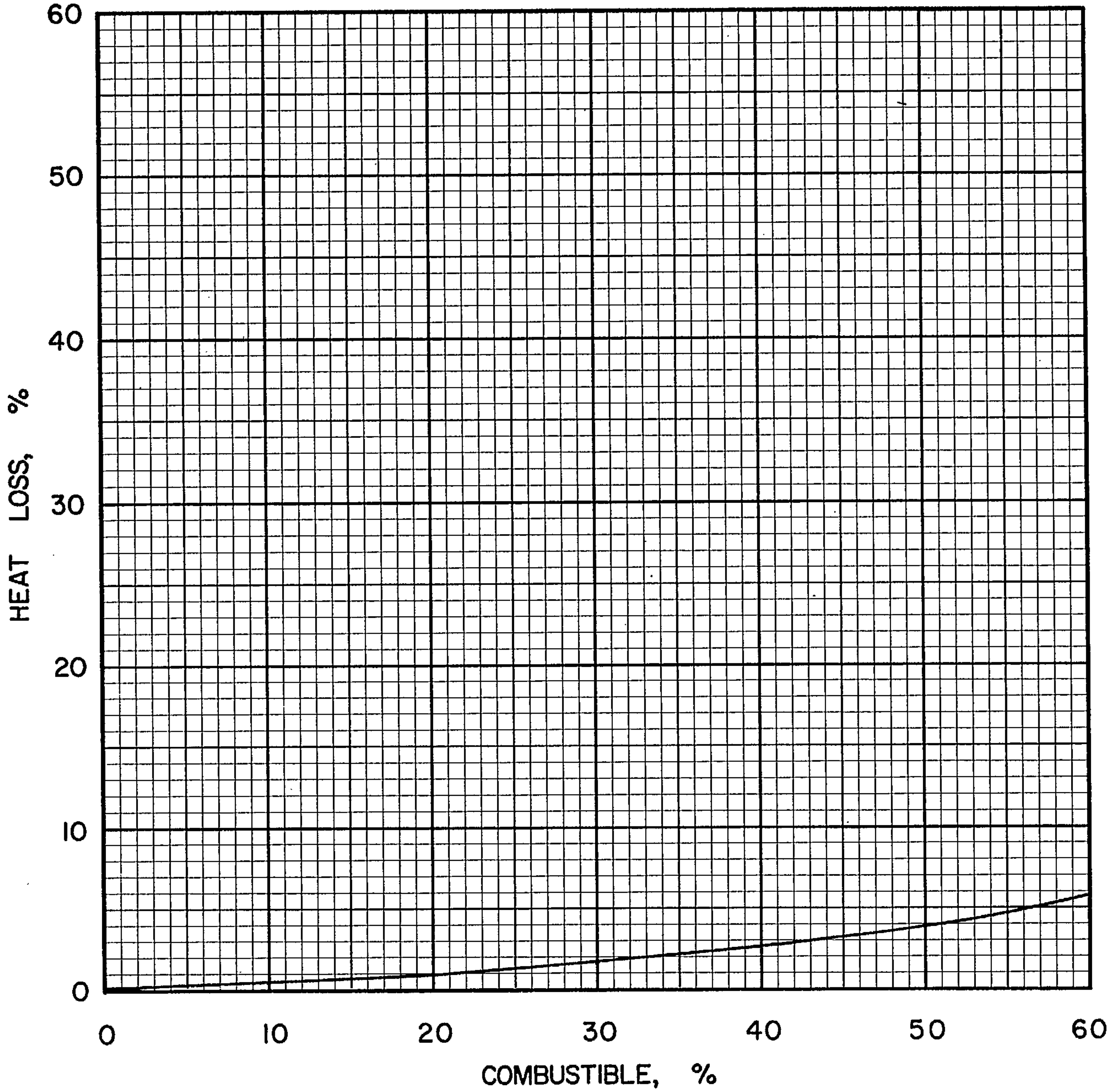


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·6·2

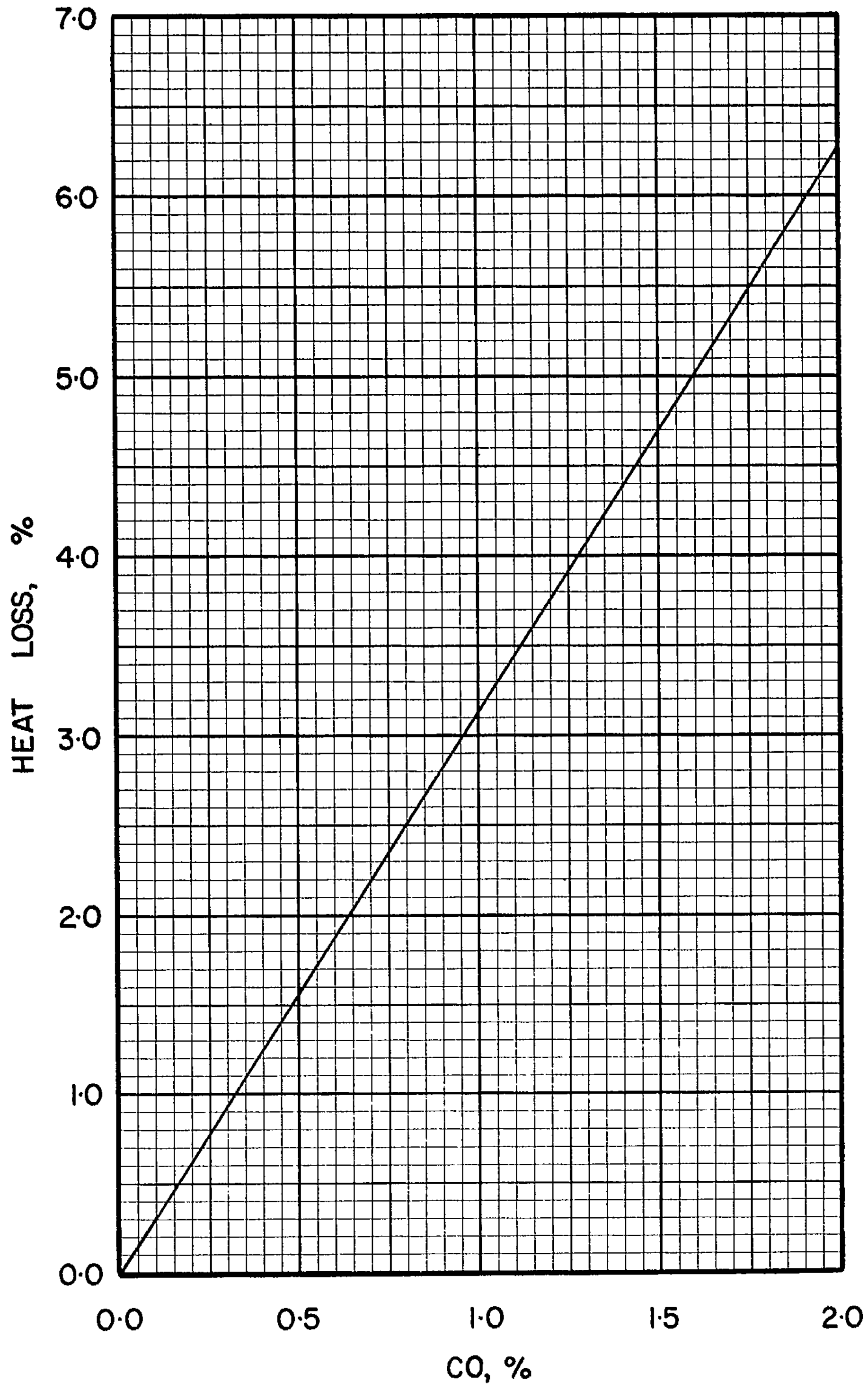


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 6·2

**COAL NS 6-3, OLD SYDNEY, DEVCO,
CAPE BRETON, 1 3/4 in. x 0**

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0662
Volatile Matter	0.3661
Fixed Carbon	0.5677
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7876
Hydrogen (H)	0.0511
Sulphur (S)	0.0201
Nitrogen (N)	0.0151
Oxygen (O)	0.0599
Ash	0.0662
Total	1.0000

Gross Calorific Value

Btu/lb:	14200
Btu/short ton:	28.40×10^6
Btu/long ton:	31.81×10^6
MJ/kg:	33.02

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 70.42	lb	
10^6 Btu	= 0.03521	short tons	
10^6 Btu	= 0.03144	long tons	

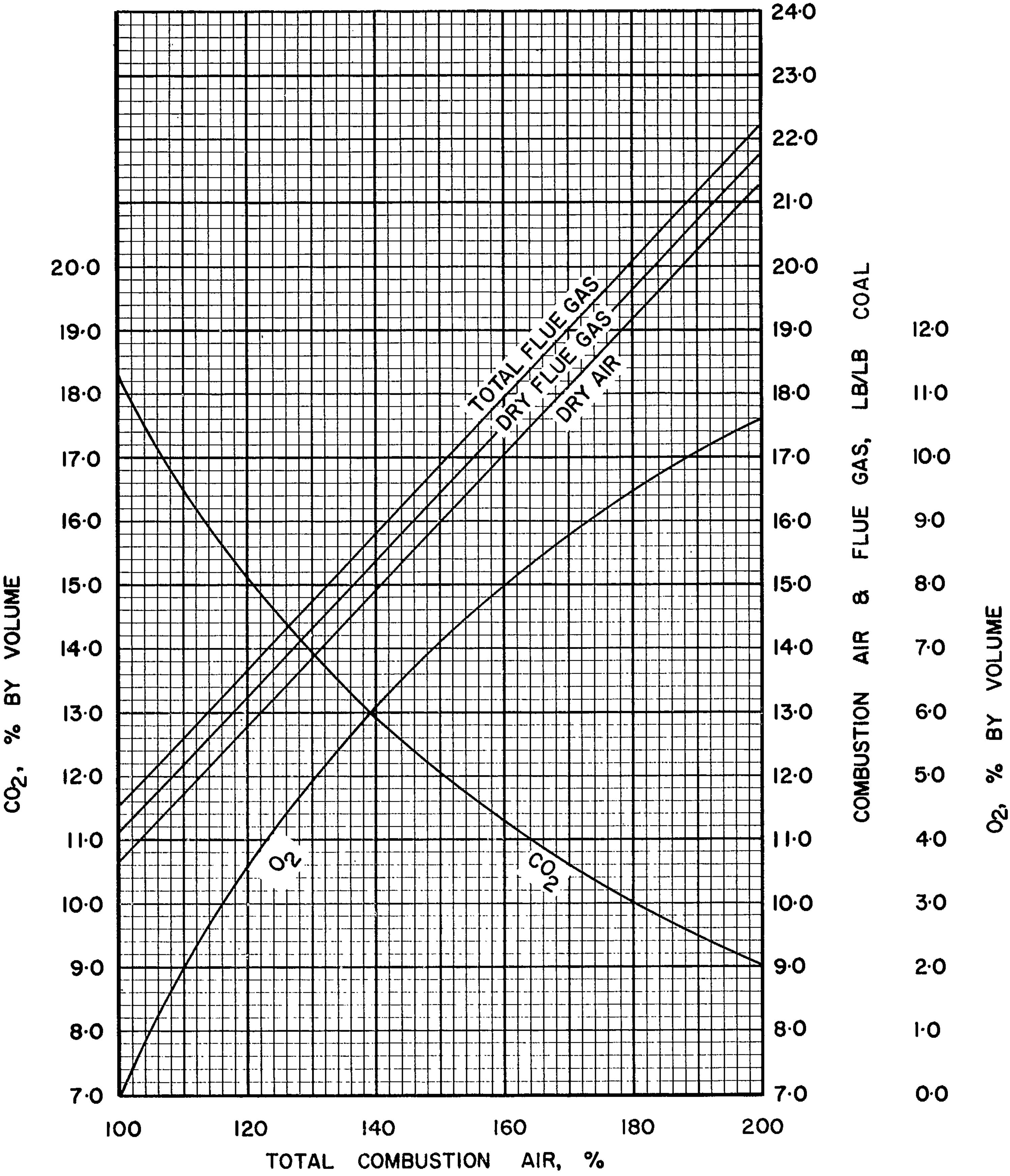


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·6·3

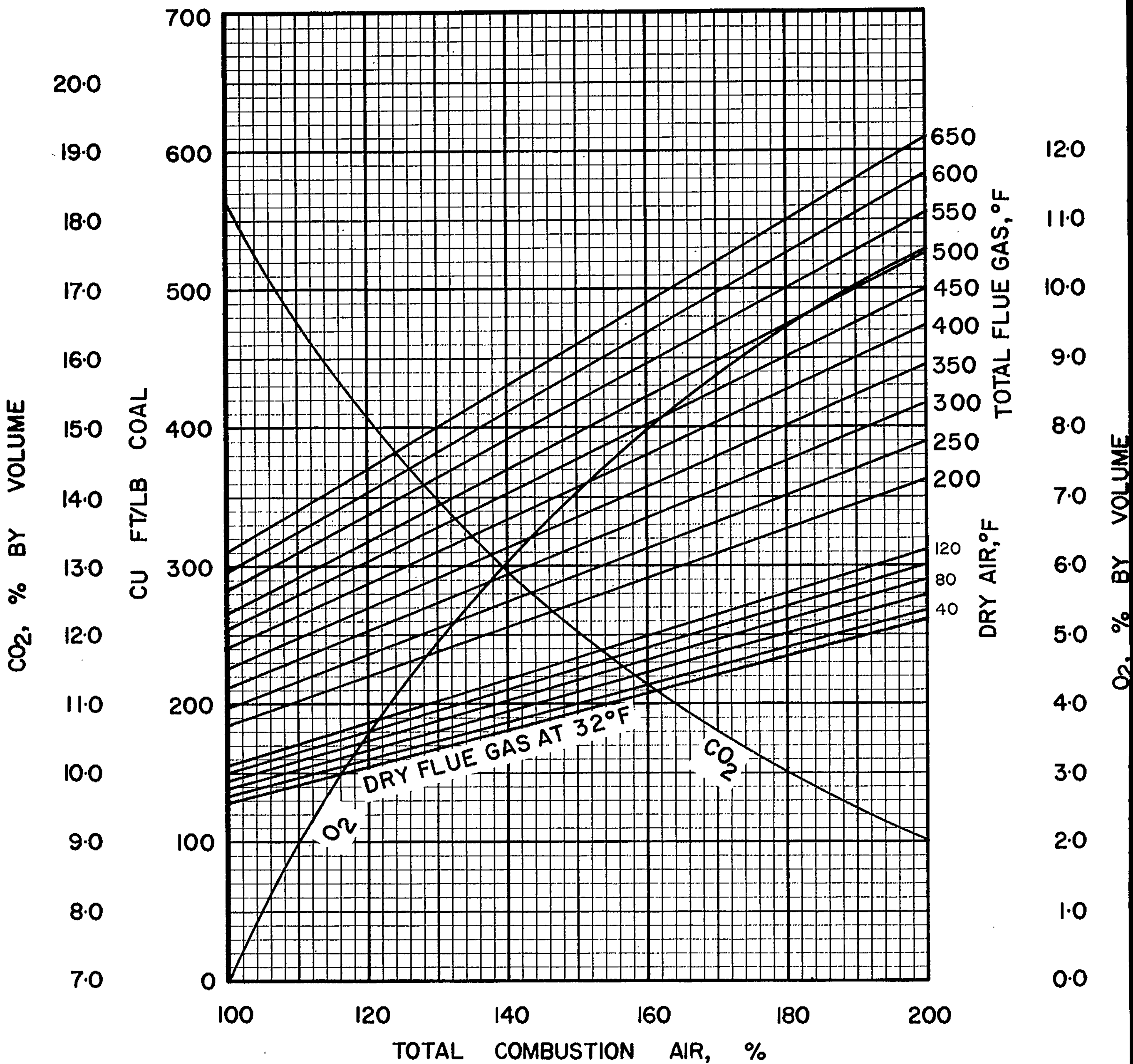


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS· 6·3

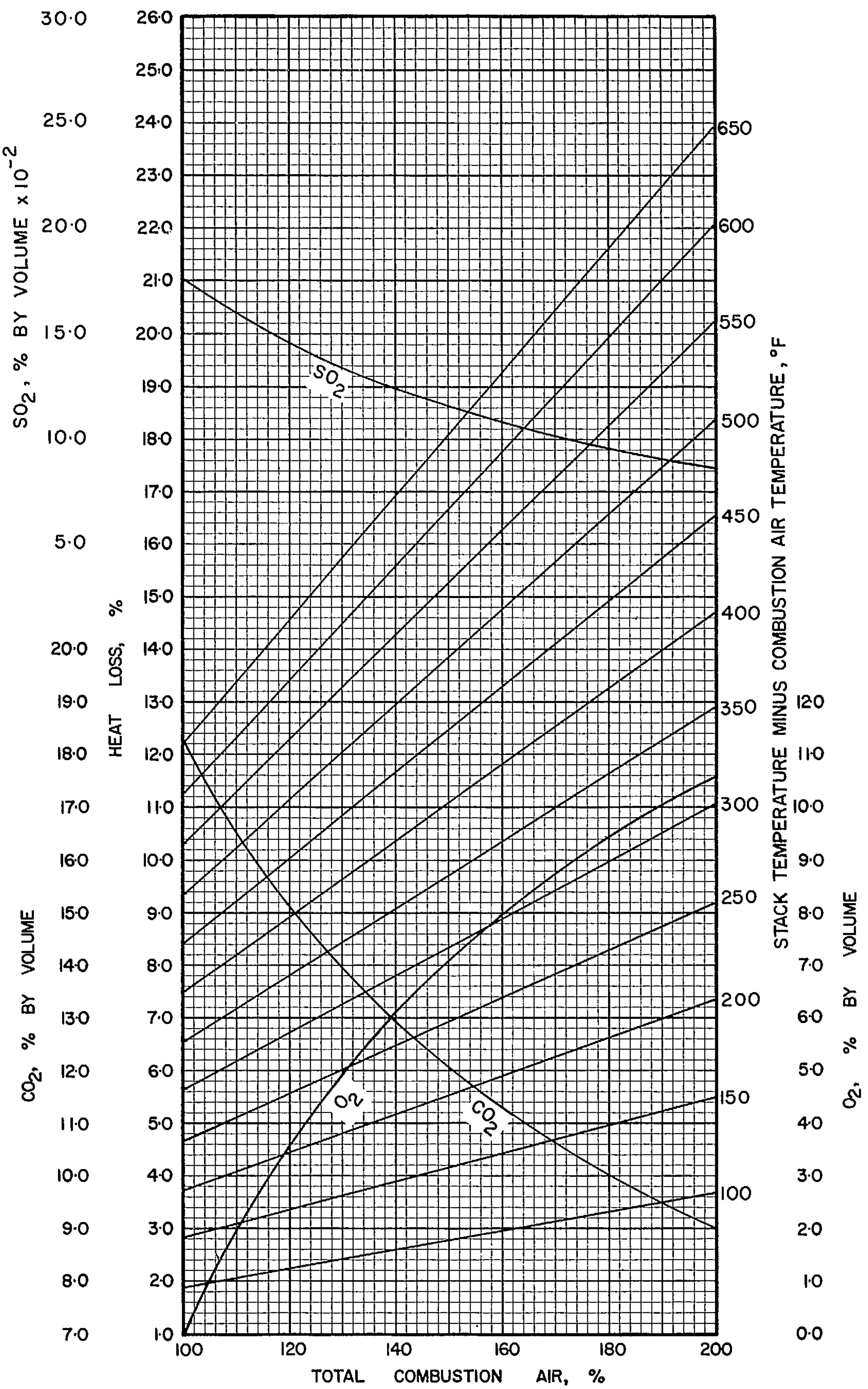


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·6·3

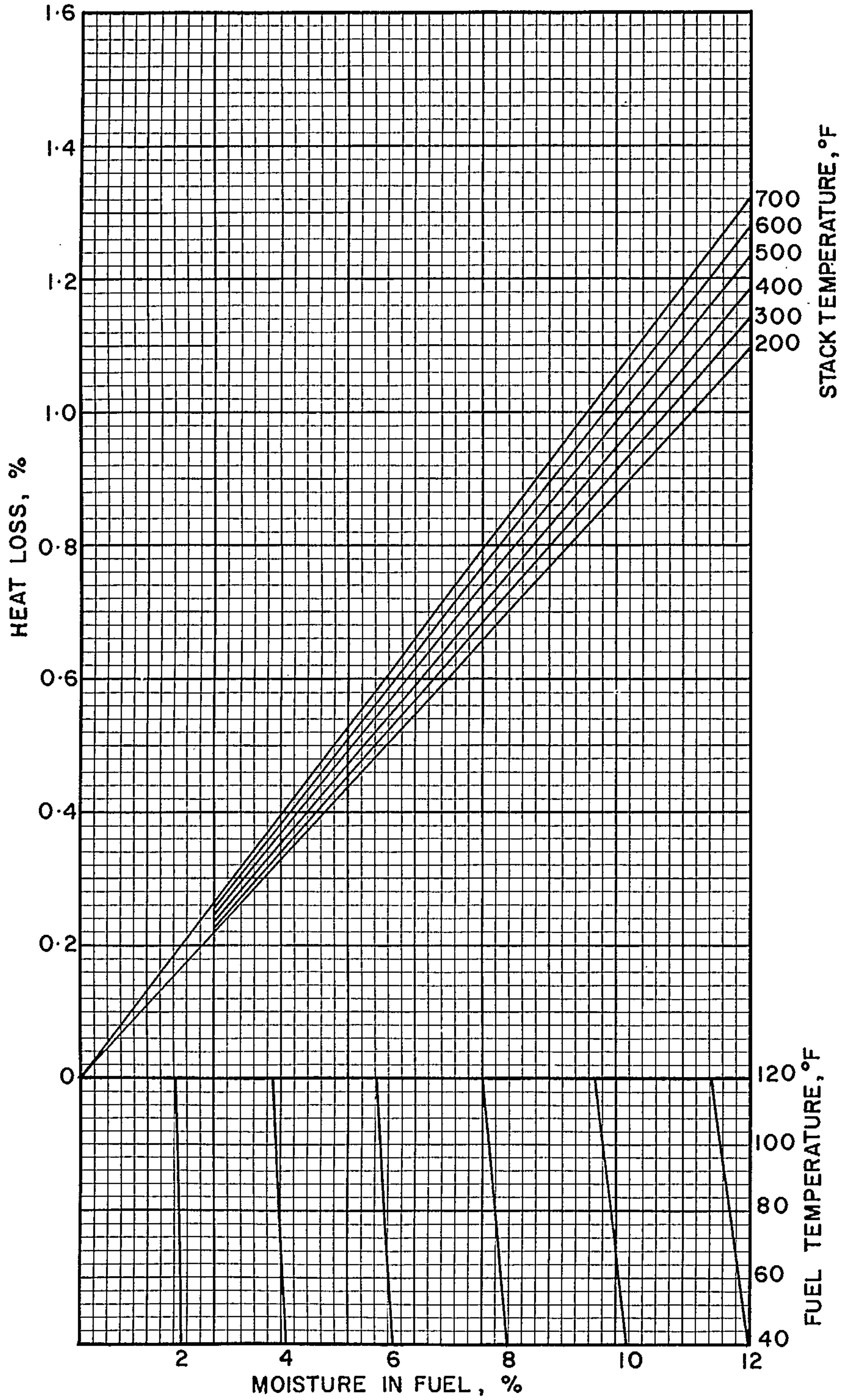


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·6·3

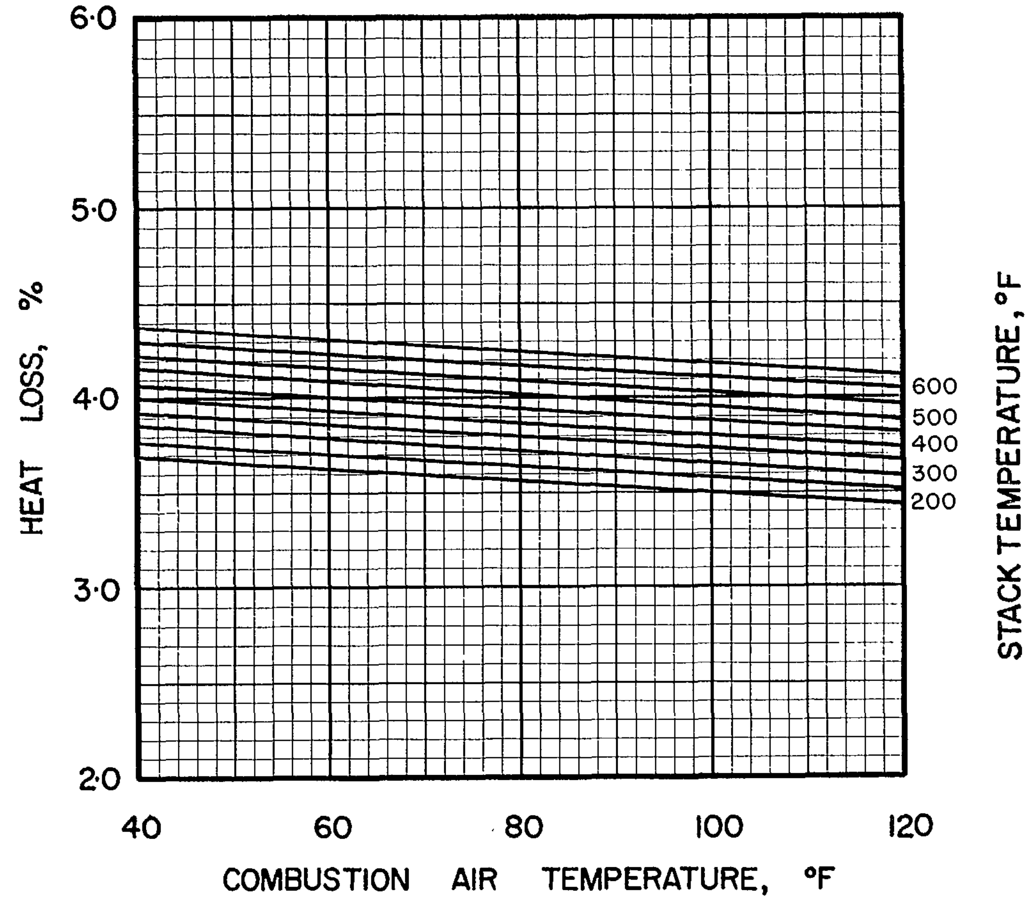


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS· 6·3

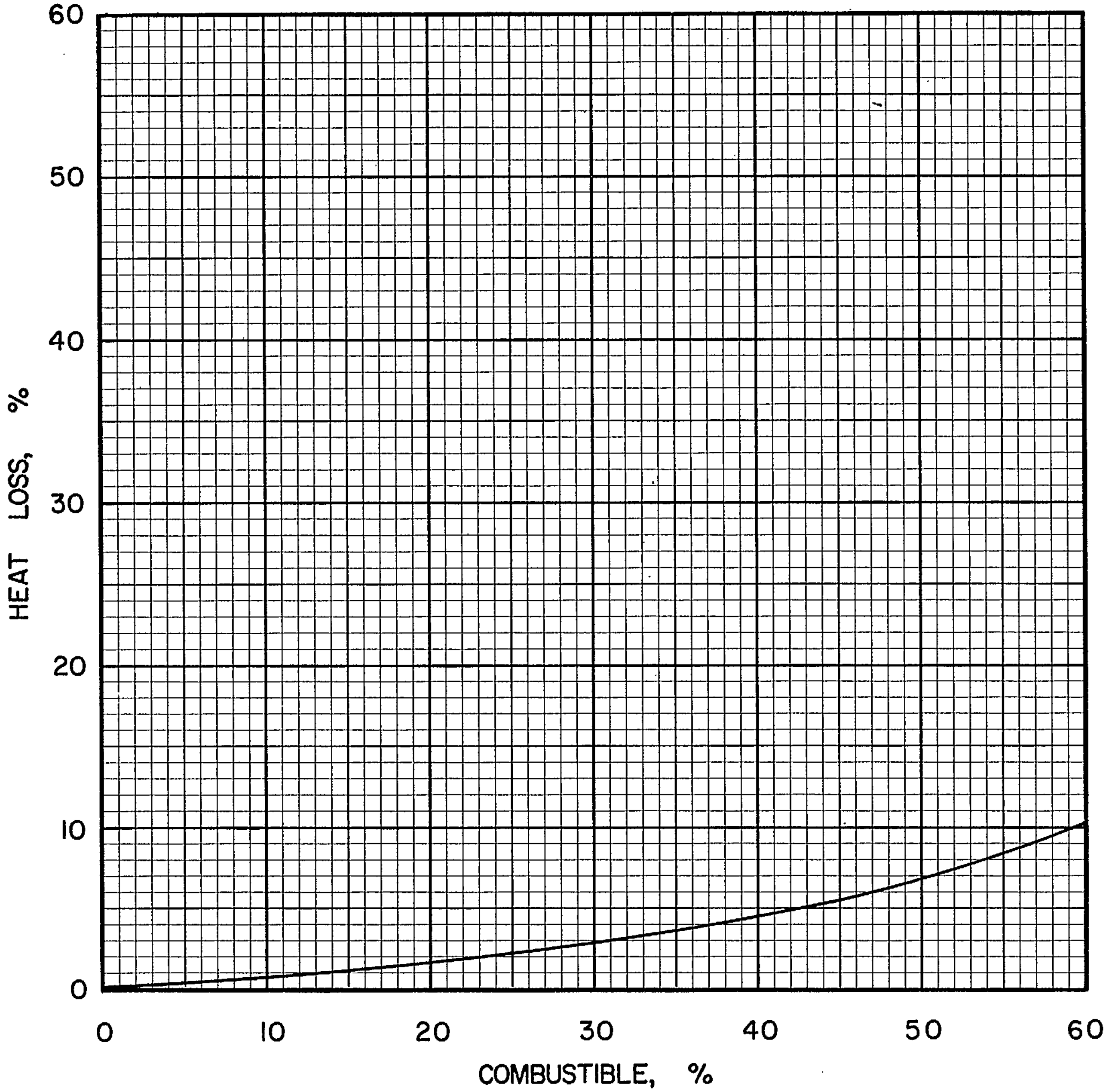


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·6·3

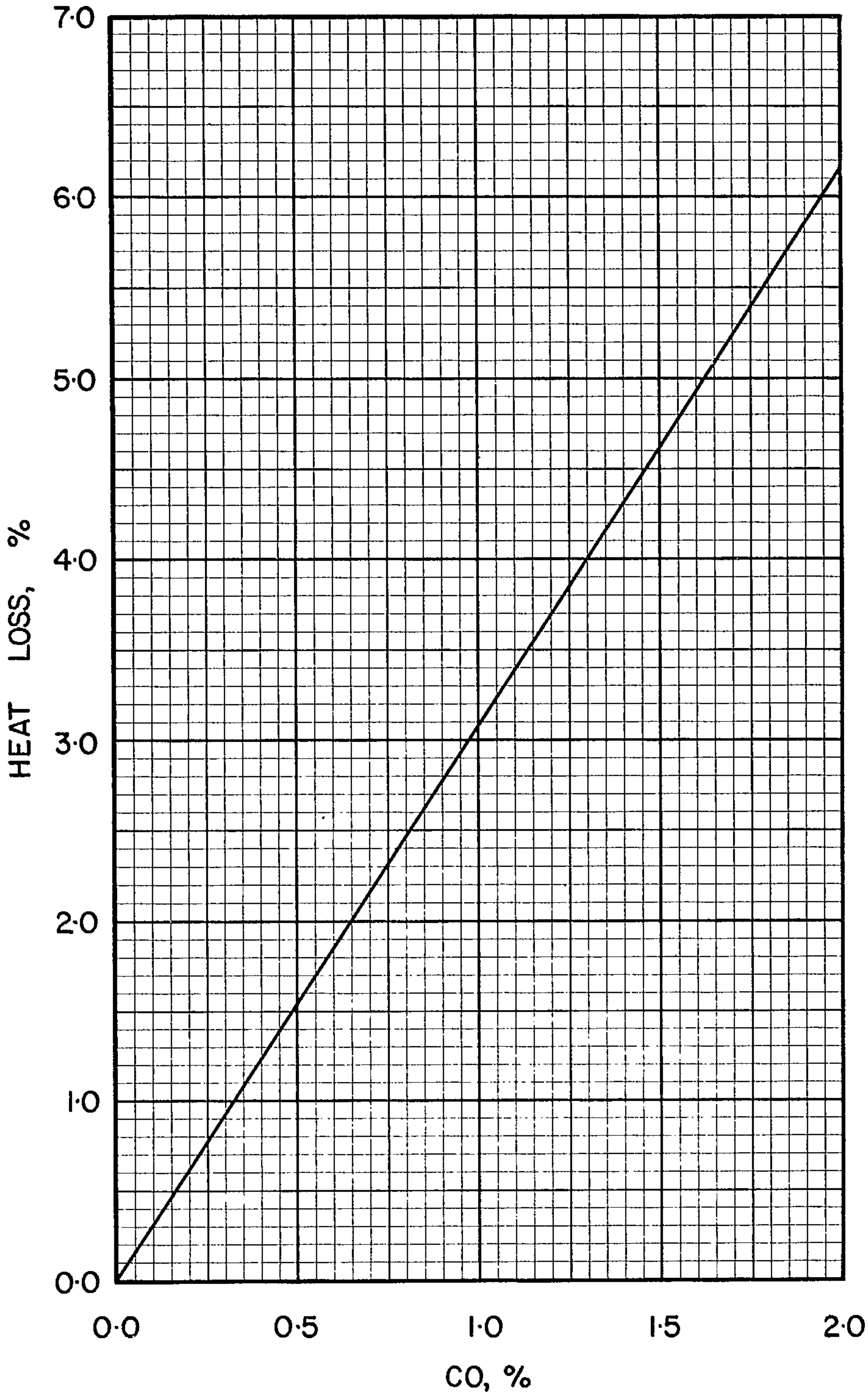


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS· 6·3

COAL NS 6-4, OLD SYDNEY, DEVCO, CAPE BRETON, – 1/4 in.

Typical Moisture Range: 0–6%

Proximate Analysis (lb/lb dry coal)

Ash	0.0908
Volatile Matter	0.3602
Fixed Carbon	0.5490
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7682
Hydrogen (H)	0.0501
Sulphur (S)	0.0258
Nitrogen (N)	0.0158
Oxygen (O)	0.0493
Ash	0.0908
Total	1.0000

Gross Calorific Value

Btu/lb:	13980
Btu/short ton:	27.96×10^6
Btu/long ton:	31.32×10^6
MJ/kg:	32.51

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 71.53 lb
10^6 Btu = 0.03577 short tons
10^6 Btu = 0.03193 long tons

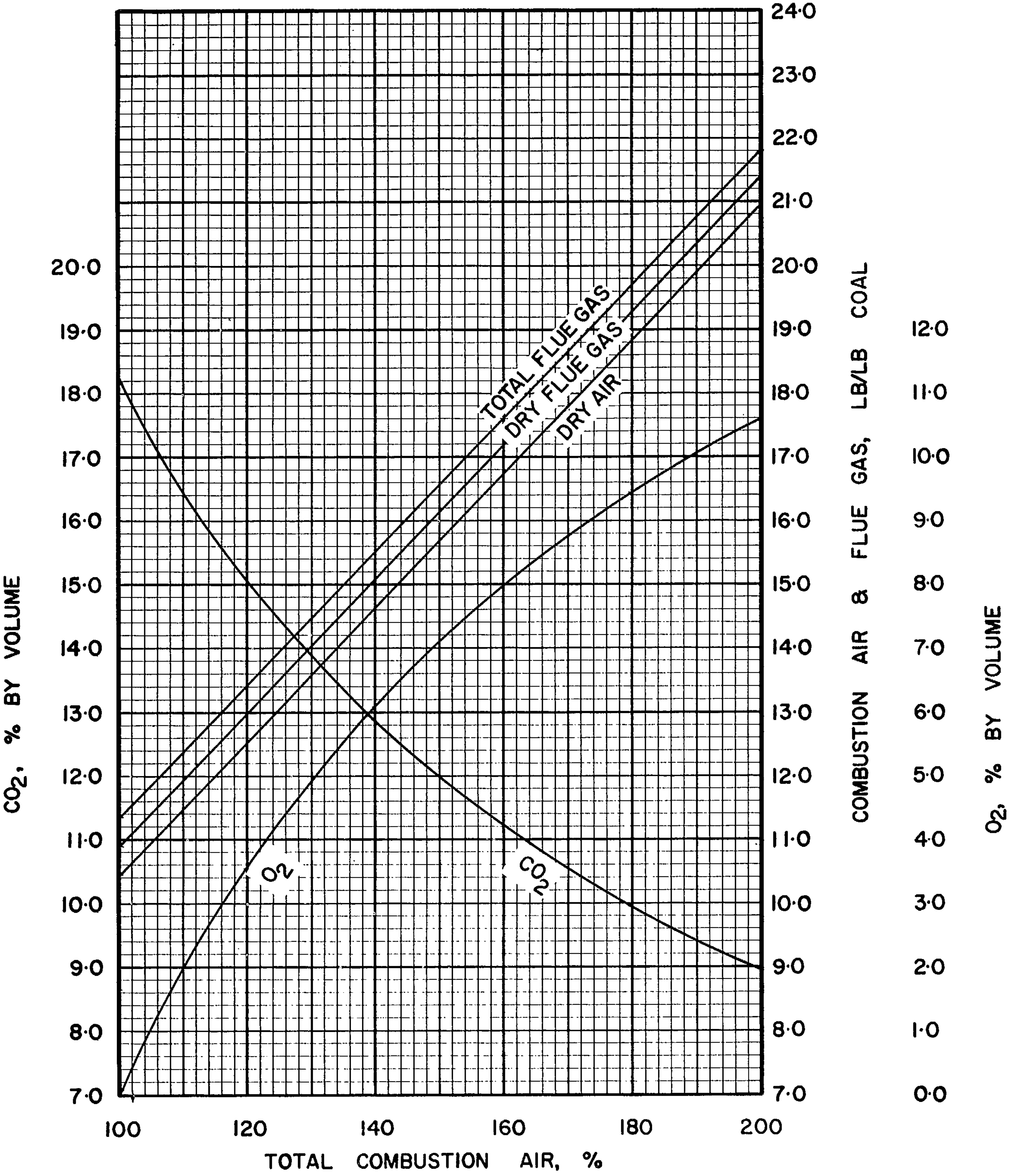


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NS·6·4

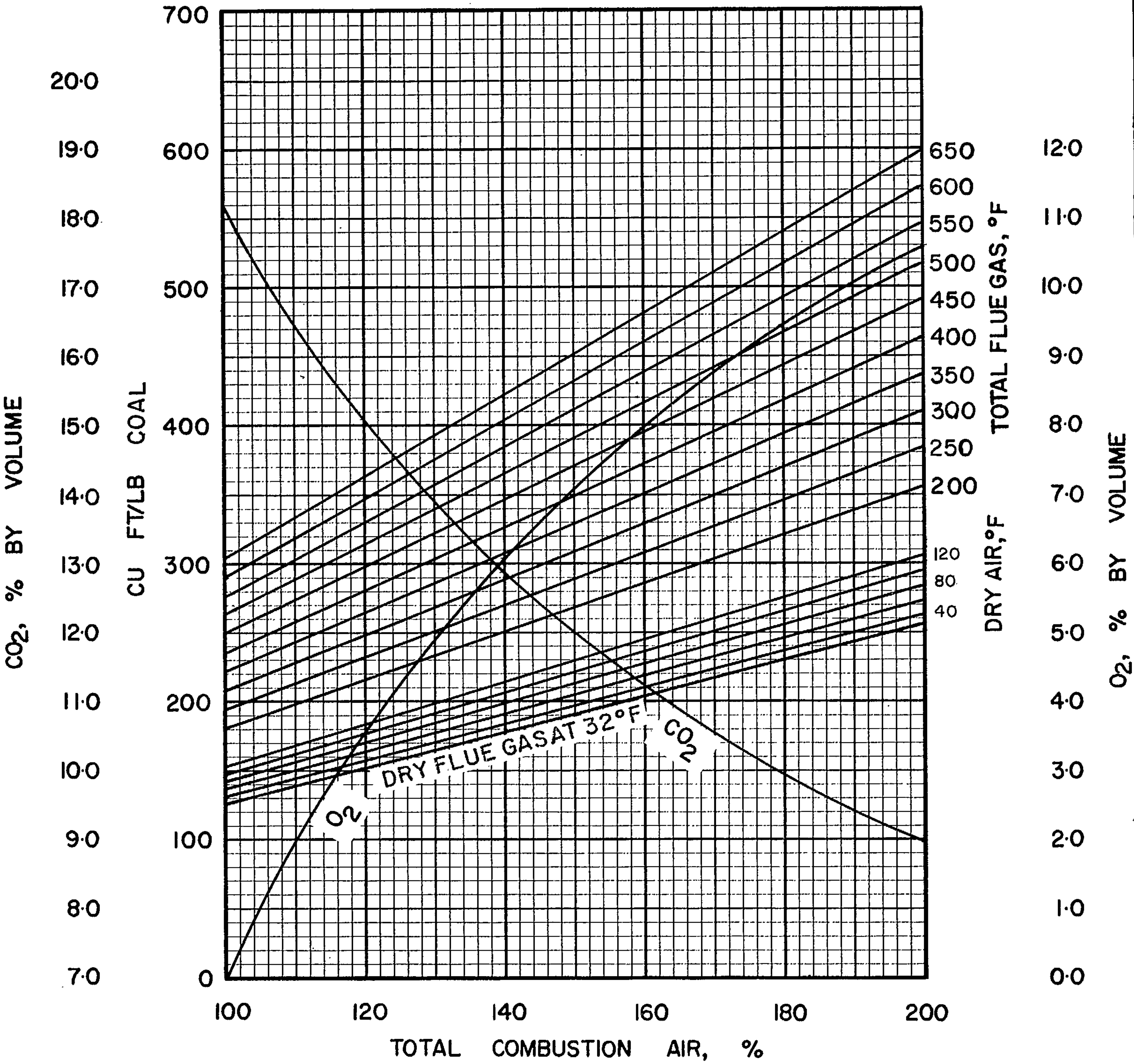


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS·6·4

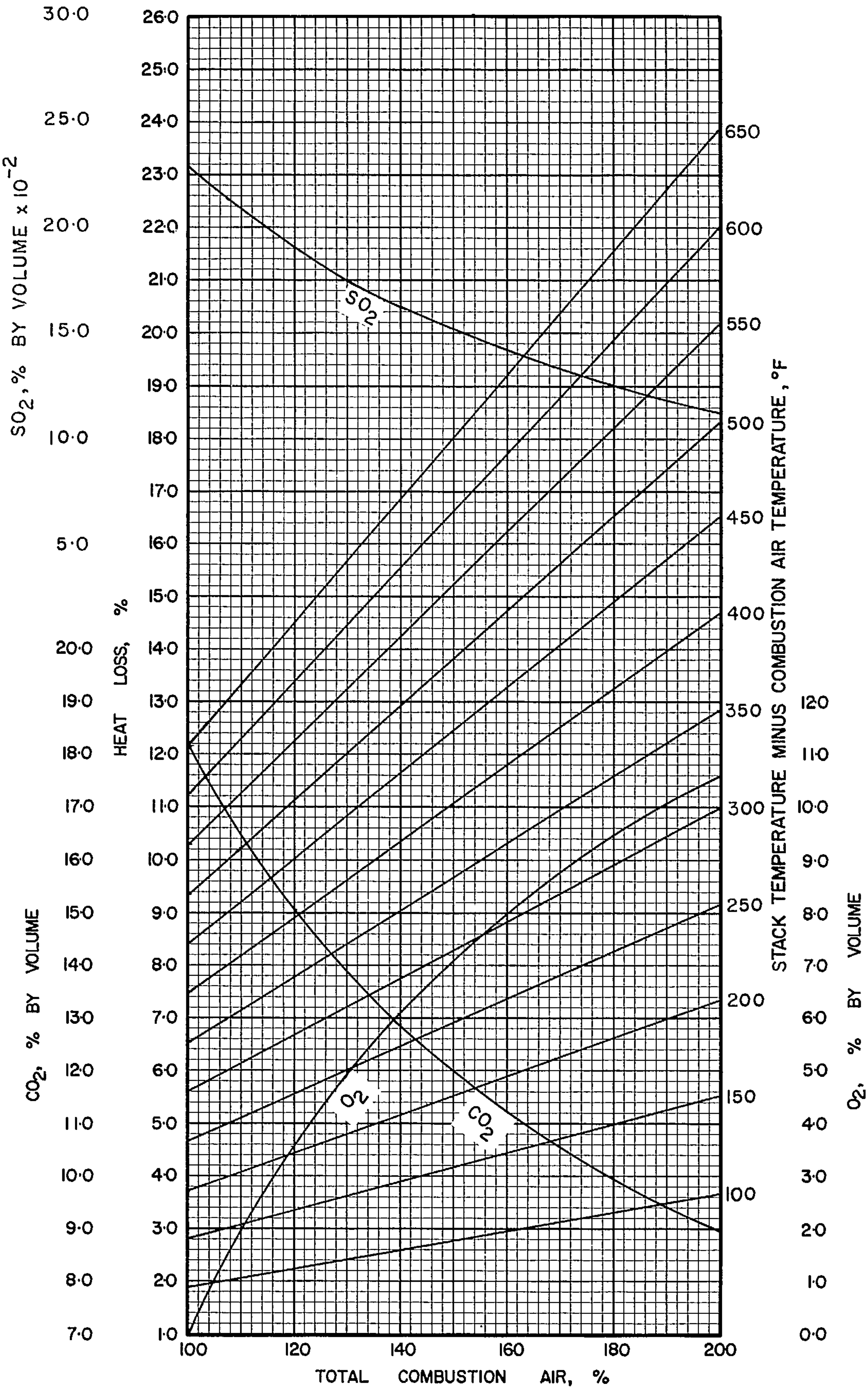


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS· 6·4

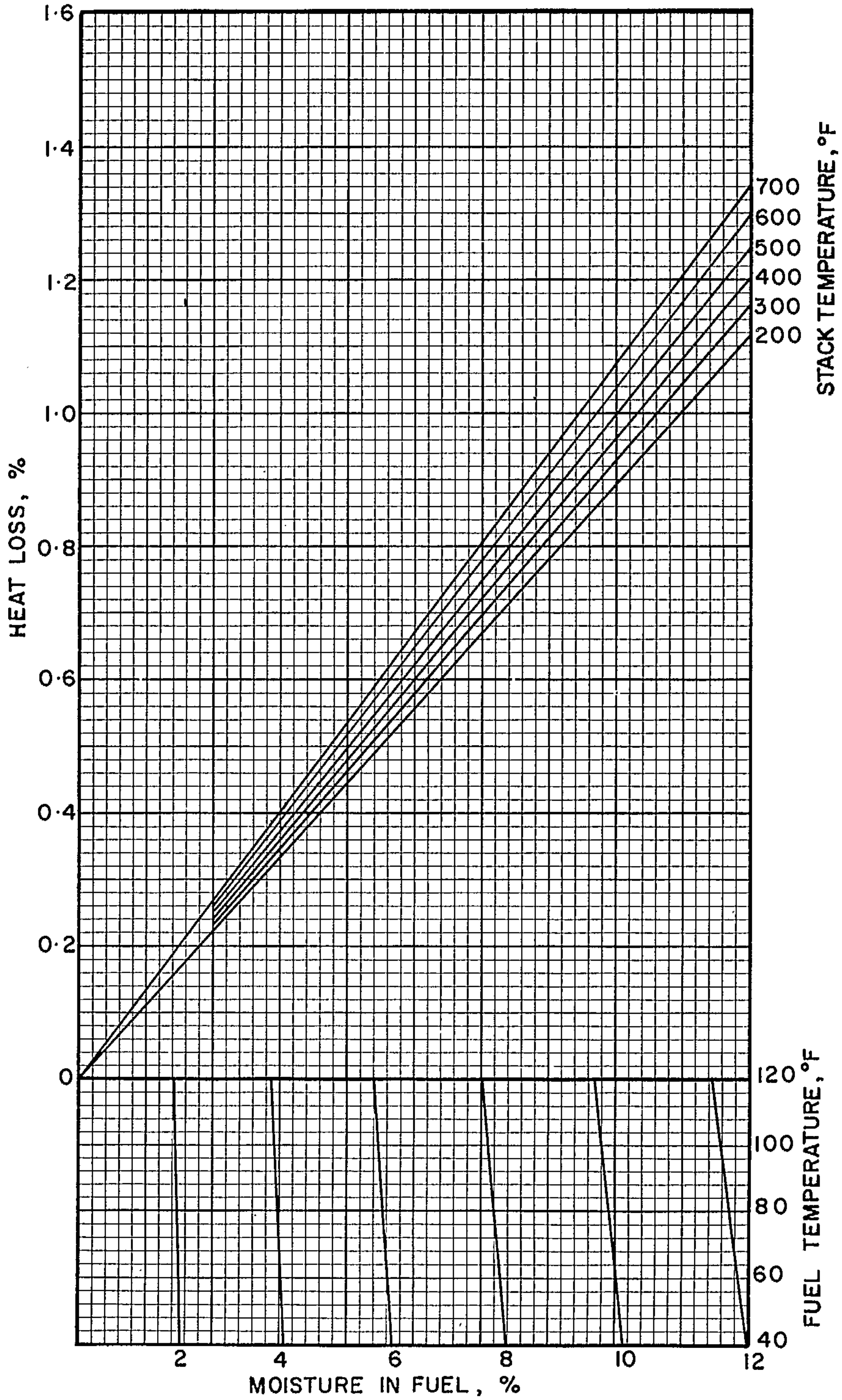


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NS·6·4

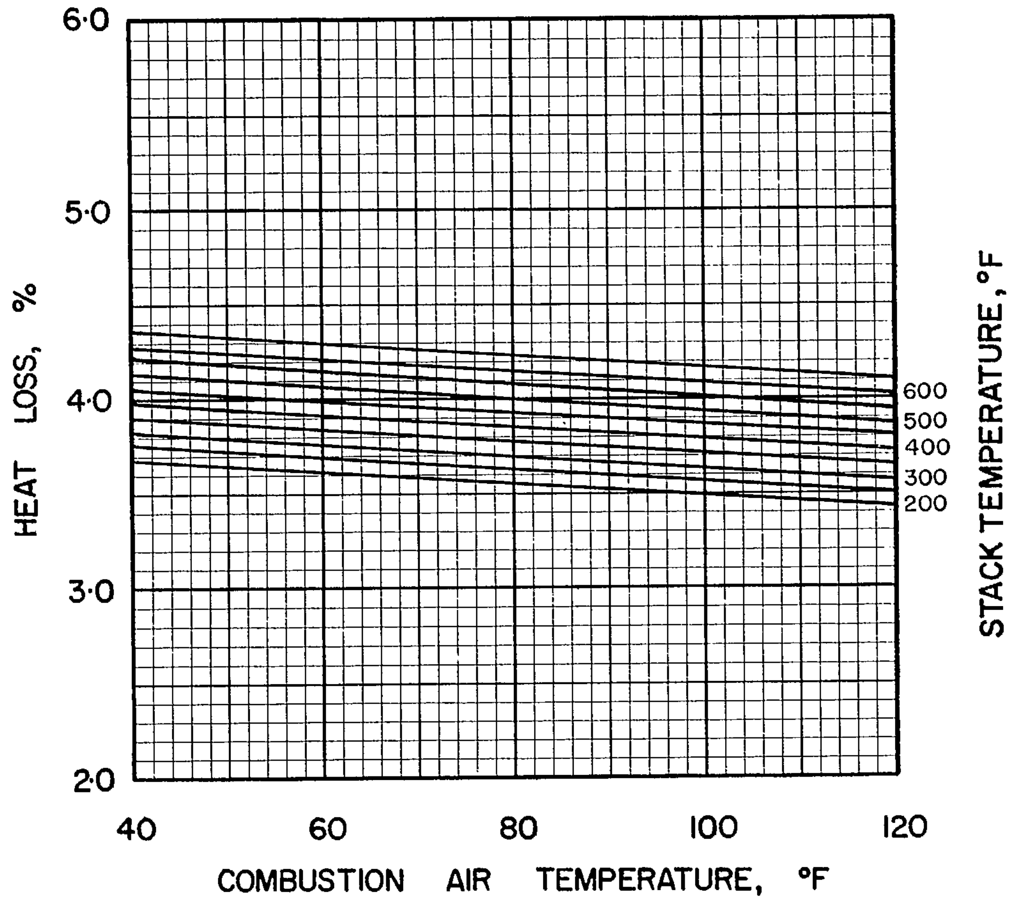


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS· 6· 4

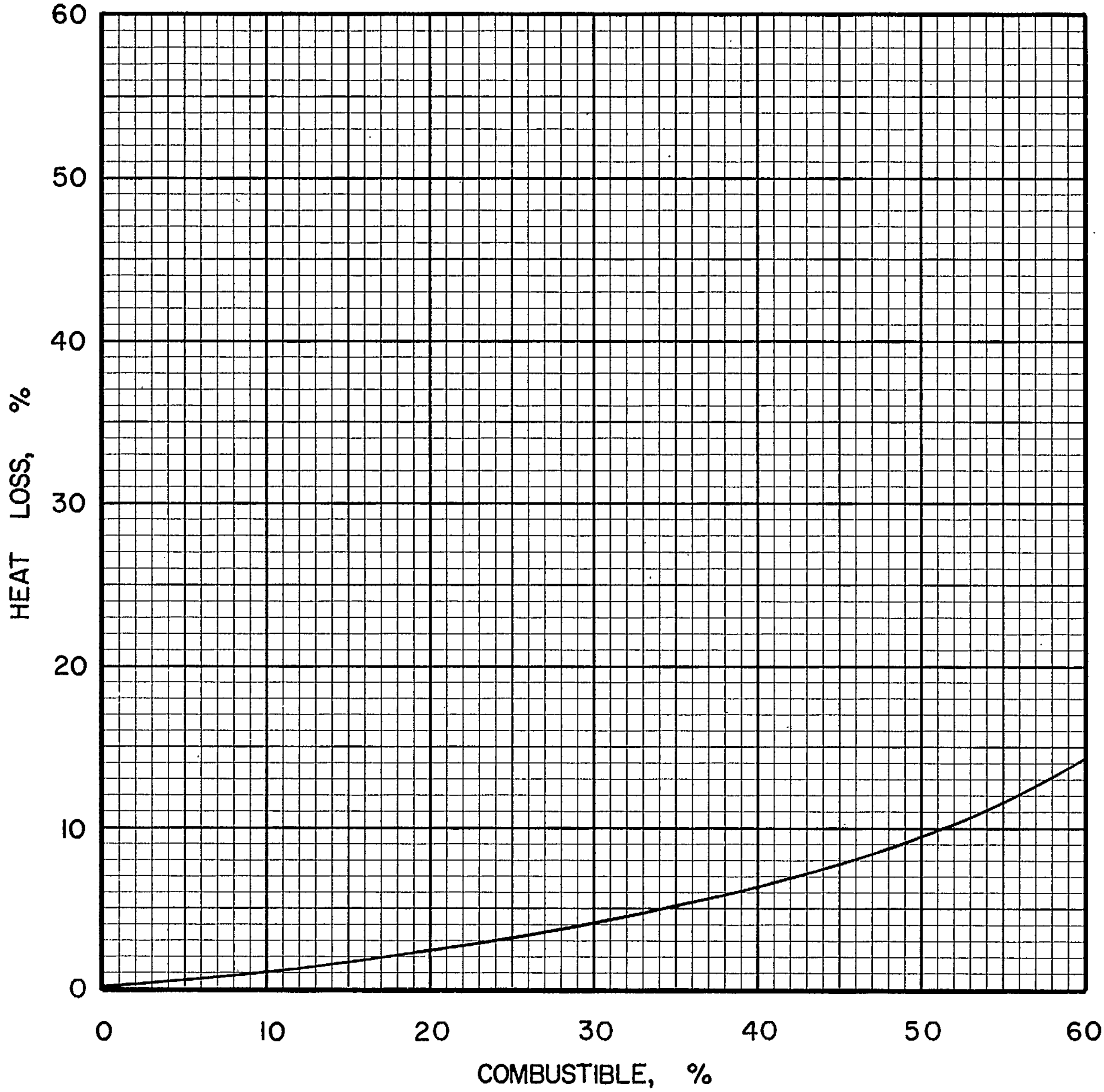


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·6·4

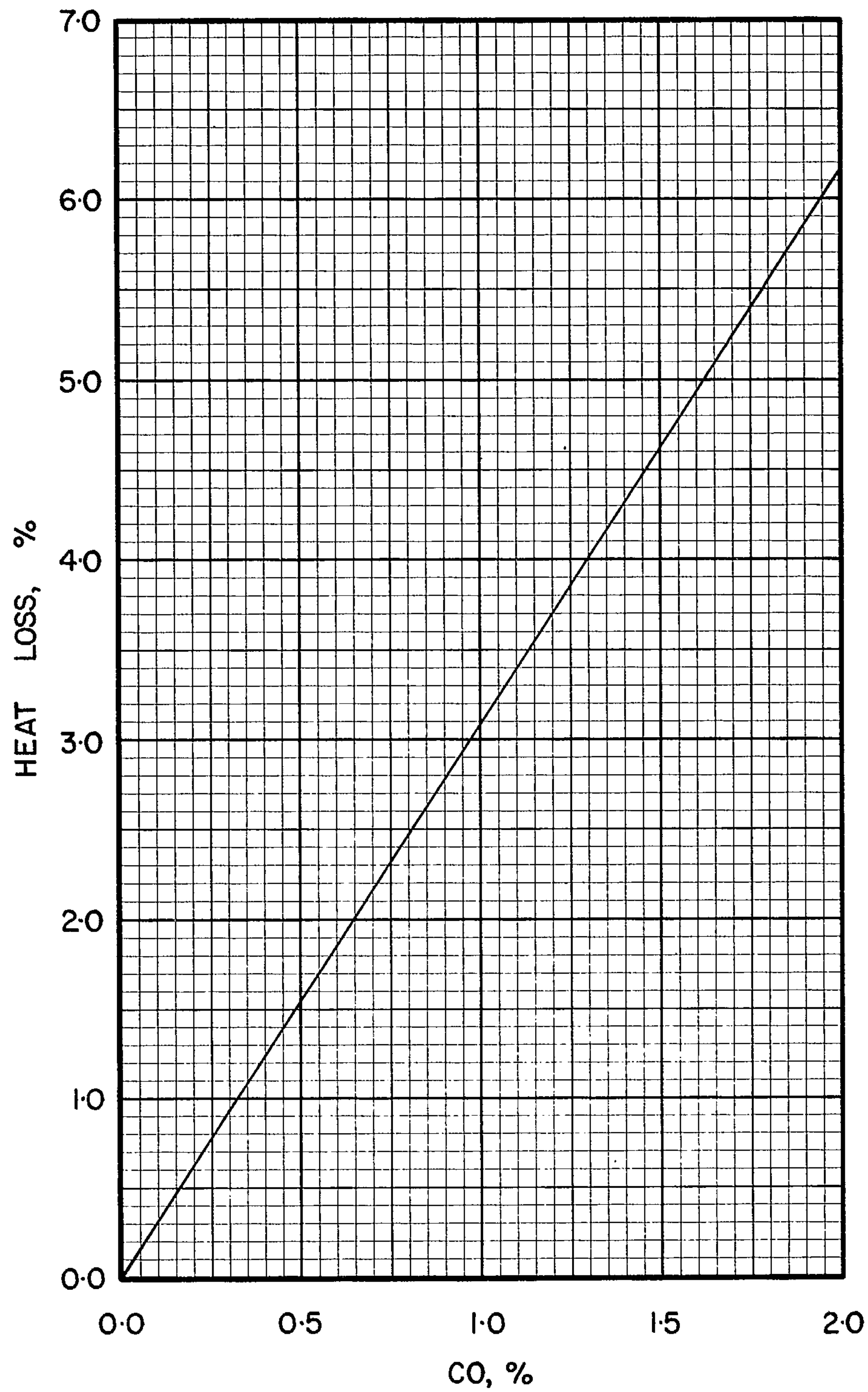


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS·6·4

COAL NS 7-1, RIVER HEBERT, JOGGINS, 1 1/8 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.2365
Volatile Matter	0.3132
Fixed Carbon	0.4503
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6120
Hydrogen (H)	0.0414
Sulphur (S)	0.0425
Nitrogen (N)	0.0127
Oxygen (O)	0.0549
Ash	0.2365
Total	1.0000

Gross Calorific Value

Btu/lb:	11130
Btu/short ton:	22.26×10^6
Btu/long ton:	24.93×10^6
MJ/kg:	25.88

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 89.85	lb	
10^6 Btu	= 0.04492	short tons	
10^6 Btu	= 0.04011	long tons	

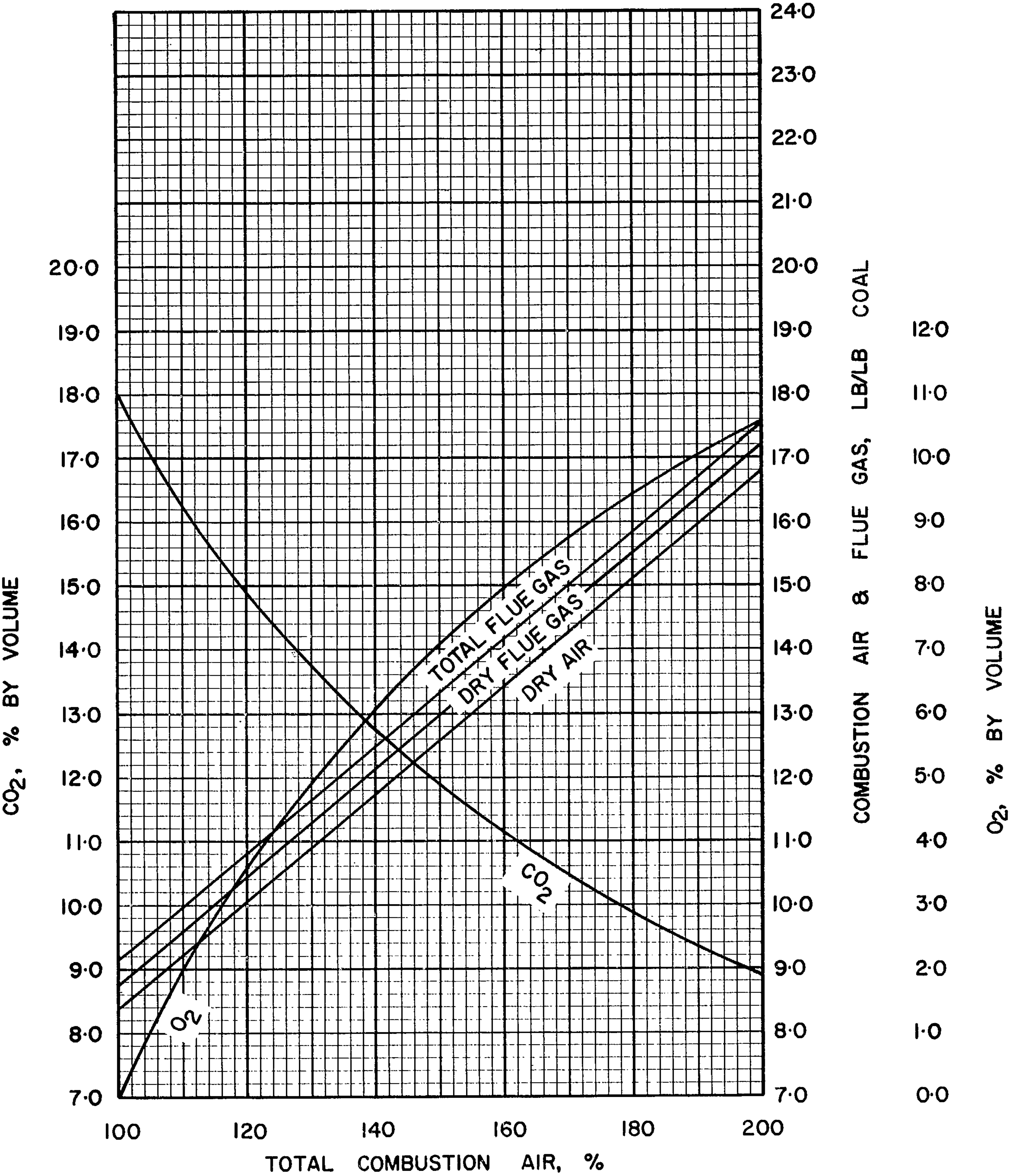


FIGURE I· COMBUSTION DATA, WEIGHT BASIS NS· 7·1

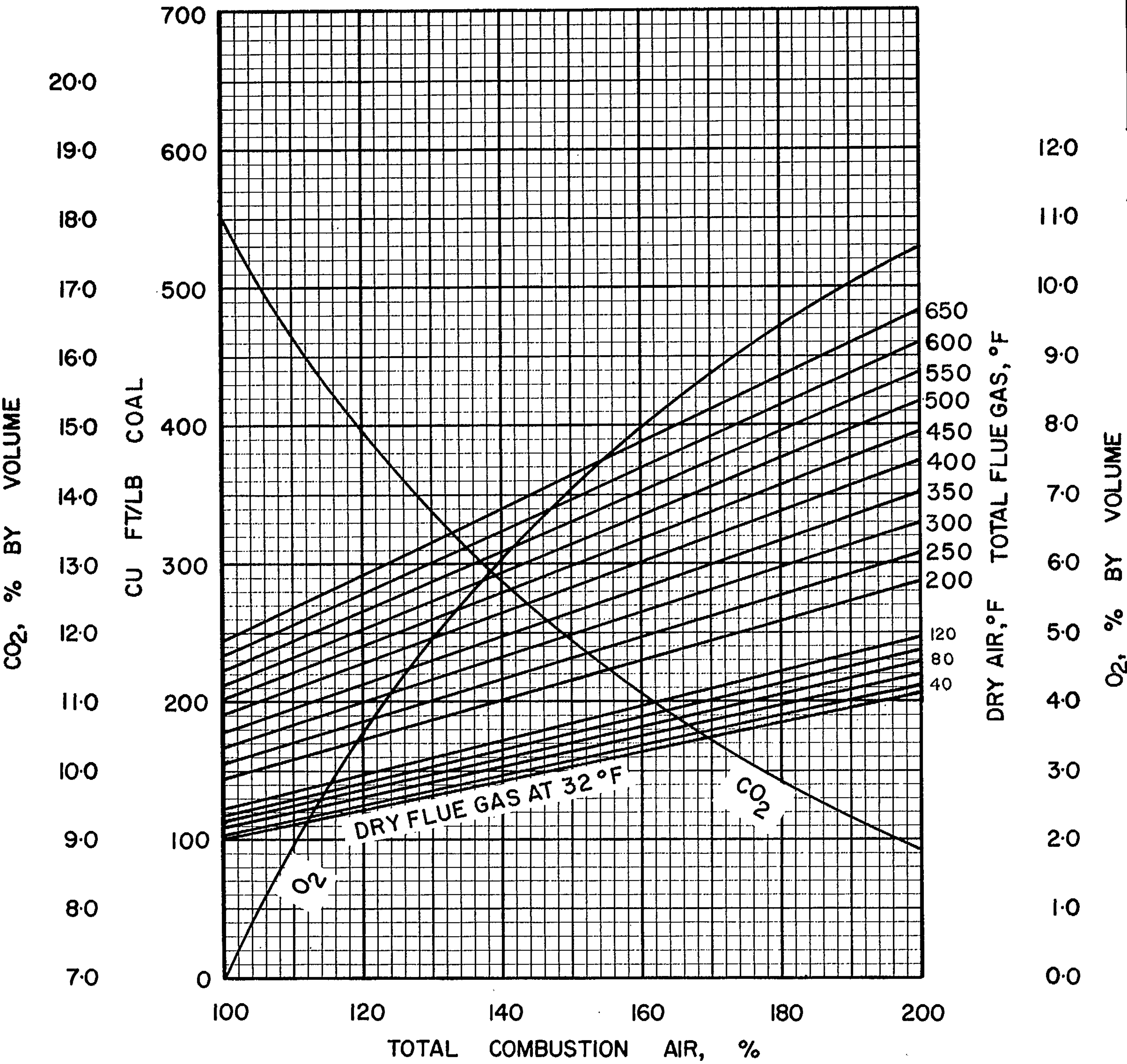


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS· 7·1

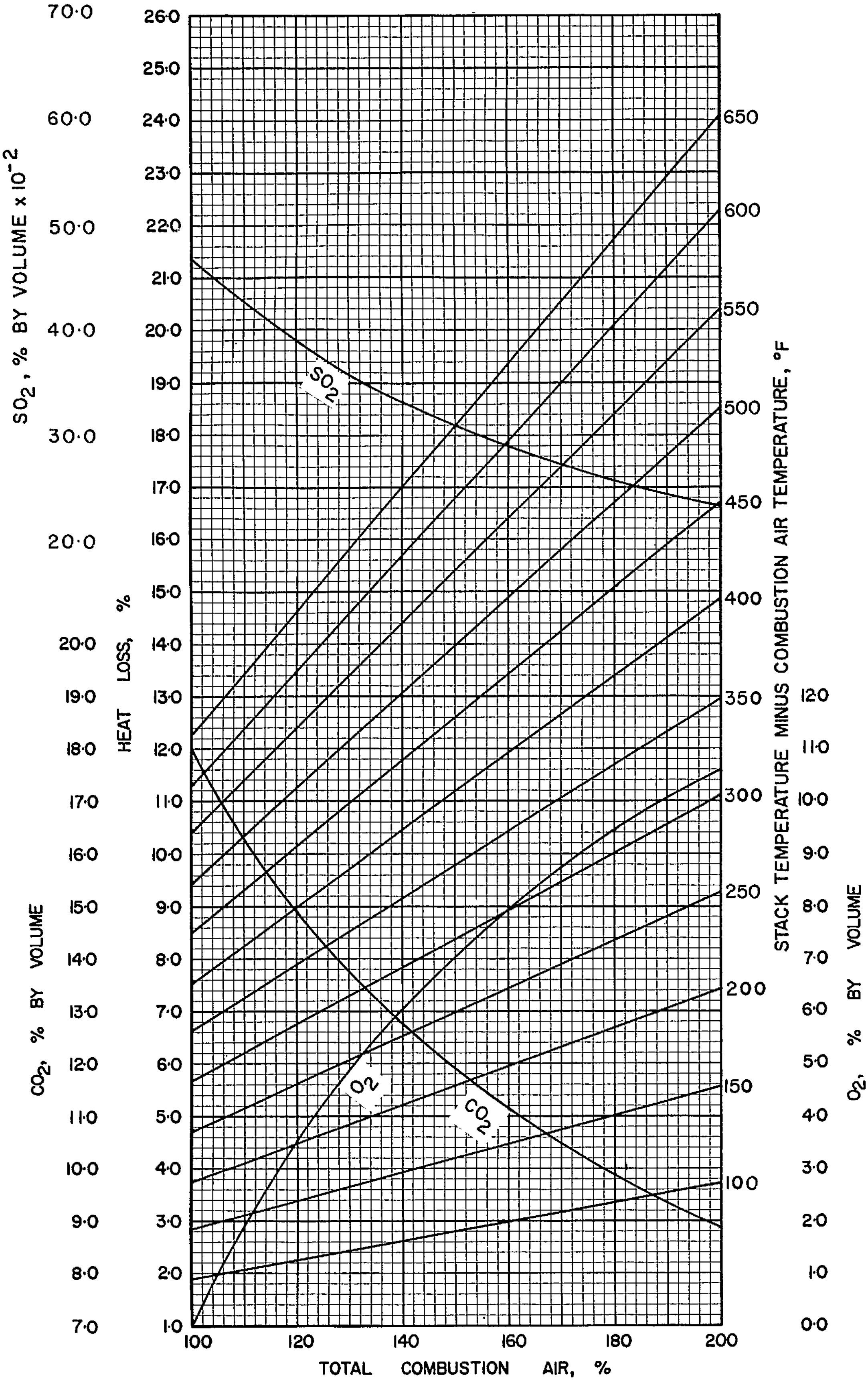


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS NS· 7· I

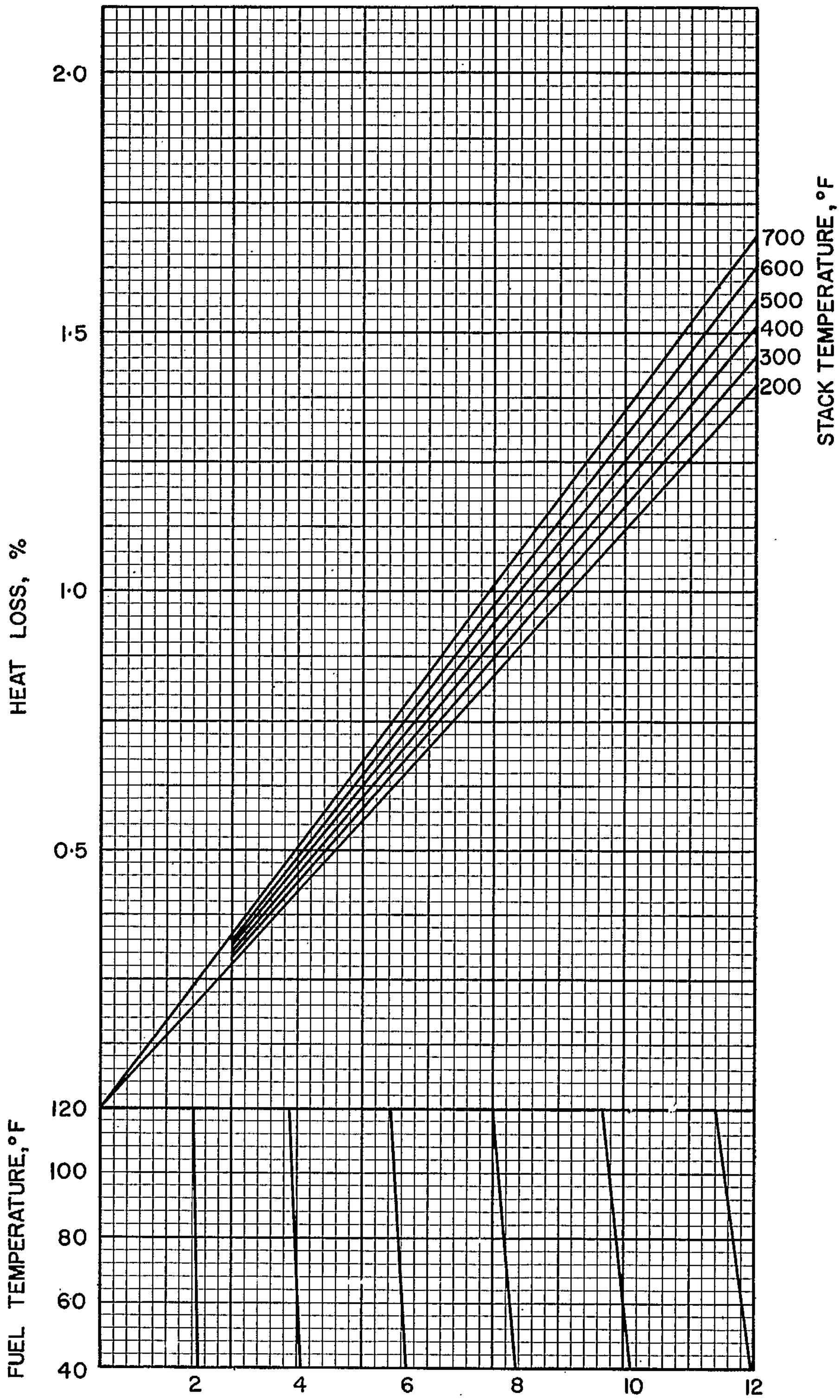


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS· 7·1

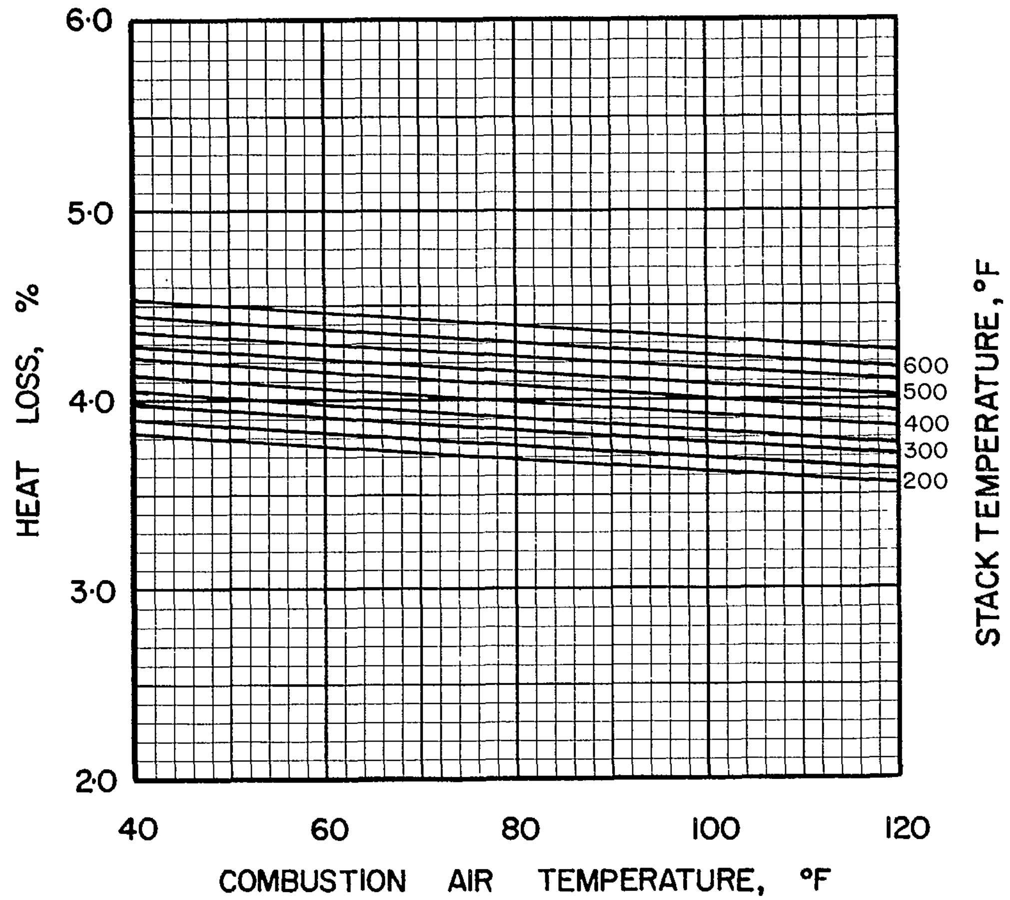


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS· 7· 1

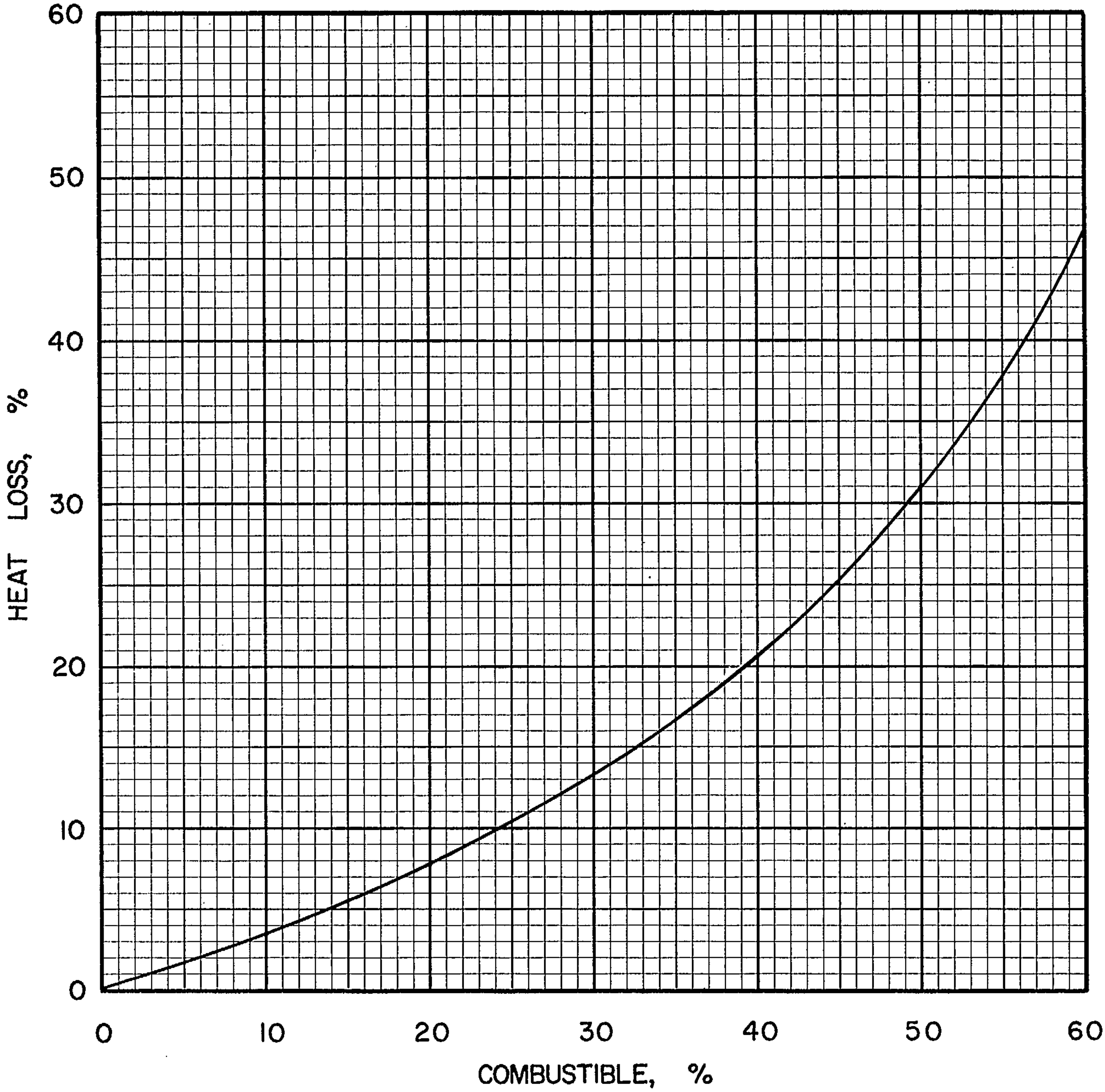


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS· 7·1

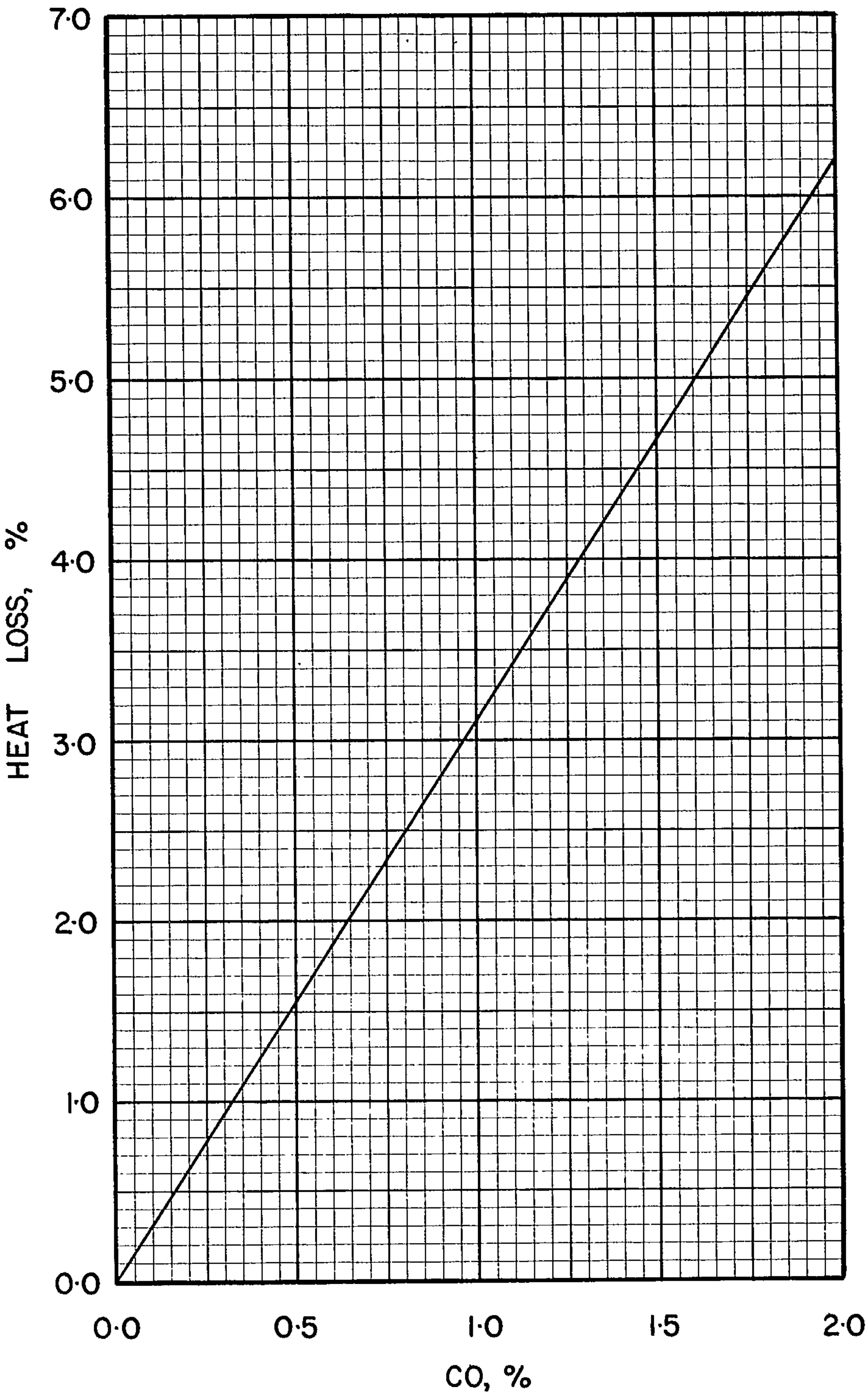


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS · 7 · 1

COAL NS 8-1, SPRINGHILL, CUMBERLAND, 3/8 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.2136
Volatile Matter	0.3013
Fixed Carbon	0.4851
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6589
Hydrogen (H)	0.0410
Sulphur (S)	0.0247
Nitrogen (N)	0.0100
Oxygen (O)	0.0518
Ash	0.2136
Total	1.0000

Gross Calorific Value

Btu/lb:	11250
Btu/short ton:	22.50×10^6
Btu/long ton:	25.20×10^6
MJ/kg:	26.16

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 88.89	lb	
10^6 Btu	= 0.04444	short tons	
10^6 Btu	= 0.03968	long tons	

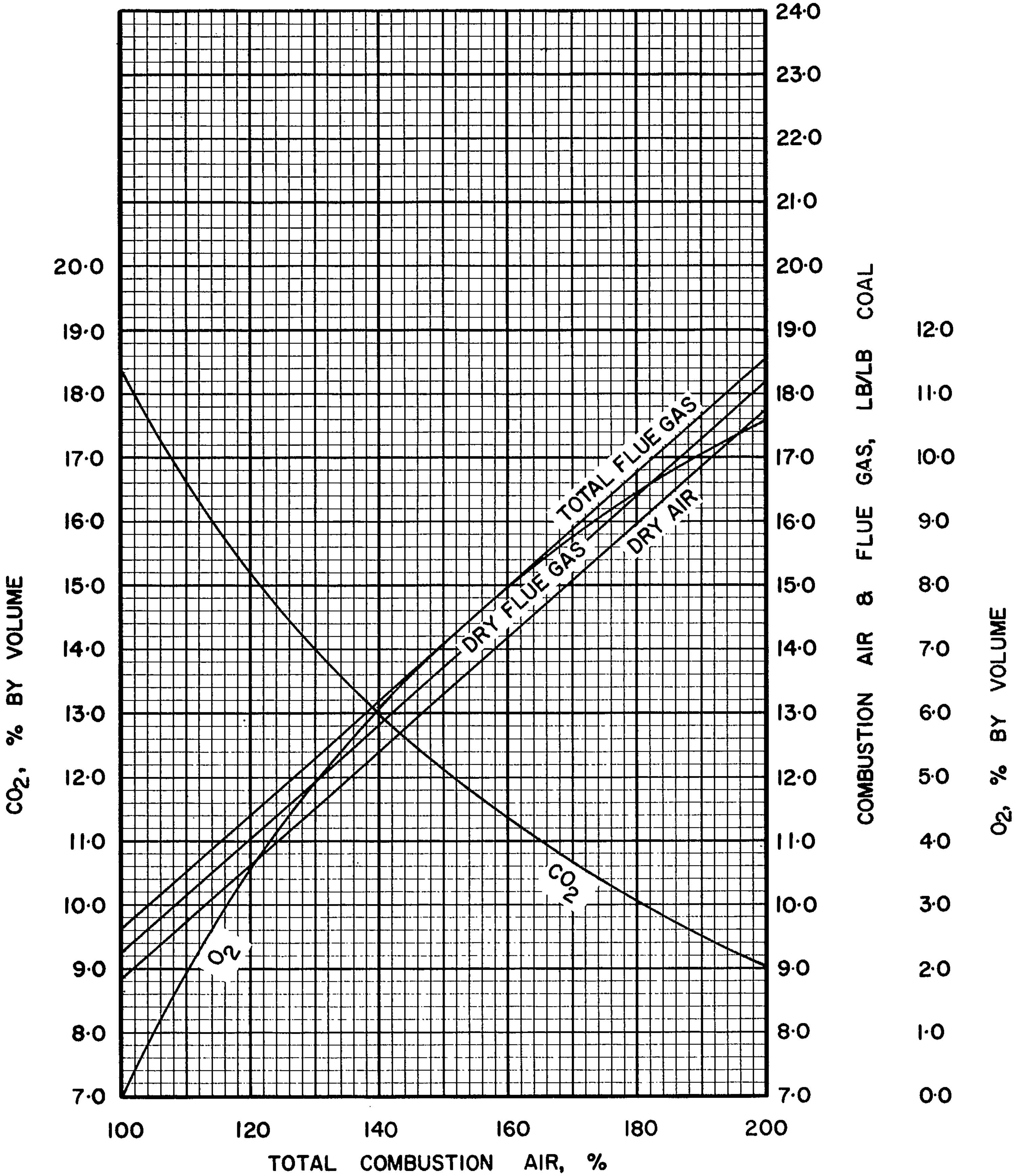


FIGURE I· COMBUSTION DATA, WEIGHT BASIS

NS·8·I

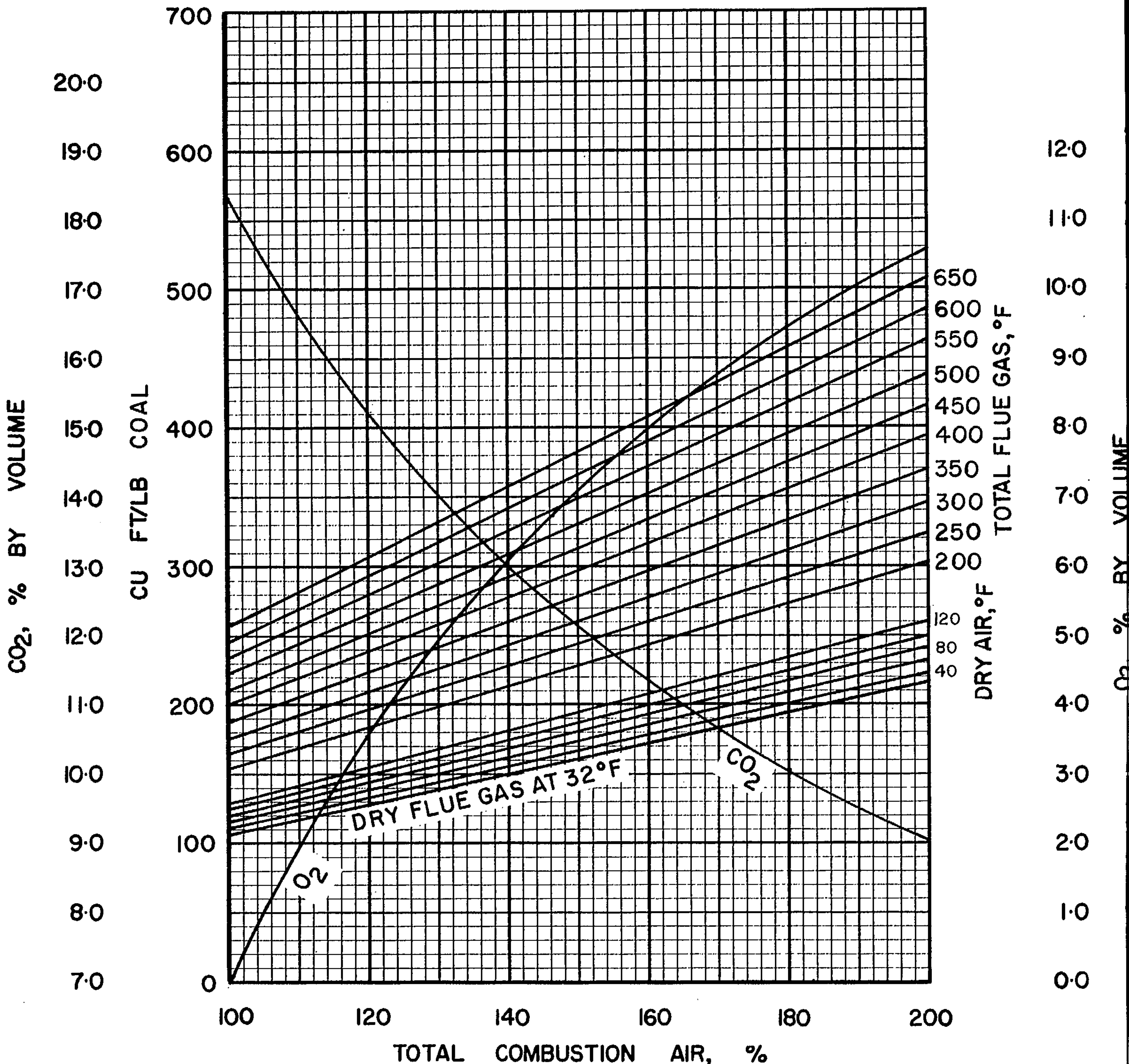


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NS · 8 · 1

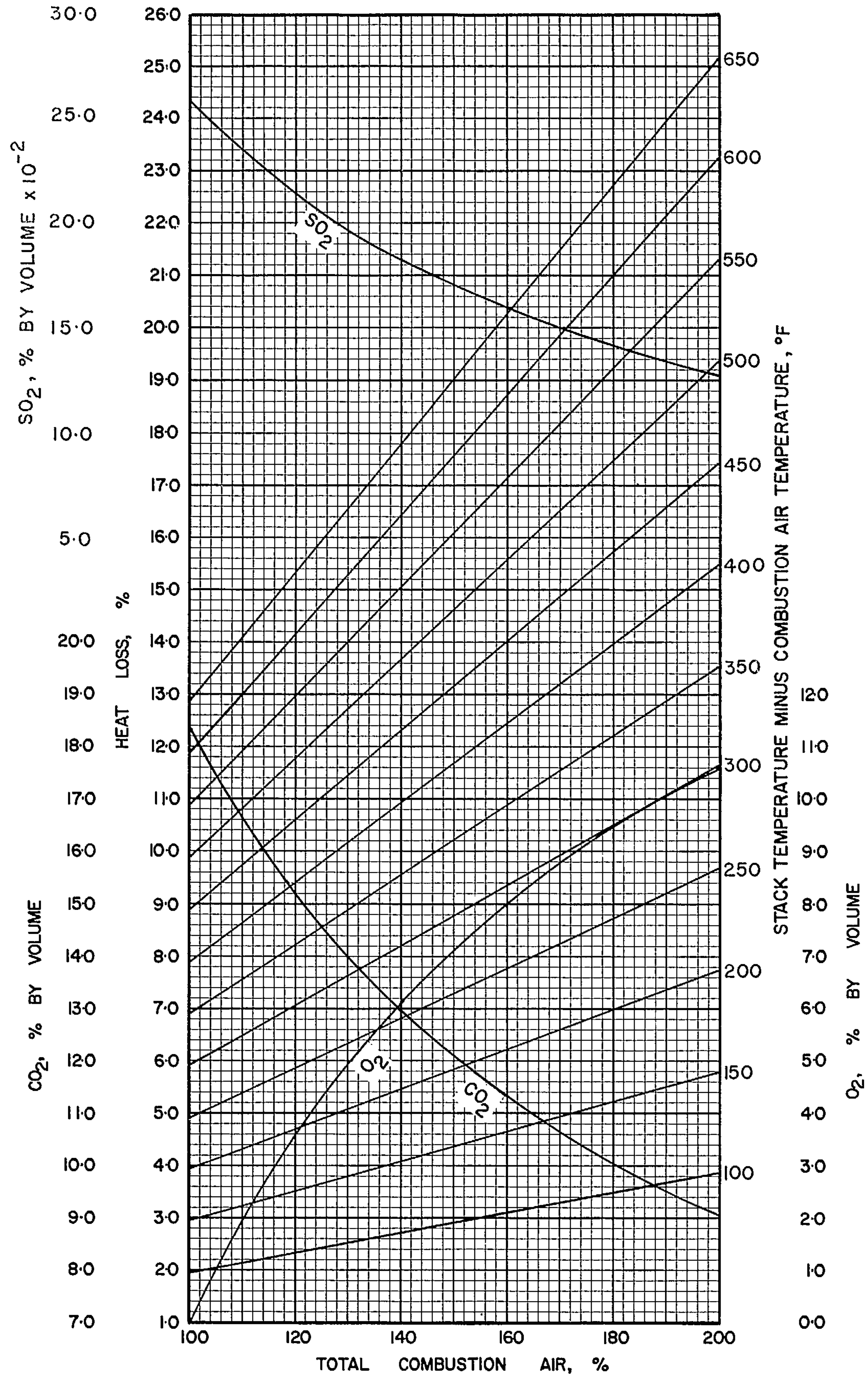


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NS·8·1

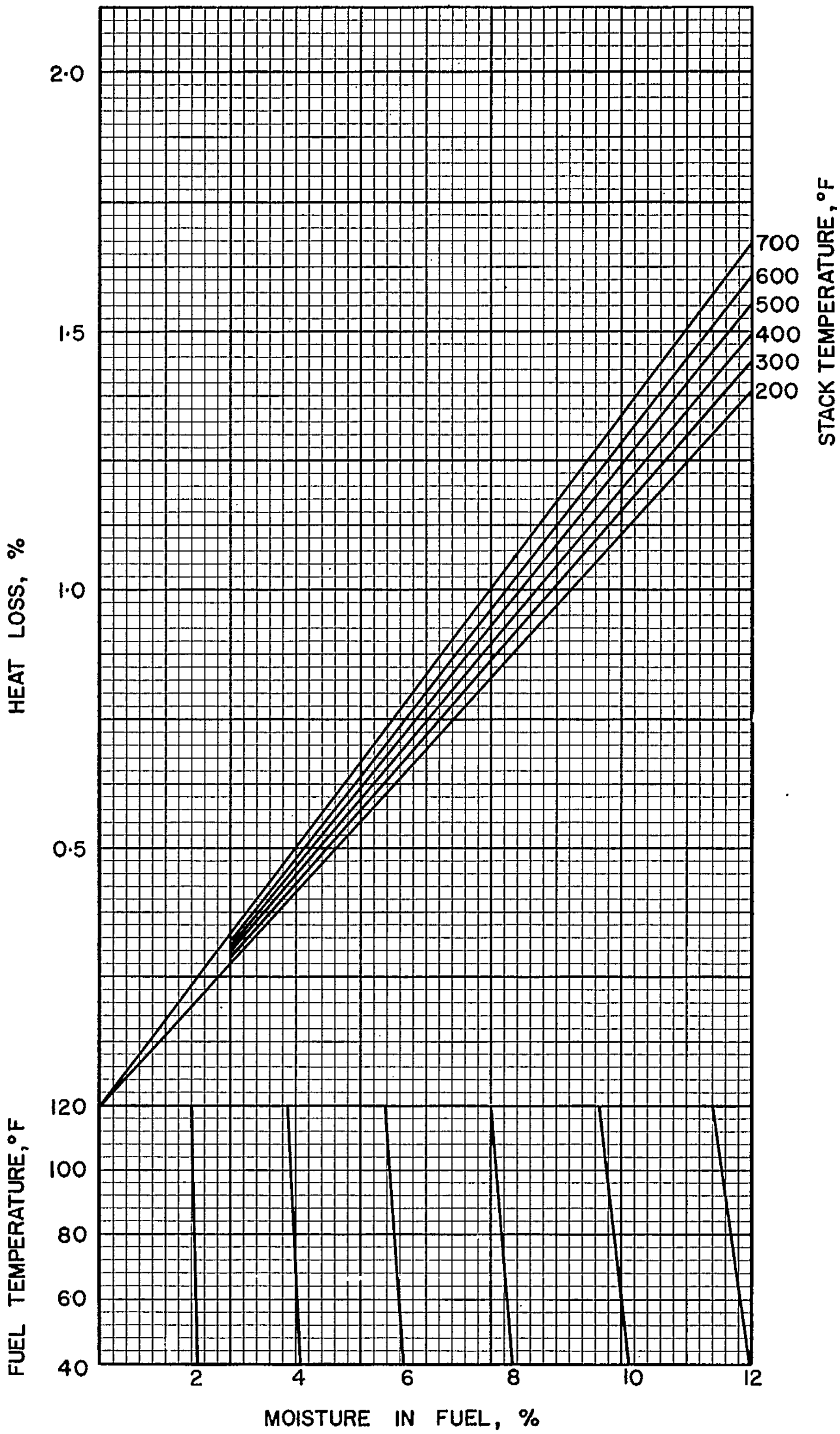


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NS·8·I

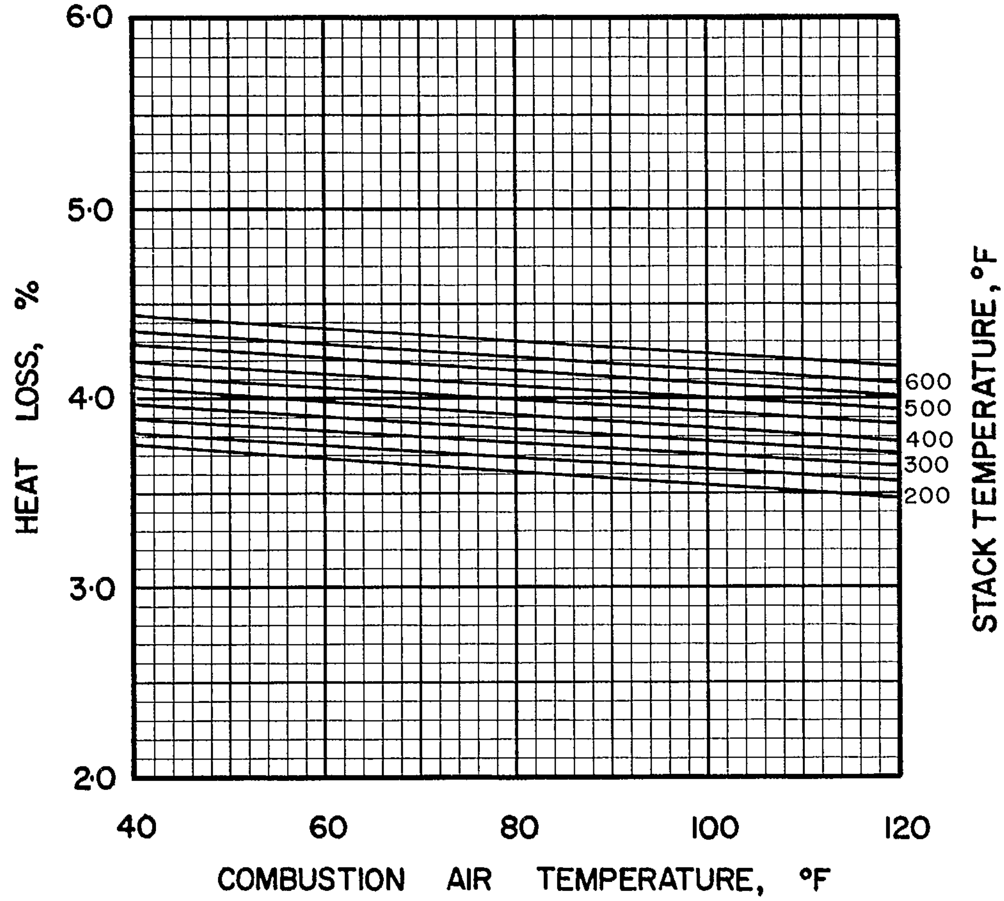


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NS·8·1

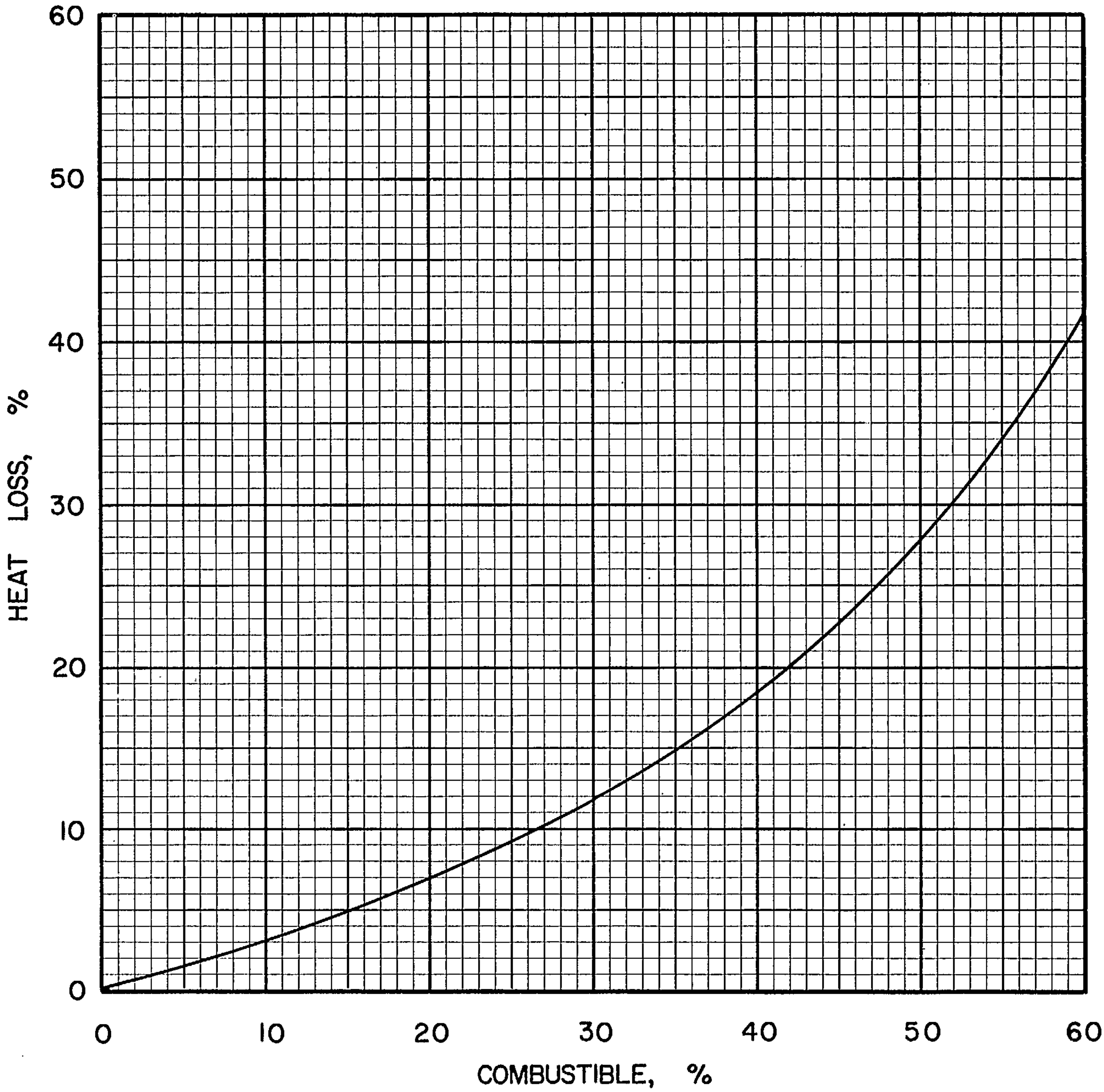


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NS·8·1

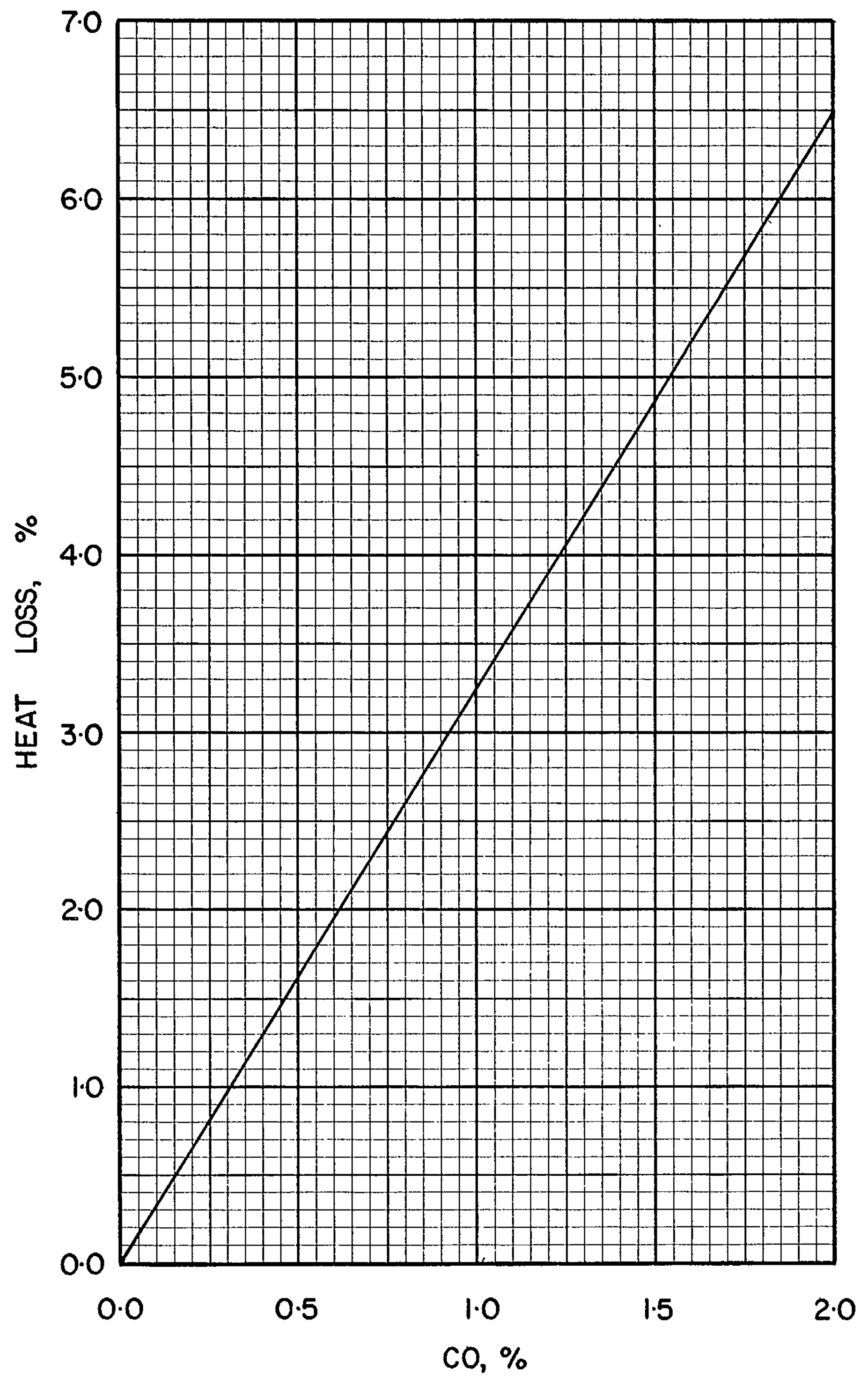


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NS · 8 · 1

COAL NB 1-1, AVON, N.B. COAL LTD., MINTO, 1 1/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1475
Volatile Matter	0.3295
Fixed Carbon	0.5230
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6965
Hydrogen (H)	0.0458
Sulphur (S)	0.0699
Nitrogen (N)	0.0081
Oxygen (O)	0.0322
Ash	0.1475
Total	1.0000

Gross Calorific Value

Btu/lb:	12740
Btu/short ton:	25.48×10^6
Btu/long ton:	28.54×10^6
MJ/kg:	29.63

Conversion Factors

1 short ton	= 0.8929	long tons	=	2000 lb
10^6 Btu	= 78.49	lb		
10^6 Btu	= 0.03925	short tons		
10^6 Btu	= 0.03504	long tons		

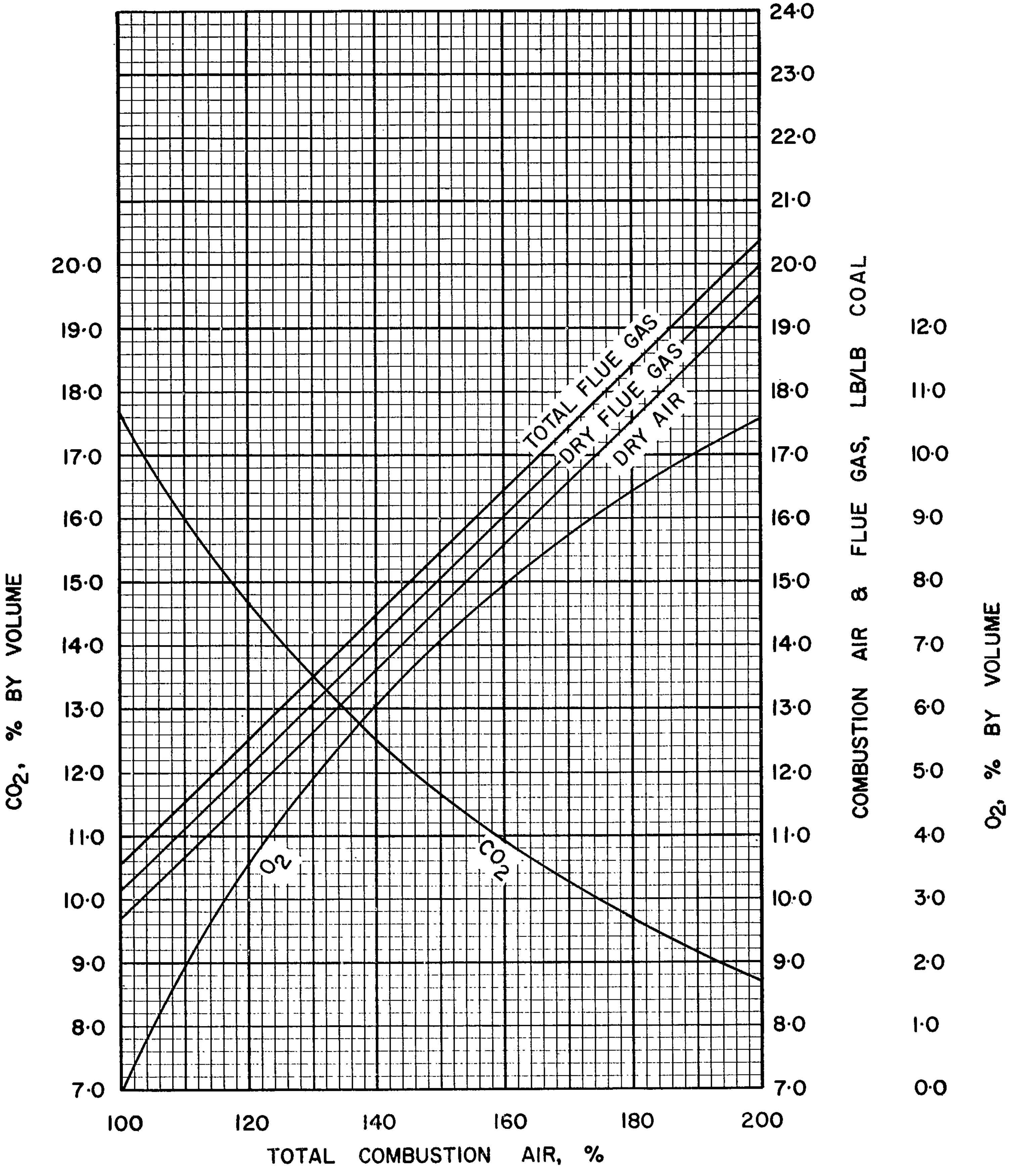


FIGURE I· COMBUSTION DATA, WEIGHT BASIS NB·1·1

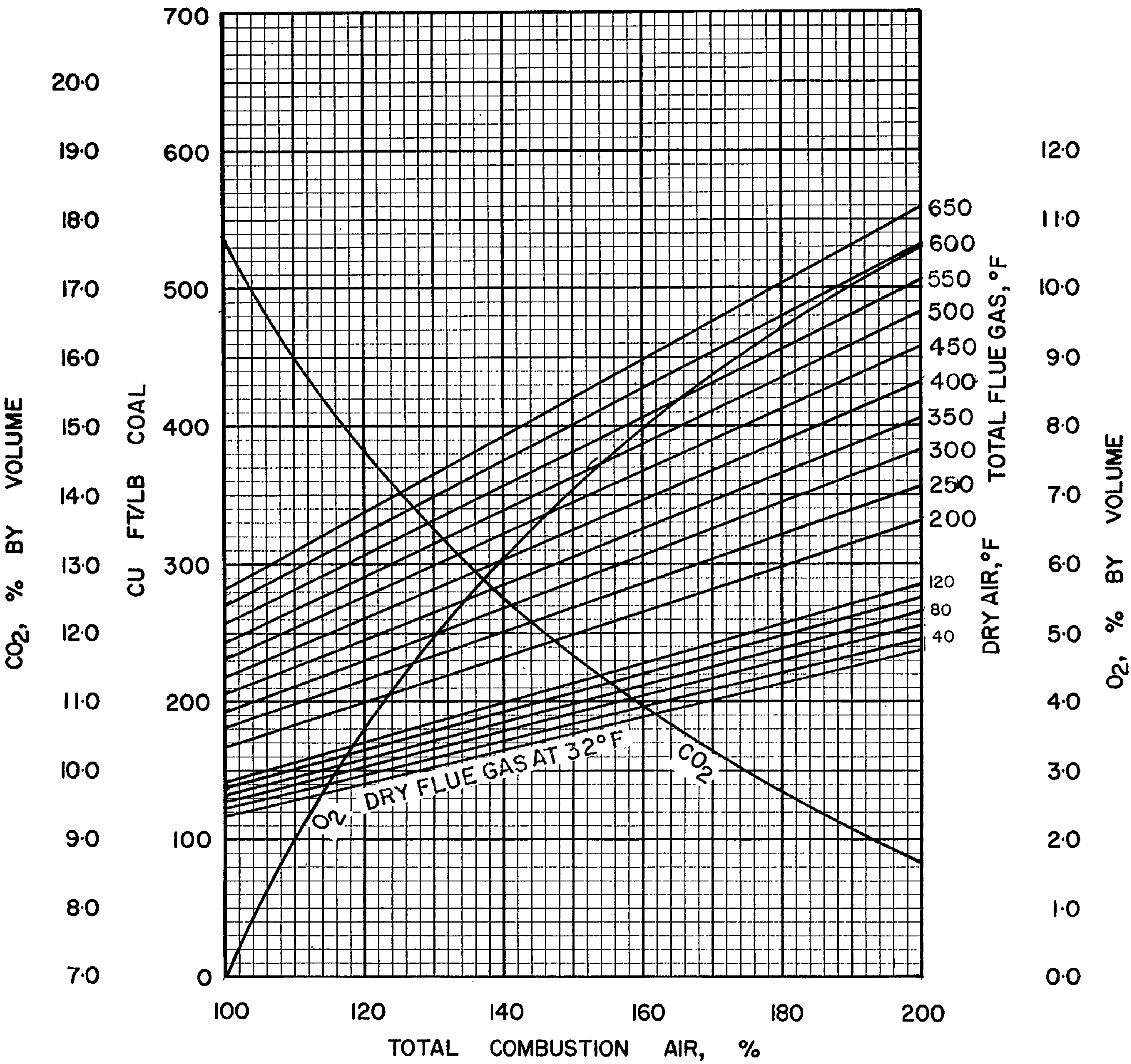


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

NB·1·1

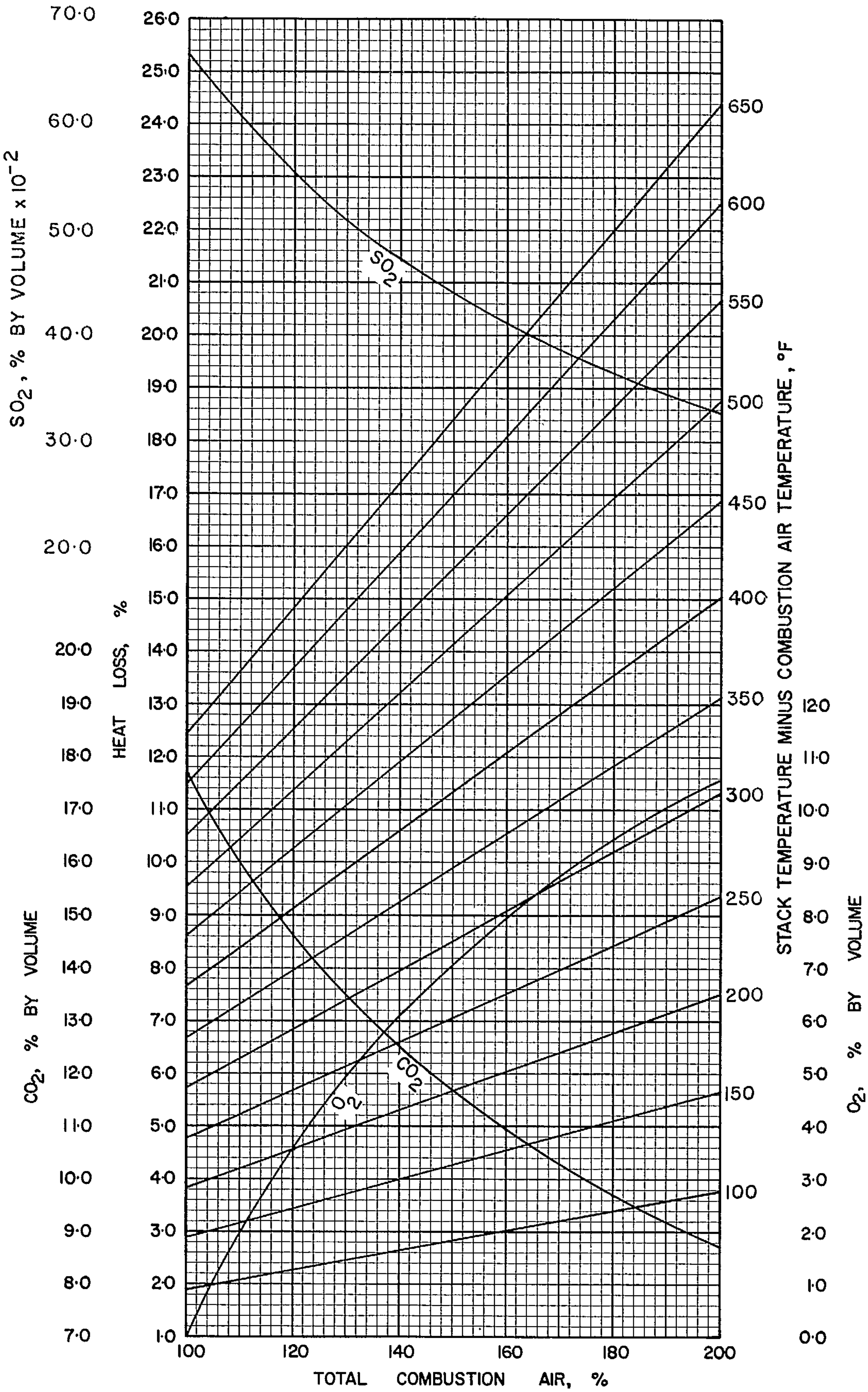


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·1·1

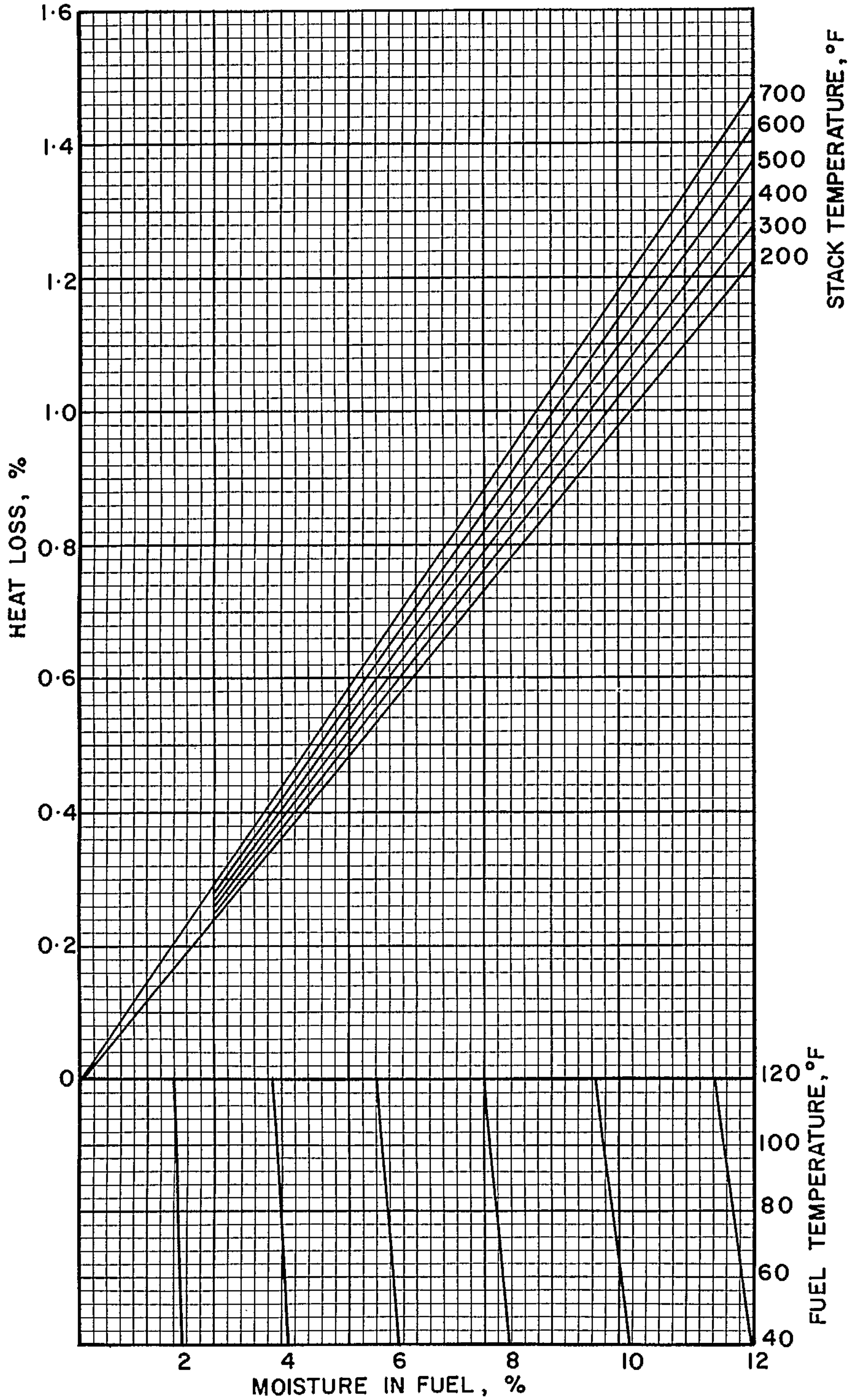


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NB·1·1

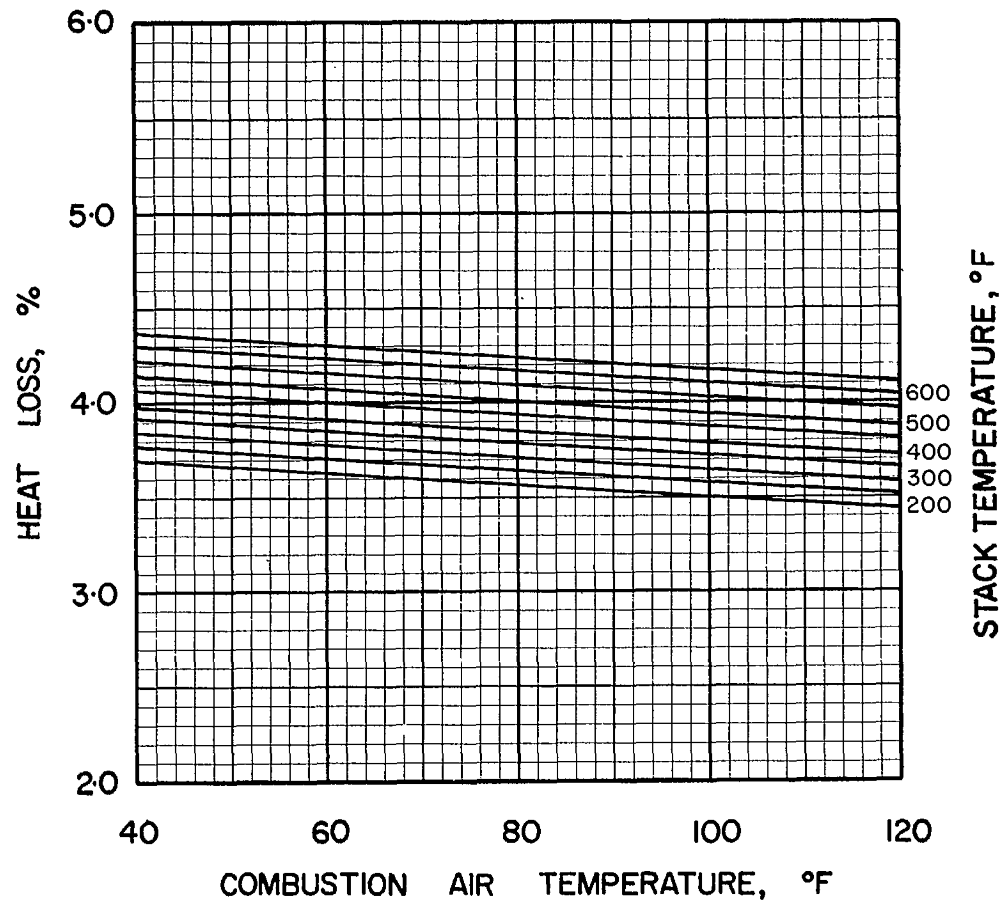


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB · I · I

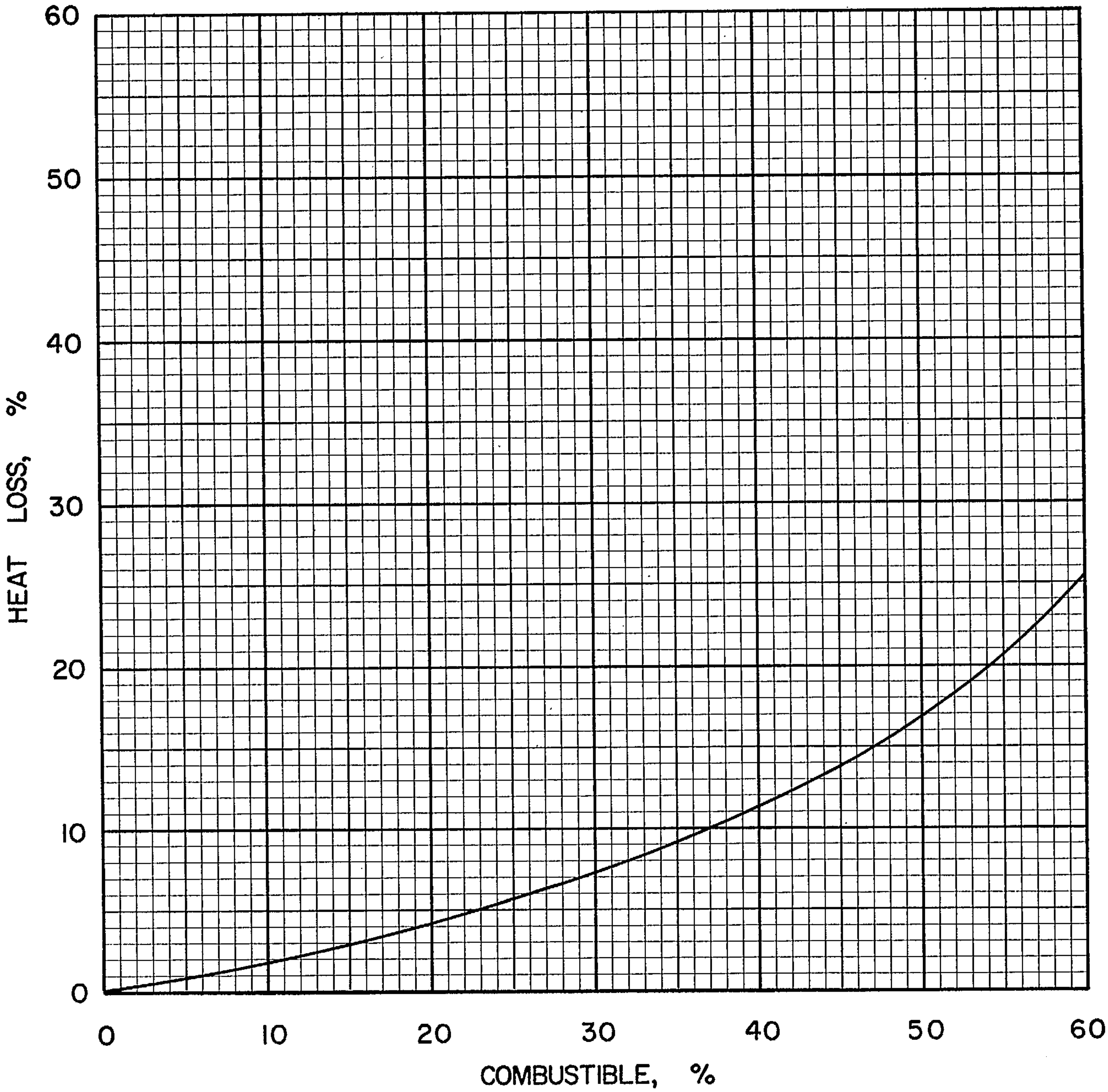


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·1·1

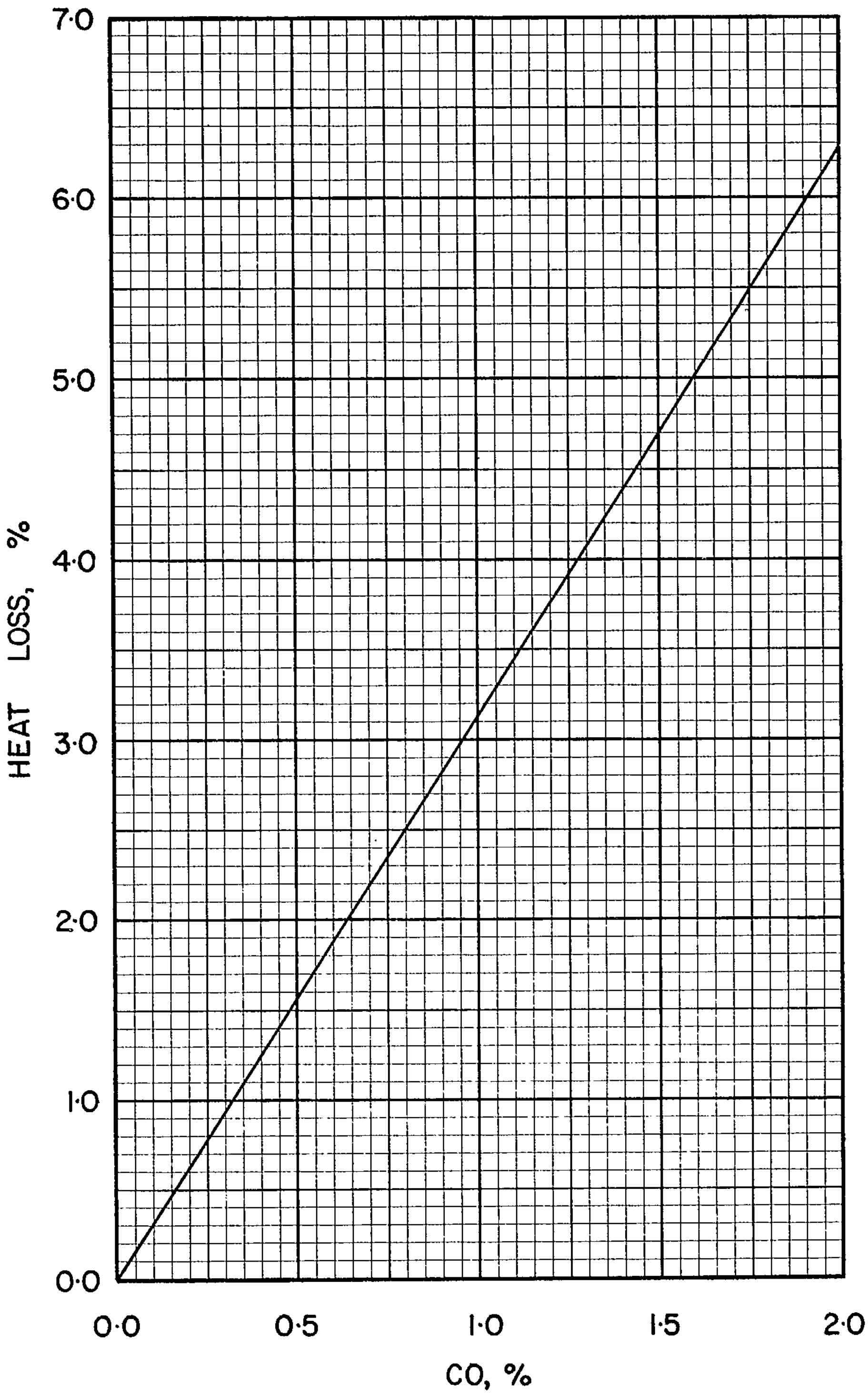


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB·1·1

COAL NB 1-2, AVON, N.B. COAL LTD., MINTO, 3/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1758
Volatile Matter	0.3276
Fixed Carbon	0.4966
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6731
Hydrogen (H)	0.0446
Sulphur (S)	0.0741
Nitrogen (N)	0.0080
Oxygen (O)	0.0244
Ash	0.1758
Total	1.0000

Gross Calorific Value

Btu/lb:	12340
Btu/short ton:	24.68×10^6
Btu/long ton:	27.64×10^6
MJ/kg:	28.70

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 81.04	lb	
10^6 Btu	= 0.04052	short tons	
10^6 Btu	= 0.03618	long tons	

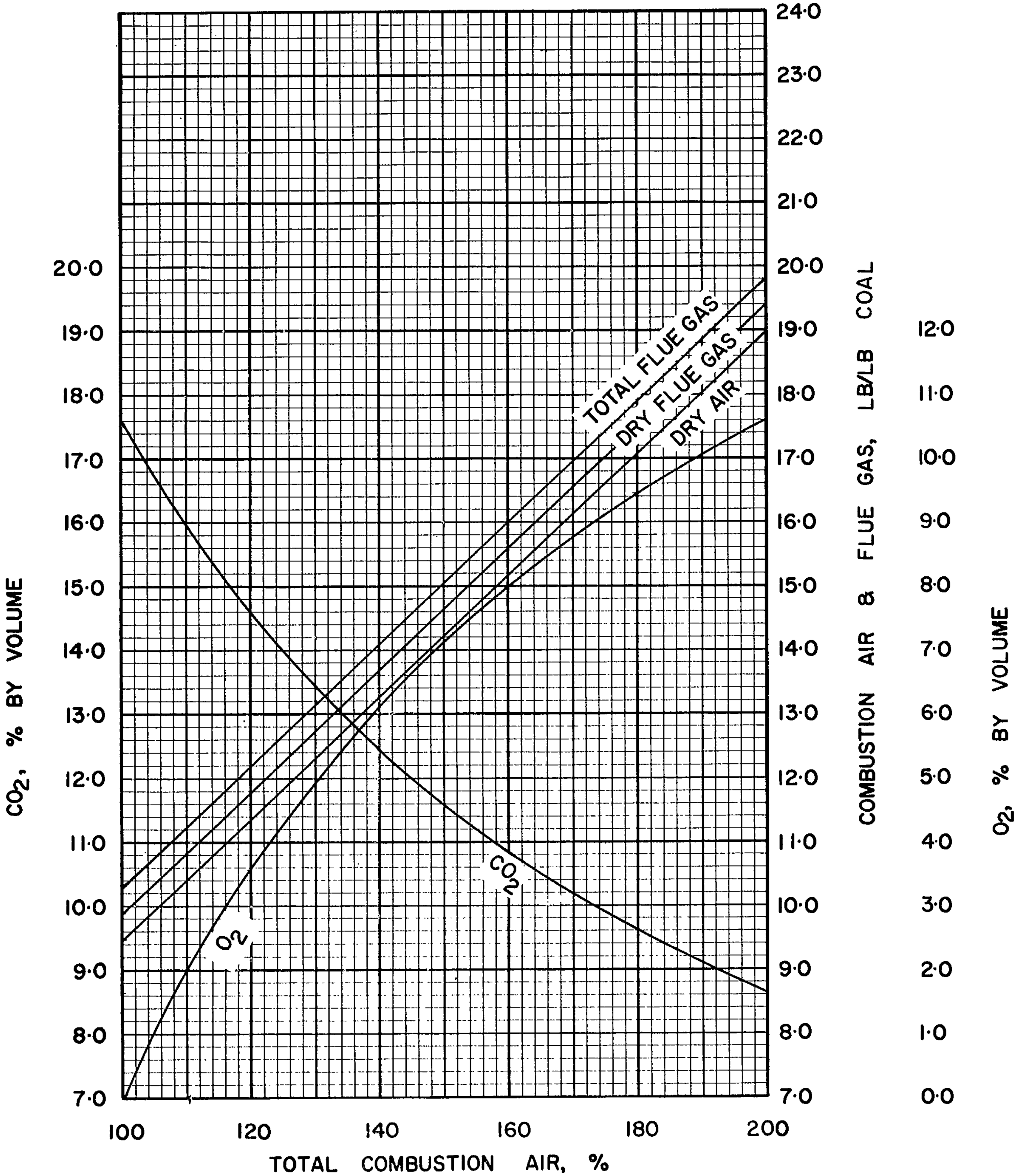
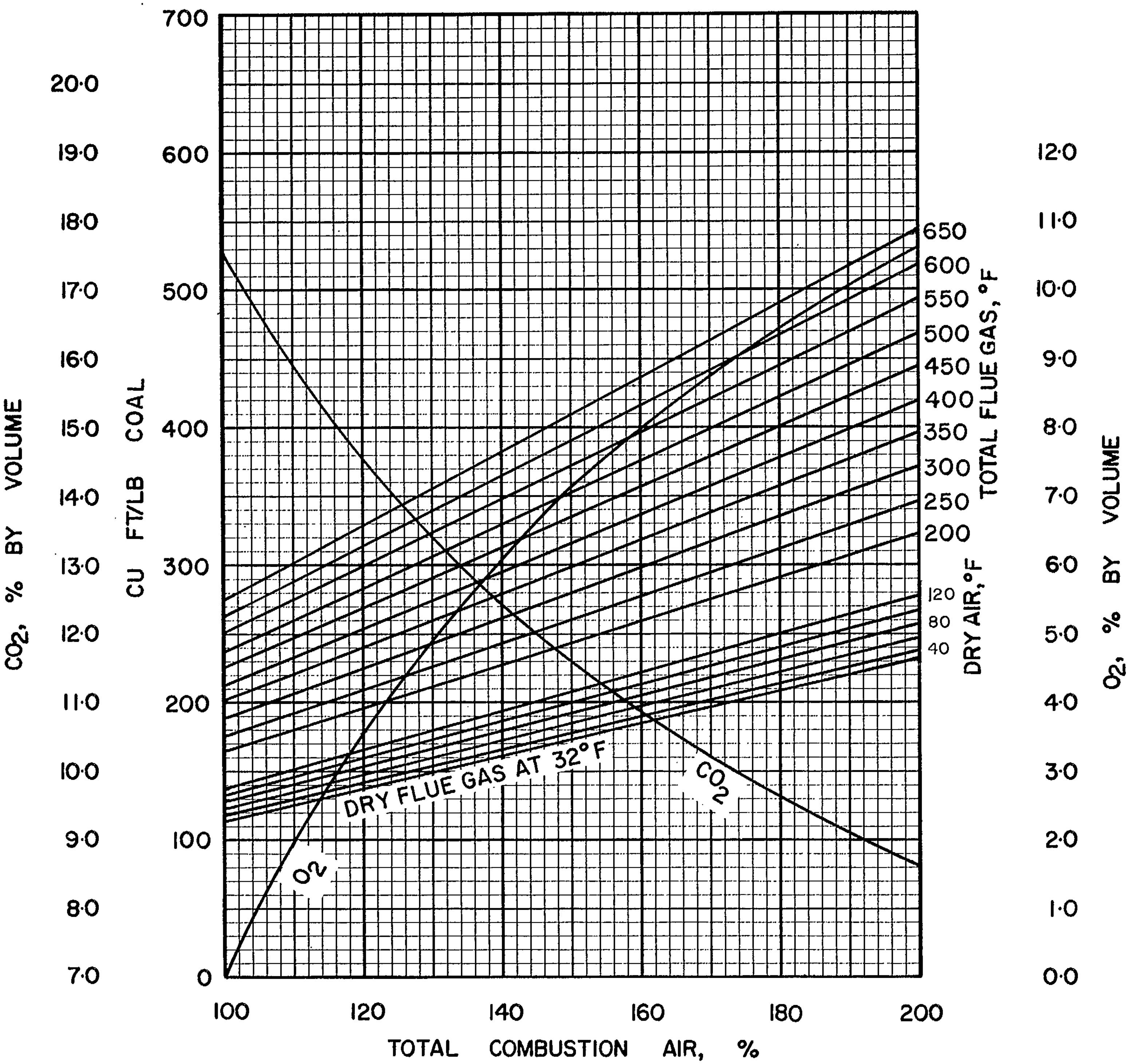


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NB·1·2



NB·1·2

FIGURE 2· COMBUSTION DATA, VOLUME BASIS

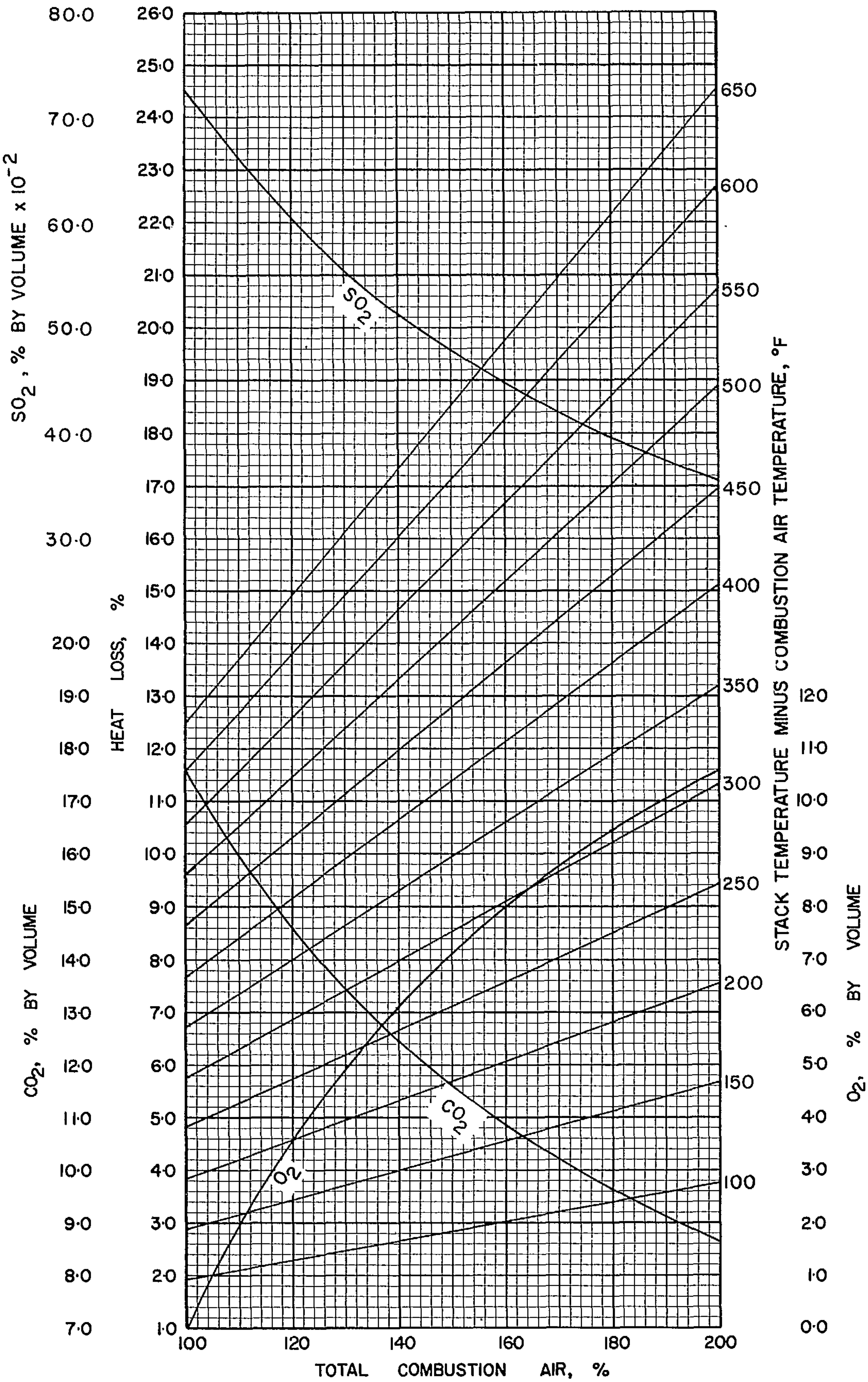


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·1·2

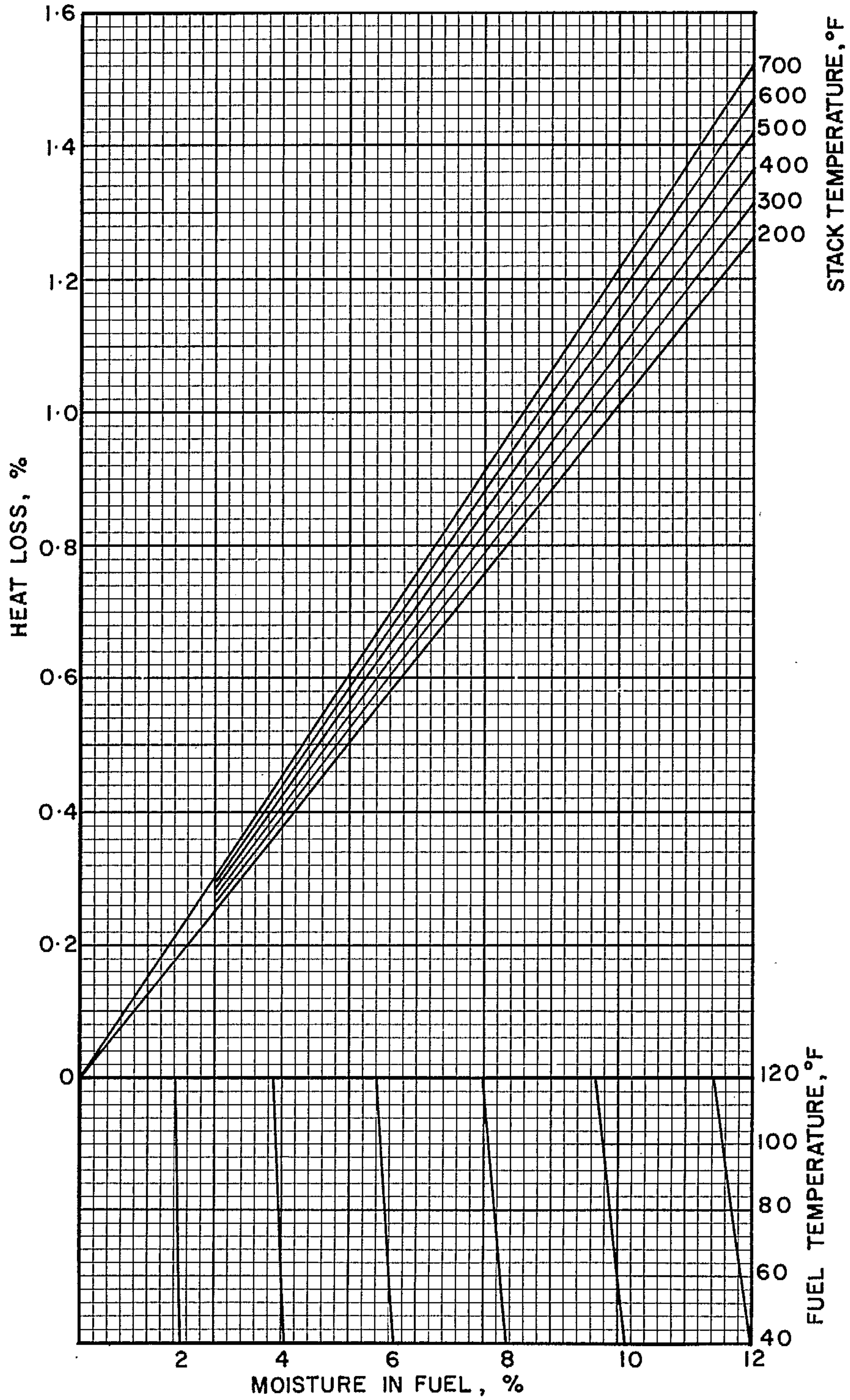


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NB·1·2

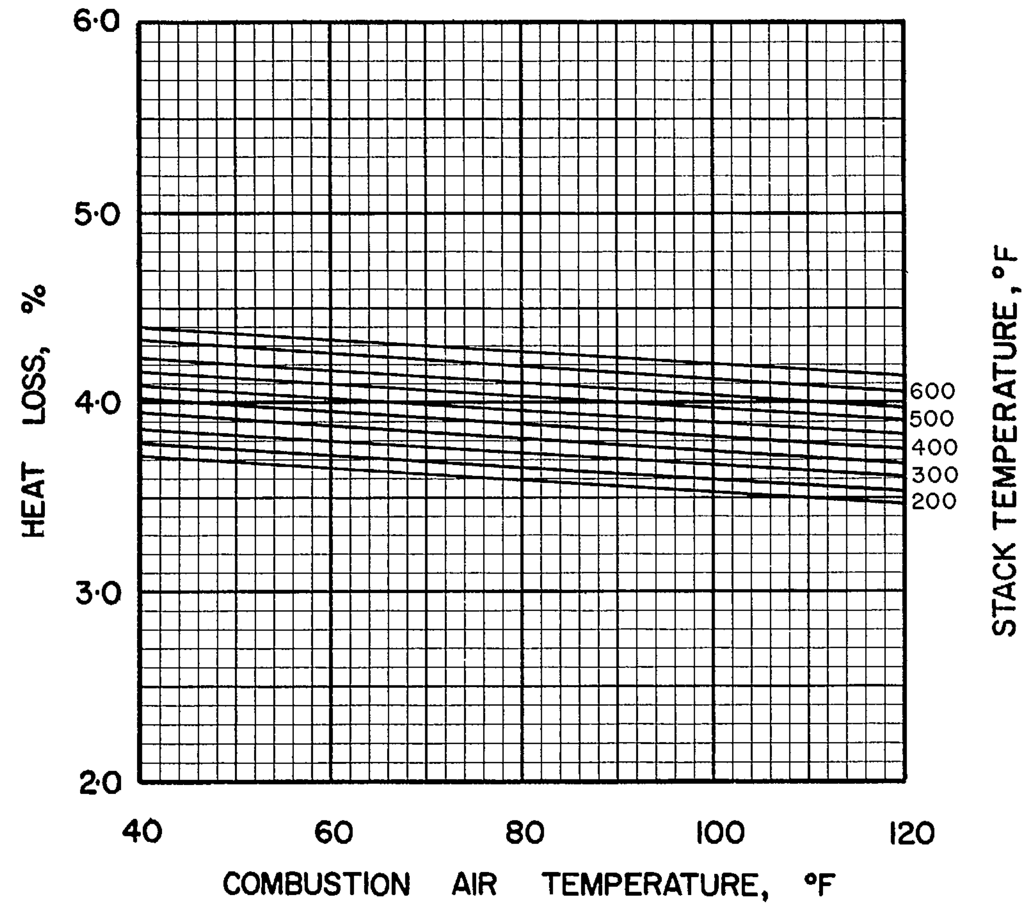


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB·1·2

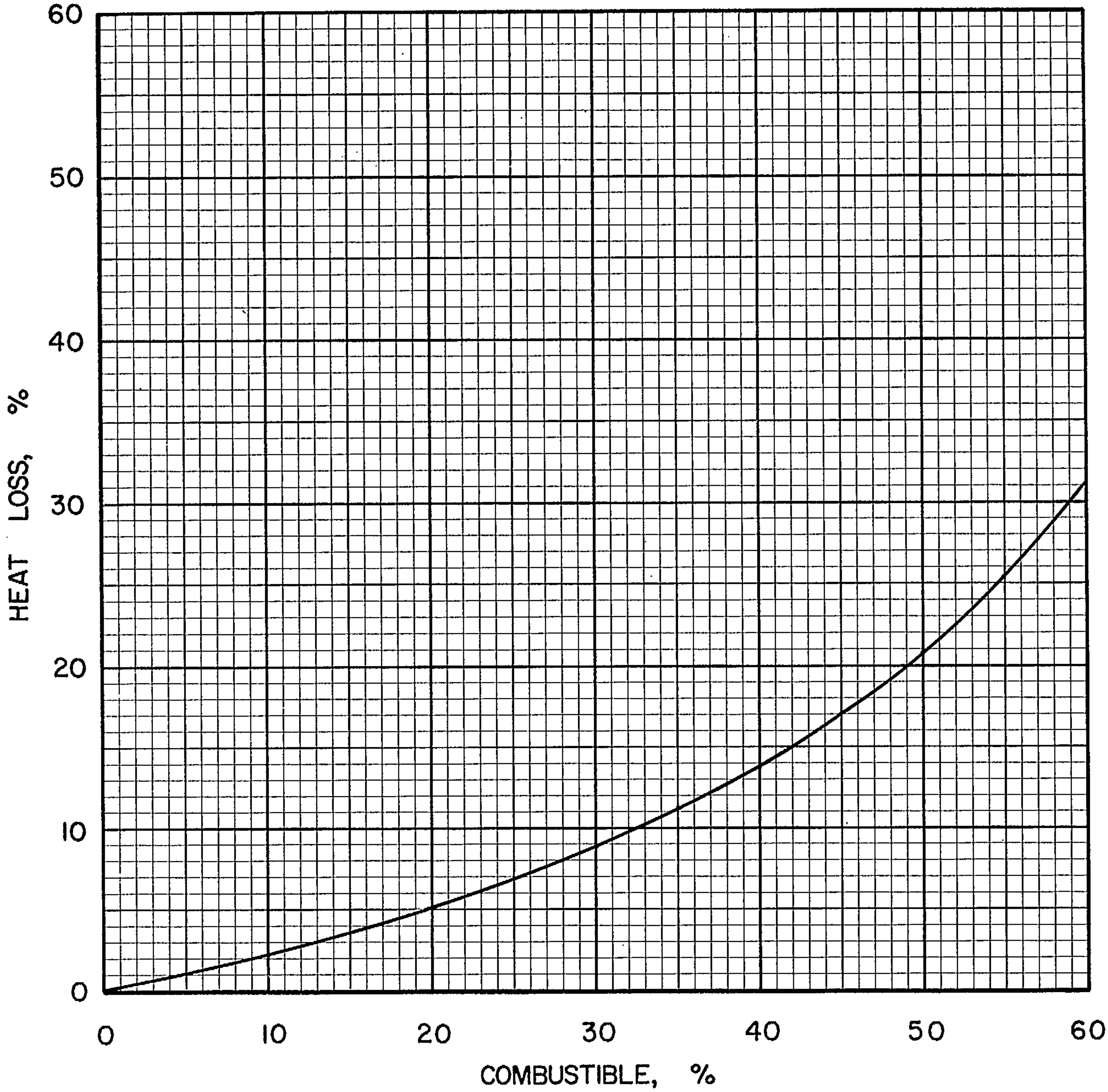


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·1·2

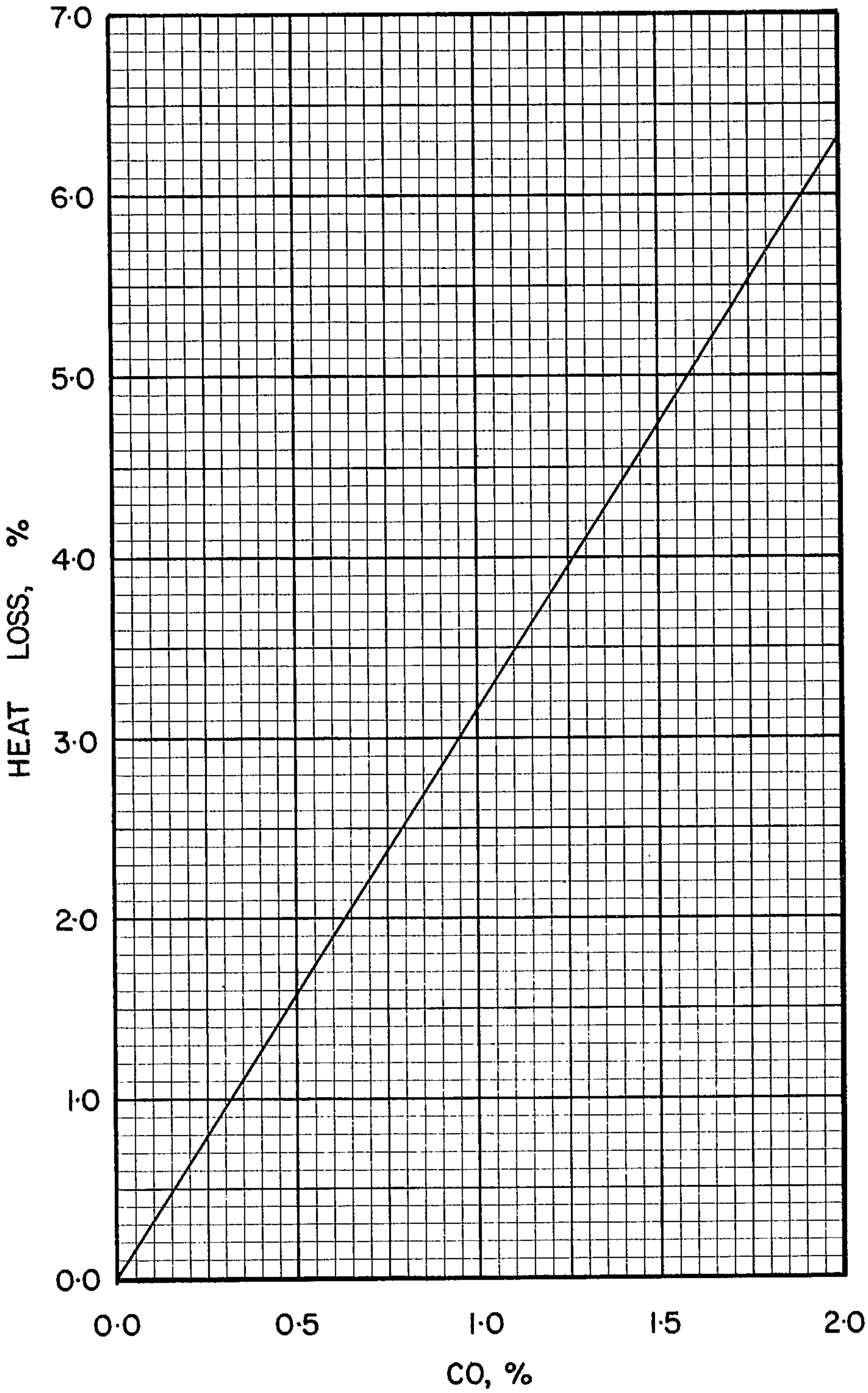


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB · 1 · 2

COAL NB 1-3, AVON, N.B. COAL LTD., MINTO, 1/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1211
Volatile Matter	0.3499
Fixed Carbon	0.5290
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.7280
Hydrogen (H)	0.0480
Sulphur (S)	0.0634
Nitrogen (N)	0.0087
Oxygen (O)	0.0308
Ash	0.1211
Total	1.0000

Gross Calorific Value

Btu/lb:	13370
Btu/short ton:	26.74×10^6
Btu/long ton:	29.95×10^6
MJ/kg:	31.09

Conversion Factors

1 short ton	=	0.8929	long tons	=	2000 lb
10^6 Btu	=	74.79	lb		
10^6 Btu	=	0.03740	short tons		
10^6 Btu	=	0.03339	long tons		

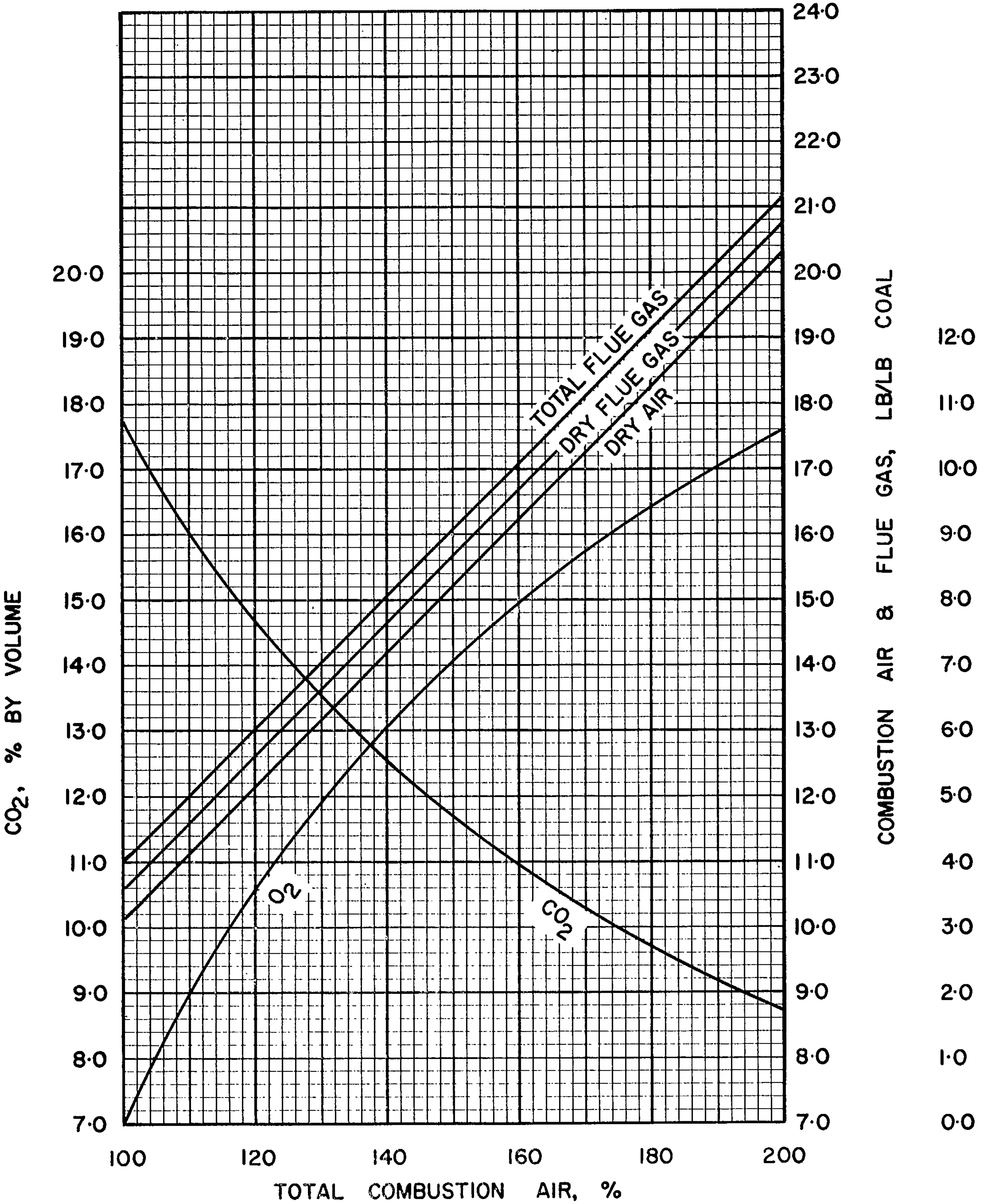


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NB·1·3

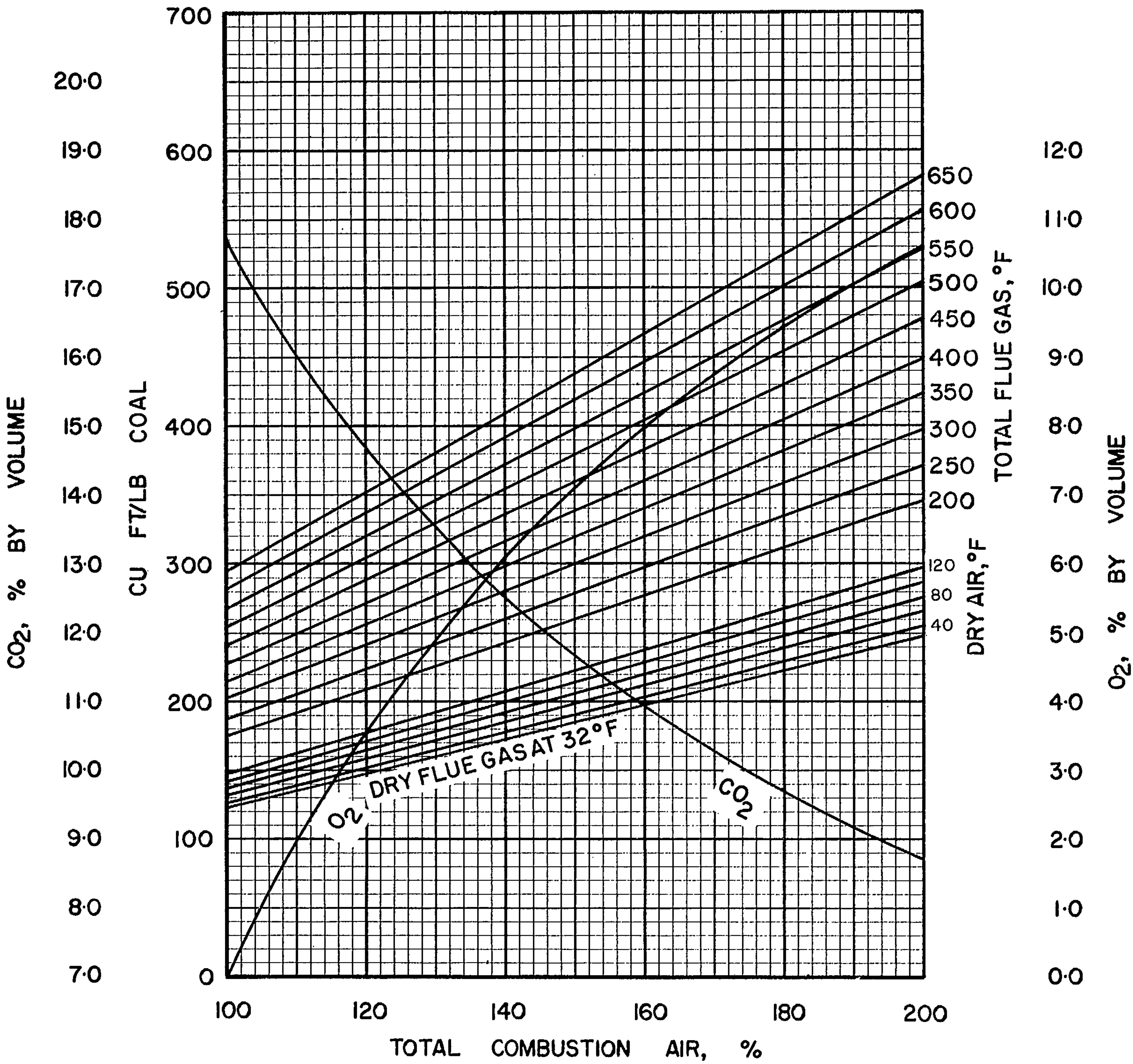


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NB·1·3

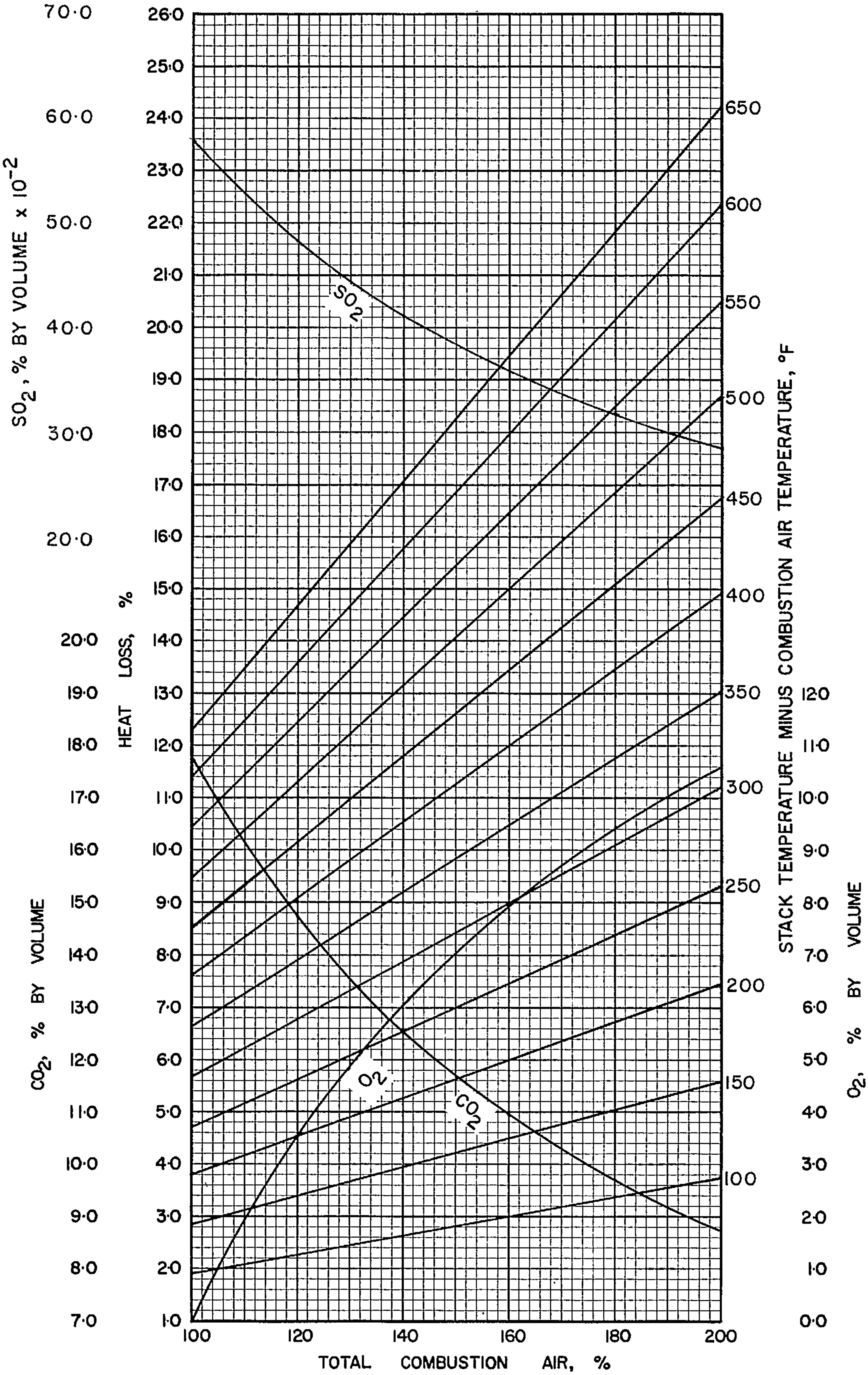


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·1·3

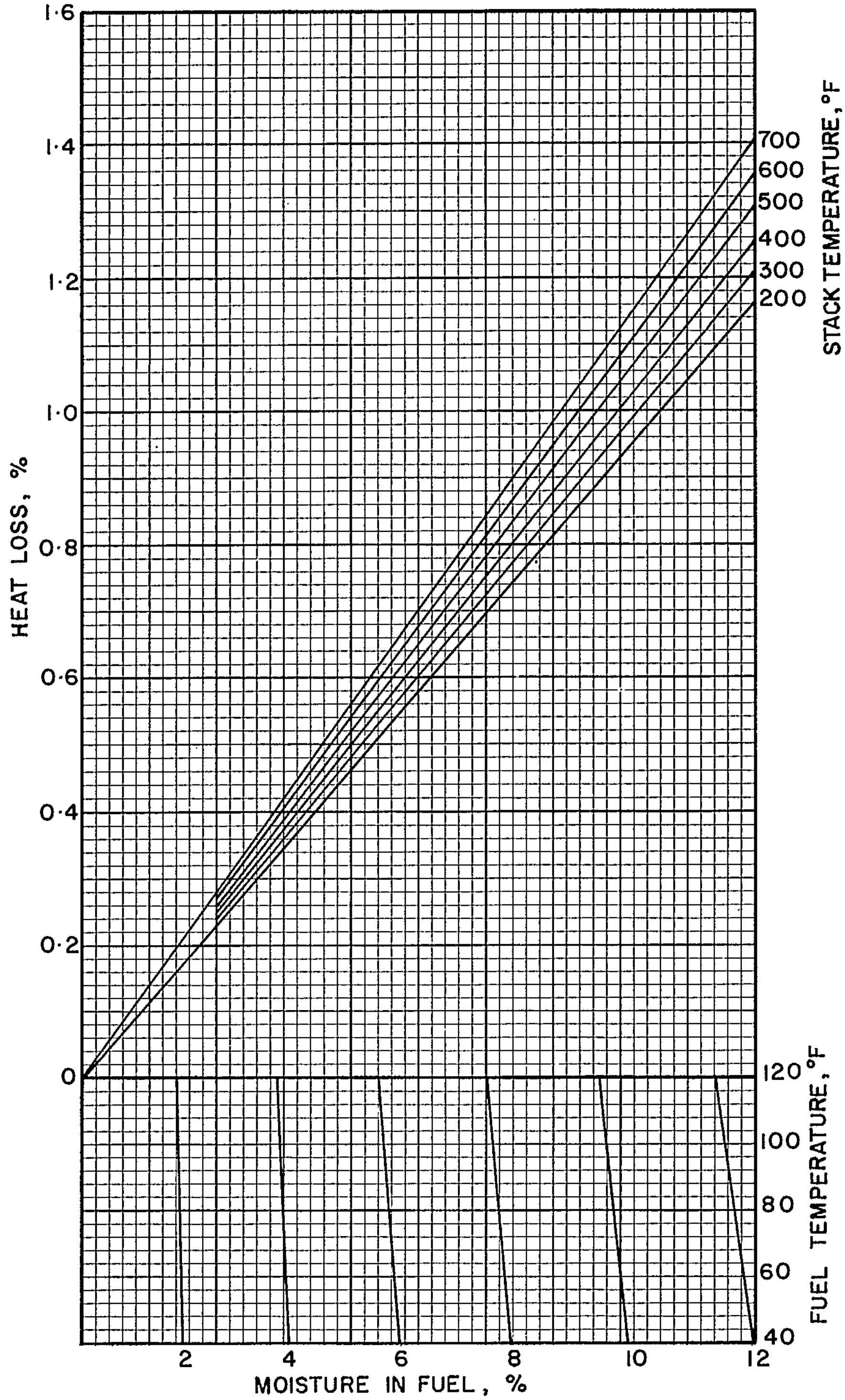


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NB · I · 3

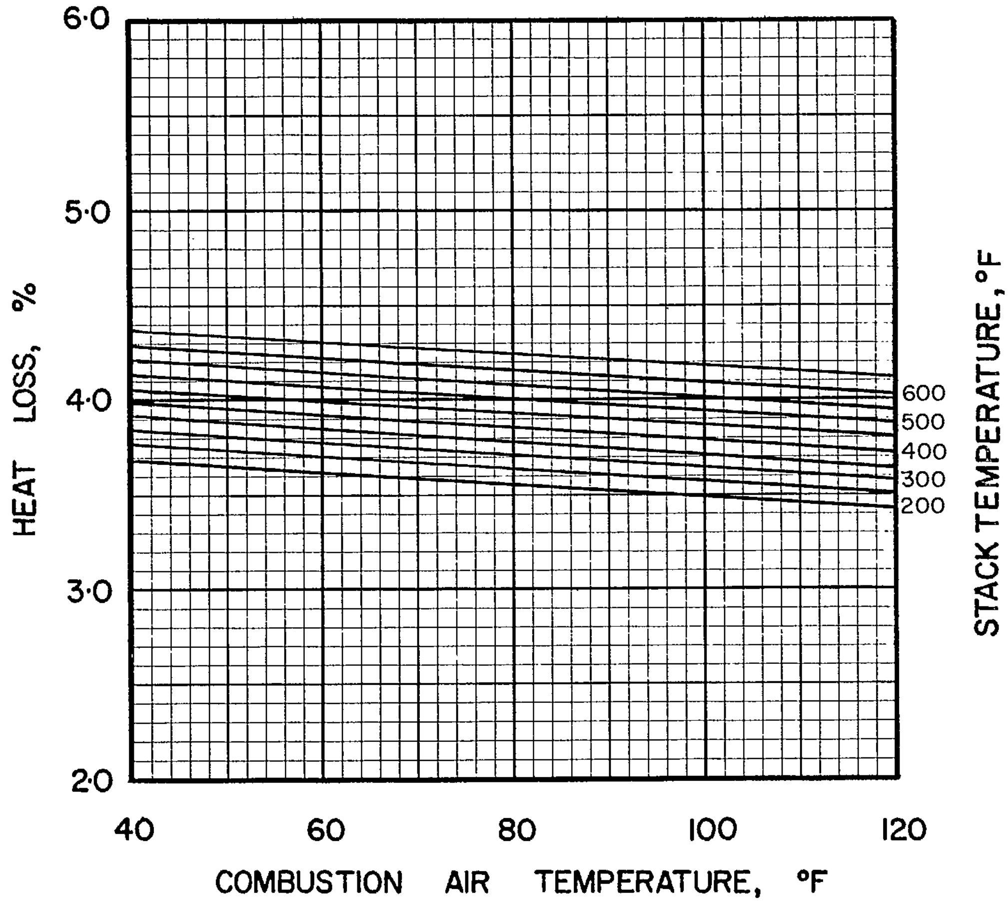


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB·1·3

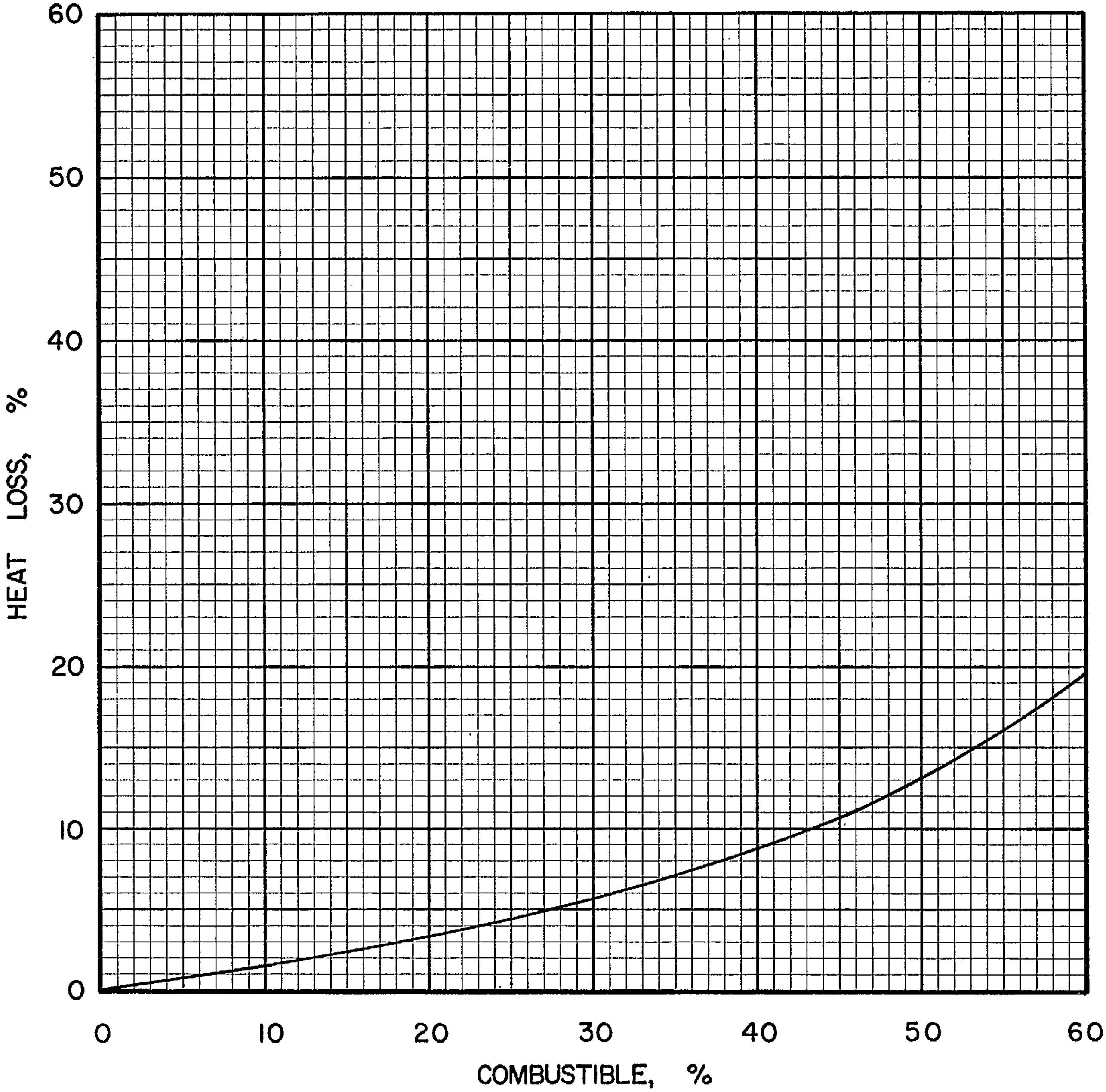


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·1·3

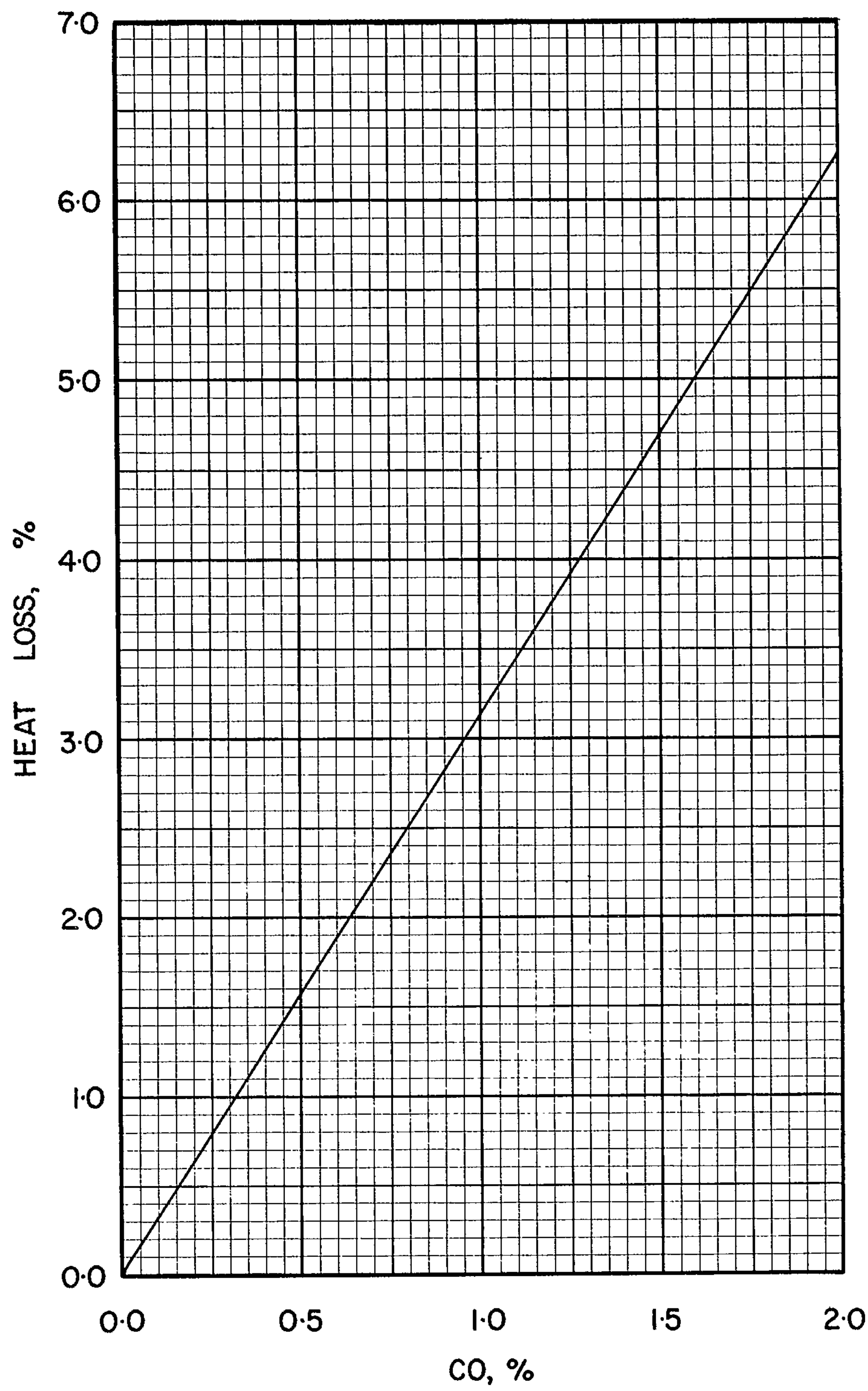


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB·1·3

COAL NB 2-1, D.W. & R.A. MILLS, N.B. COAL LTD., MINTO, 2 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1859
Volatile Matter	0.3209
Fixed Carbon	0.4932
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6658
Hydrogen (H)	0.0435
Sulphur (S)	0.0654
Nitrogen (N)	0.0089
Oxygen (O)	0.0305
Ash	0.1859
Total	1.0000

Gross Calorific Value

Btu/lb:	12290
Btu/short ton:	24.58×10^6
Btu/long ton:	27.53×10^6
MJ/kg:	28.58

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 81.37 lb
10^6 Btu = 0.04068 short tons
10^6 Btu = 0.03632 long tons

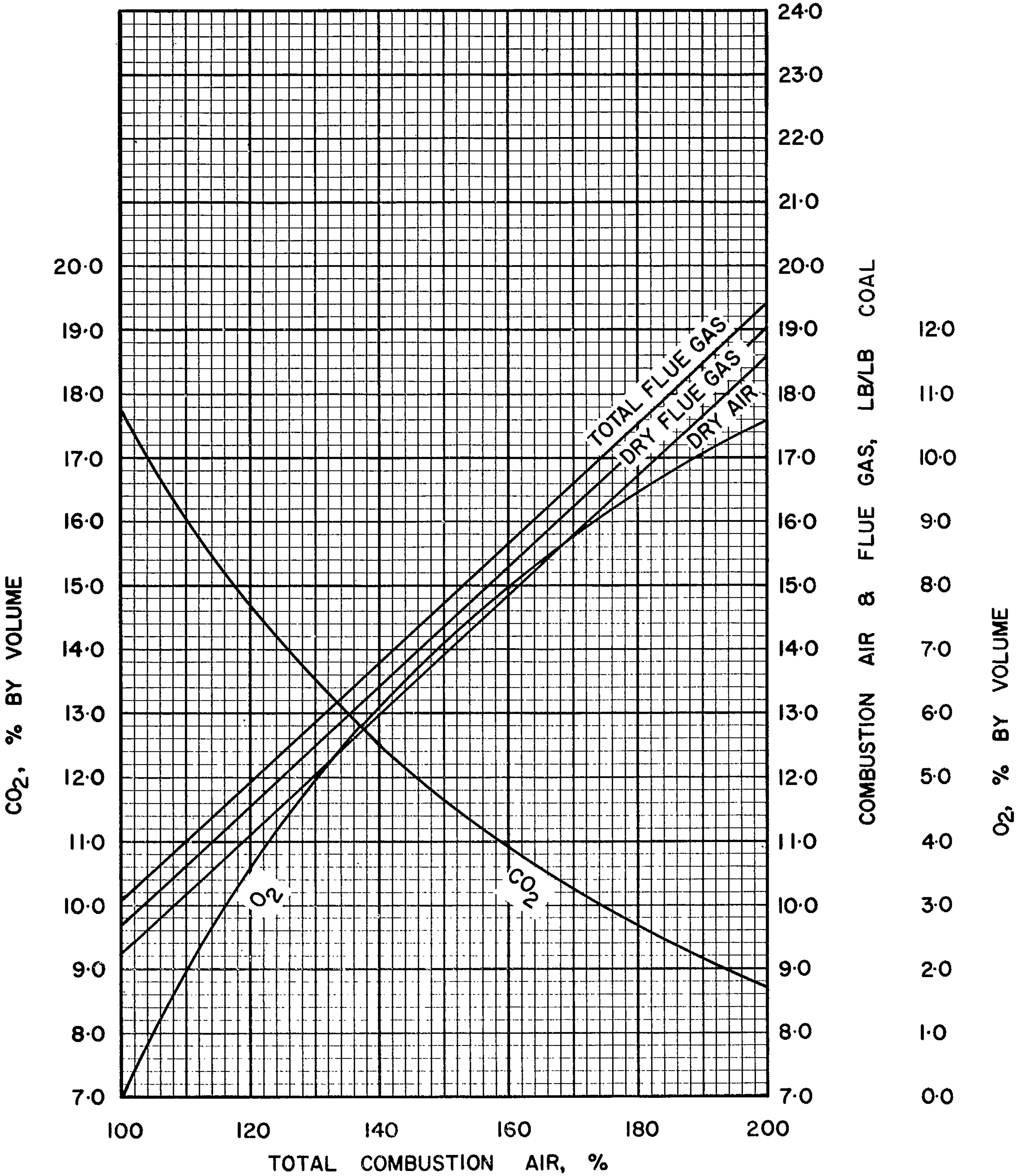


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NB·2·1

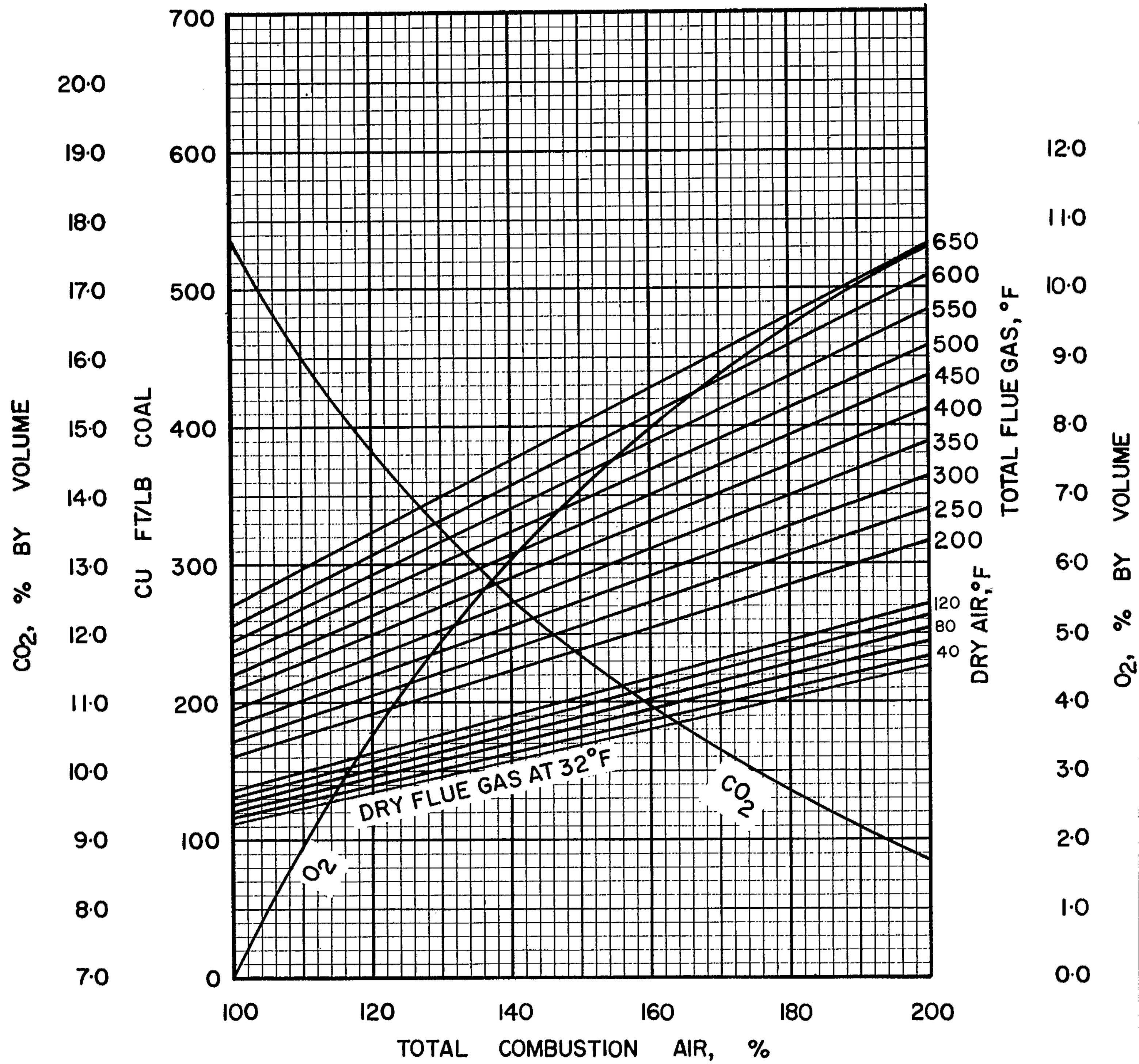


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NB·2·1

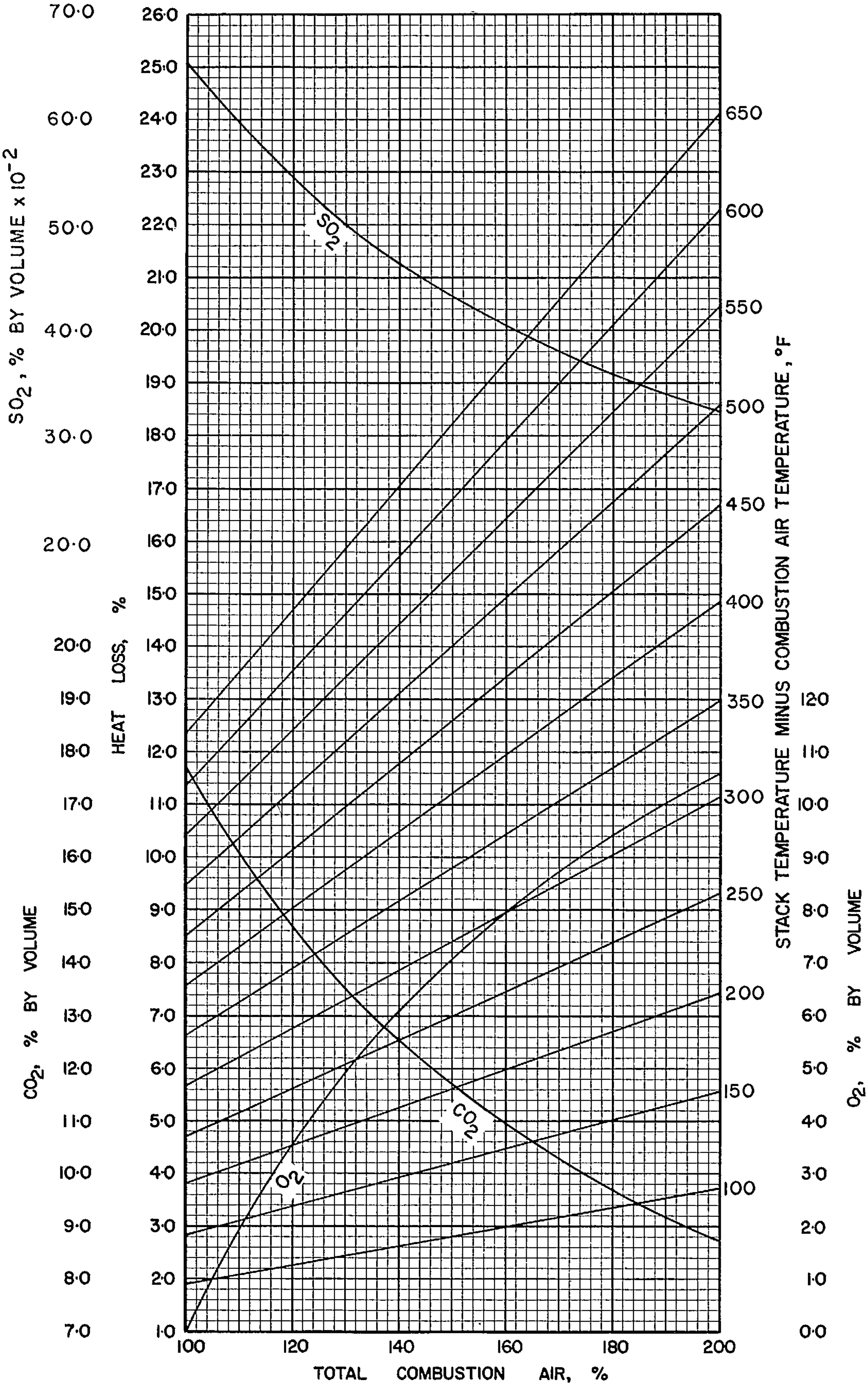


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·2·1

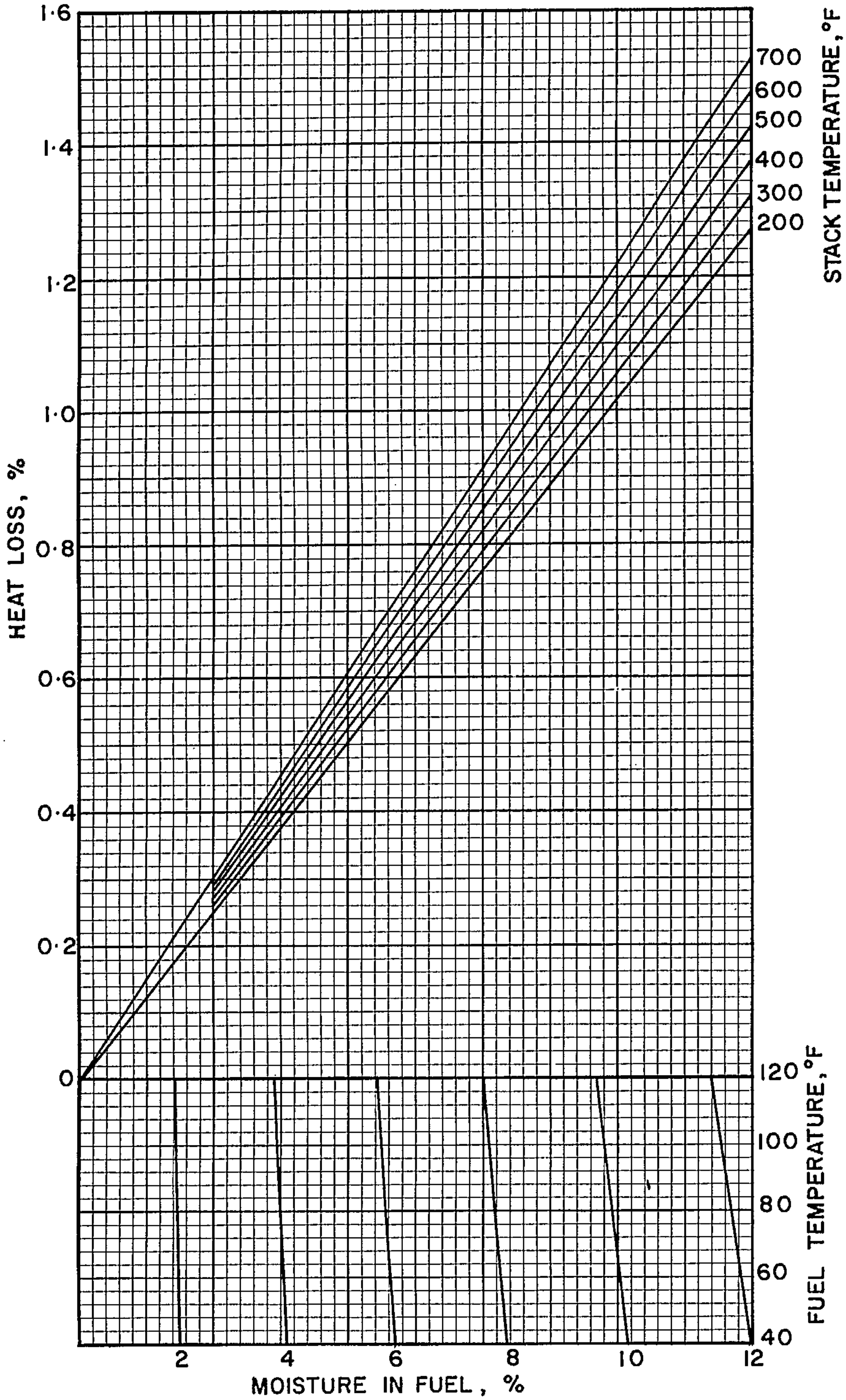


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NB·2·1

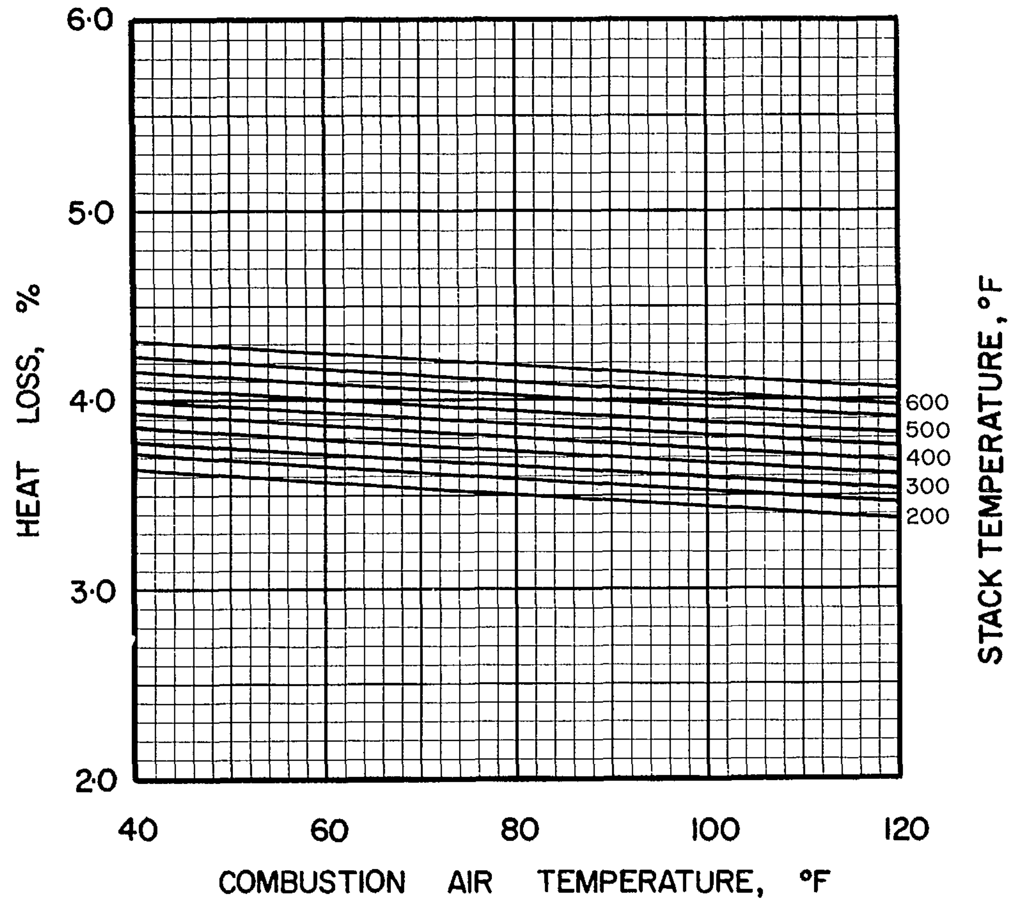


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB·2·1

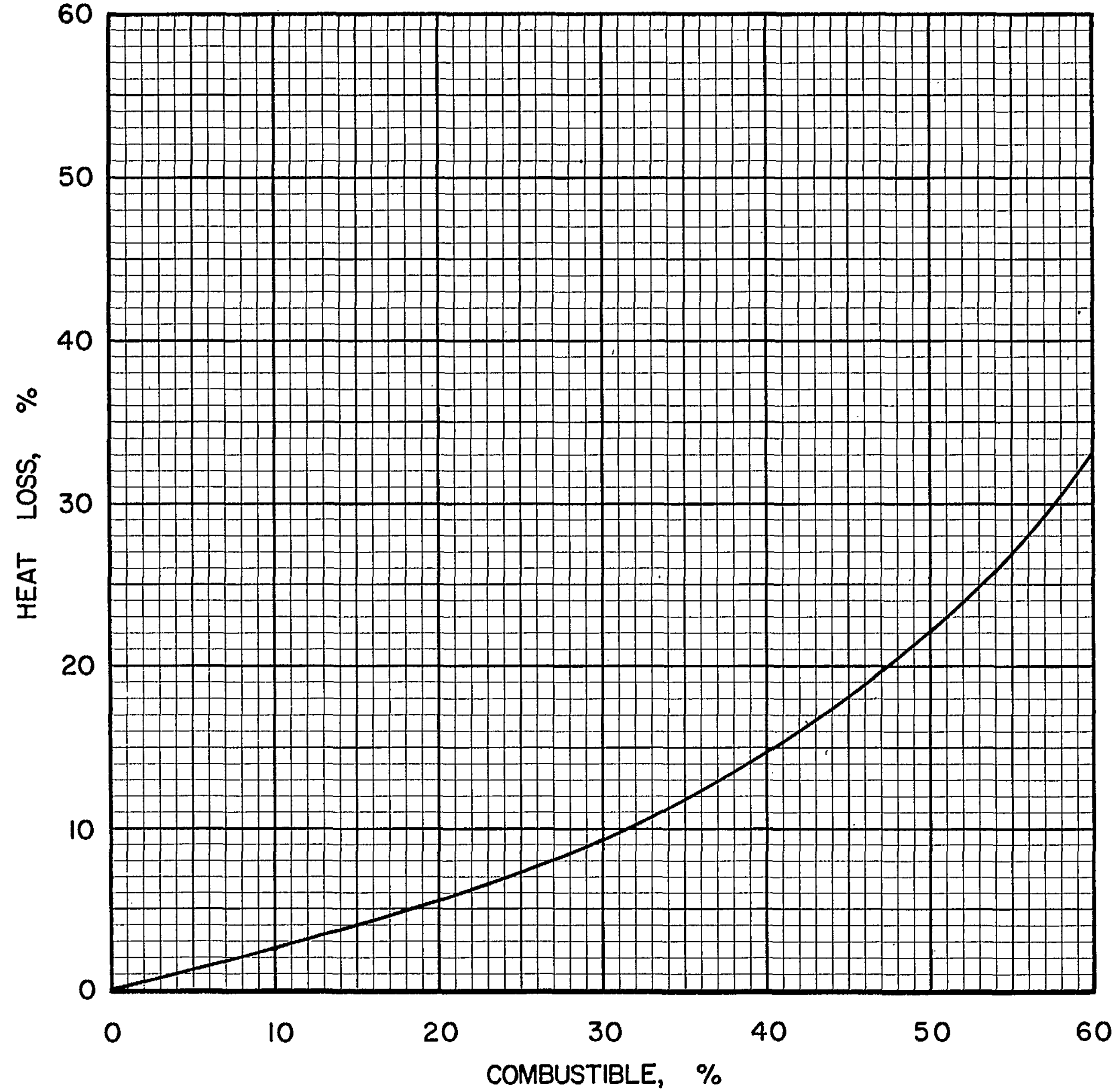


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·2·1

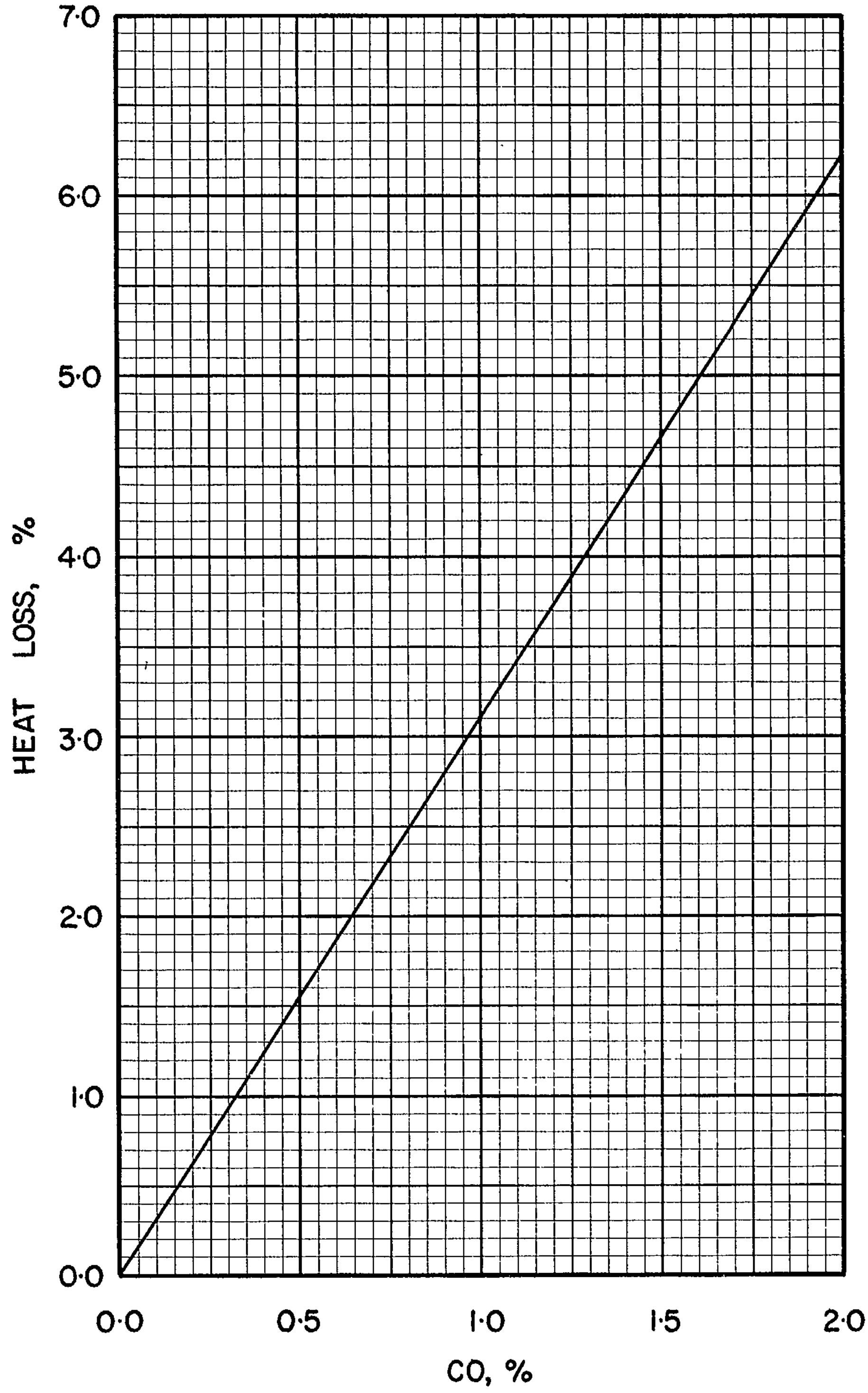


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB · 2 · 1

COAL NB 2-2, D.W. & R.A. MILLS, N.B. COAL LTD., MINTO, 3/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1774
Volatile Matter	0.3288
Fixed Carbon	0.4938
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6722
Hydrogen (H)	0.0449
Sulphur (S)	0.0618
Nitrogen (N)	0.0079
Oxygen (O)	0.0358
Ash	0.1774
Total	1.0000

Gross Calorific Value

Btu/lb:	12420
Btu/short ton:	24.84×10^6
Btu/long ton:	27.82×10^6
MJ/kg:	28.88

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 80.52	lb	
10^6 Btu	= 0.04026	short tons	
10^6 Btu	= 0.03594	long tons	

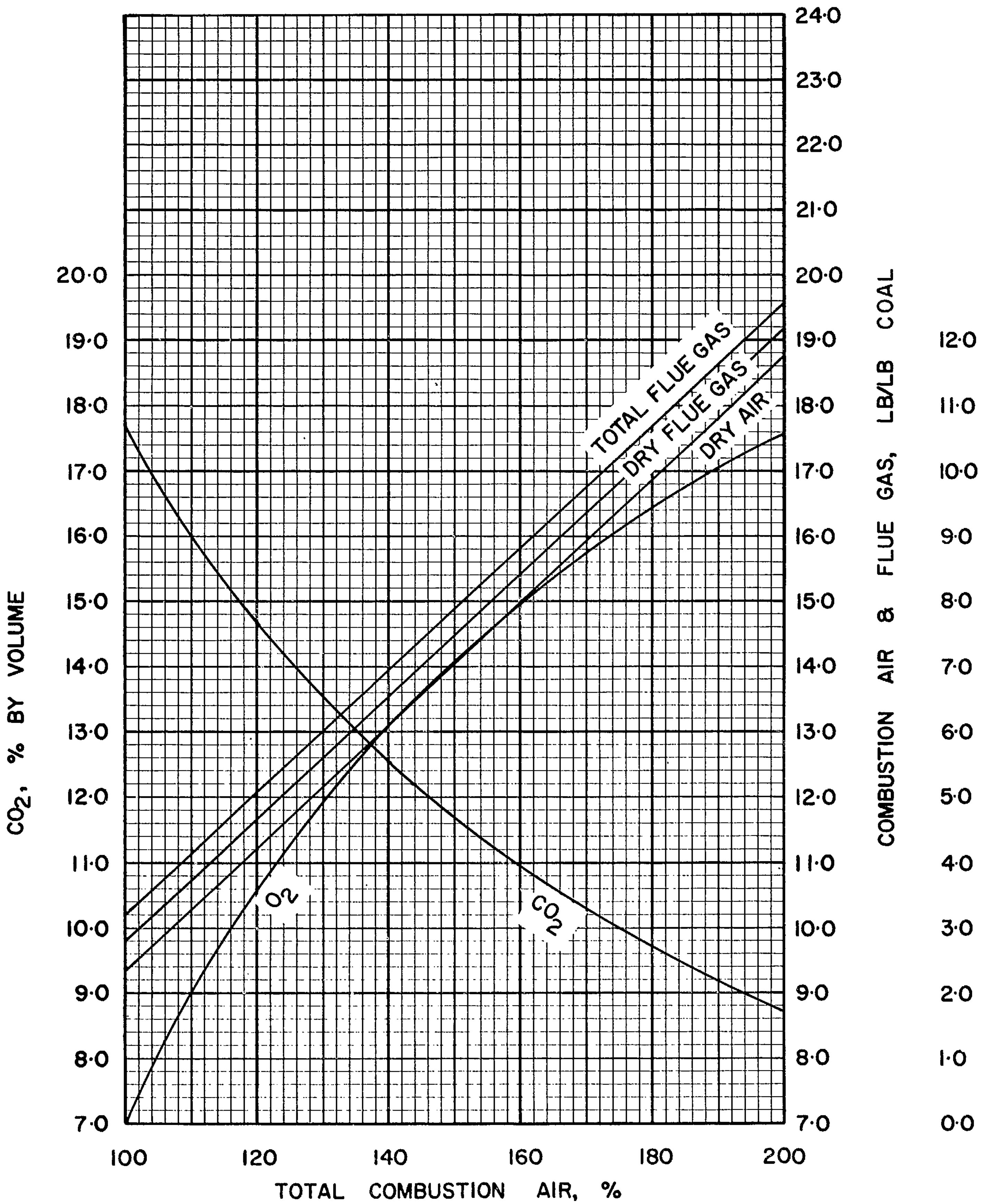


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NB·2·2

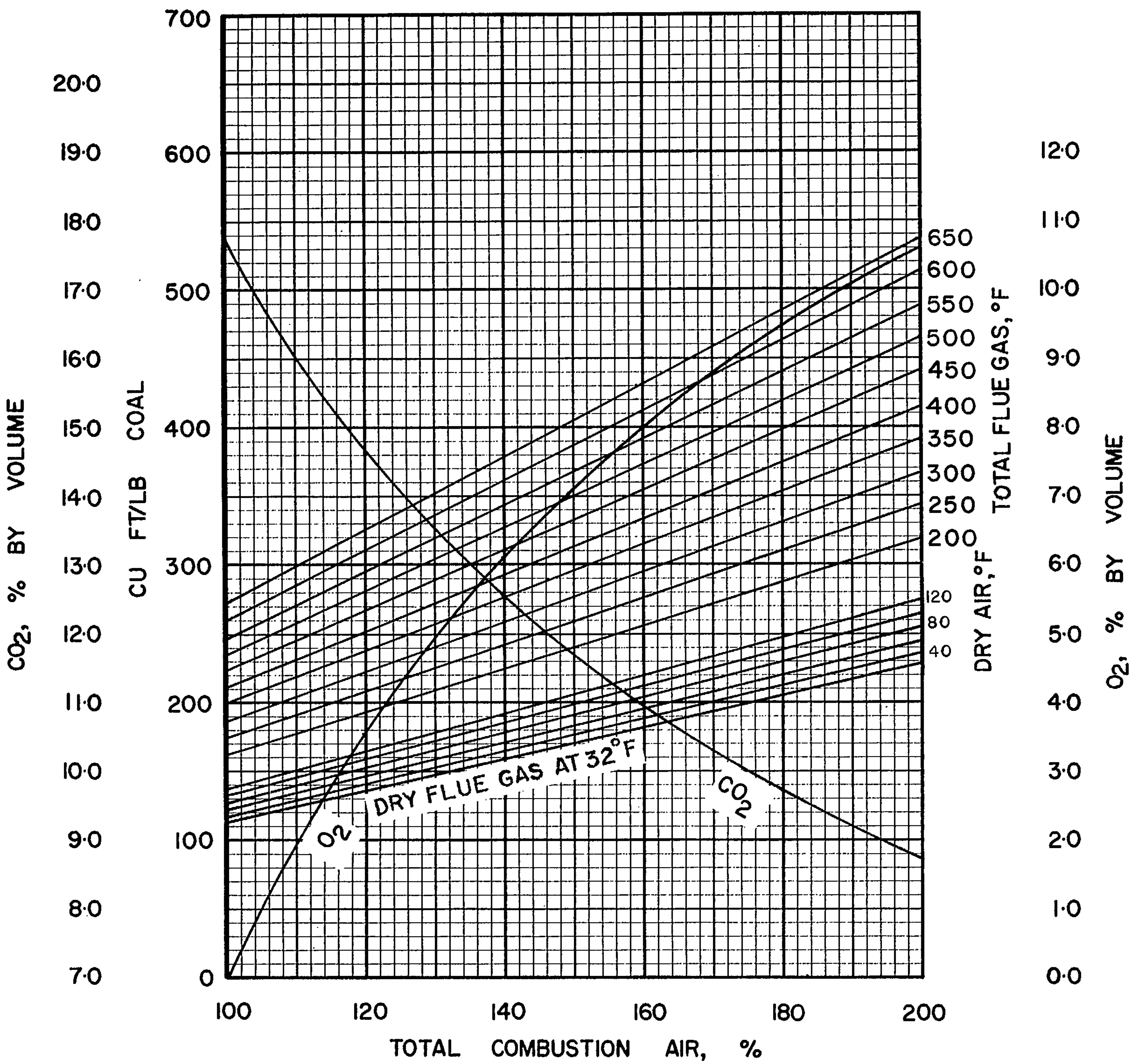


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NB·2·2

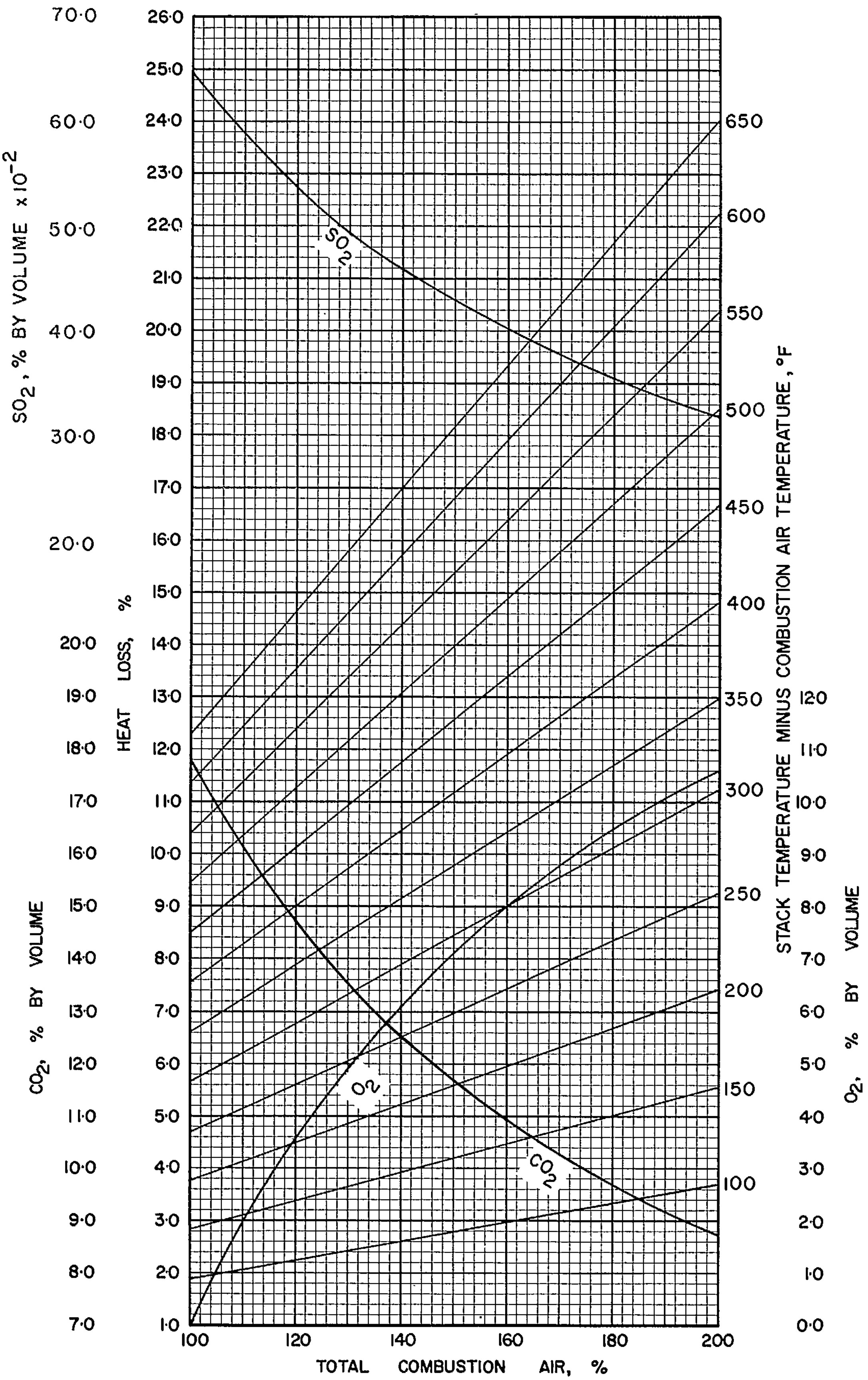


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·2·2

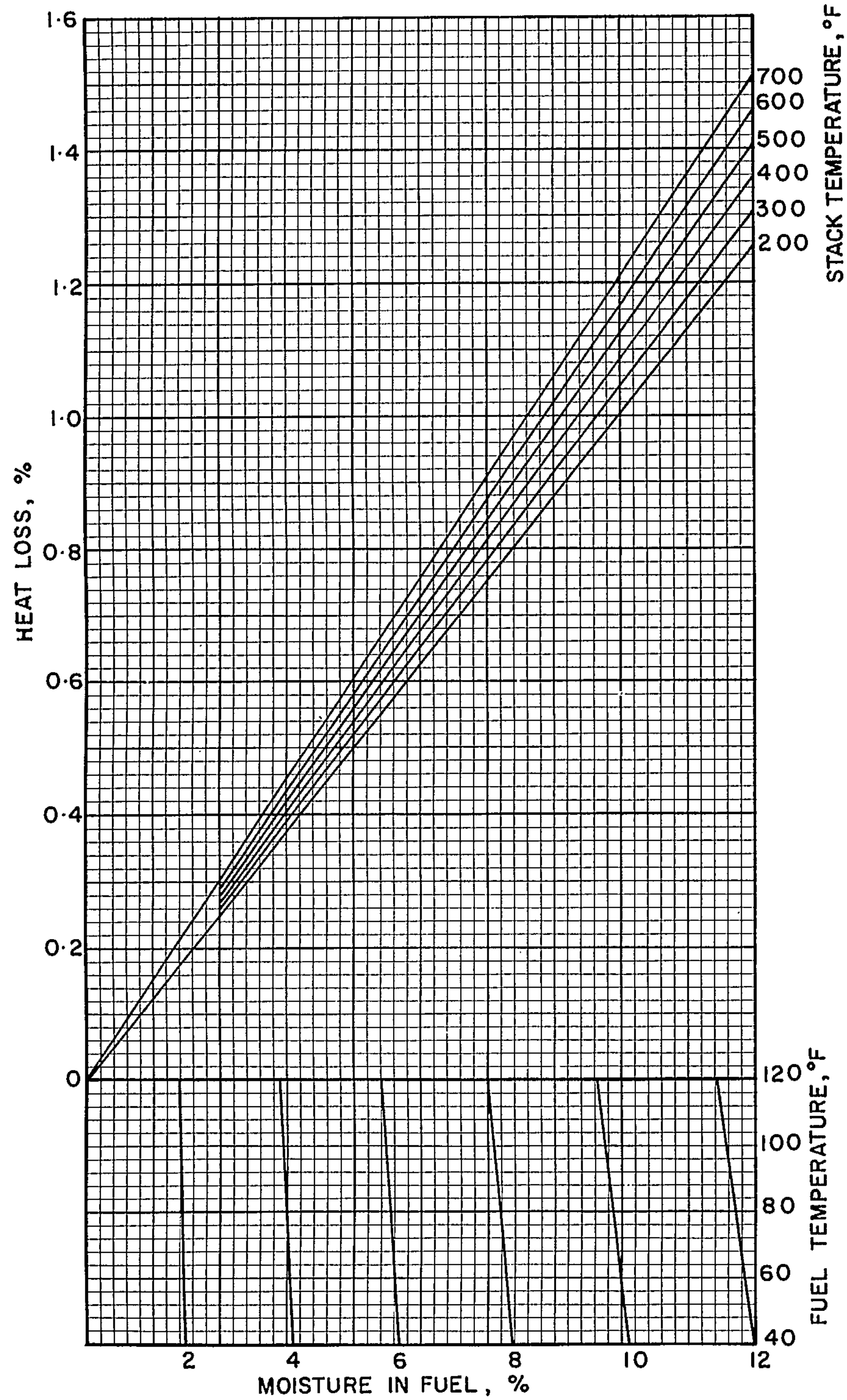


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

NB·2·2

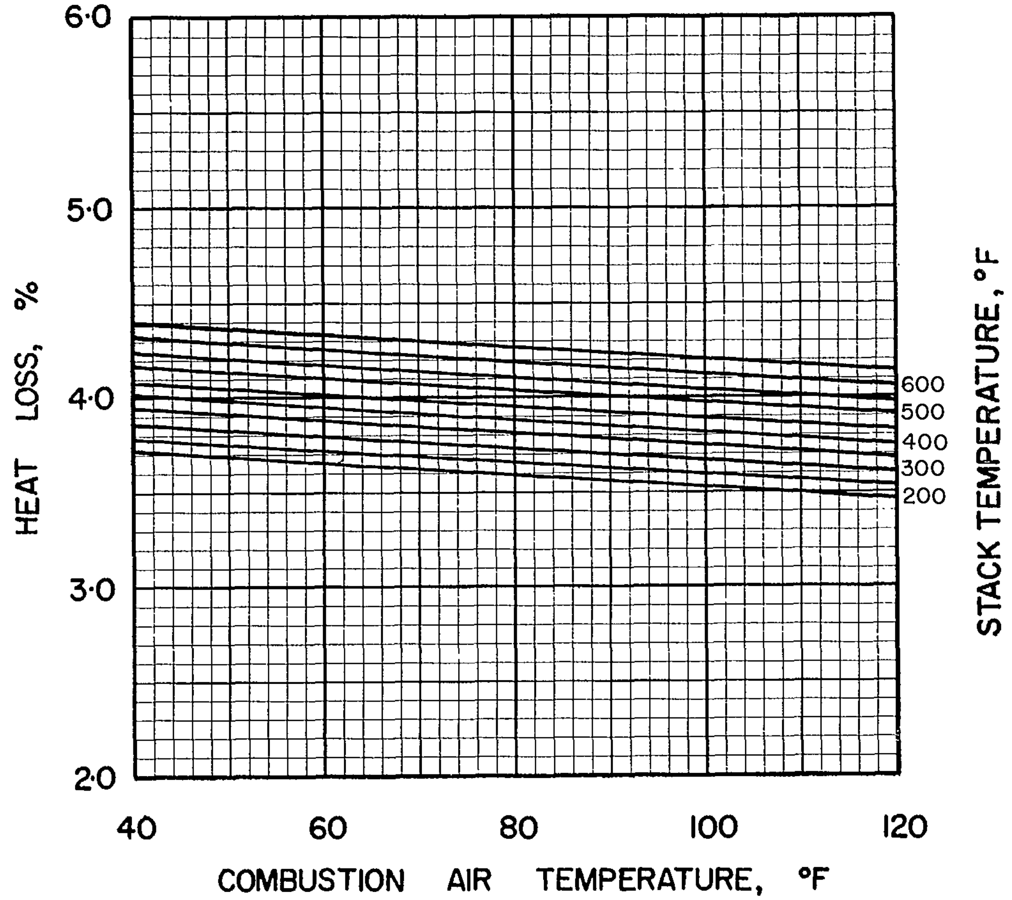


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB·2·2

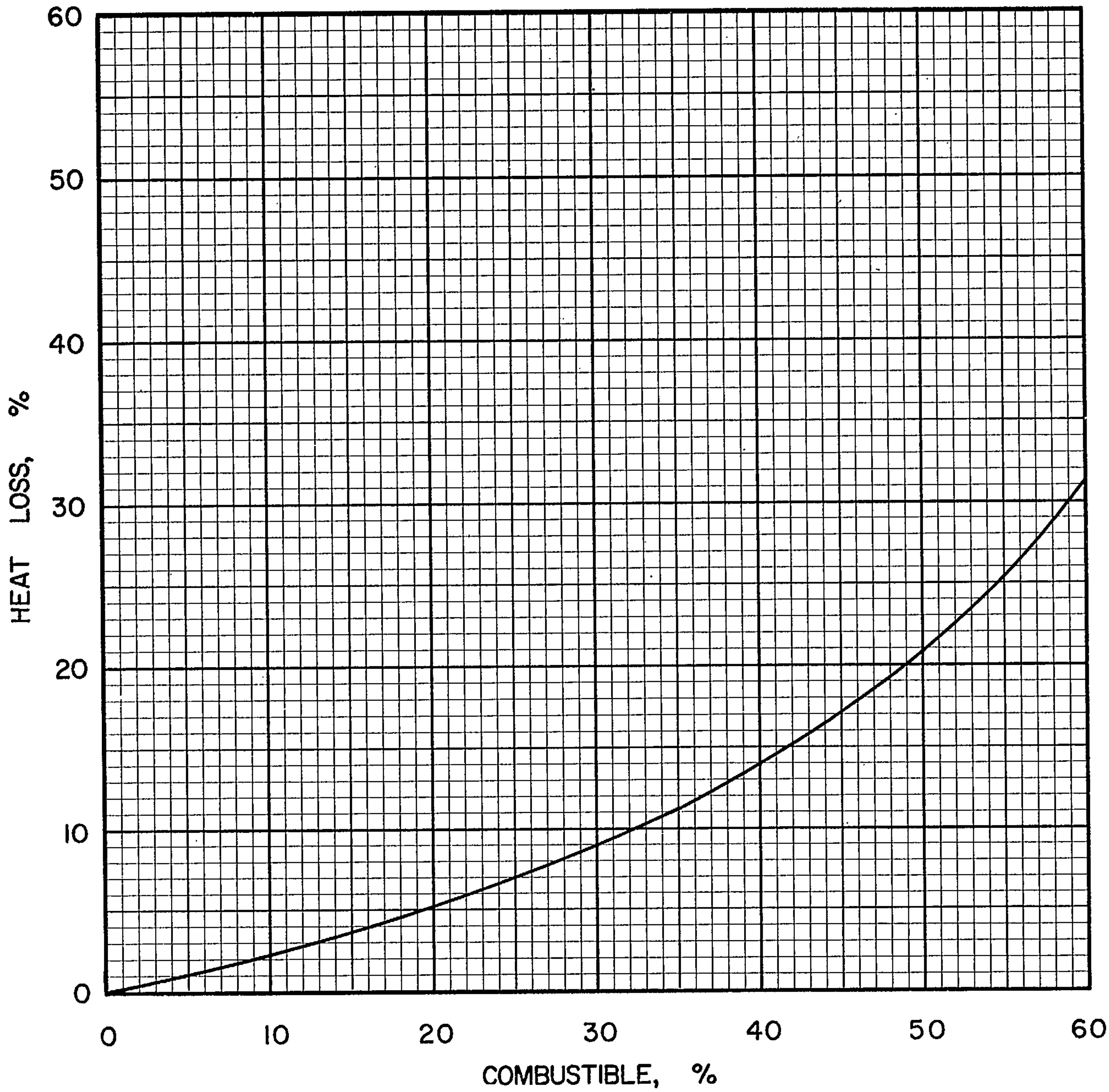


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·2·2

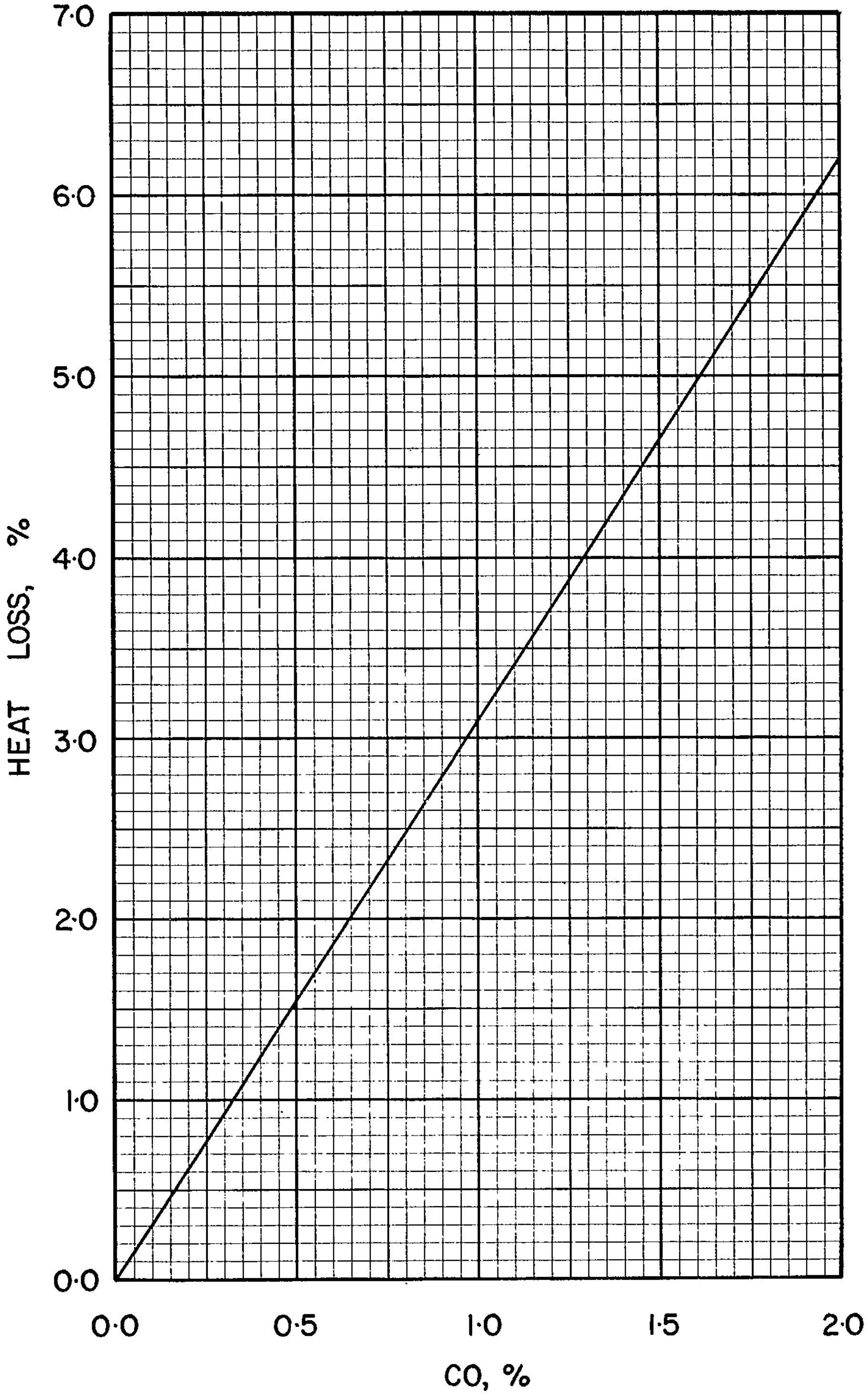


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB · 2 · 2

COAL NB 3-1, V.C. MCMANN, N.B. COAL LTD., MINTO, 1 1/4 in. x 0

Typical Moisture Range: 0–8%

Proximate Analysis (lb/lb dry coal)

Ash	0.1845
Volatile Matter	0.3336
Fixed Carbon	0.4819
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6675
Hydrogen (H)	0.0455
Sulphur (S)	0.0644
Nitrogen (N)	0.0085
Oxygen (O)	0.0296
Ash	0.1845
Total	1.0000

Gross Calorific Value

Btu/lb:	12230
Btu/short ton:	24.46×10^6
Btu/long ton:	27.40×10^6
MJ/kg:	28.44

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	81.77	lb	
10^6 Btu	=	0.04088	short tons	
10^6 Btu	=	0.03650	long tons	

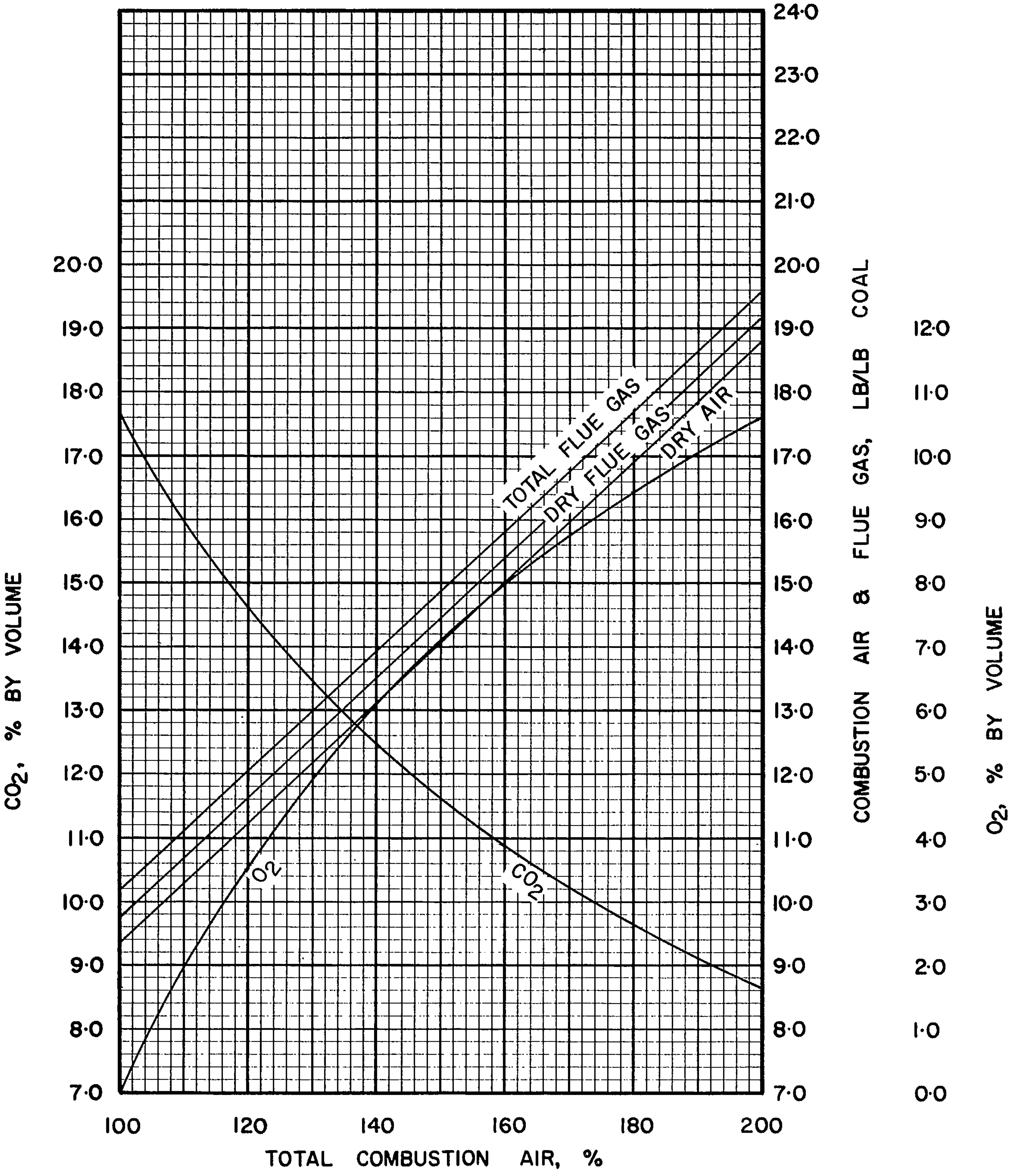


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS NB·3·1

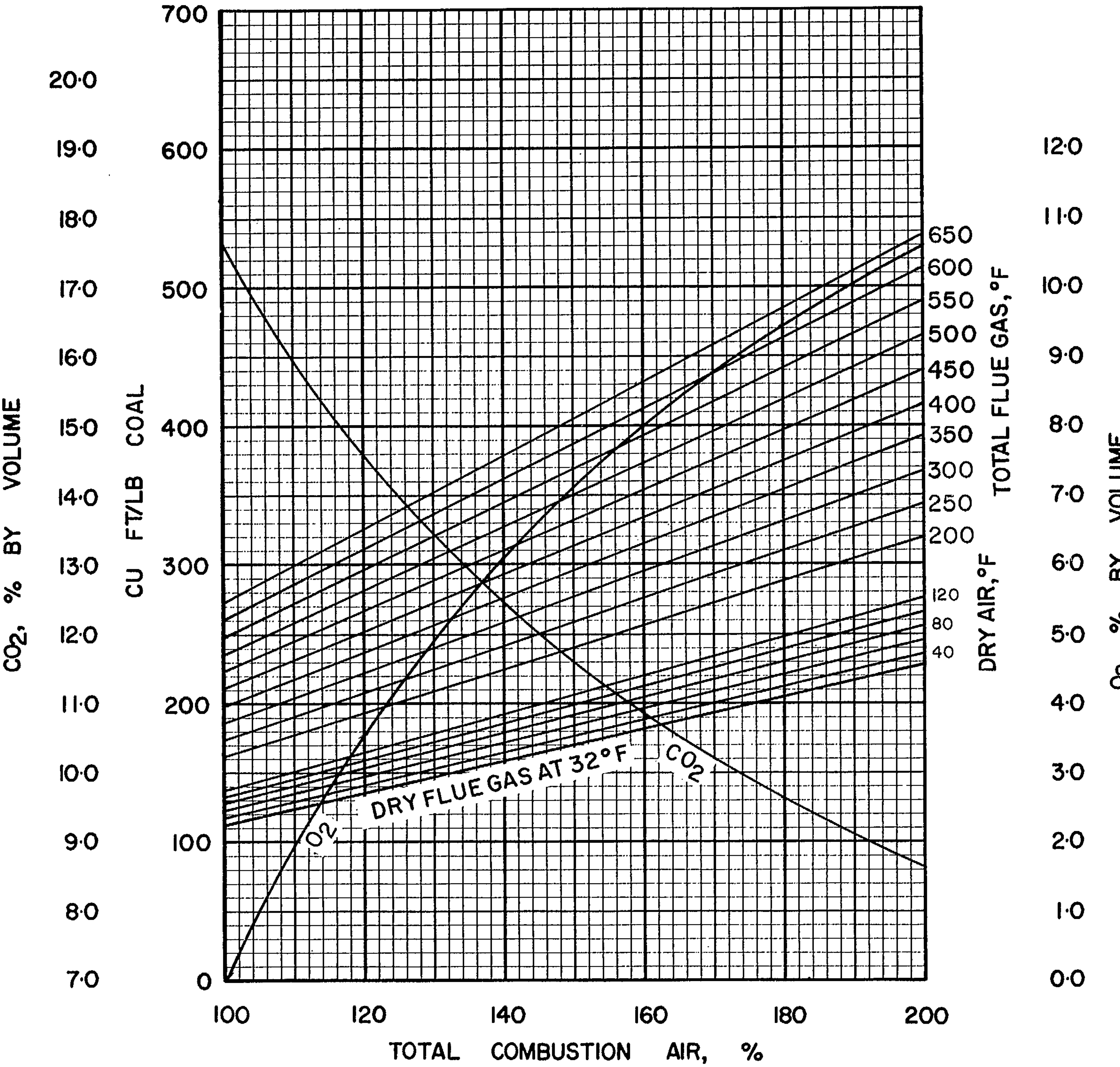


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

NB·3·1

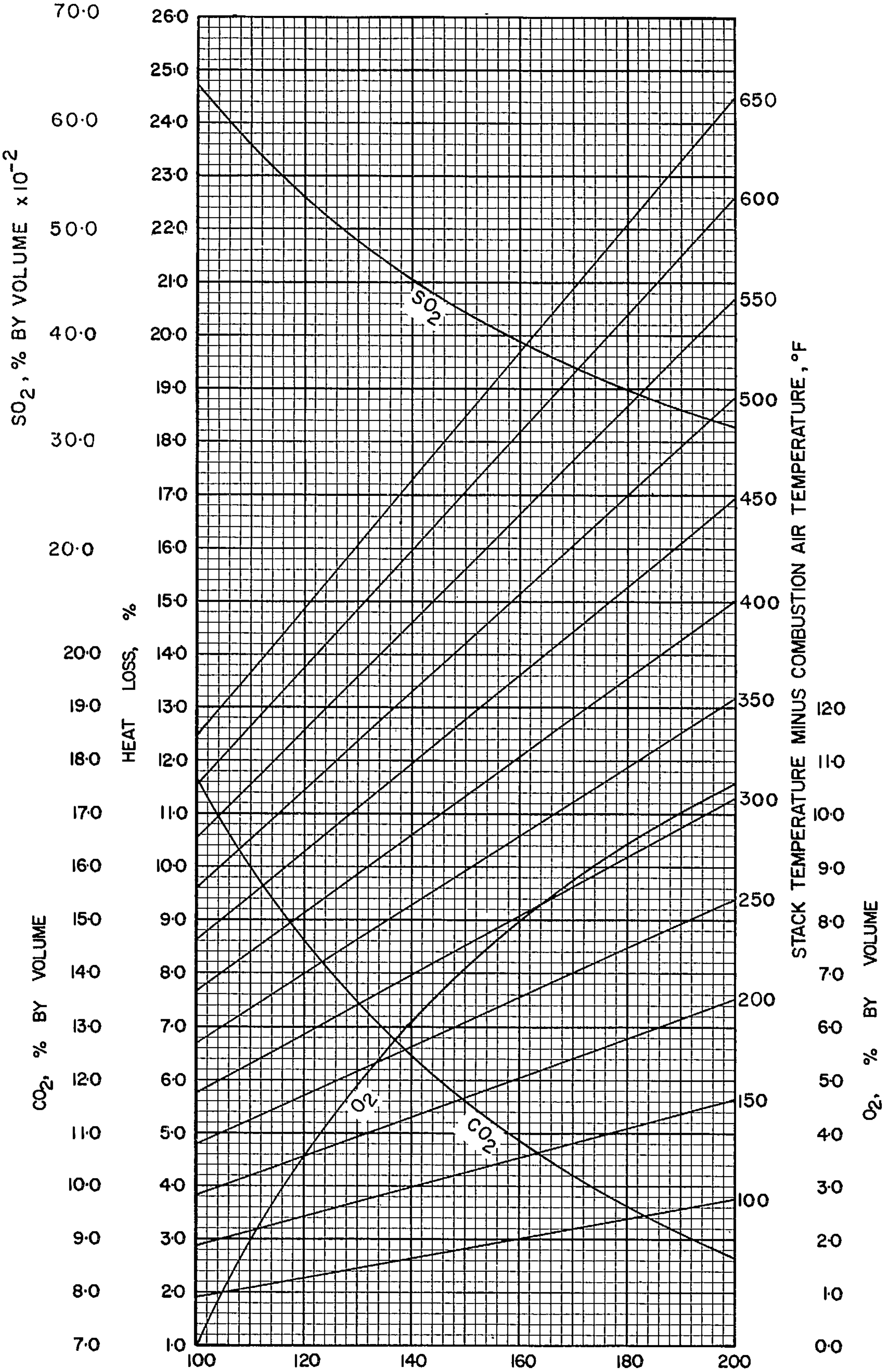


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

NB·3·1

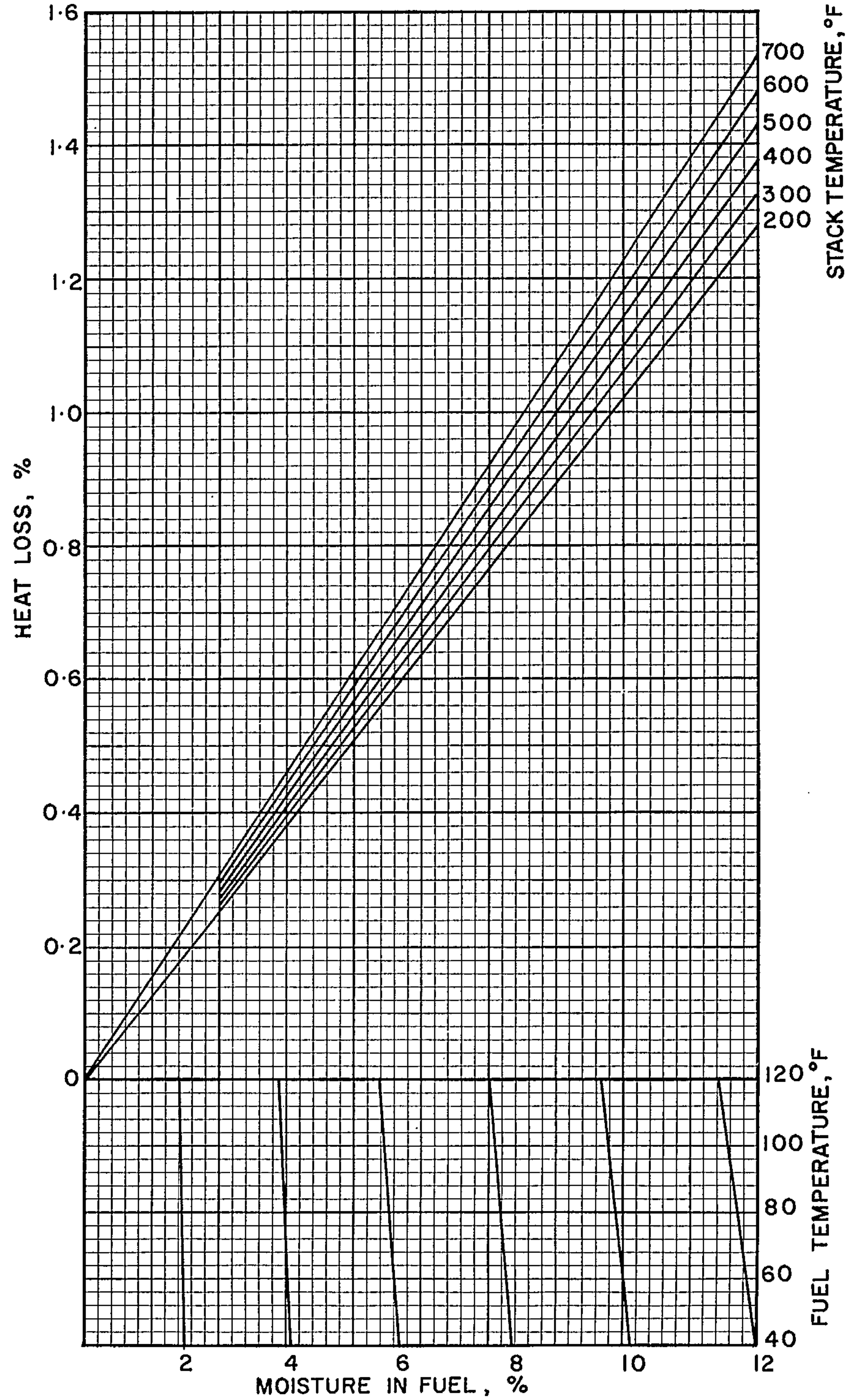


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

NB· 3·1

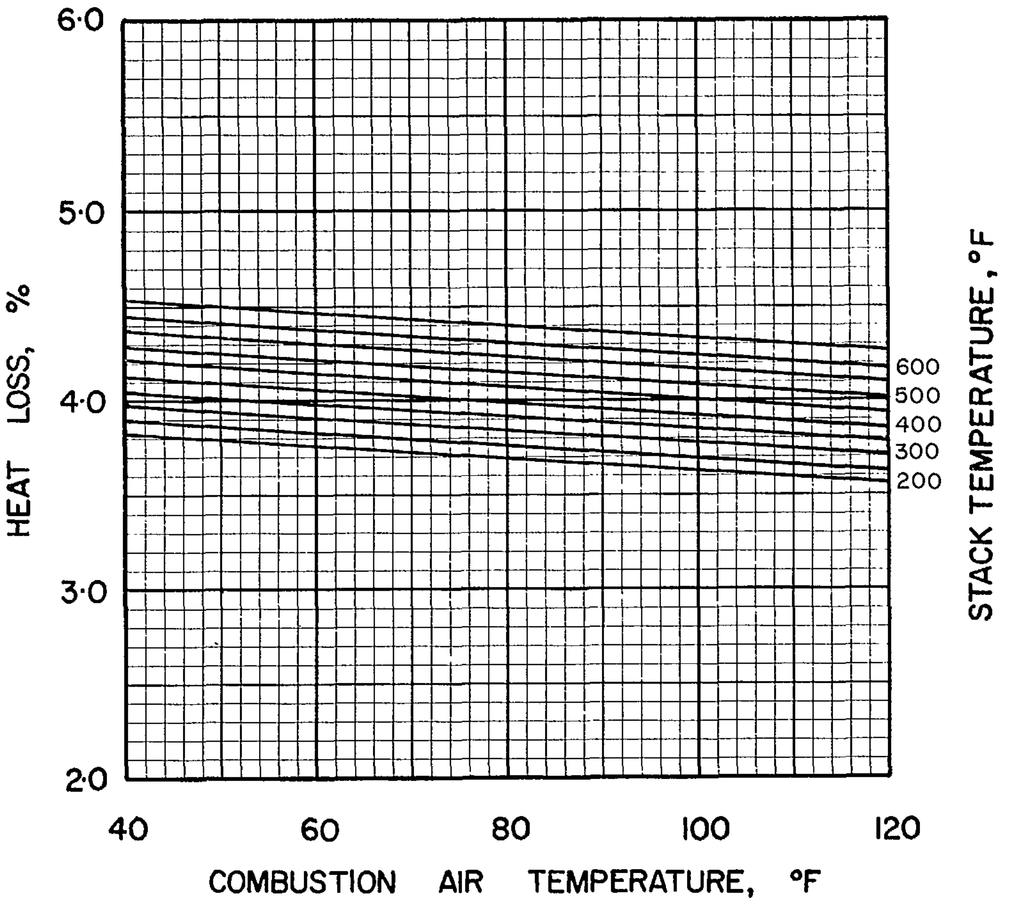


FIGURE 5 HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

NB·3·1

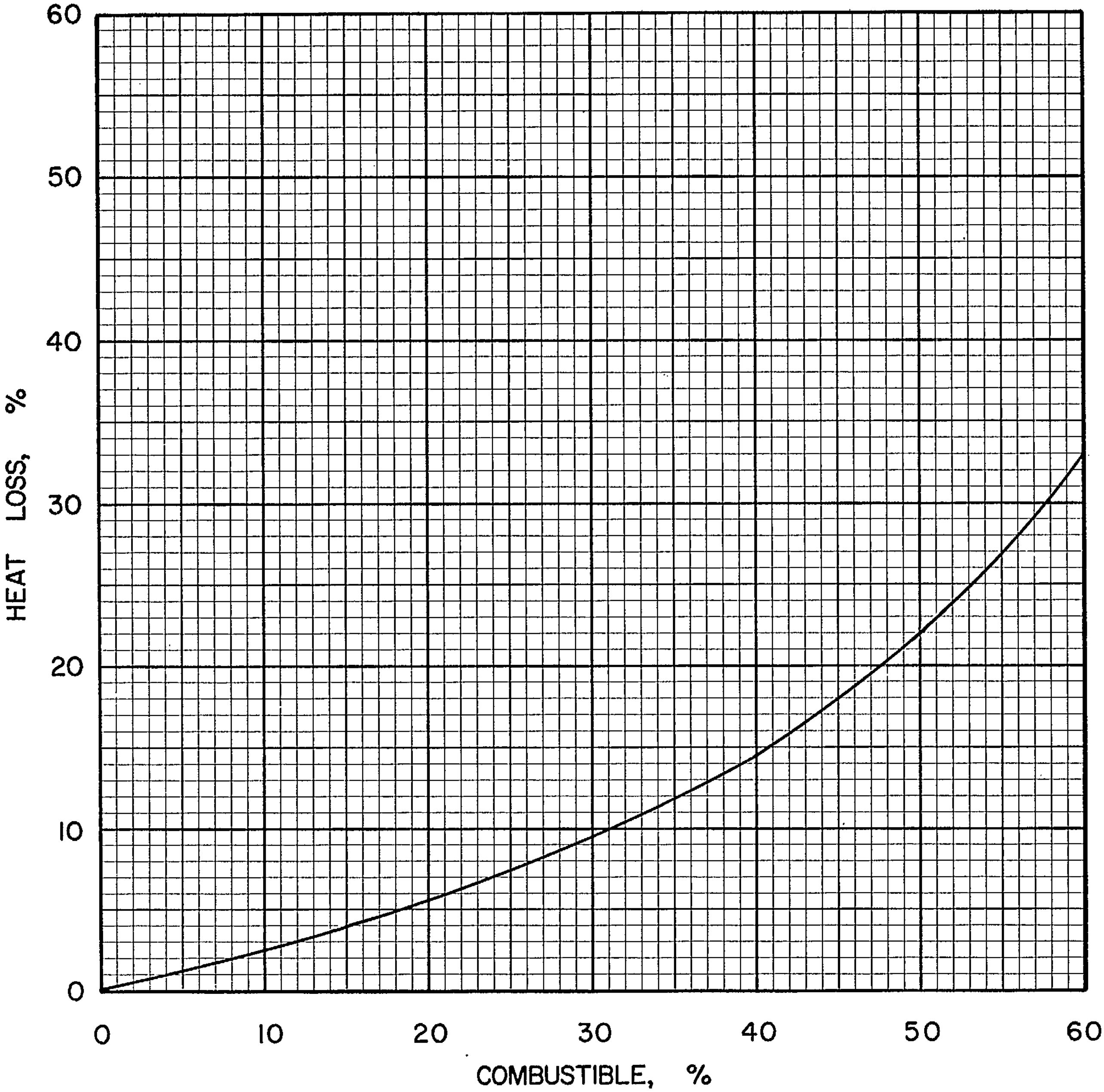


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

NB·3·1

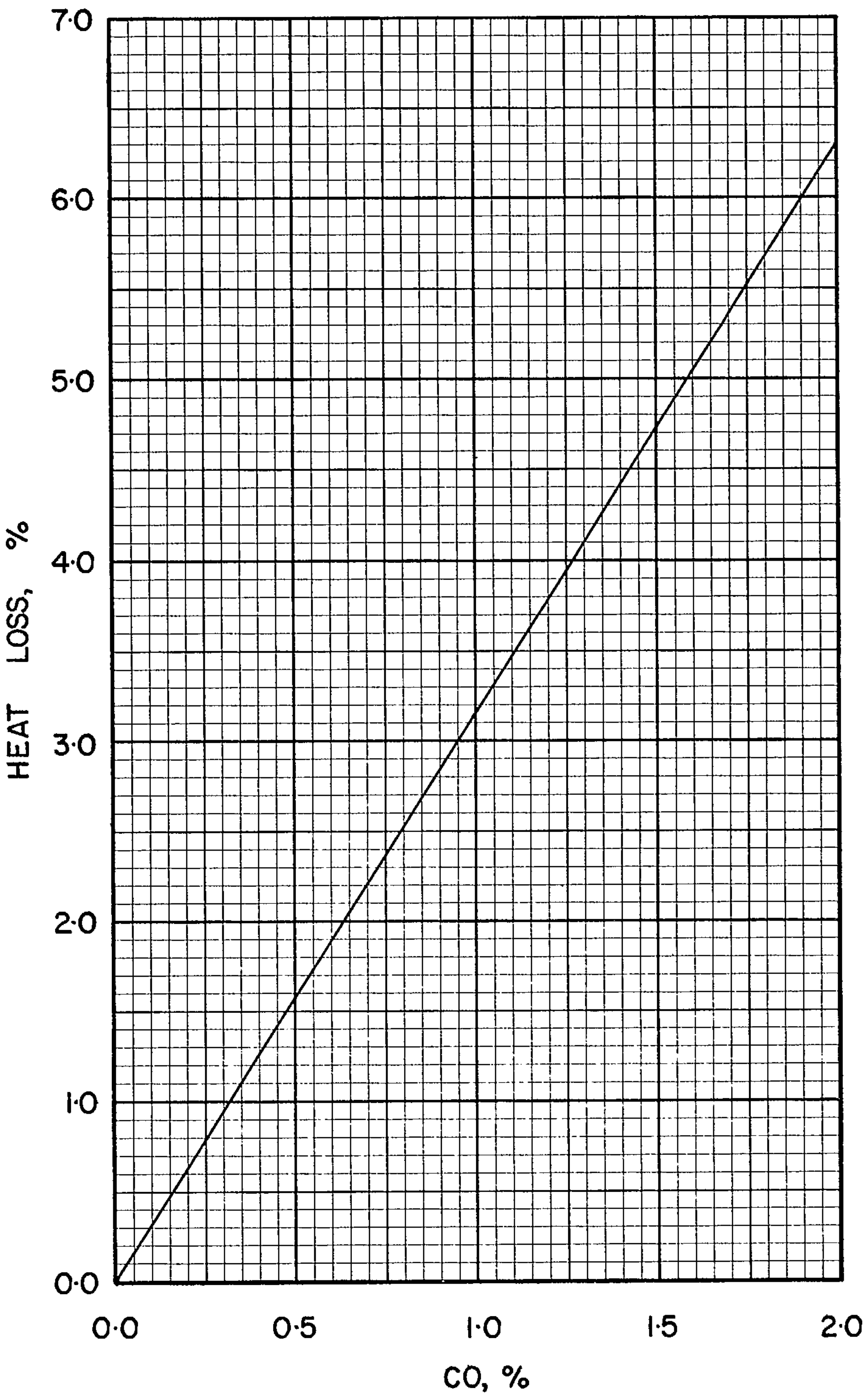


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

NB· 3·1

COAL 0 1-1, ONAKAWANA LIGNITE MINE RUN

Typical Moisture Range: 40–55%

Proximate Analysis (lb/lb dry coal)

Ash	0.1307
Volatile Matter	0.4133
Fixed Carbon	0.4560
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6412
Hydrogen (H)	0.0393
Sulphur (S)	0.0079
Nitrogen (N)	0.0106
Oxygen (O)	0.1703
Ash	0.1307
Total	1.0000

Gross Calorific Value

Btu/lb:	10300
Btu/short ton:	20.60×10^6
Btu/long ton:	23.07×10^6
MJ/kg:	23.93

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	97.09	lb	
10^6 Btu	=	0.04854	short tons	
10^6 Btu	=	0.04334	long tons	

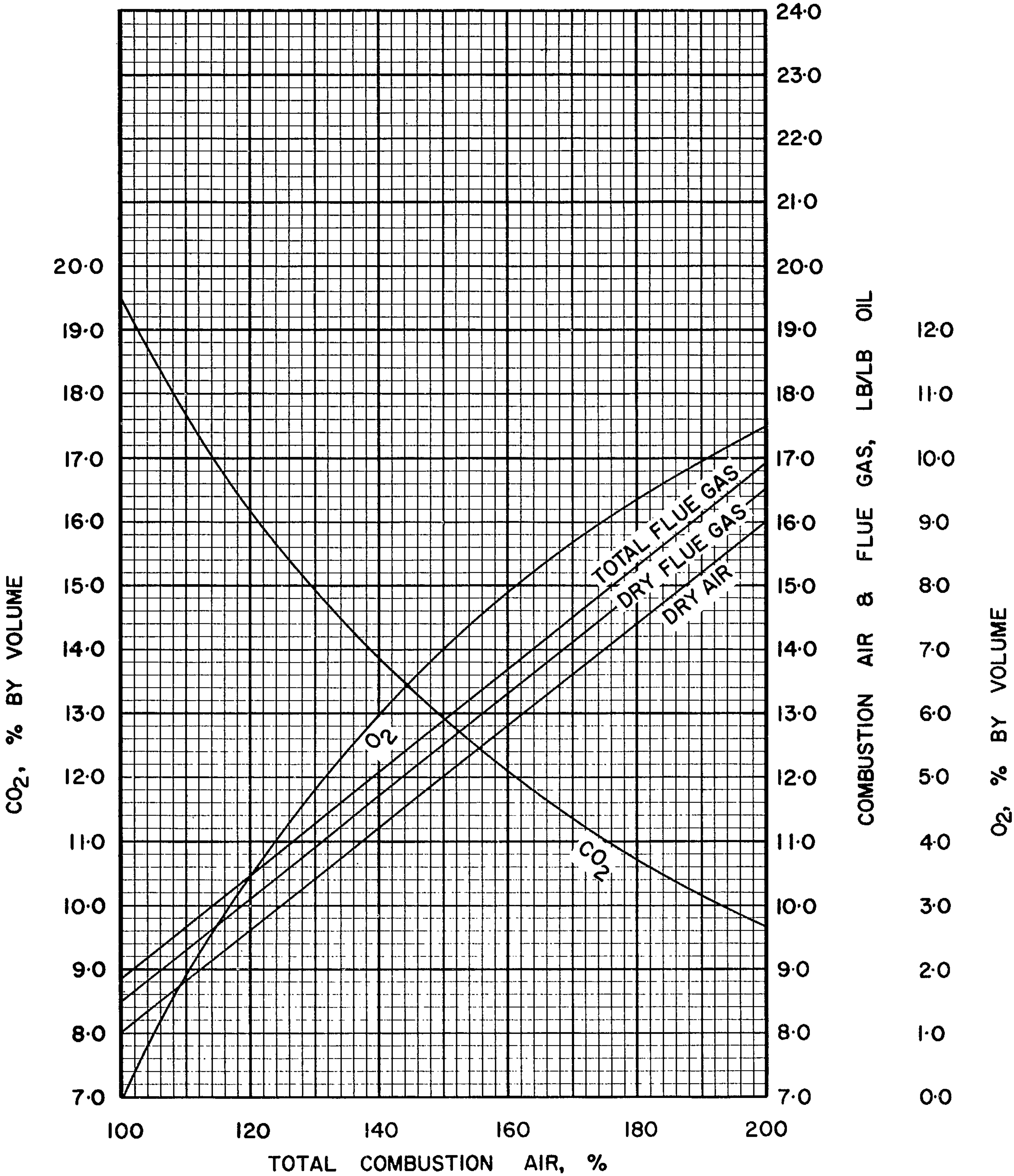


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

0·1·1

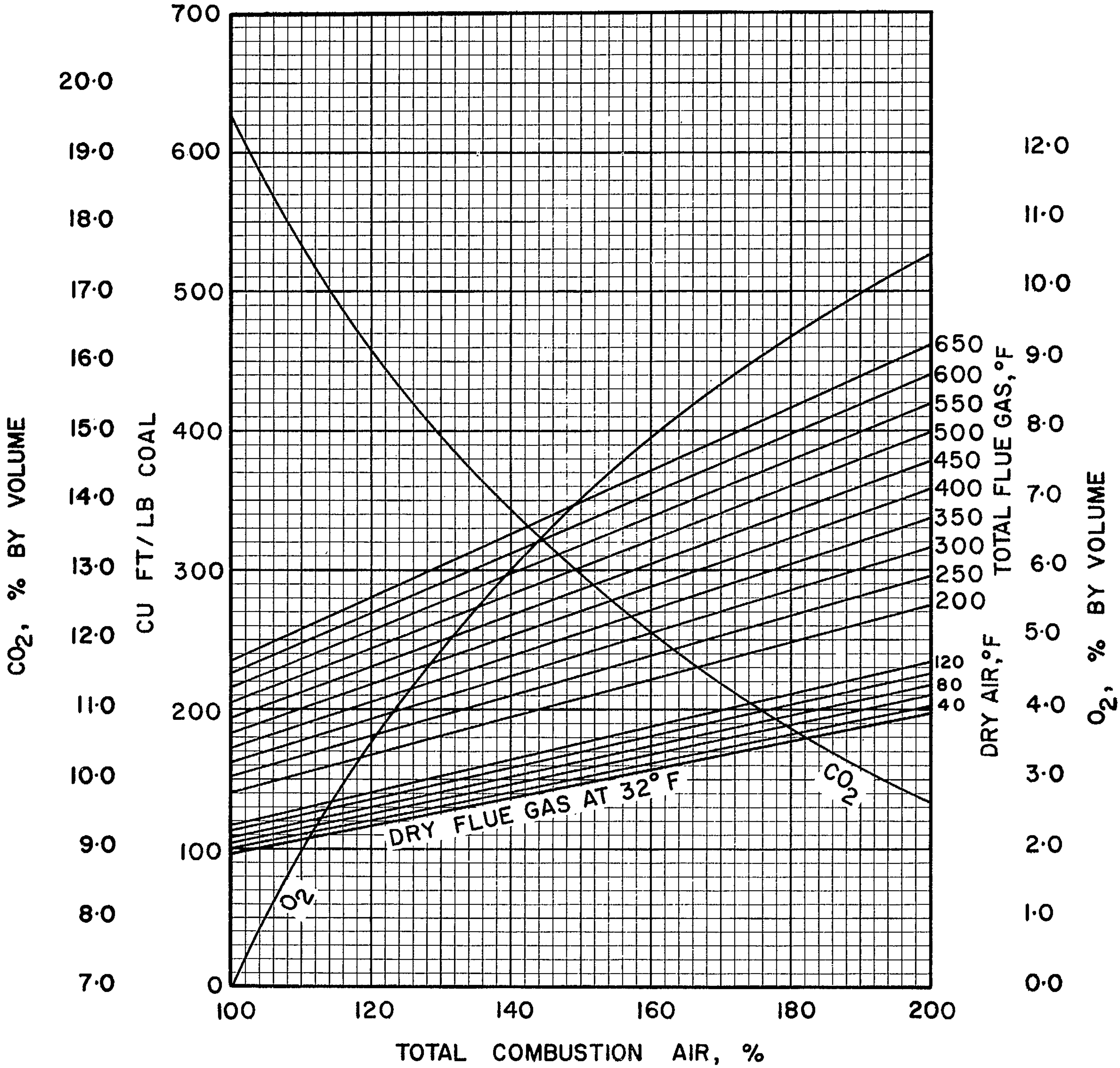


FIGURE 2. COMBUSTION DATA, VOLUME BASIS.

0·1·1

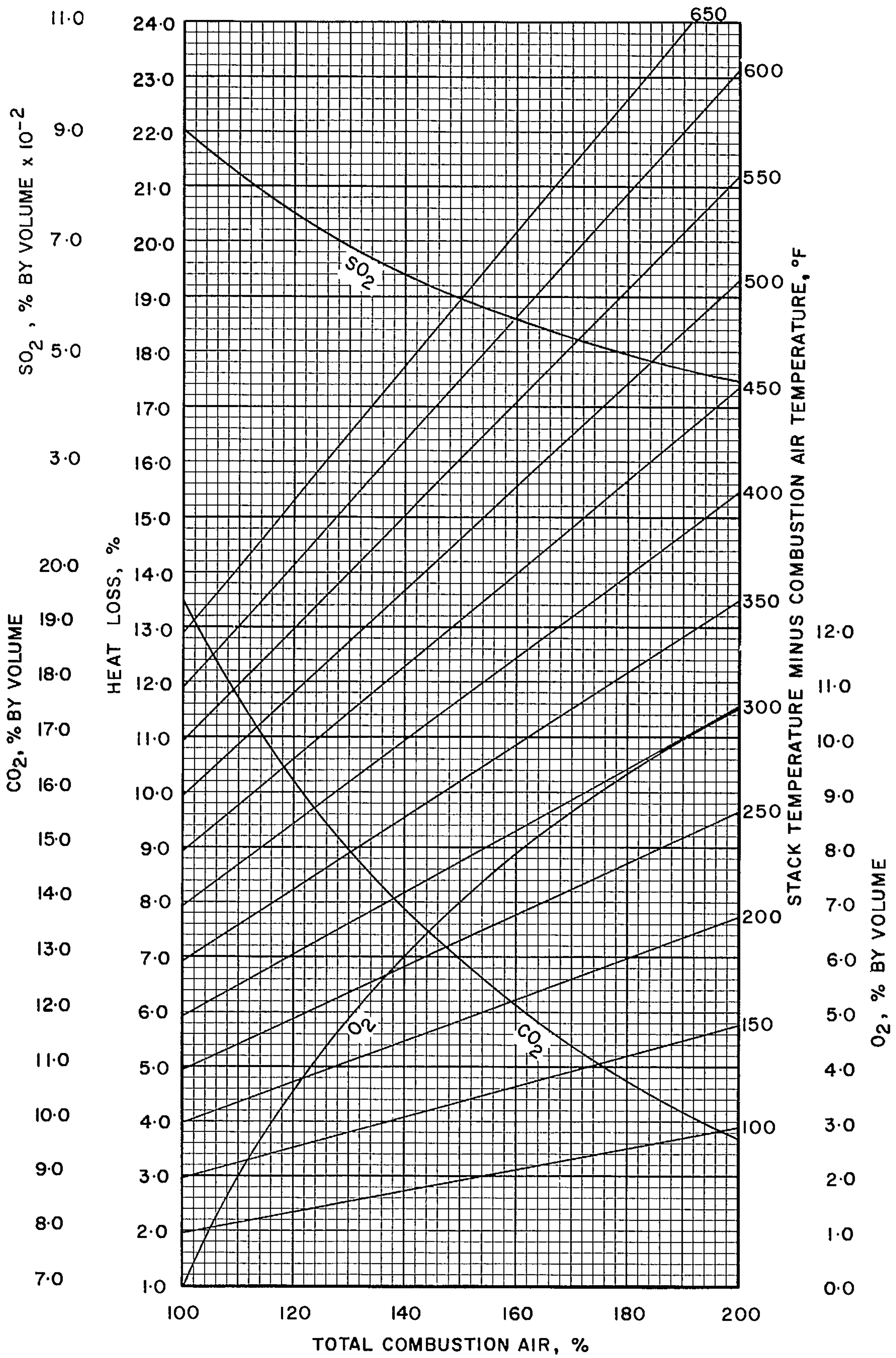


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS·

0·1·1

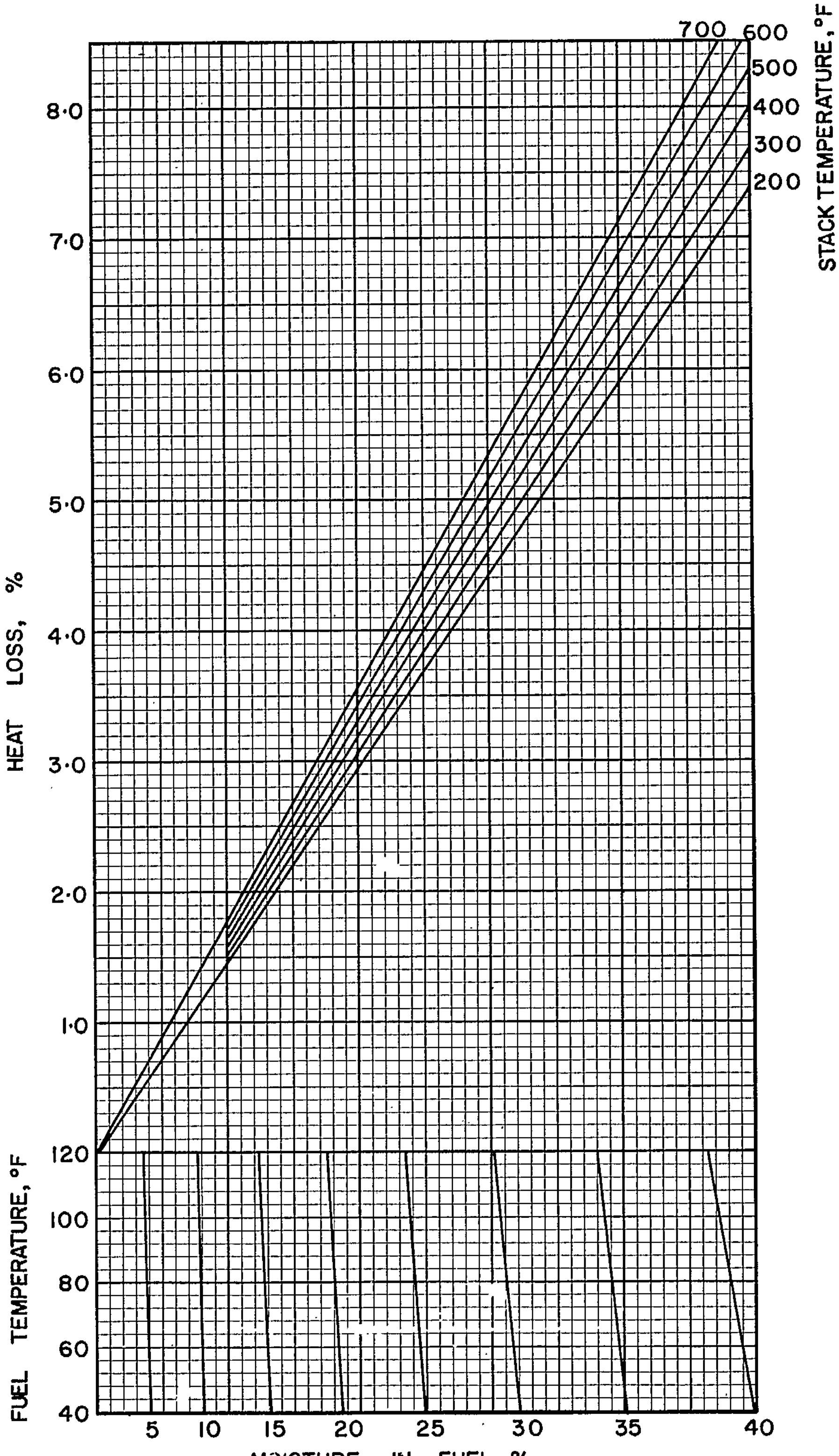


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

0·1·1

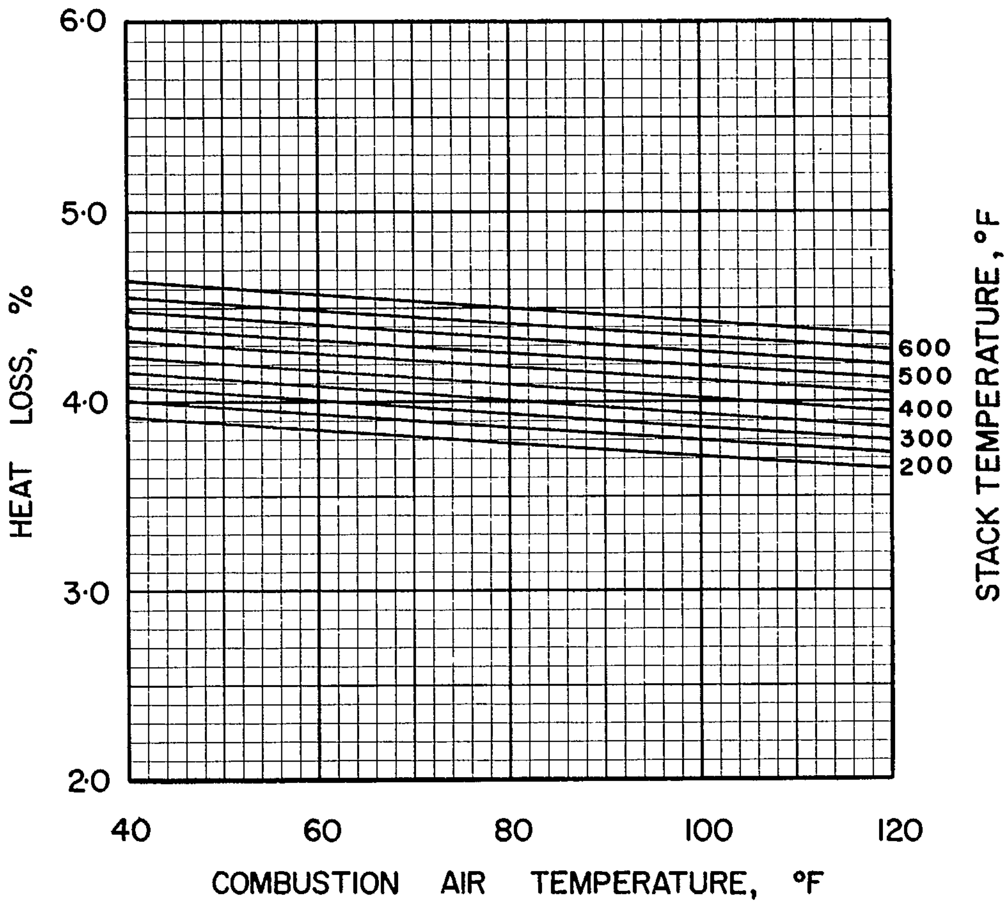


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

0·1·1

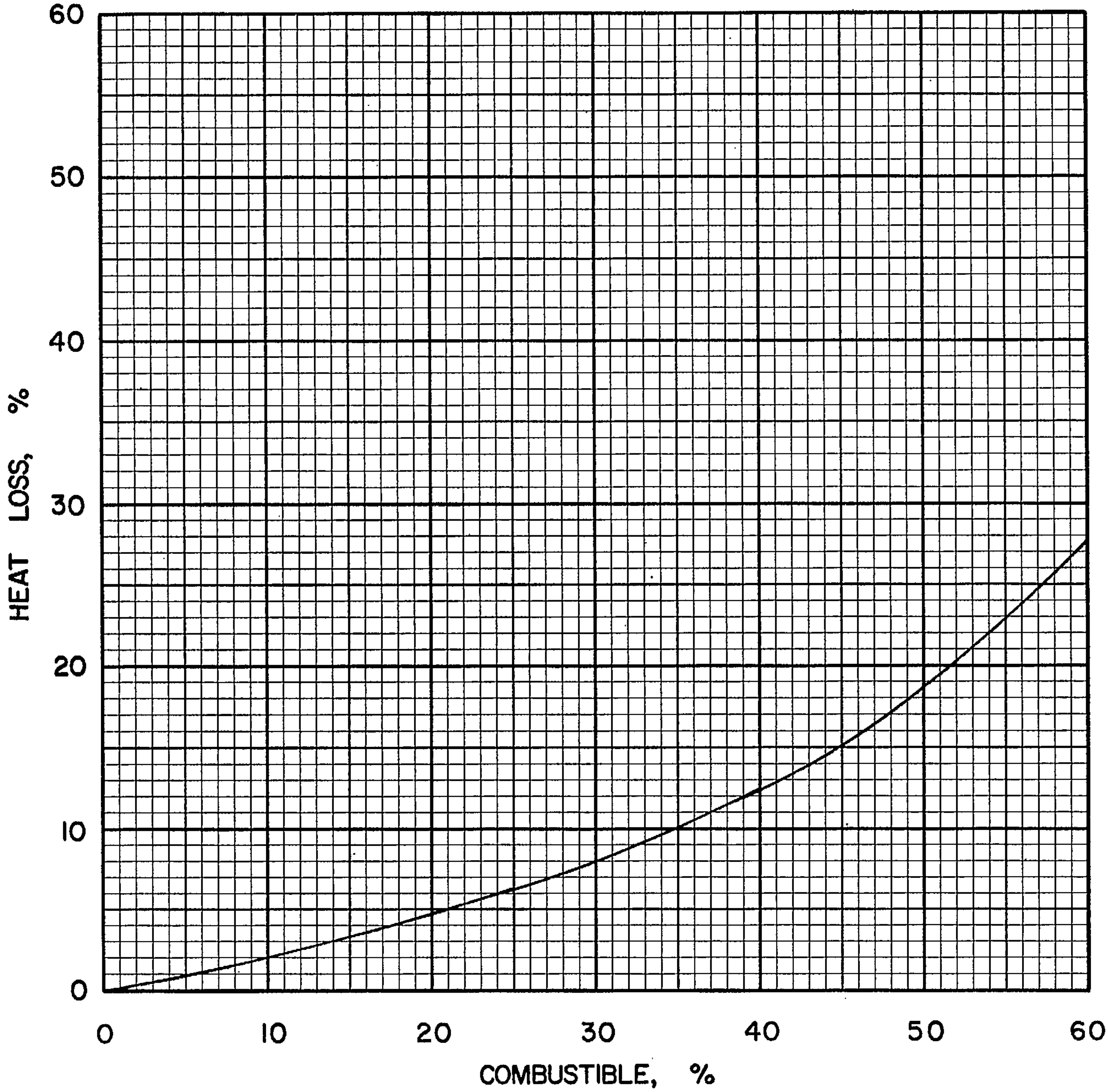


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

0·1·1

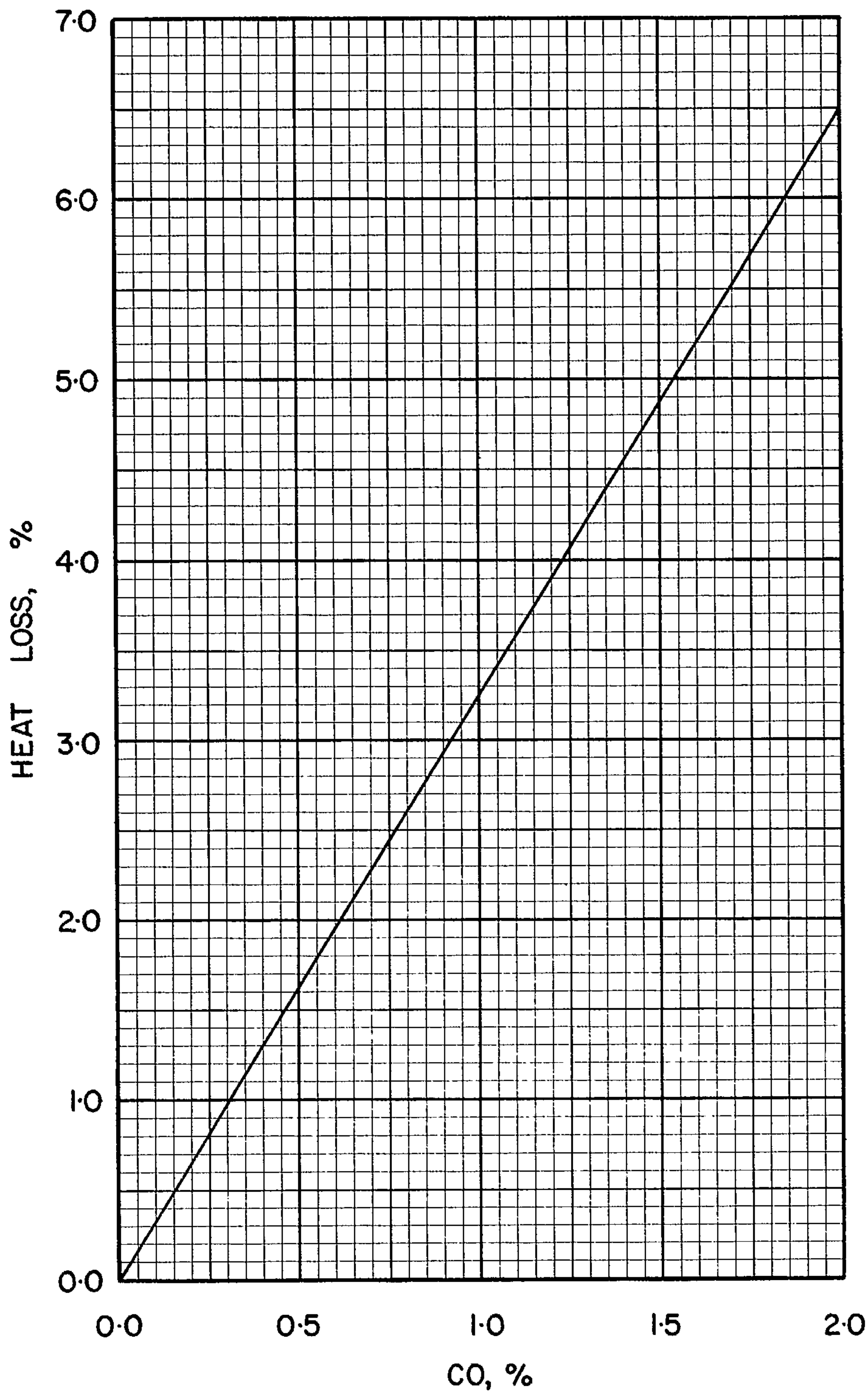


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

0·1·1

**COAL S 1-1, BATTLE RIVER COAL CO. LTD.,
ESTEVAN LIGNITE, 1 1/2 in. x 1/2 in.**

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.1027
Volatile Matter	0.3969
Fixed Carbon	0.5004
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6634
Hydrogen (H)	0.0417
Sulphur (S)	0.0133
Nitrogen (N)	0.0107
Oxygen (O)	0.1682
Ash	0.1027
Total	1.0000

Gross Calorific Value

Btu/lb:	10820
Btu/short ton:	21.64×10^6
Btu/long ton:	24.24×10^6
MJ/kg:	25.16

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 92.42 lb
10^6 Btu = 0.04621 short tons
10^6 Btu = 0.04126 long tons

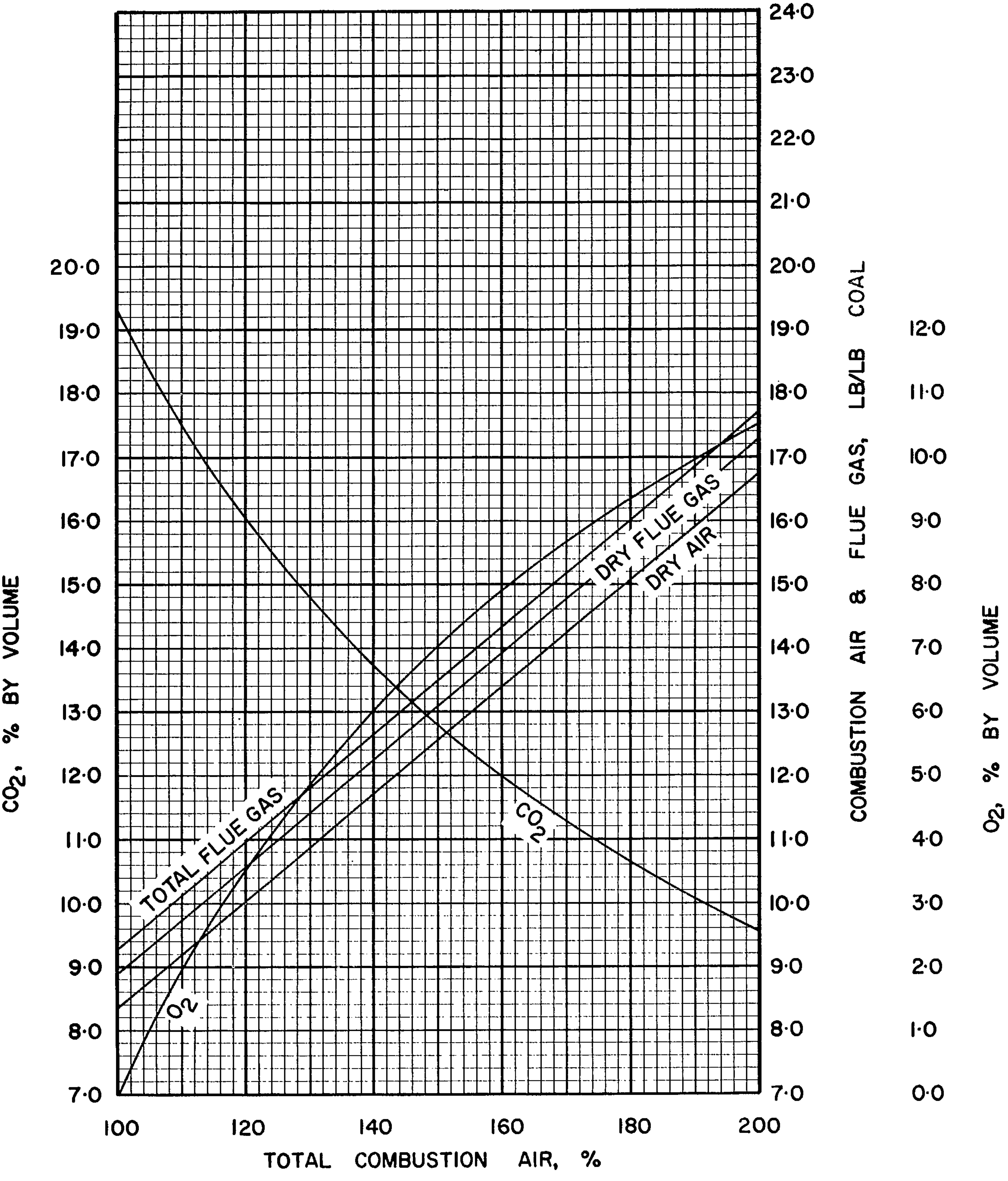


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS S·1·1

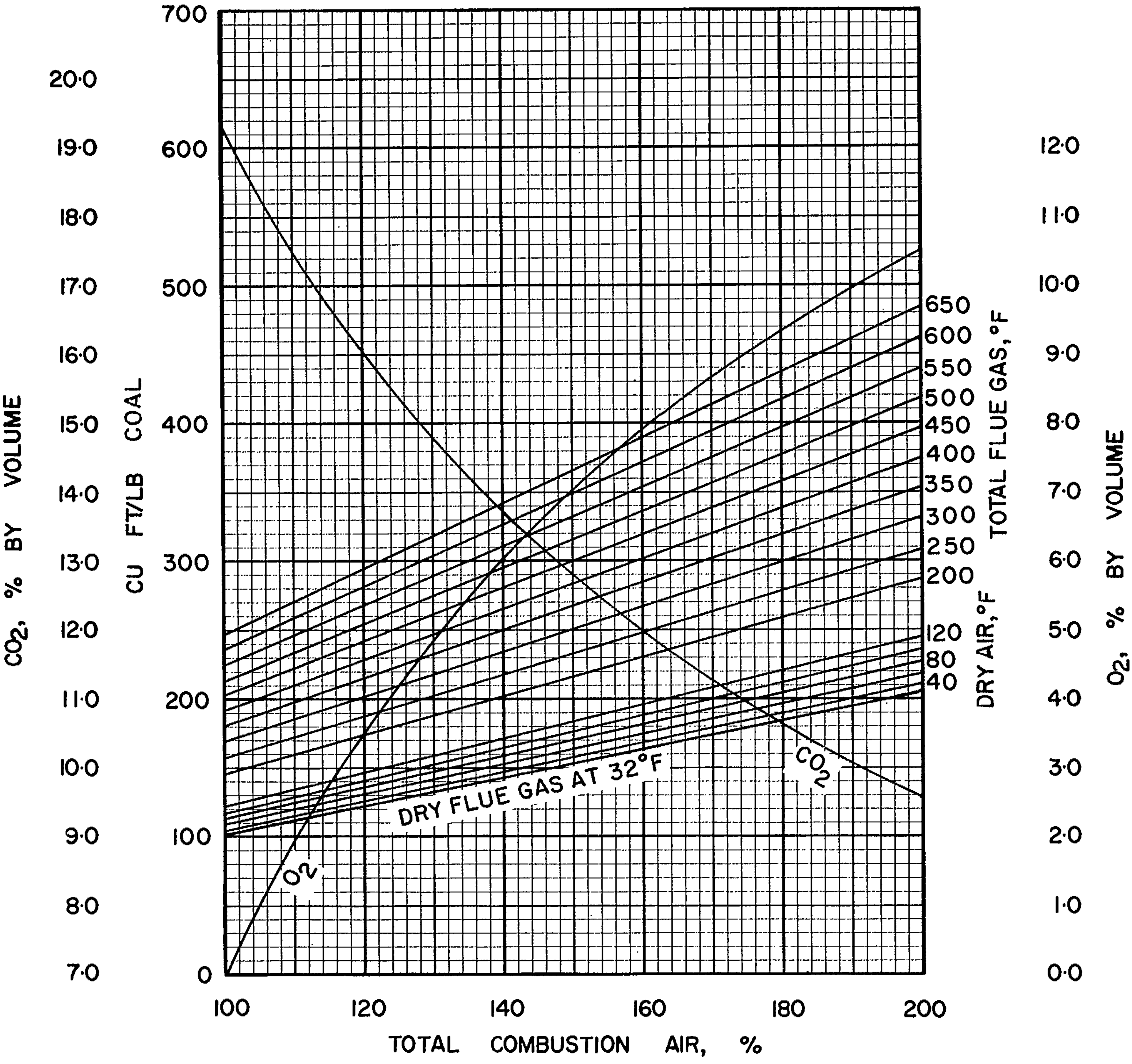


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S · 1 · 1

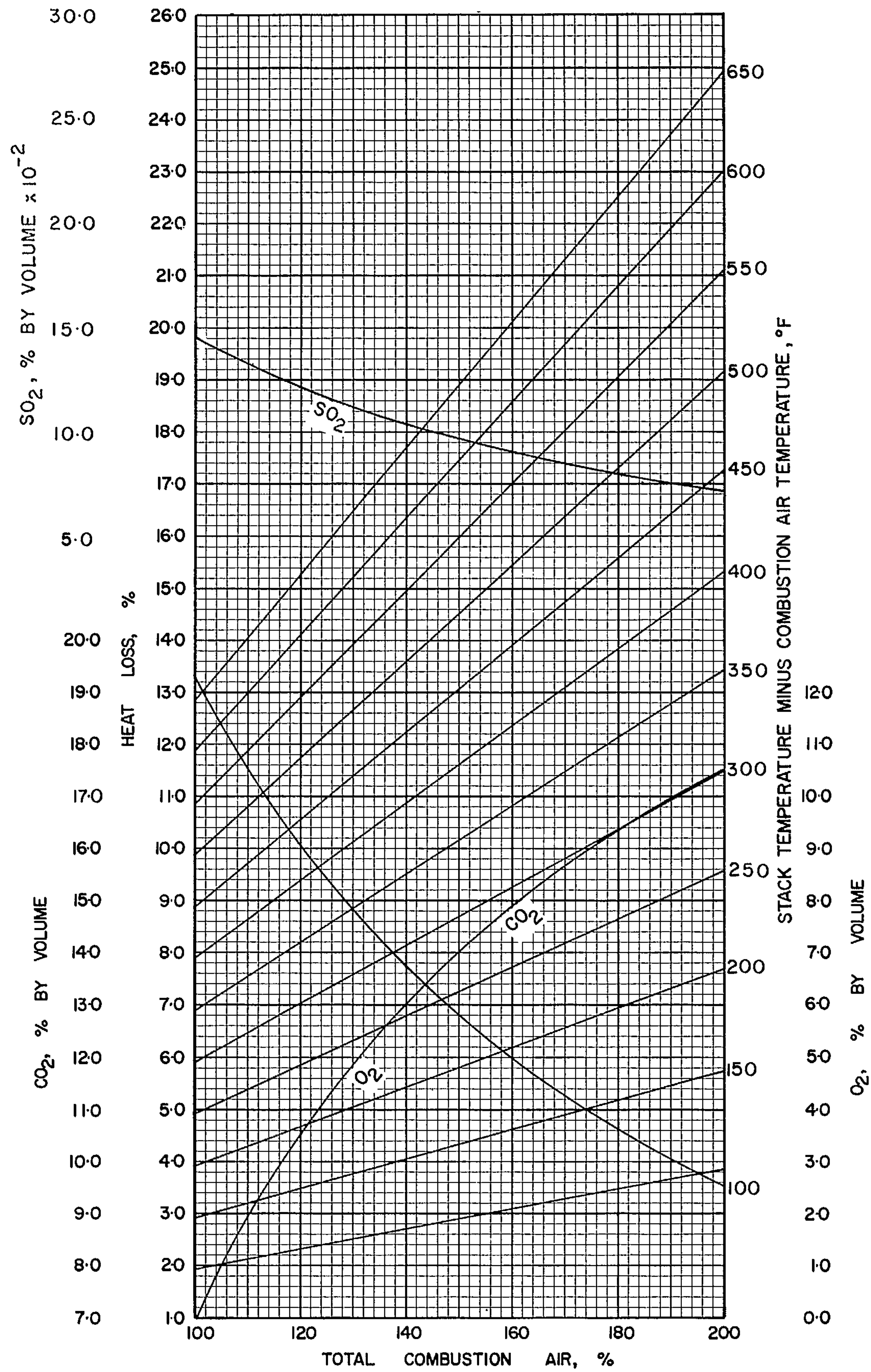


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·1·1

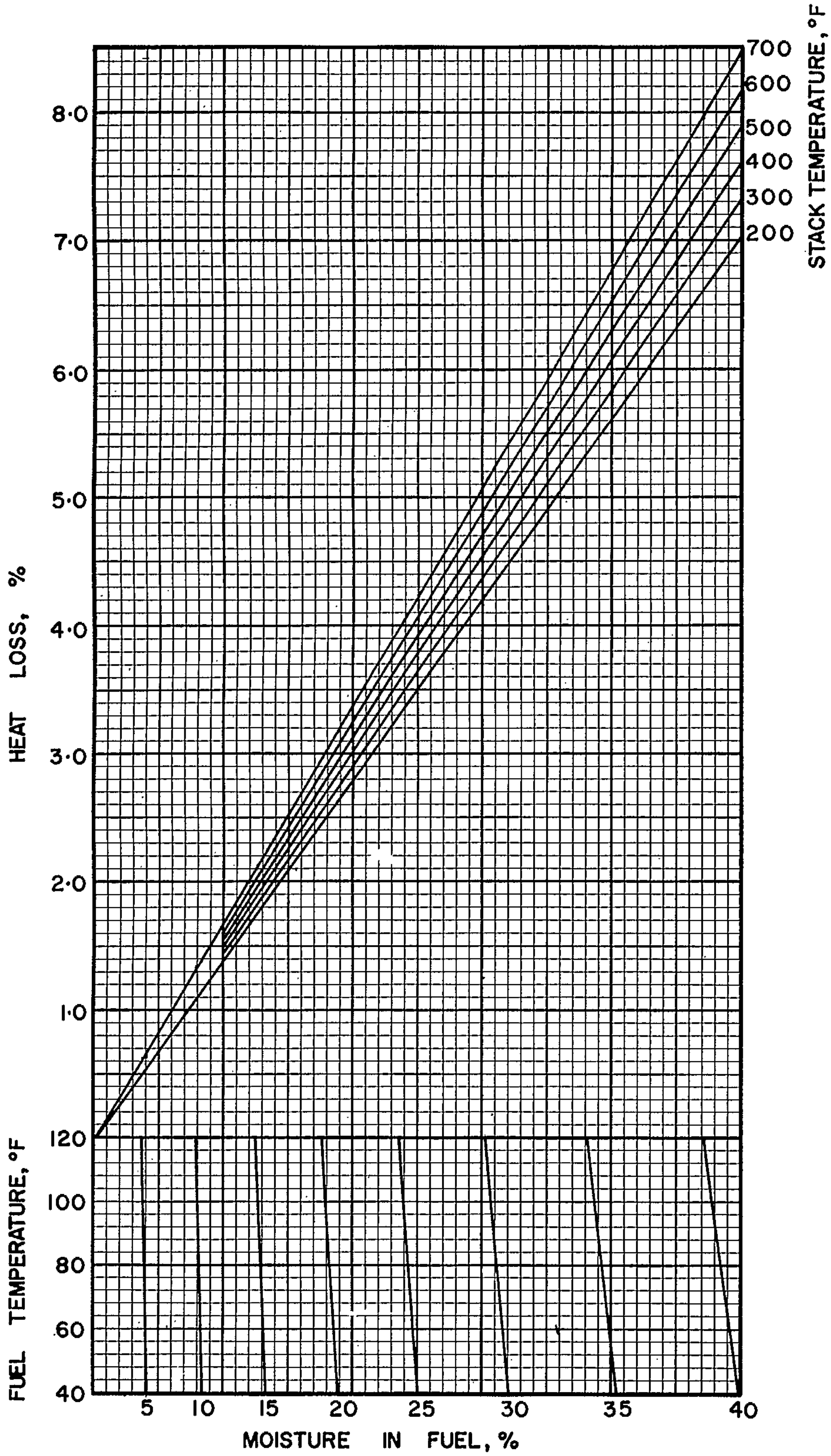


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·1·1

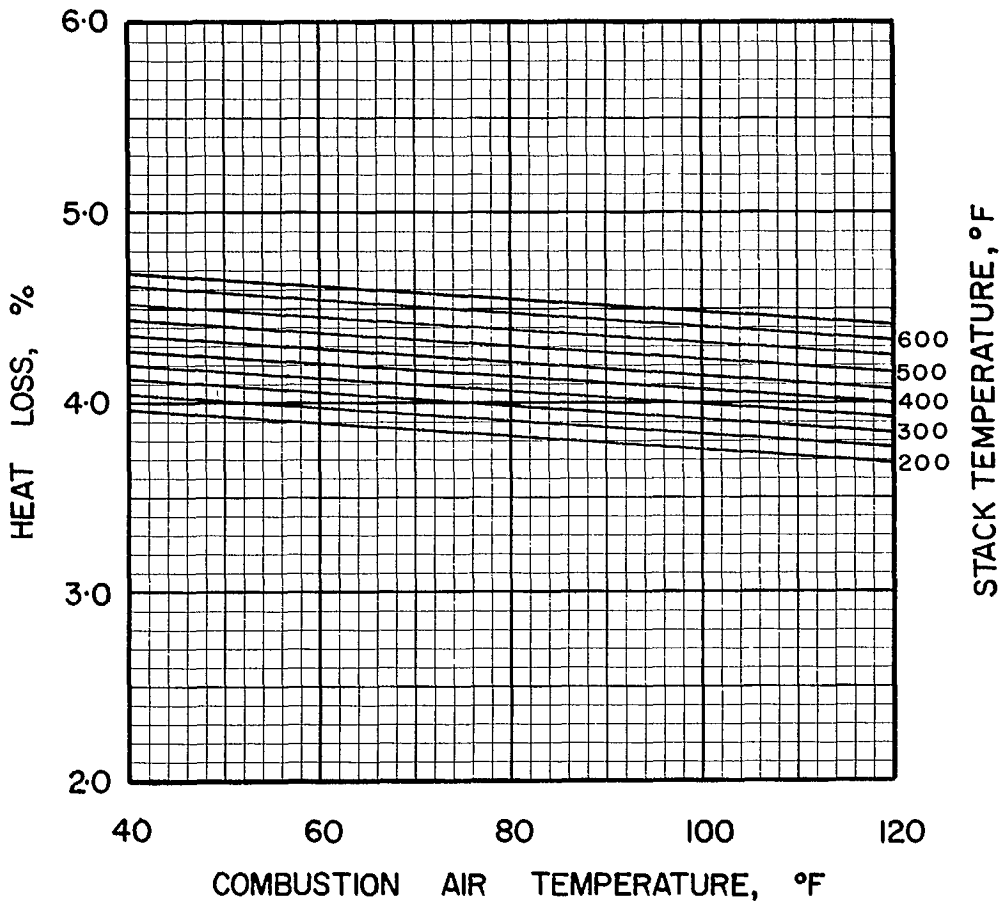


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S · I · I

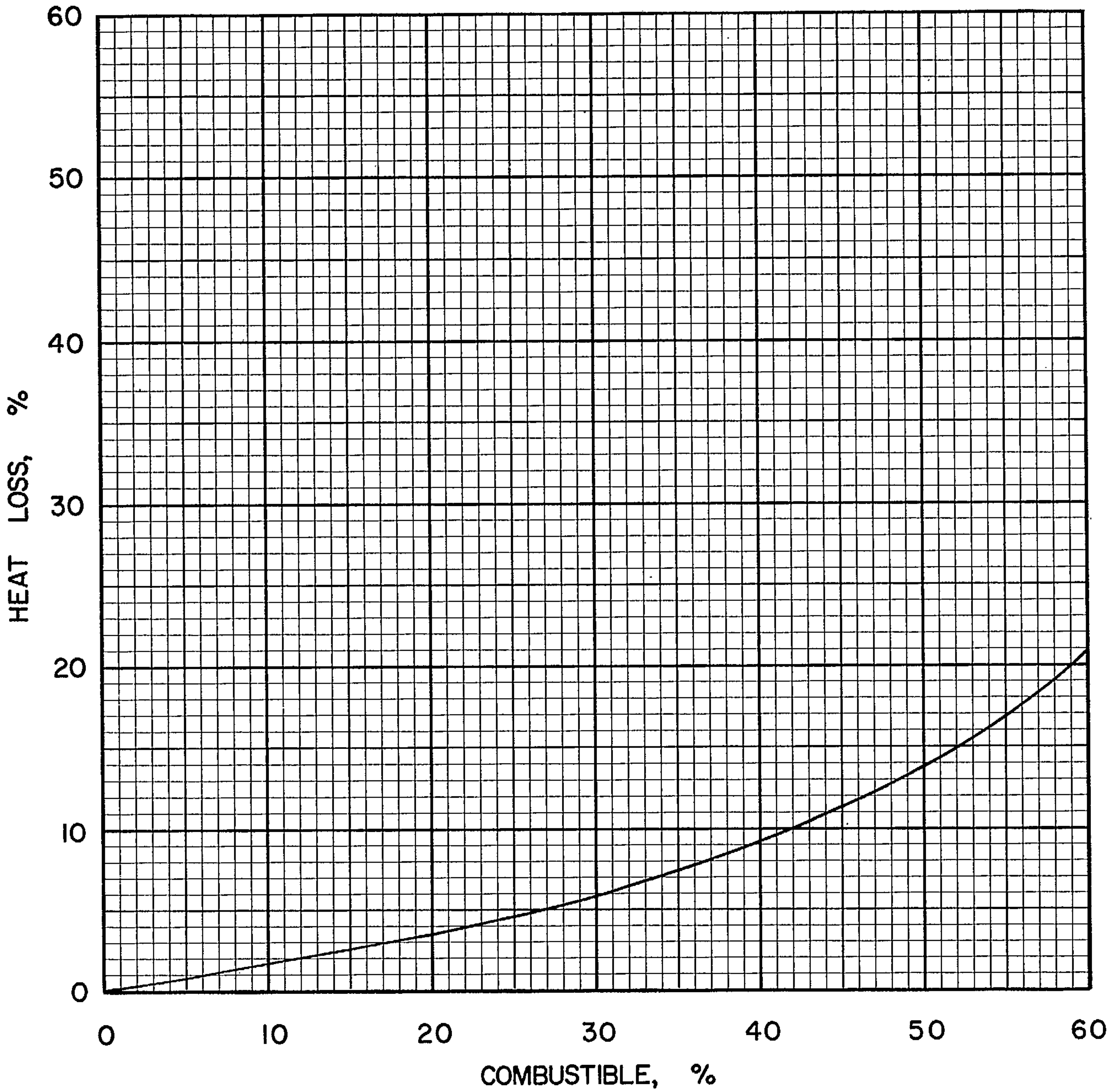


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·1·1

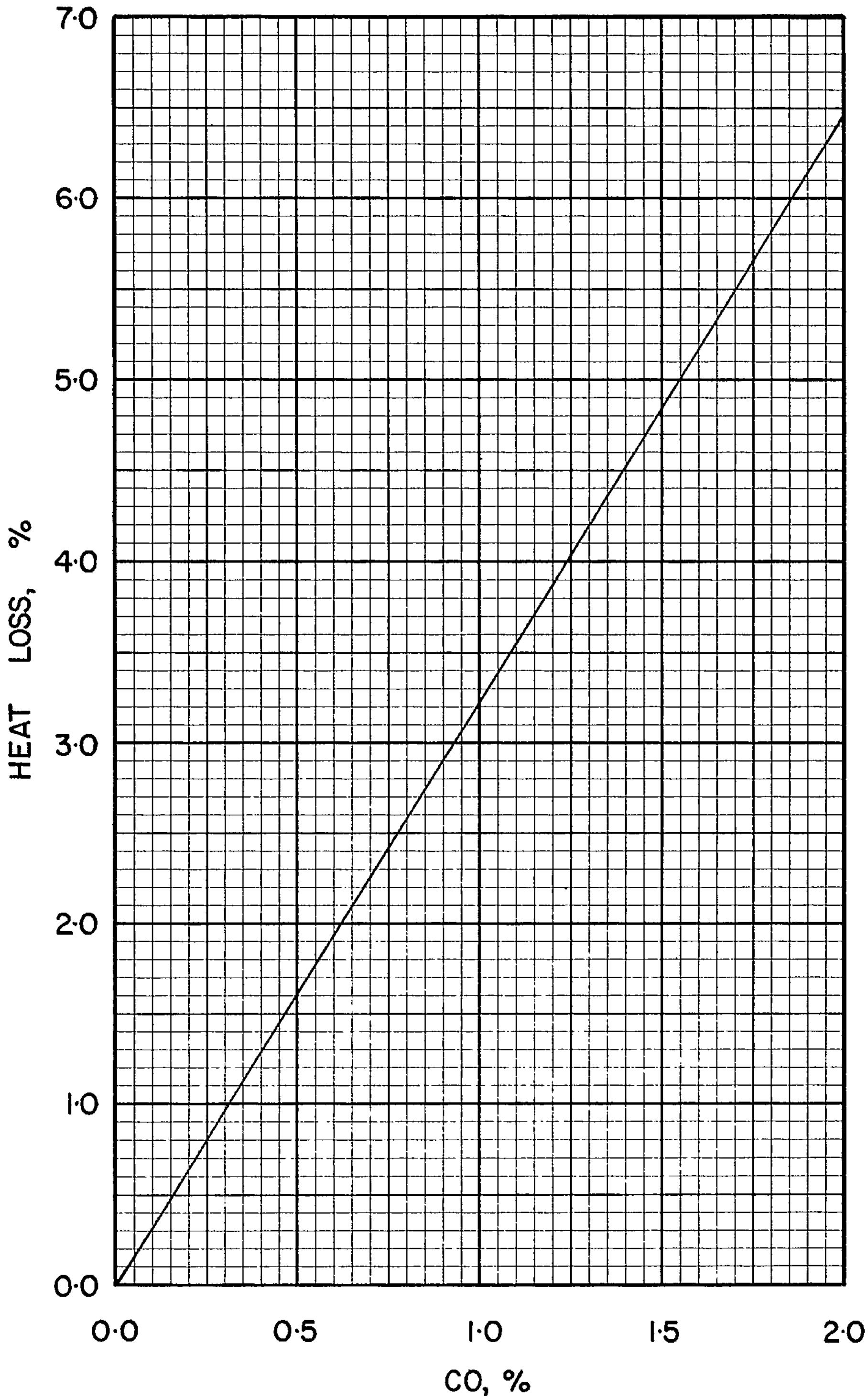


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·1·1

COAL S 1-2, BATTLE RIVER COAL CO. LTD., ESTEVAN LIGNITE, – 1/2 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.1123
Volatile Matter	0.3936
Fixed Carbon	0.4941
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6674
Hydrogen (H)	0.0399
Sulphur (S)	0.0129
Nitrogen (N)	0.0110
Oxygen (O)	0.1565
Ash	0.1123
Total	1.0000

Gross Calorific Value

Btu/lb:	10960
Btu/short ton:	21.92×10^6
Btu/long ton:	24.55×10^6
MJ/kg:	25.49

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 91.24 lb
10^6 Btu = 0.04562 short tons
10^6 Btu = 0.04073 long tons

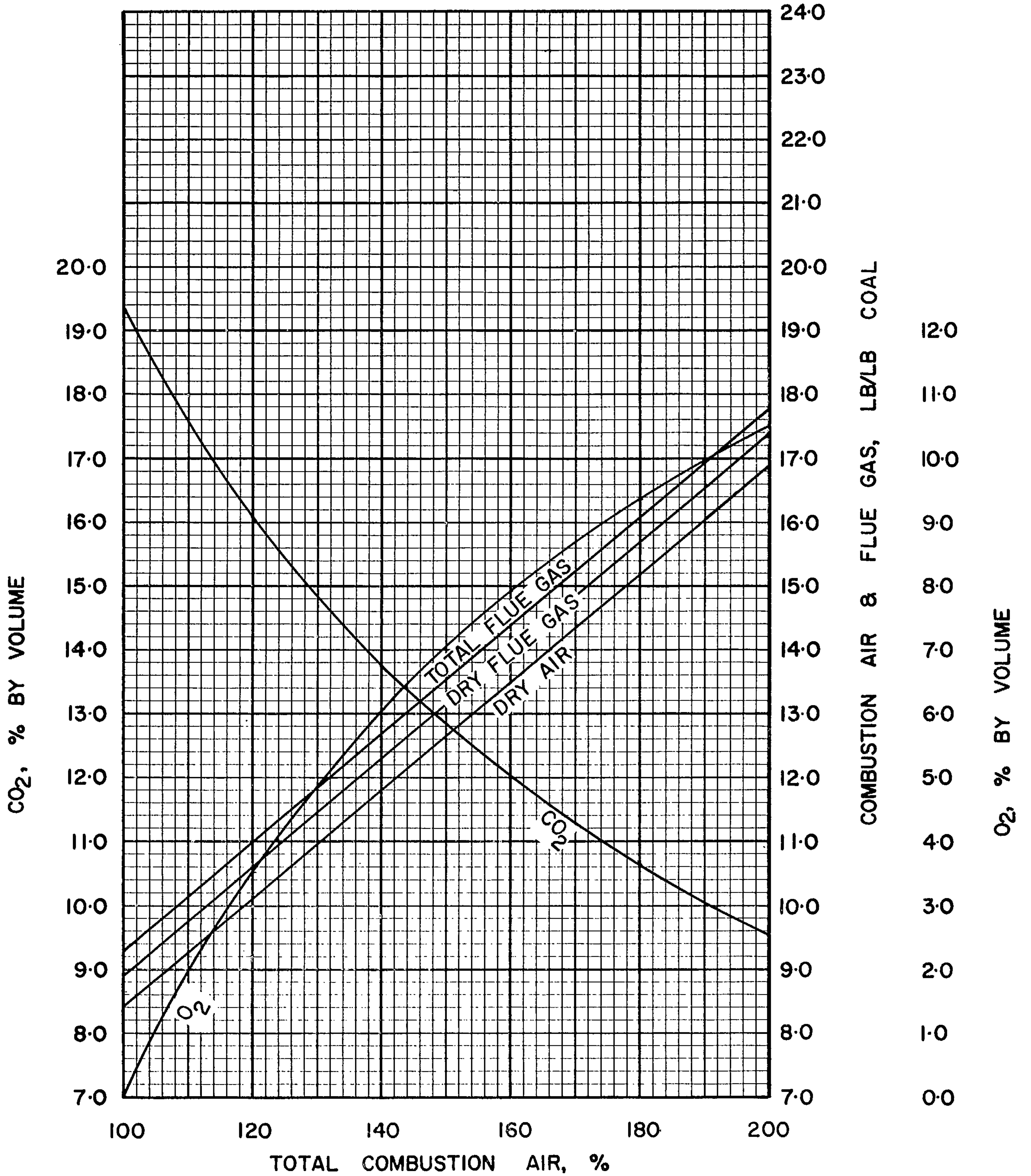


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS S·1·2

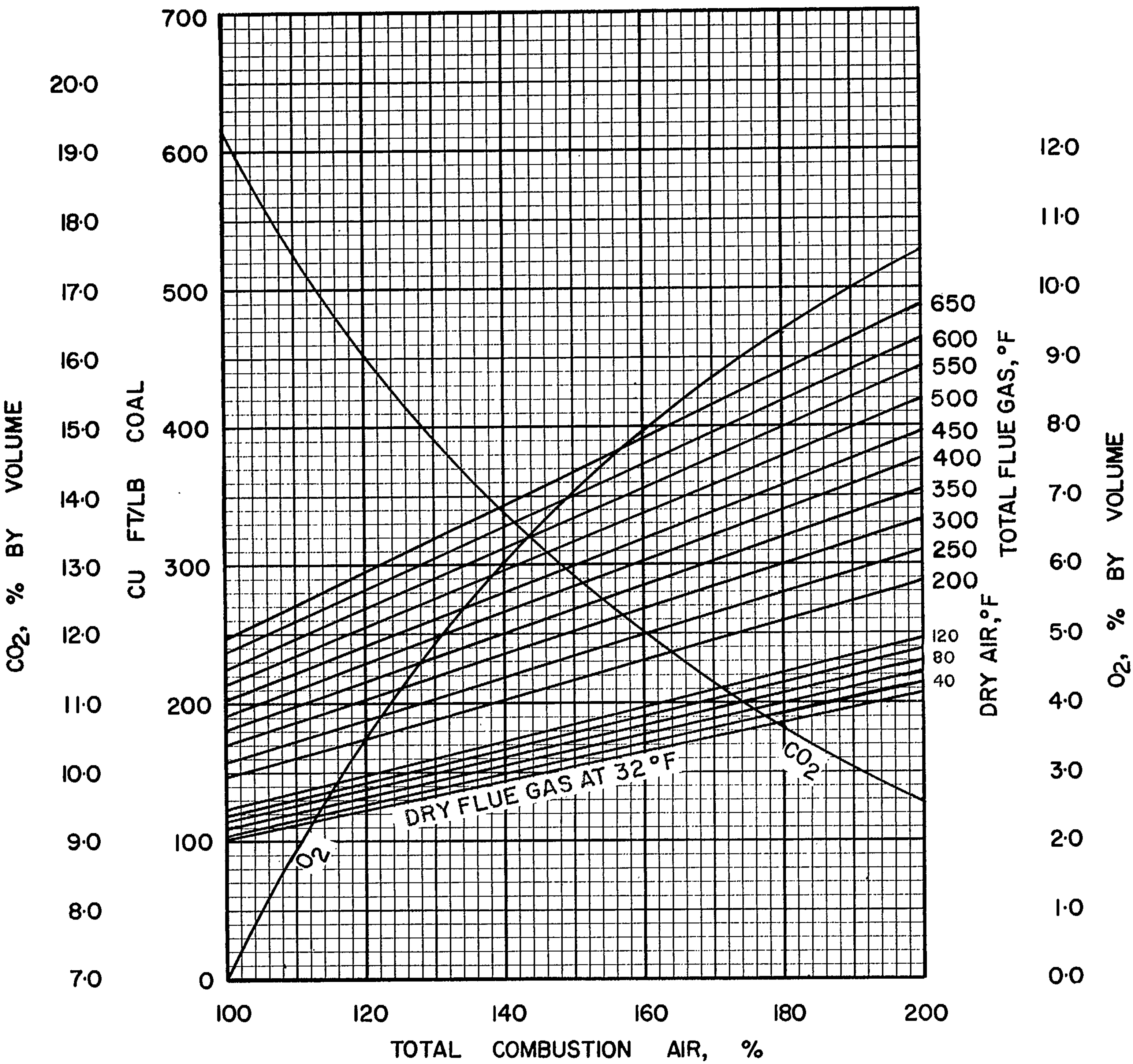


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·1·2

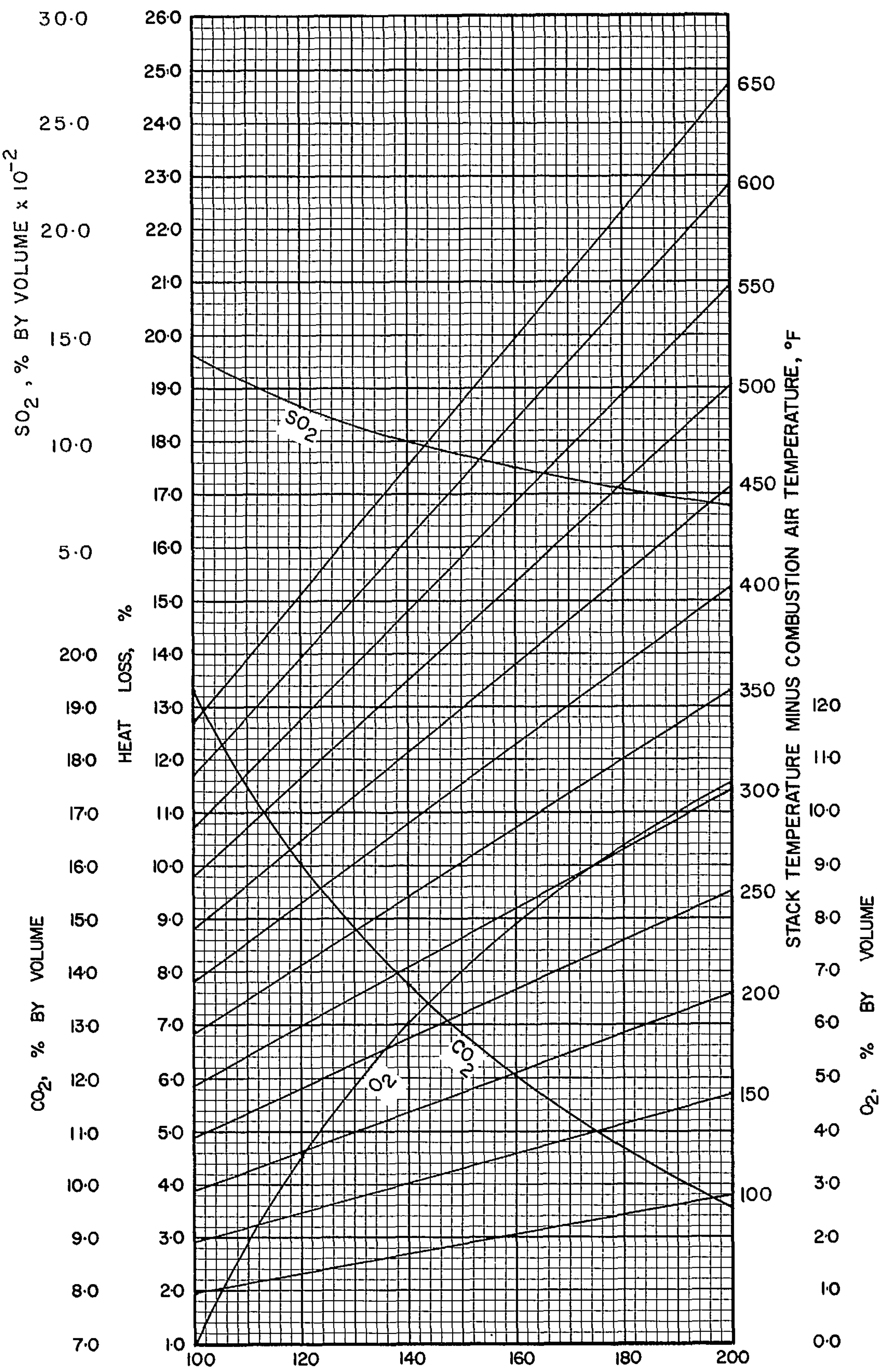


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·1·2

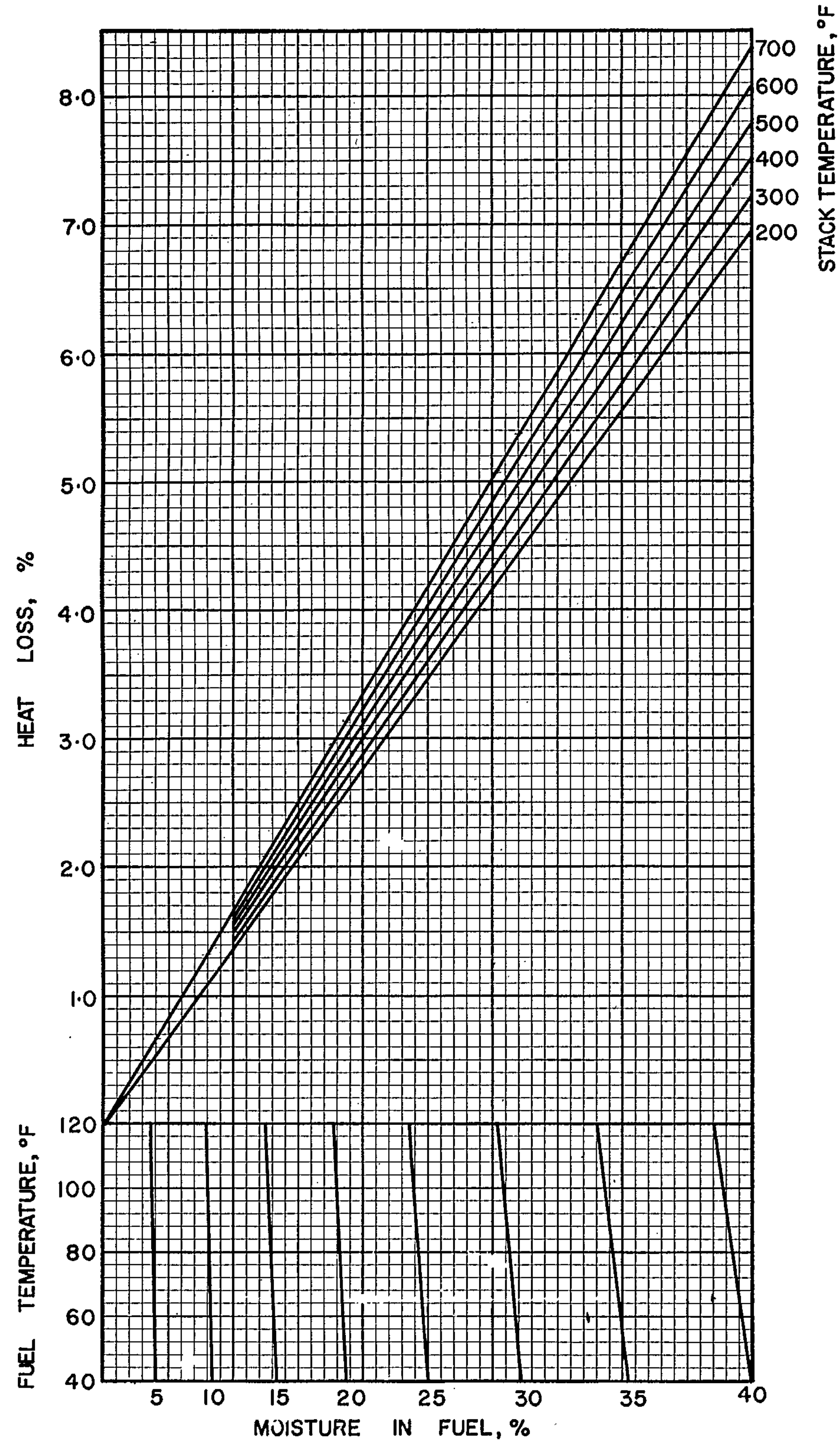


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·1·2

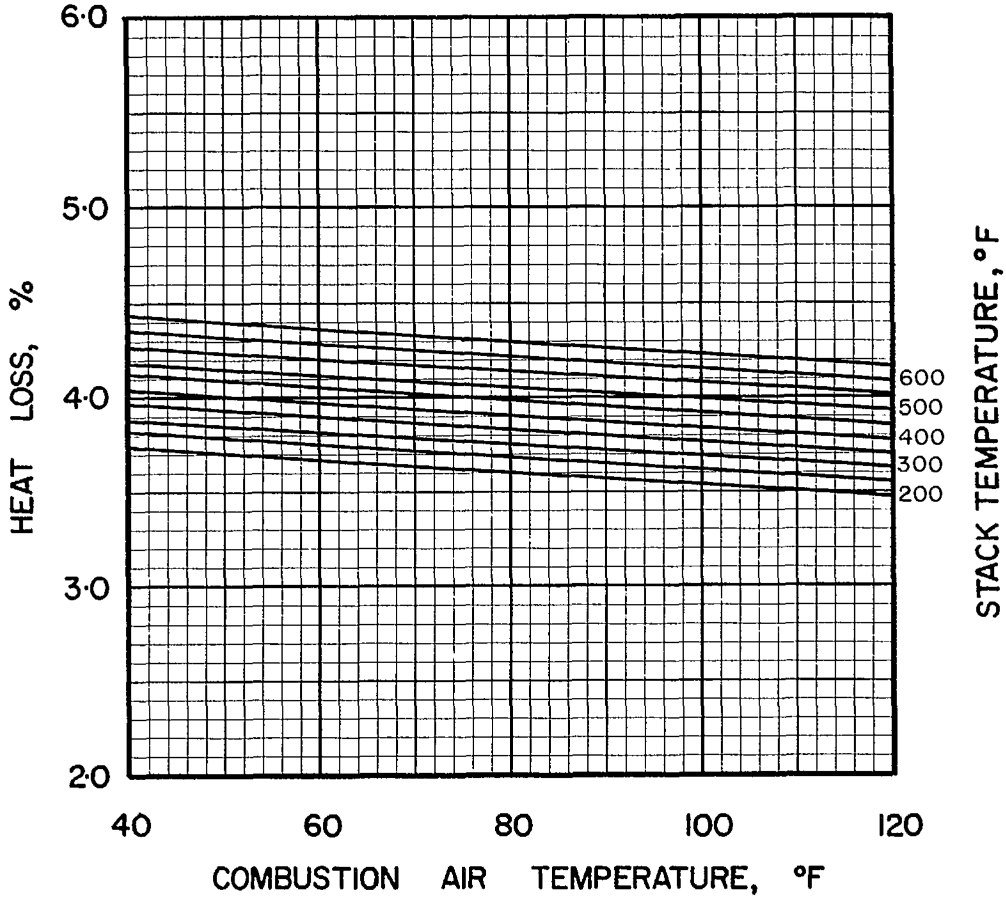


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·1·2

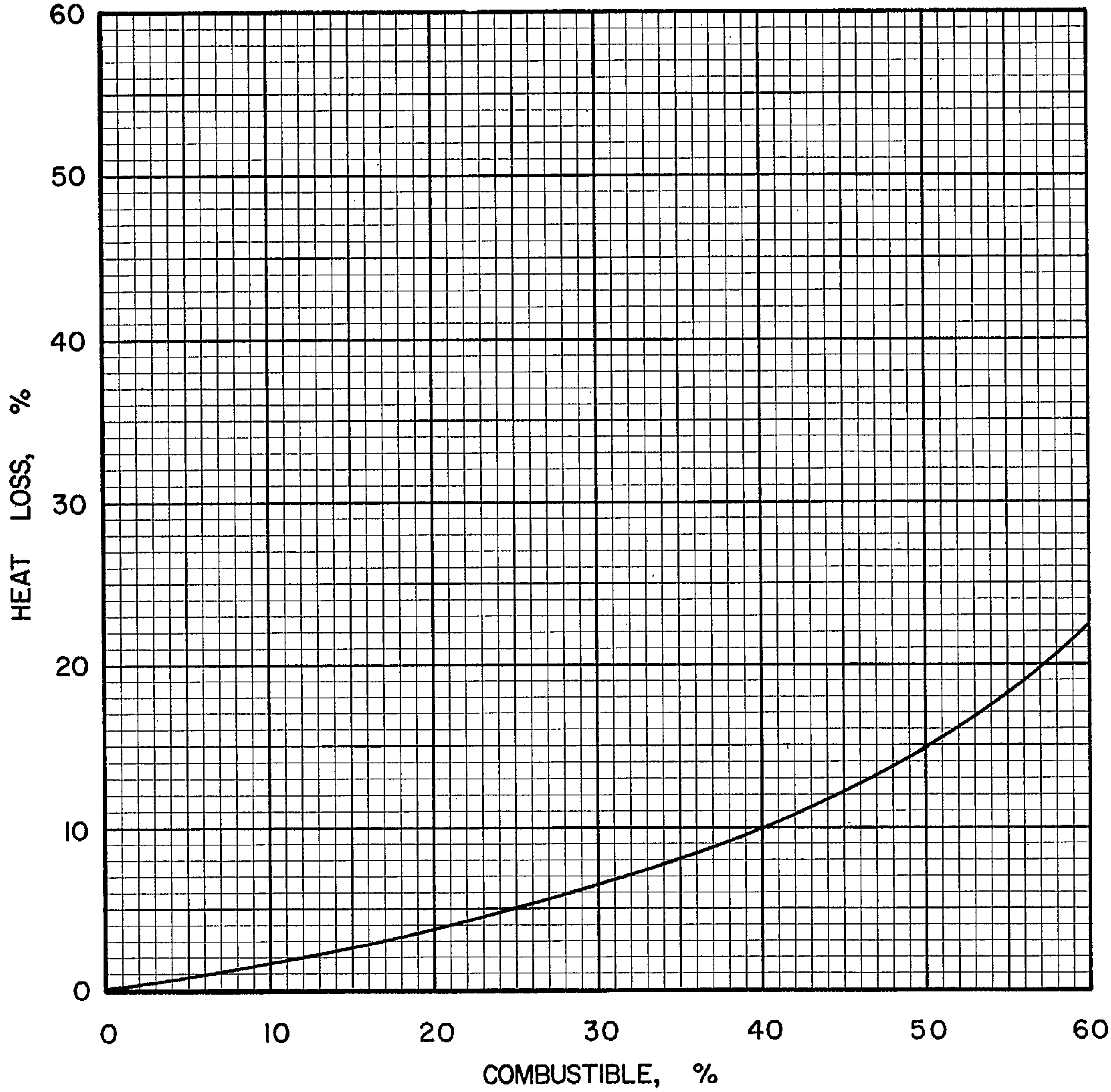


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·1·2

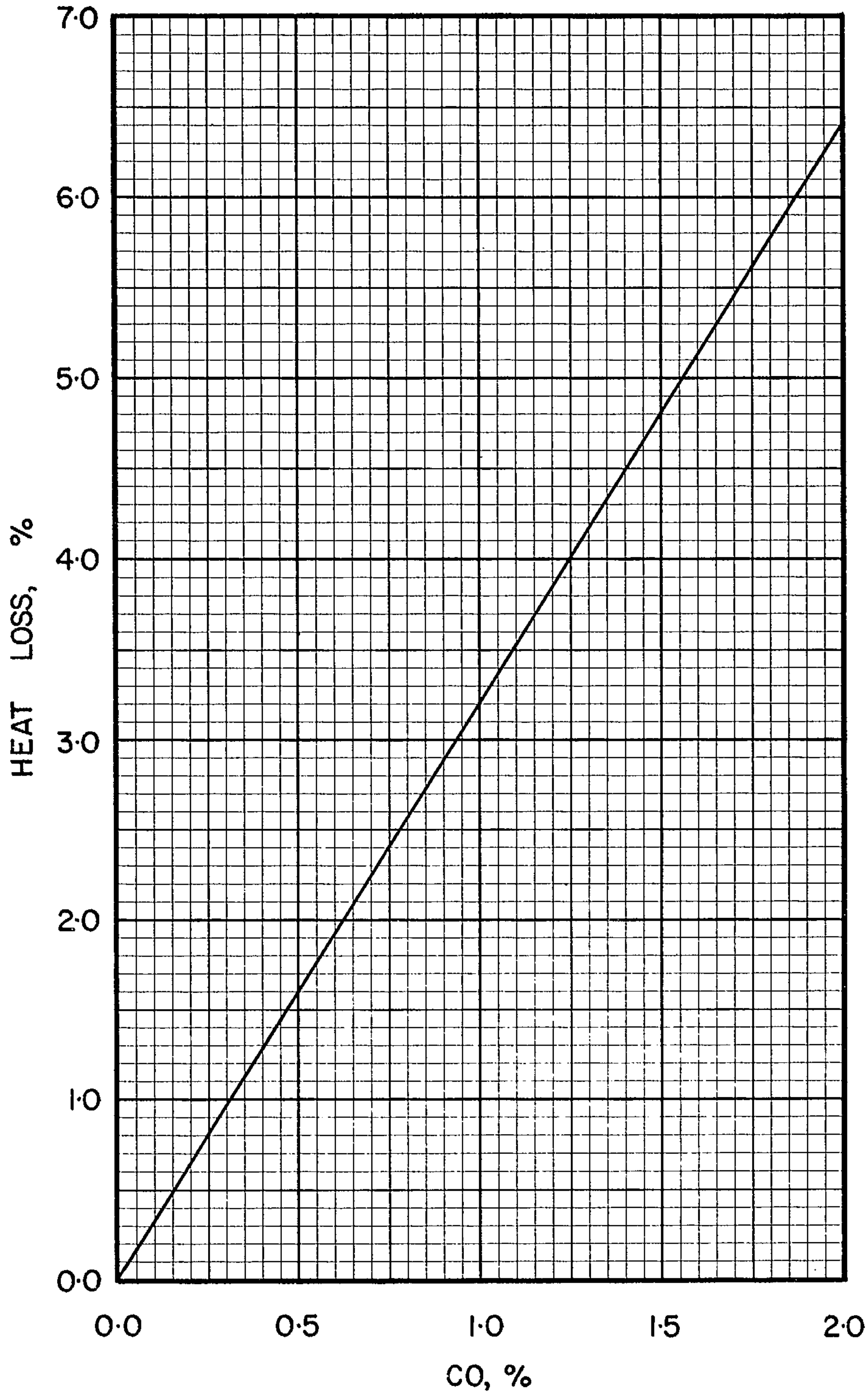


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·1·2

COAL S 1-3, BATTLE RIVER COAL CO. LTD., ESTEVAN LIGNITE, 2 in. x 1/8 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.0866
Volatile Matter	0.4104
Fixed Carbon	0.5030
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6787
Hydrogen (H)	0.0421
Sulphur (S)	0.0091
Nitrogen (N)	0.0110
Oxygen (O)	0.1725
Ash	0.0866
Total	1.0000

Gross Calorific Value

Btu/lb:	11220
Btu/short ton:	22.44×10^6
Btu/long ton:	25.13×10^6
MJ/kg:	26.09

Conversion Factors

1 short ton	=	0.8929	long tons	=	2000 lb
10^6 Btu	=	89.13	lb		
10^6 Btu	=	0.04456	short tons		
10^6 Btu	=	0.03979	long tons		

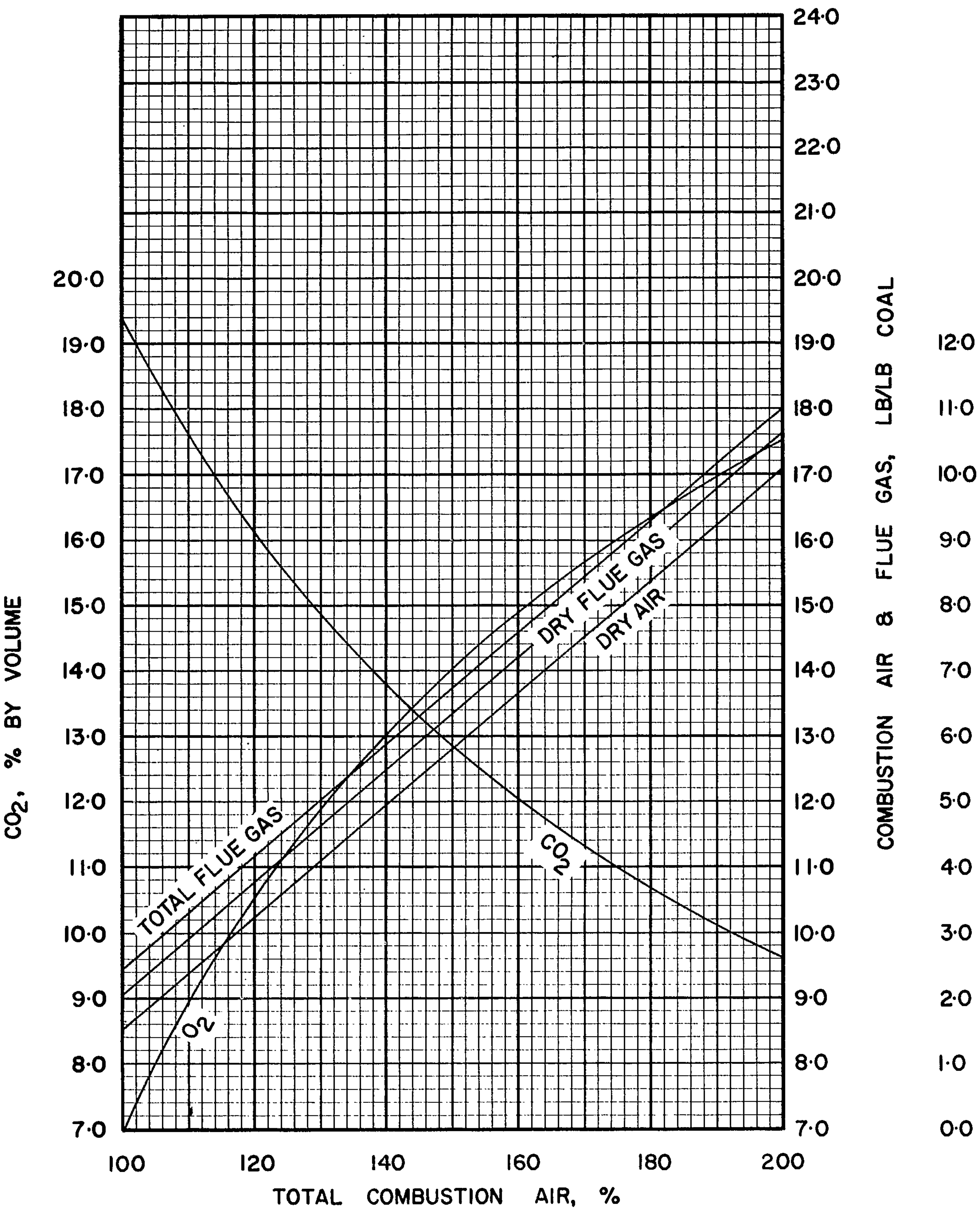


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

S·1·3

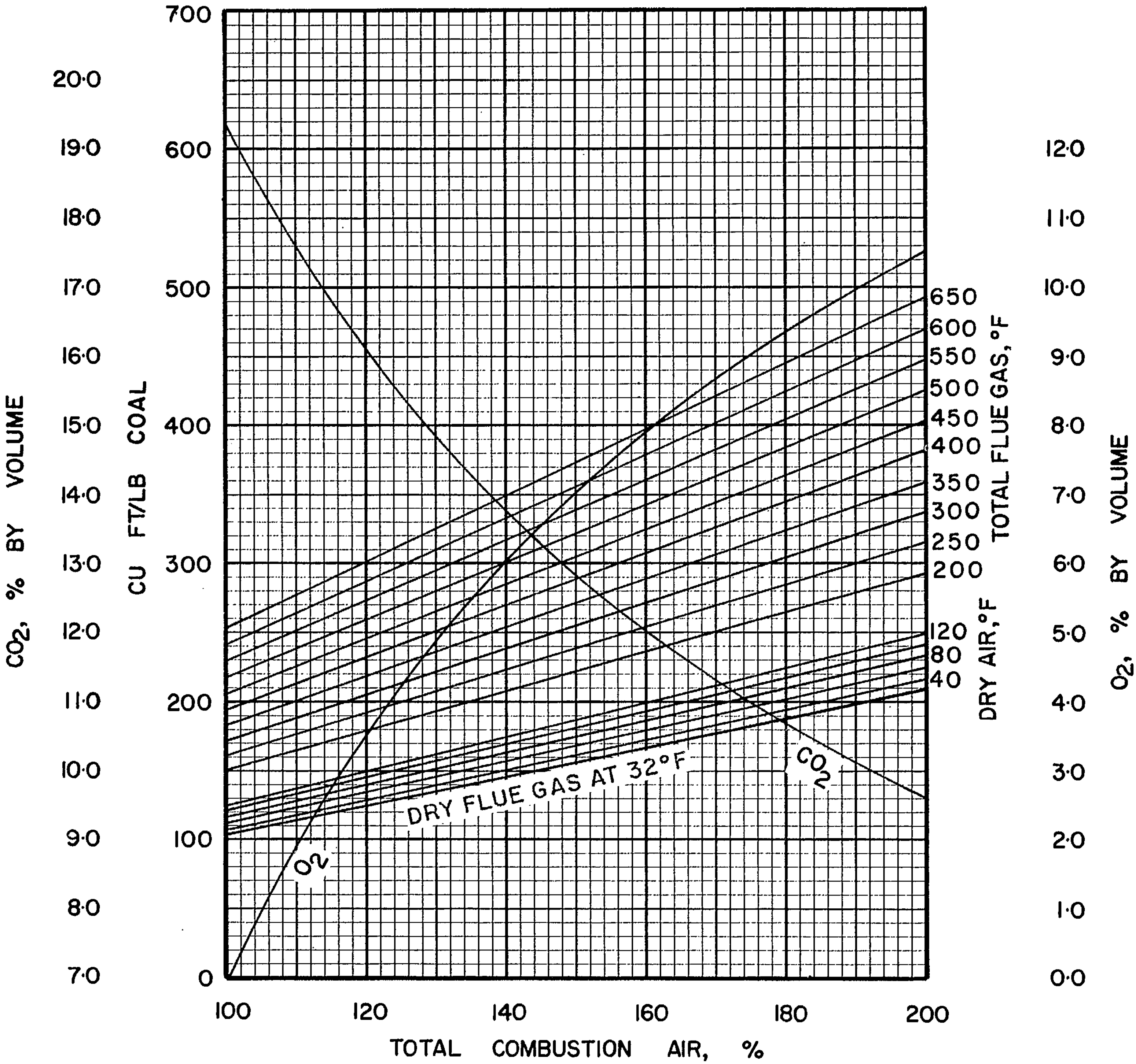


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

S·1·3

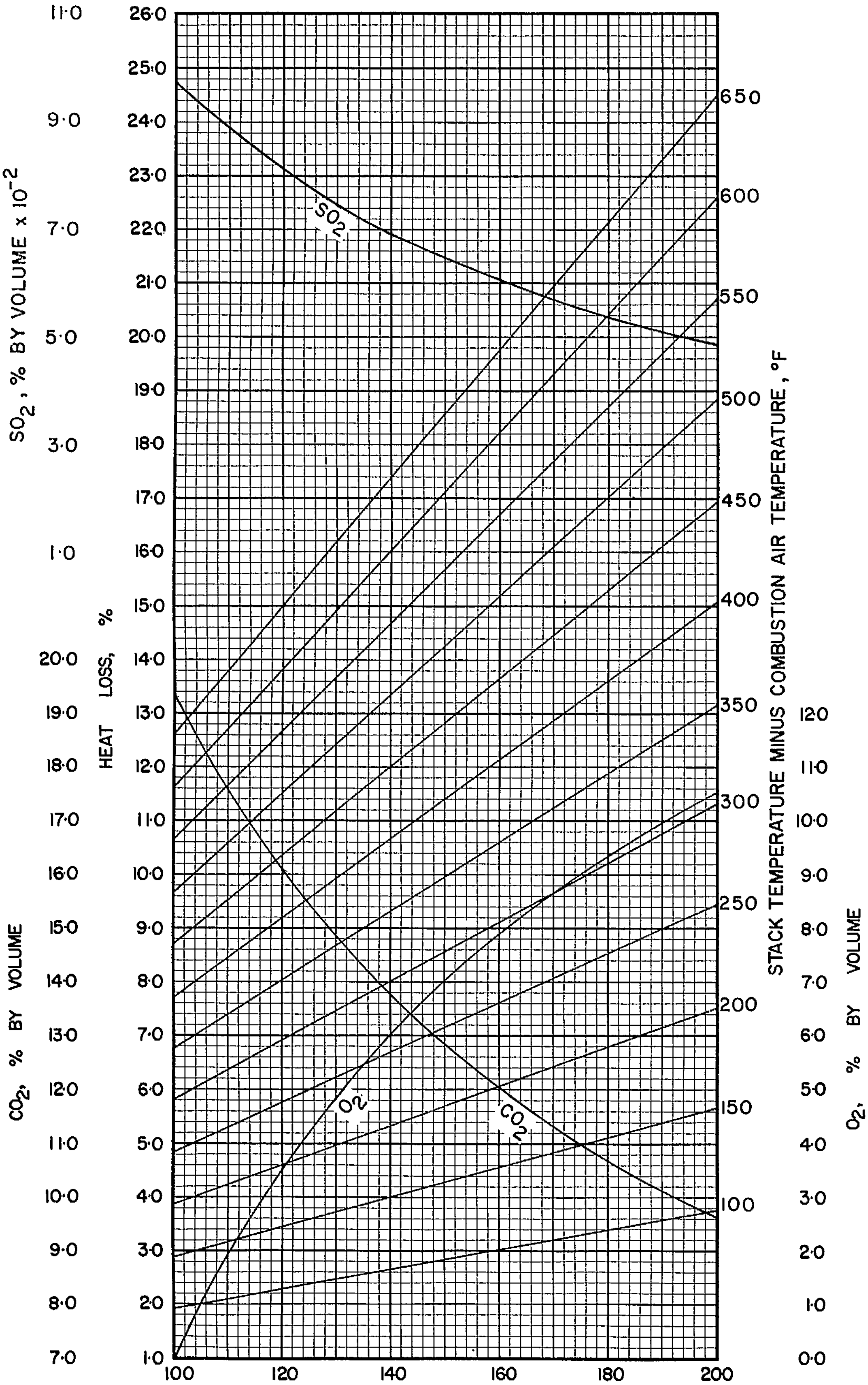


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·1·3

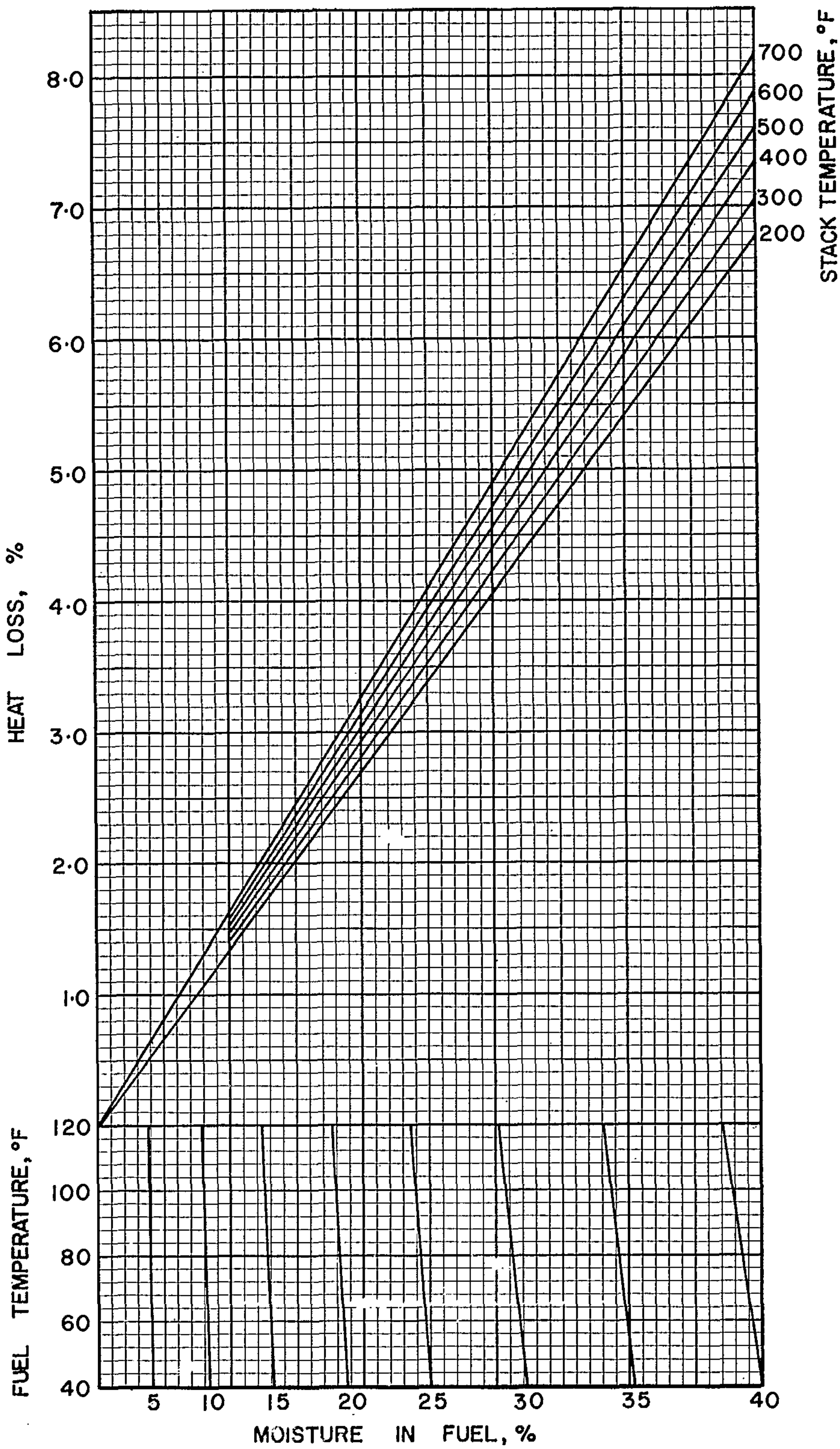


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·1·3

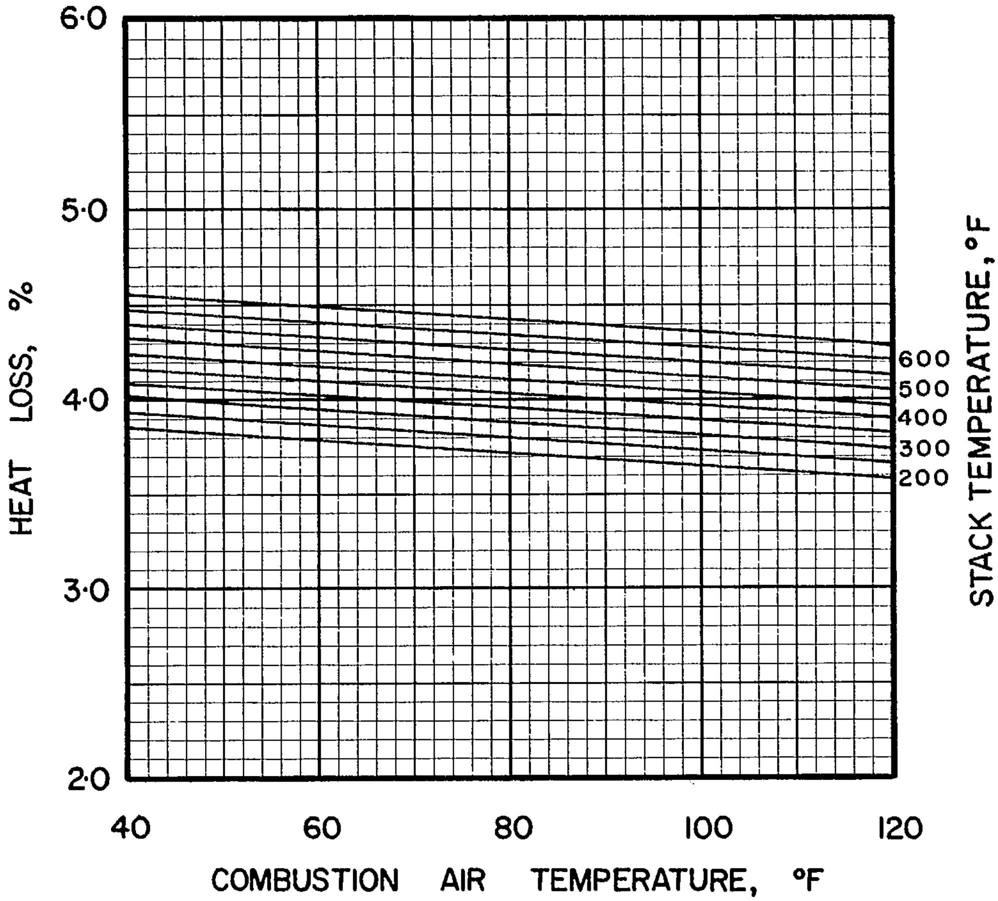


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S· 1·3

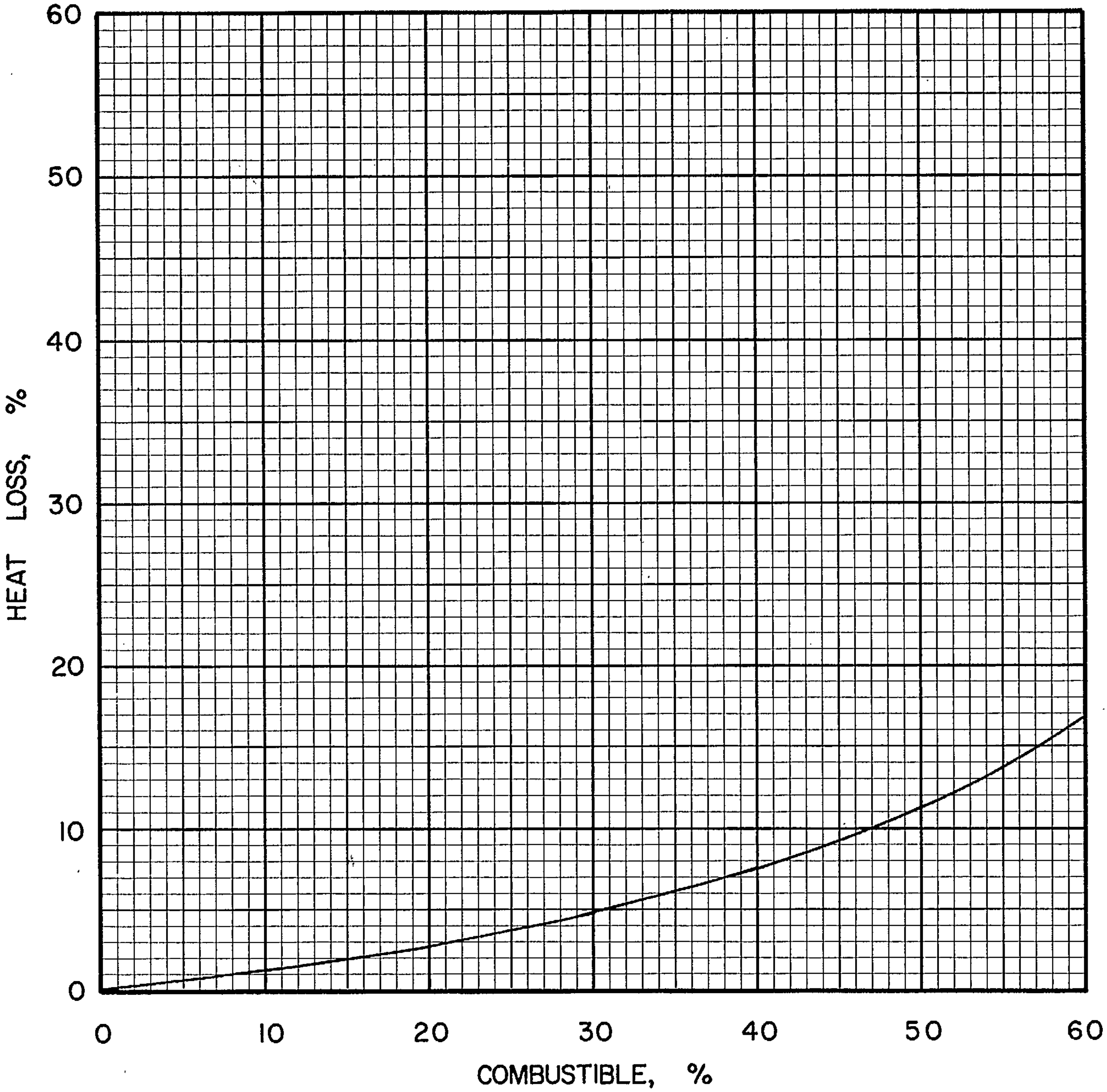


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·1·3

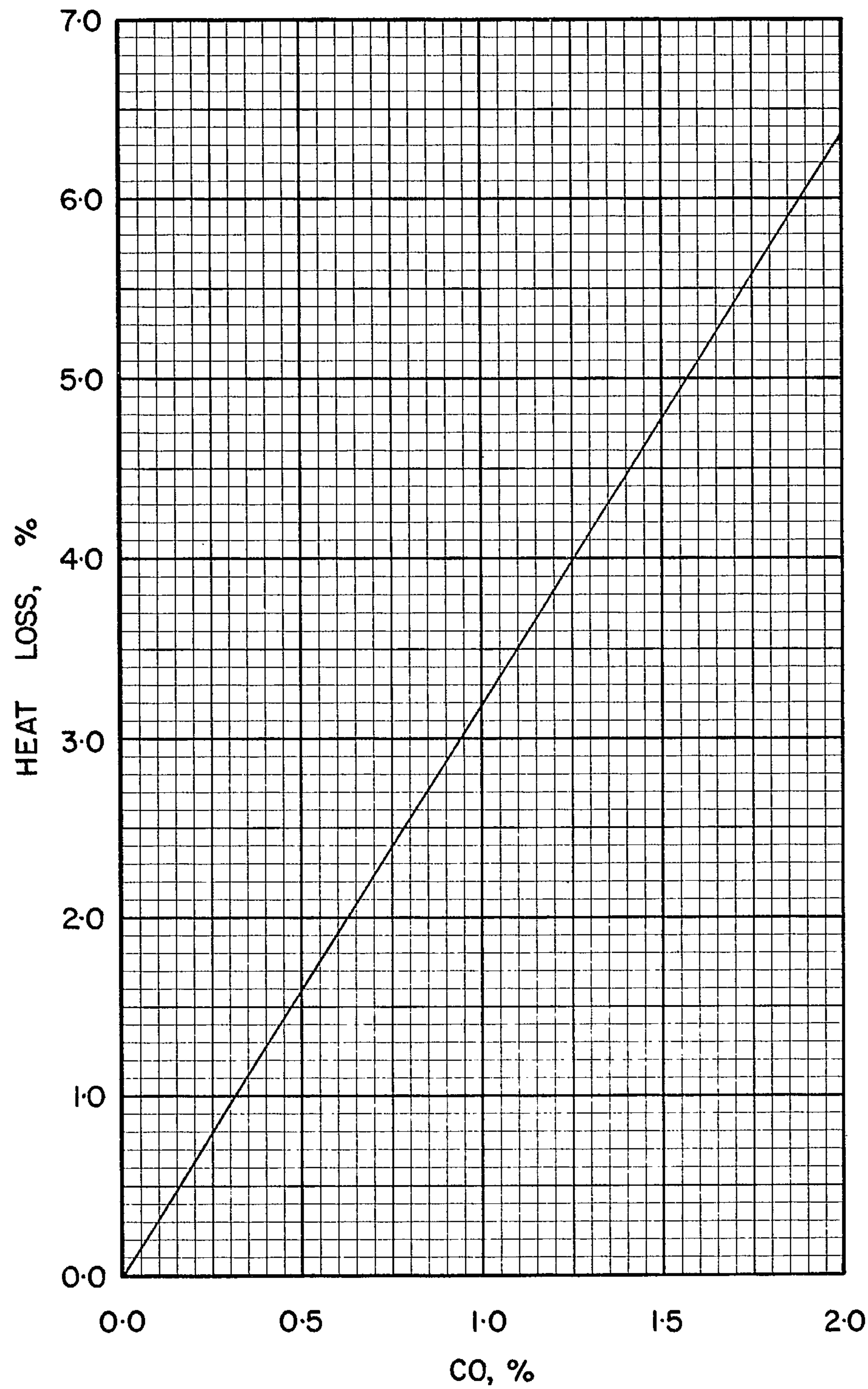


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·1·3

COAL S 2-1, MANITOBA AND SASKATCHEWAN COAL CO. LTD., BIENFAIT LIGNITE, 1 1/4 in. x 1/2 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.0850
Volatile Matter	0.4603
Fixed Carbon	0.4547
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6806
Hydrogen (H)	0.0424
Sulphur (S)	0.0082
Nitrogen (N)	0.0122
Oxygen (O)	0.1716
Ash	0.0850
Total	1.0000

Gross Calorific Value

Btu/lb:	11290
Btu/short ton:	22.58×10^6
Btu/long ton:	25.29×10^6
MJ/kg:	26.25

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 88.57 lb
10^6 Btu = 0.04429 short tons
10^6 Btu = 0.03954 long tons

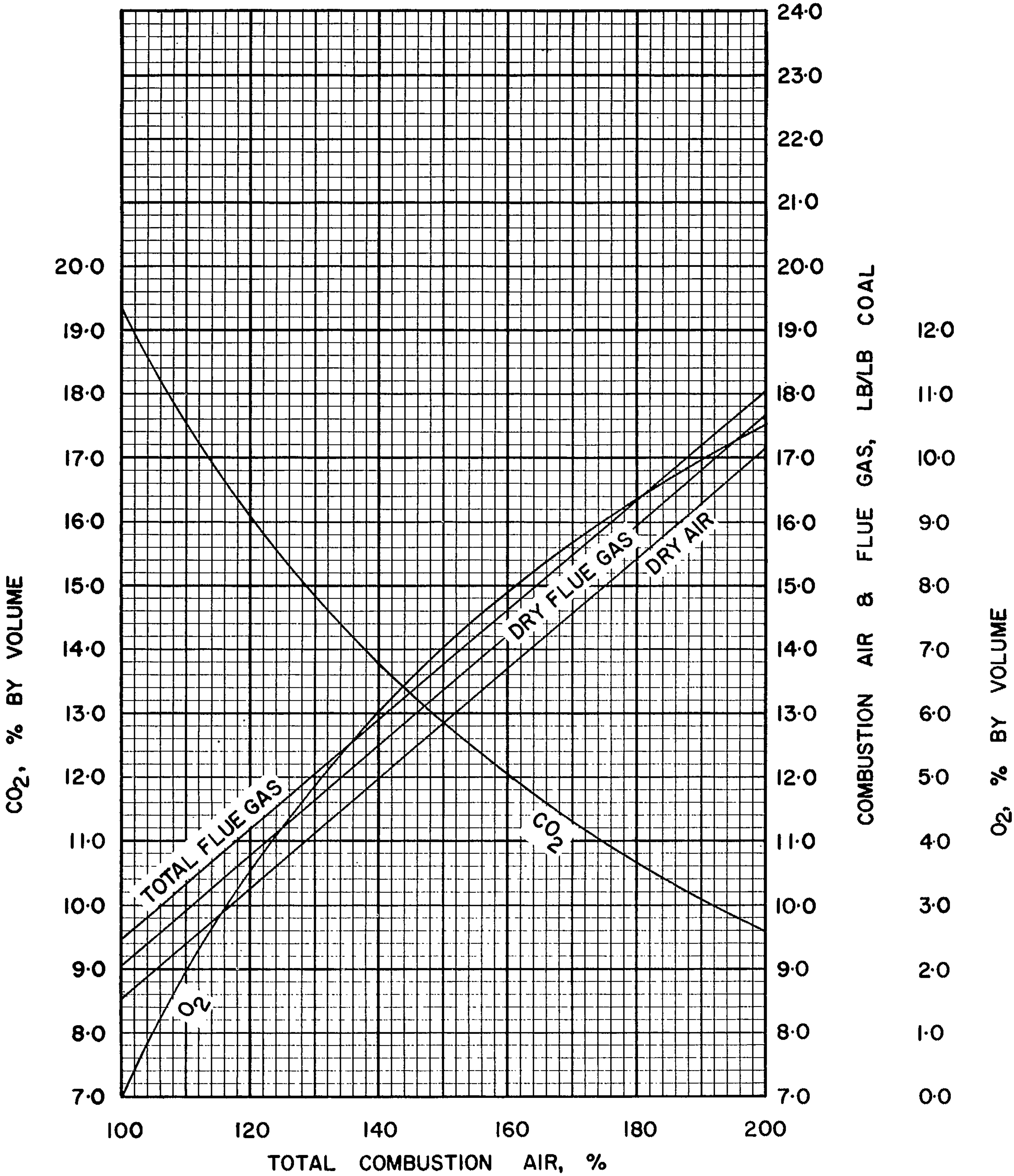


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS S·2·1

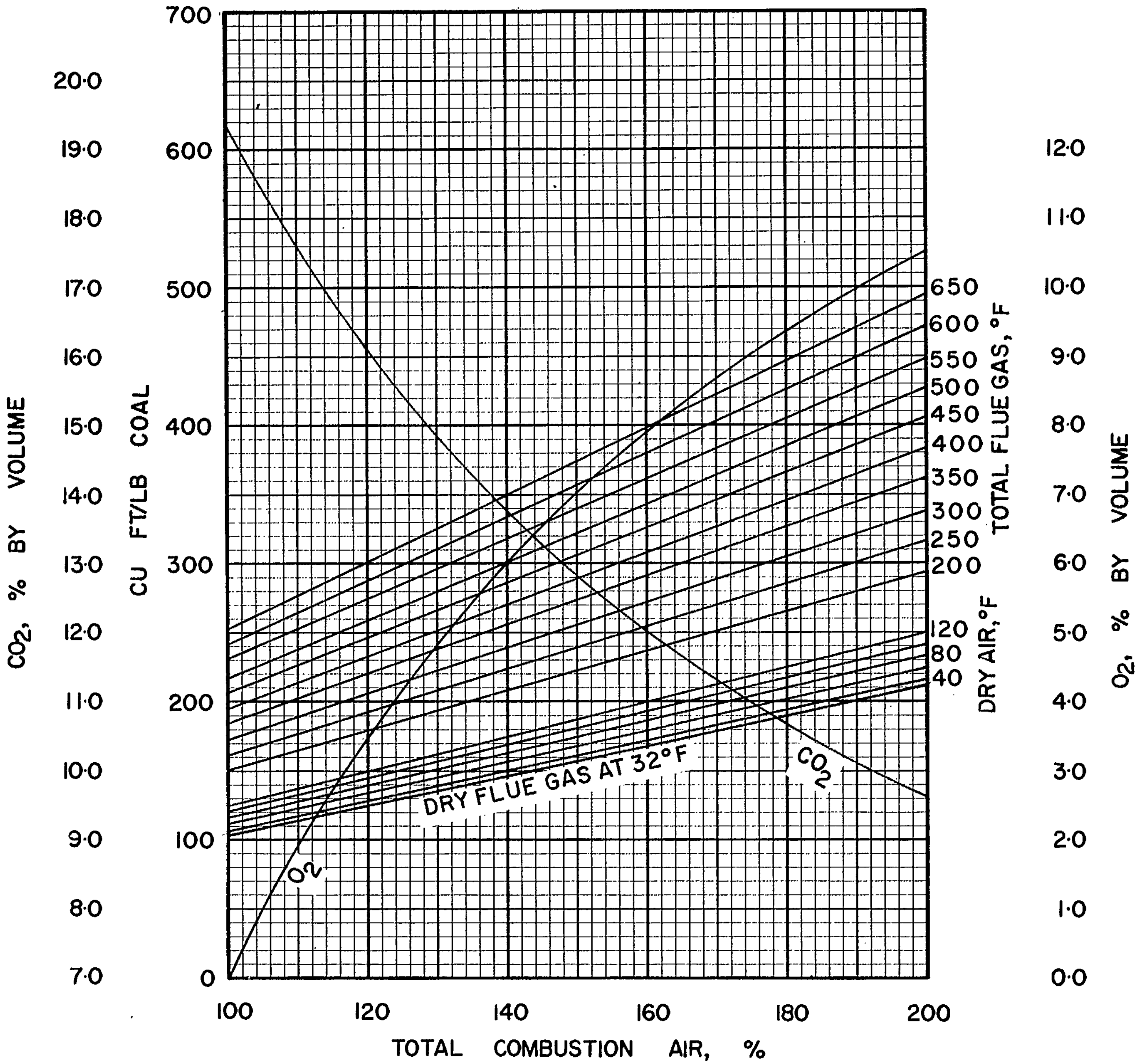


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·2·1

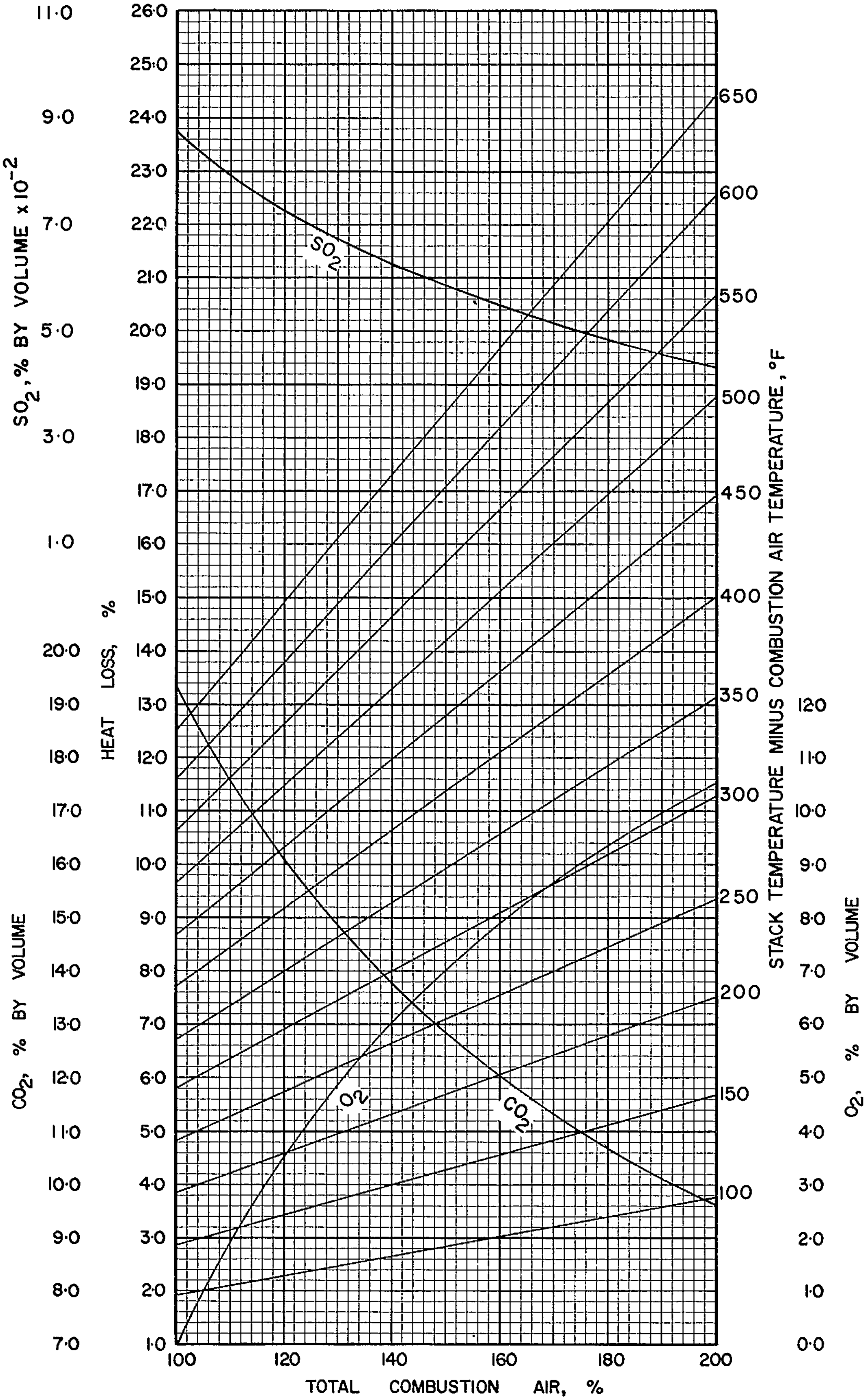


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·2·1

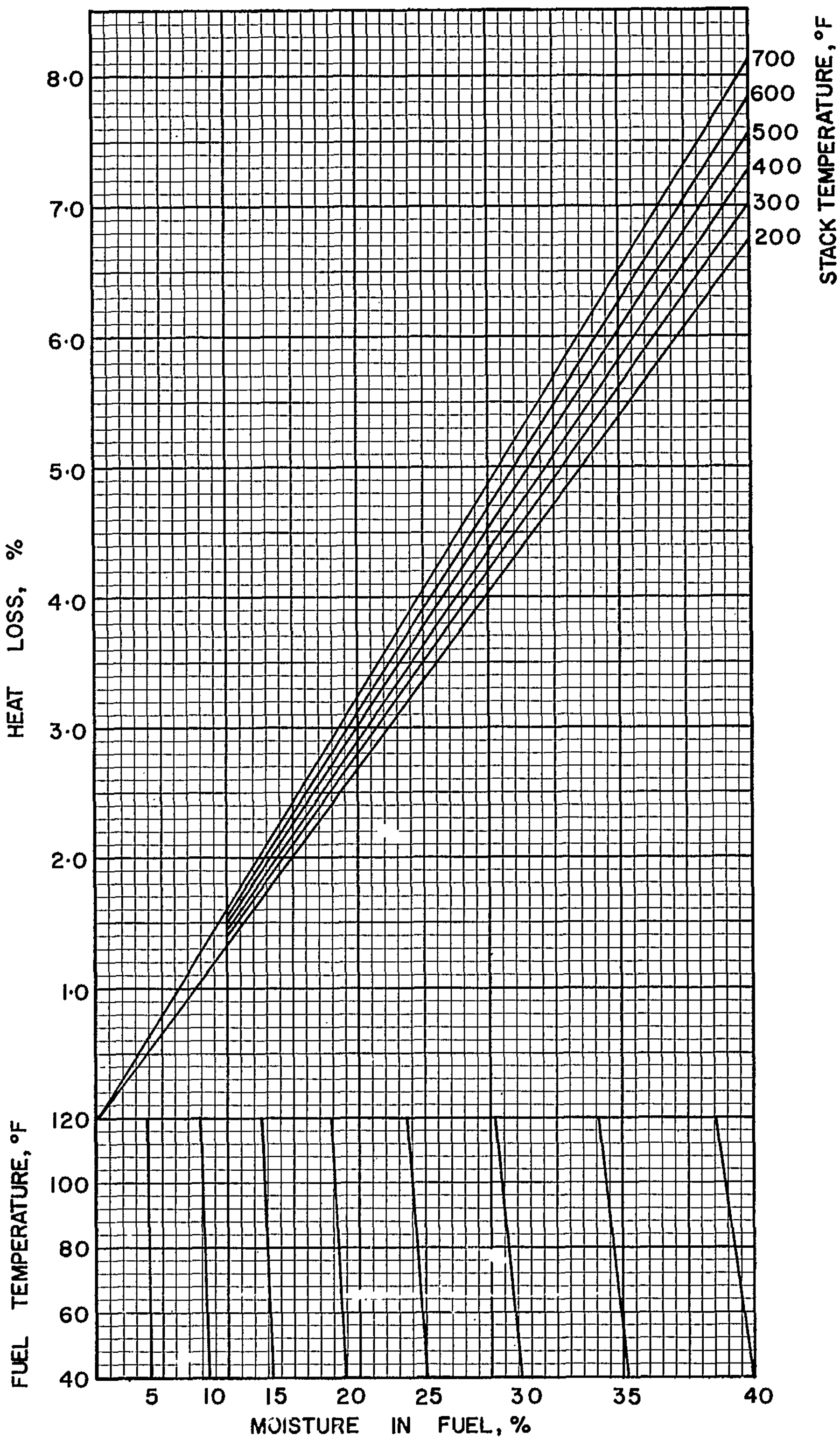


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·2·1

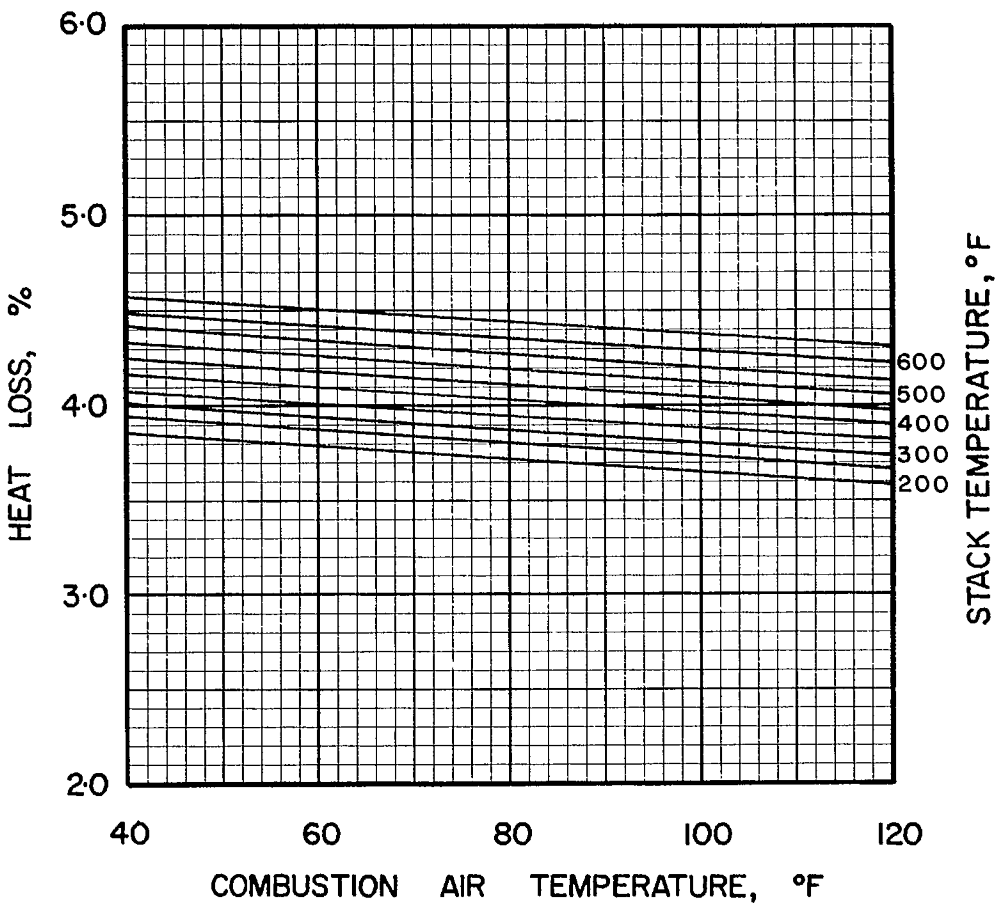


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·2·1

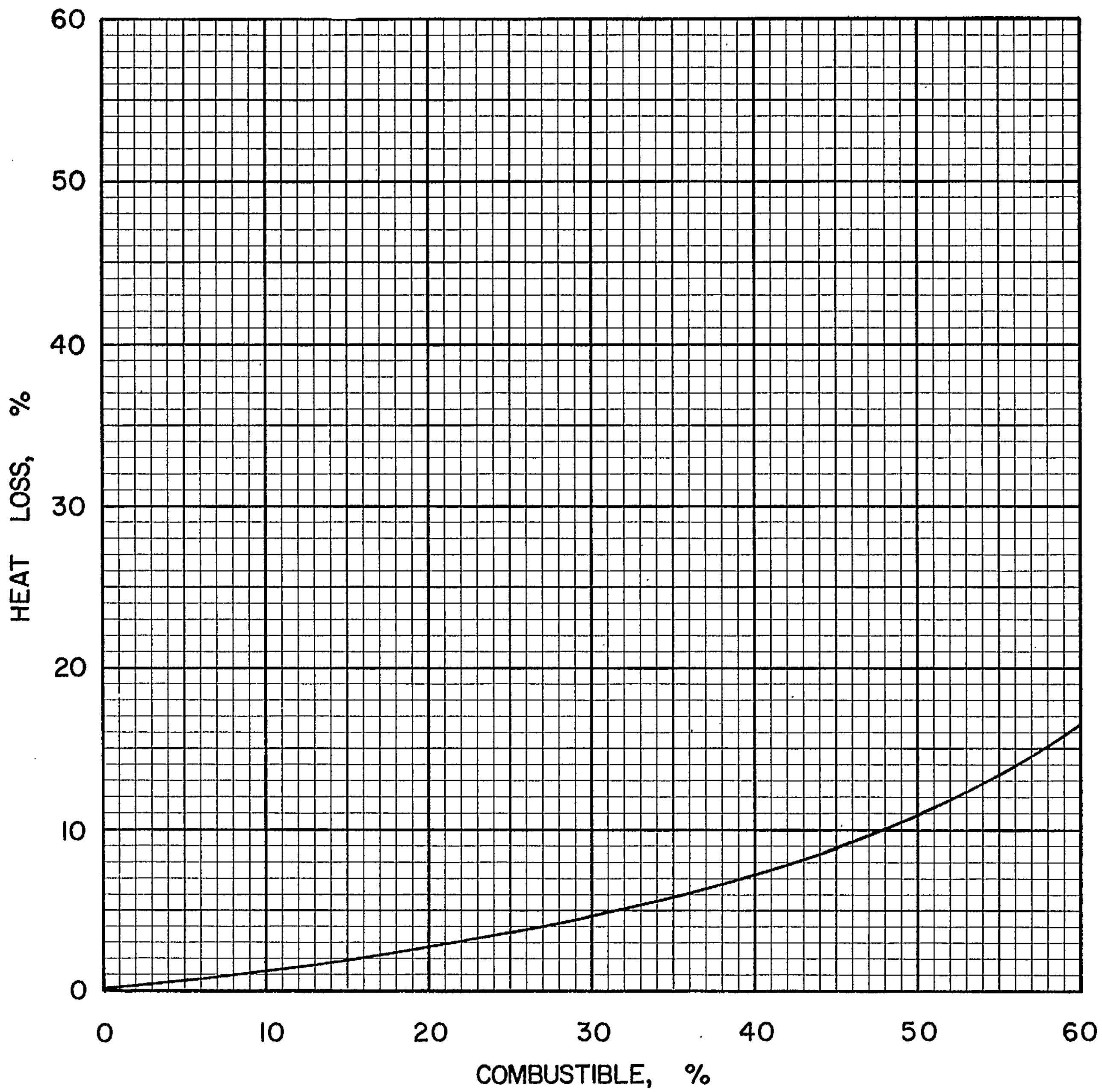


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·2·1

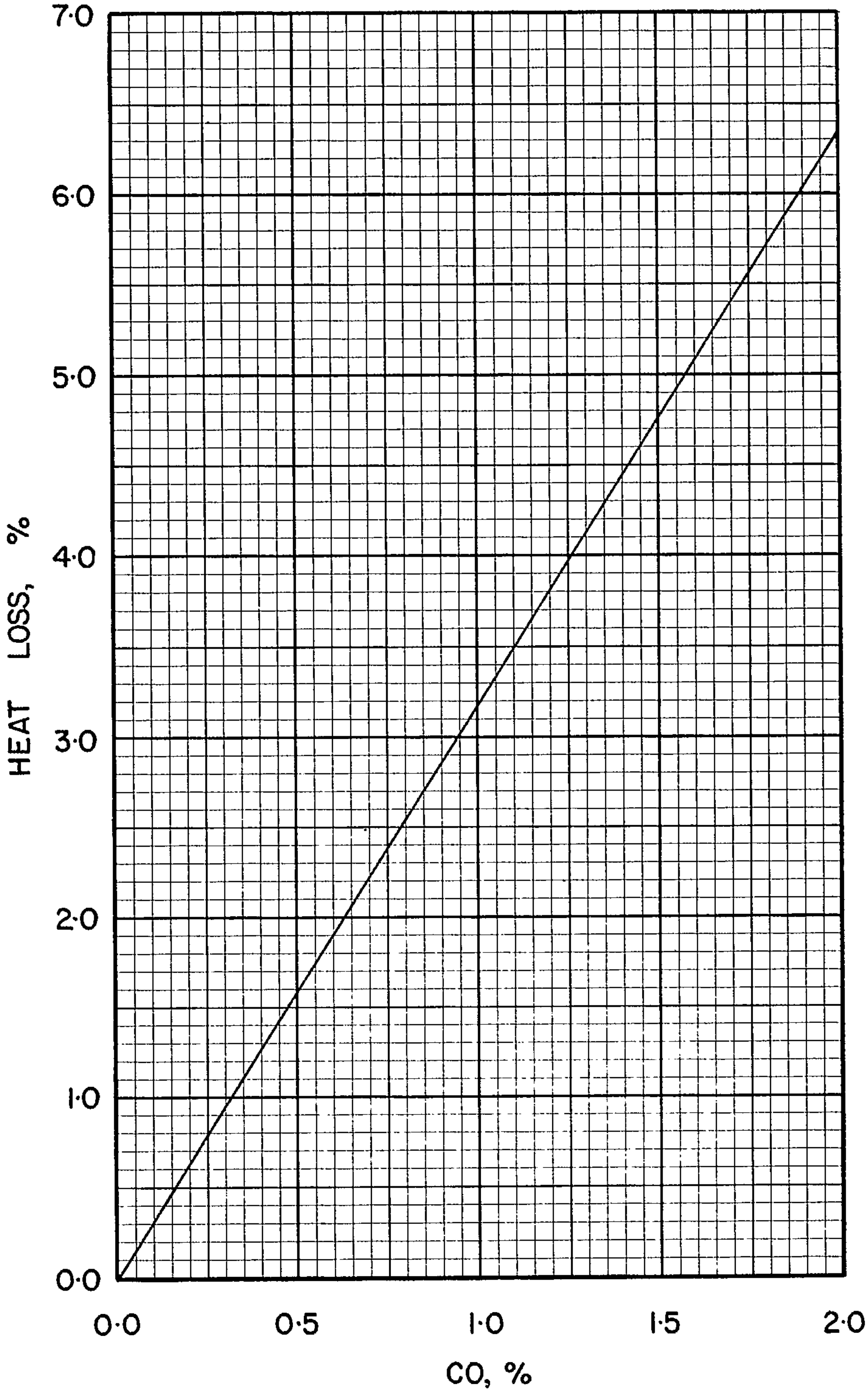


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·2·1

COAL S 2-2, MANITOBA AND SASKATCHEWAN COAL CO. LTD., BIENFAIT LIGNITE, – 1/2 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.0984
Volatile Matter	0.4011
Fixed Carbon	0.5005
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6771
Hydrogen (H)	0.0416
Sulphur (S)	0.0087
Nitrogen (N)	0.0109
Oxygen (O)	0.1633
Ash	0.0984
Total	1.0000

Gross Calorific Value

Btu/lb:	11200
Btu/short ton:	22.40×10^6
Btu/long ton:	25.09×10^6
MJ/kg:	26.05

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 89.29	lb	
10^6 Btu	= 0.04464	short tons	
10^6 Btu	= 0.03986	long tons	

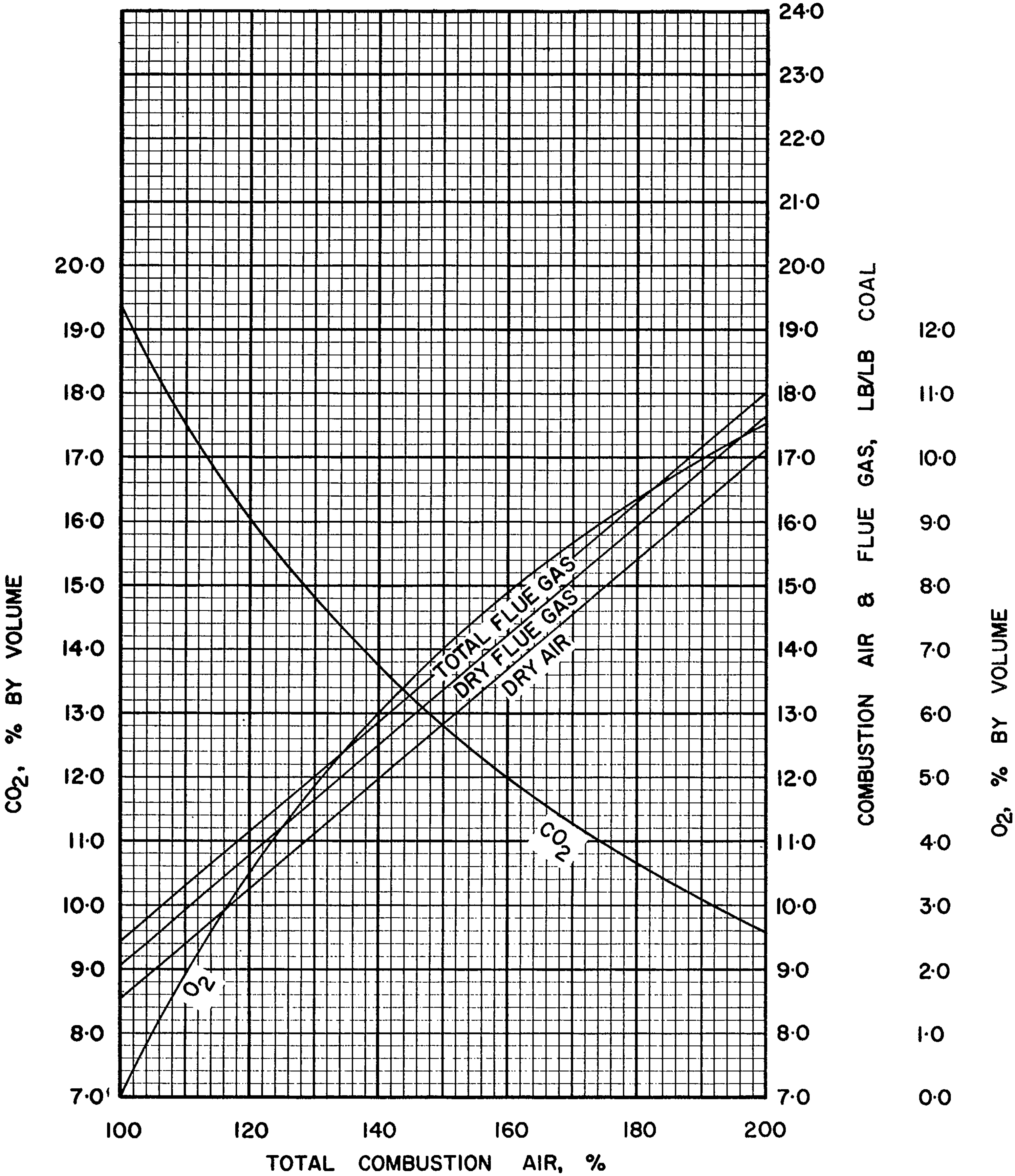


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

S·2·2

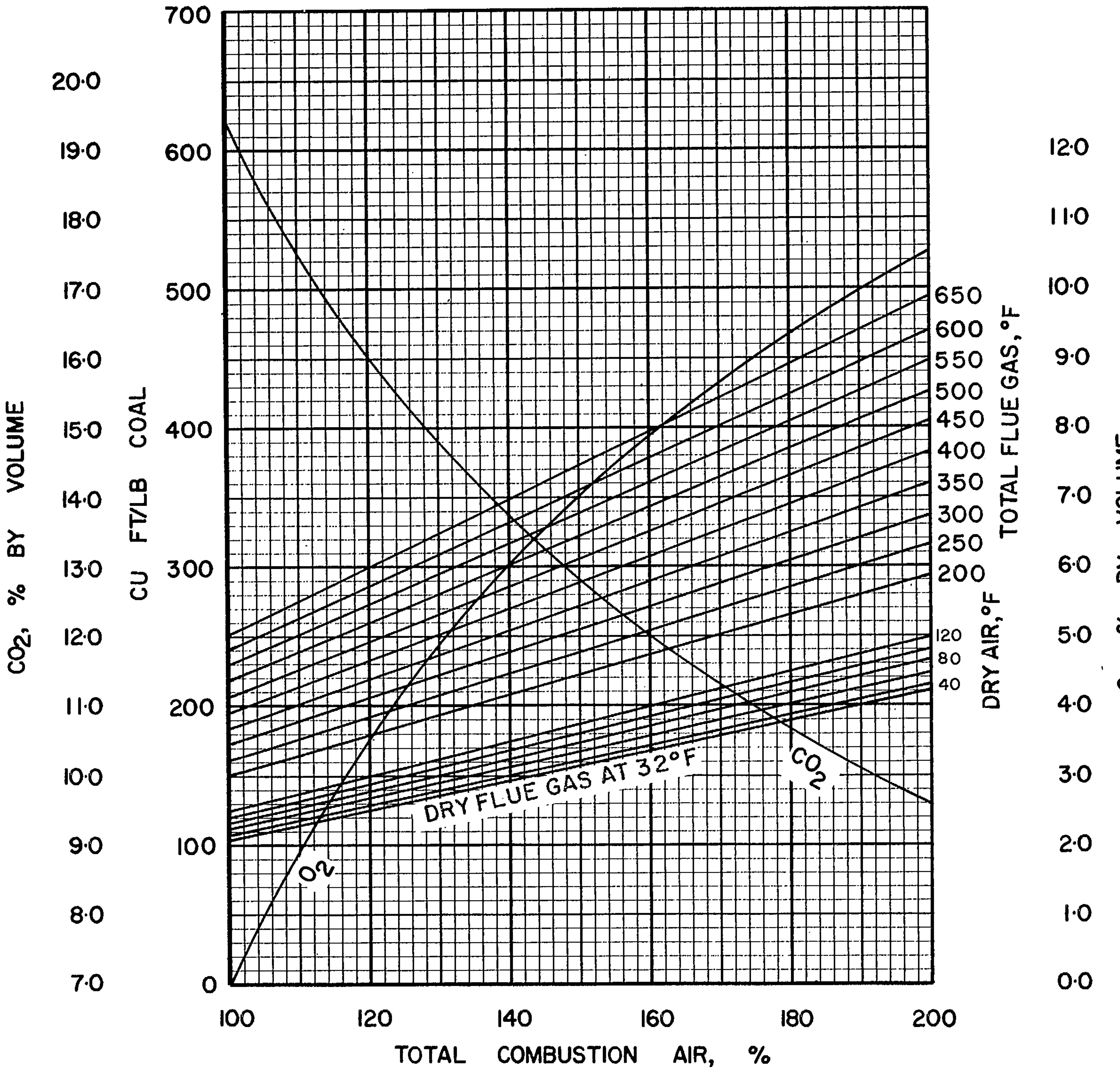


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·2·2

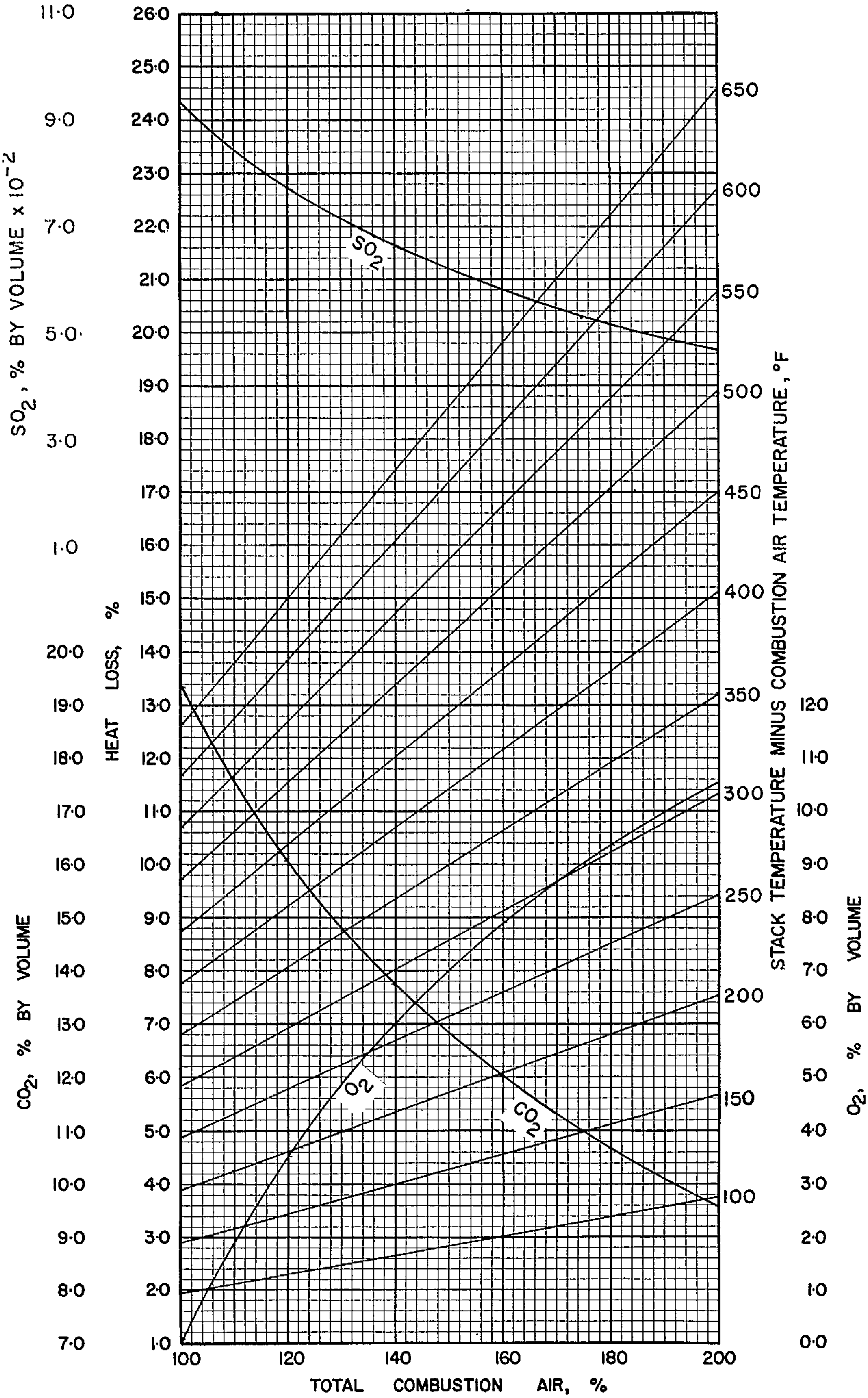


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·2·2

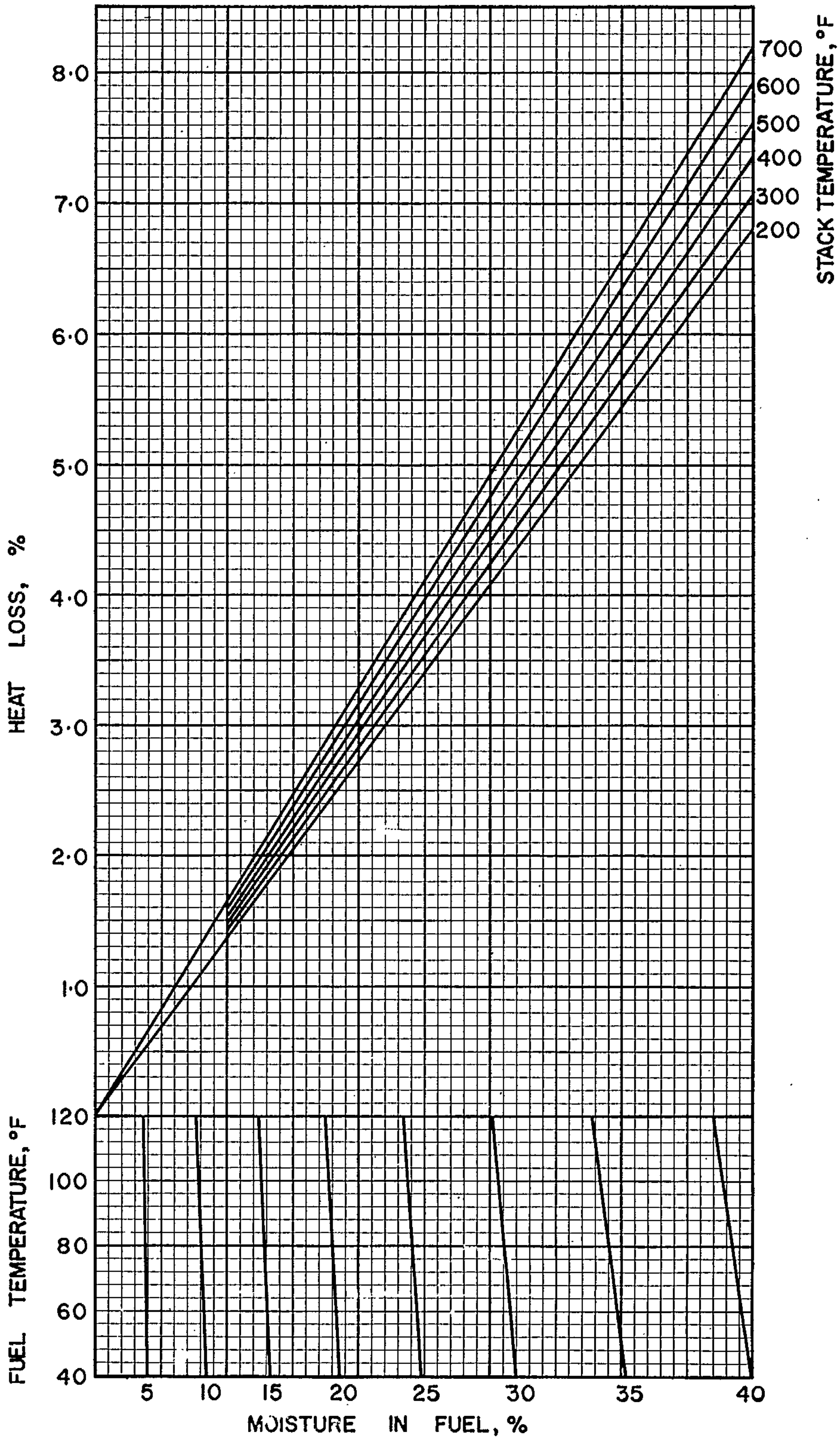


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·2·2

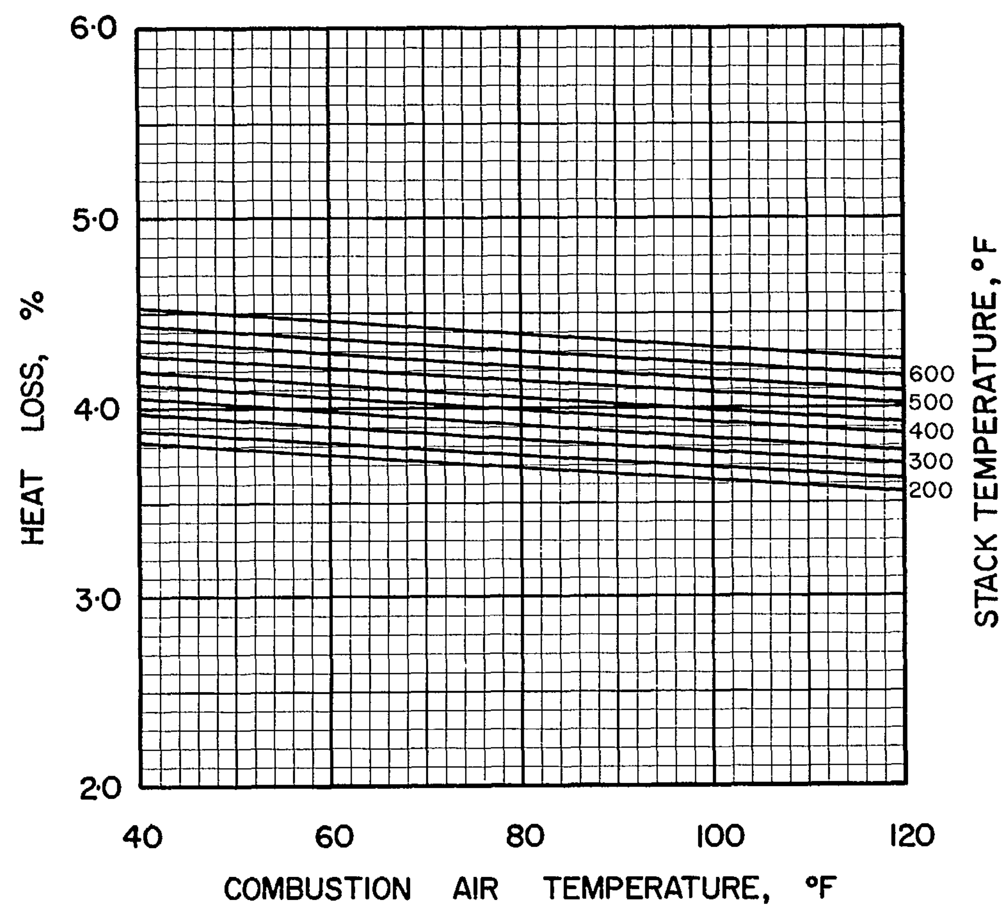


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·2·2

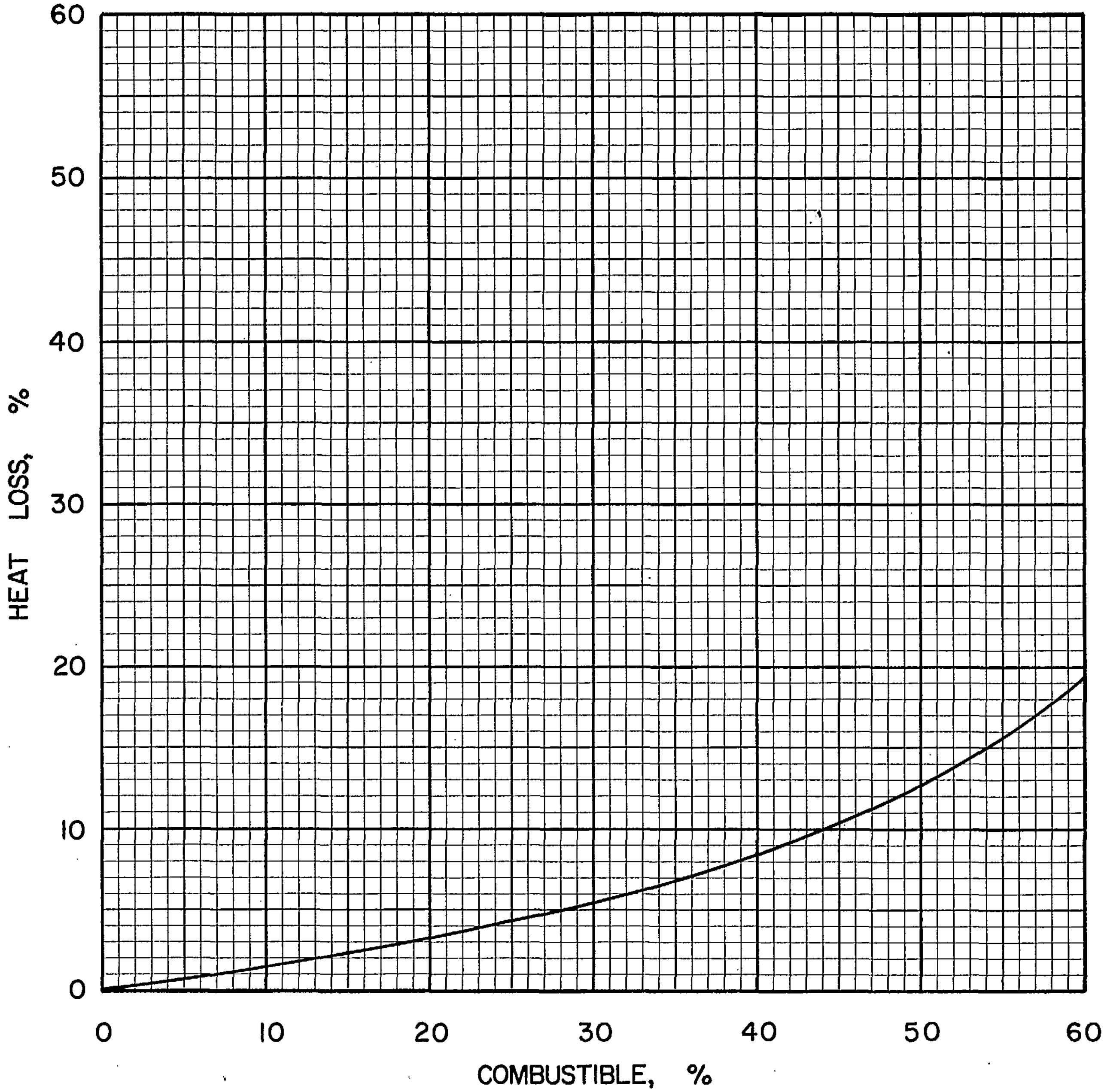


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·2·2

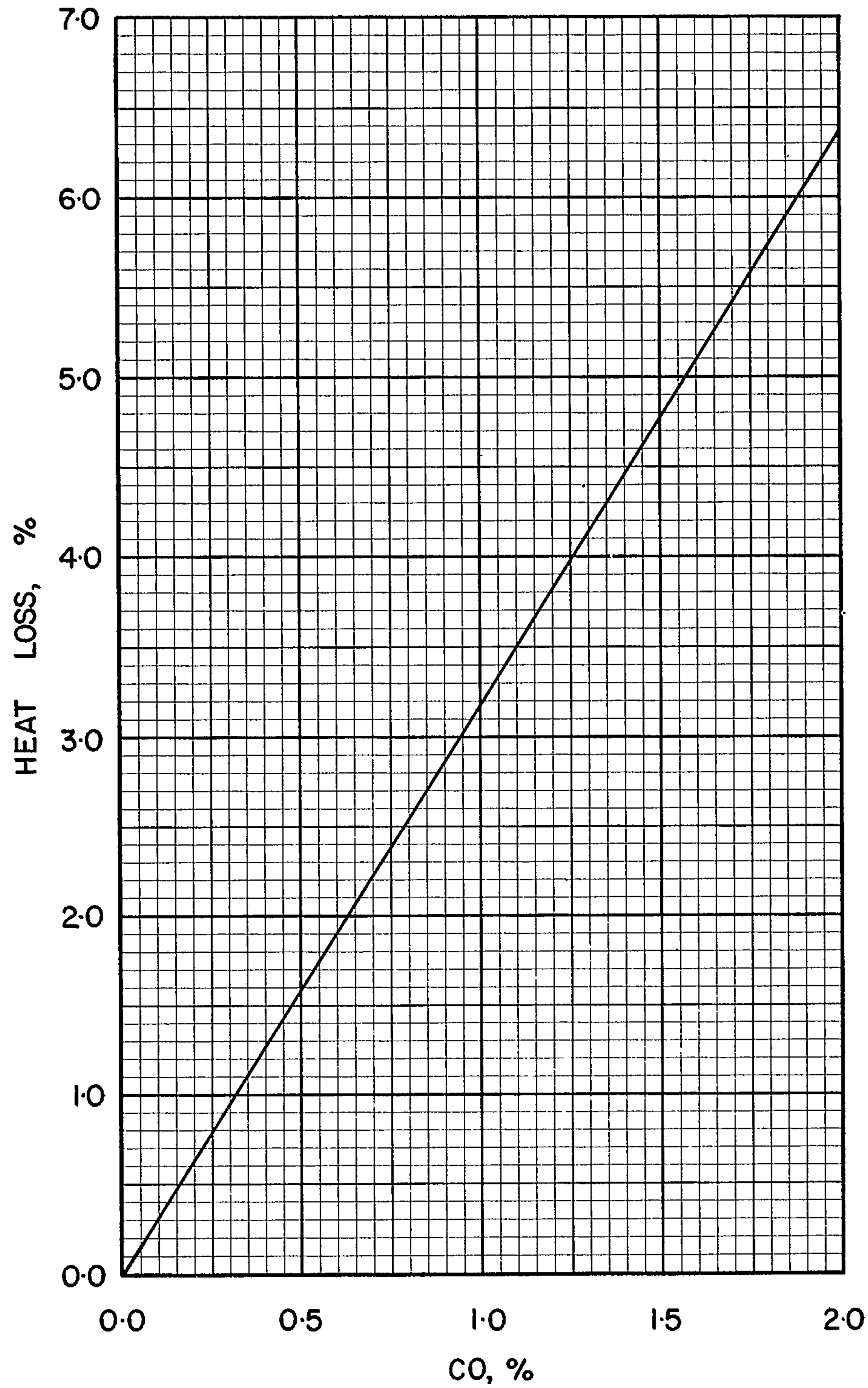


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·2·2

COAL S 2-3, MANITOBA AND SASKATCHEWAN COAL CO. LTD., BIENFAIT LIGNITE, 4 in. x 2 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.0744
Volatile Matter	0.4143
Fixed Carbon	0.5113
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6801
Hydrogen (H)	0.0440
Sulphur (S)	0.0062
Nitrogen (N)	0.0110
Oxygen (O)	0.1843
Ash	0.0744
Total	1.0000

Gross Calorific Value

Btu/lb:	11310
Btu/short ton:	22.62×10^6
Btu/long ton:	25.33×10^6
MJ/kg:	26.30

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	88.42	lb	
10^6 Btu	=	0.04421	short tons	
10^6 Btu	=	0.03947	long tons	

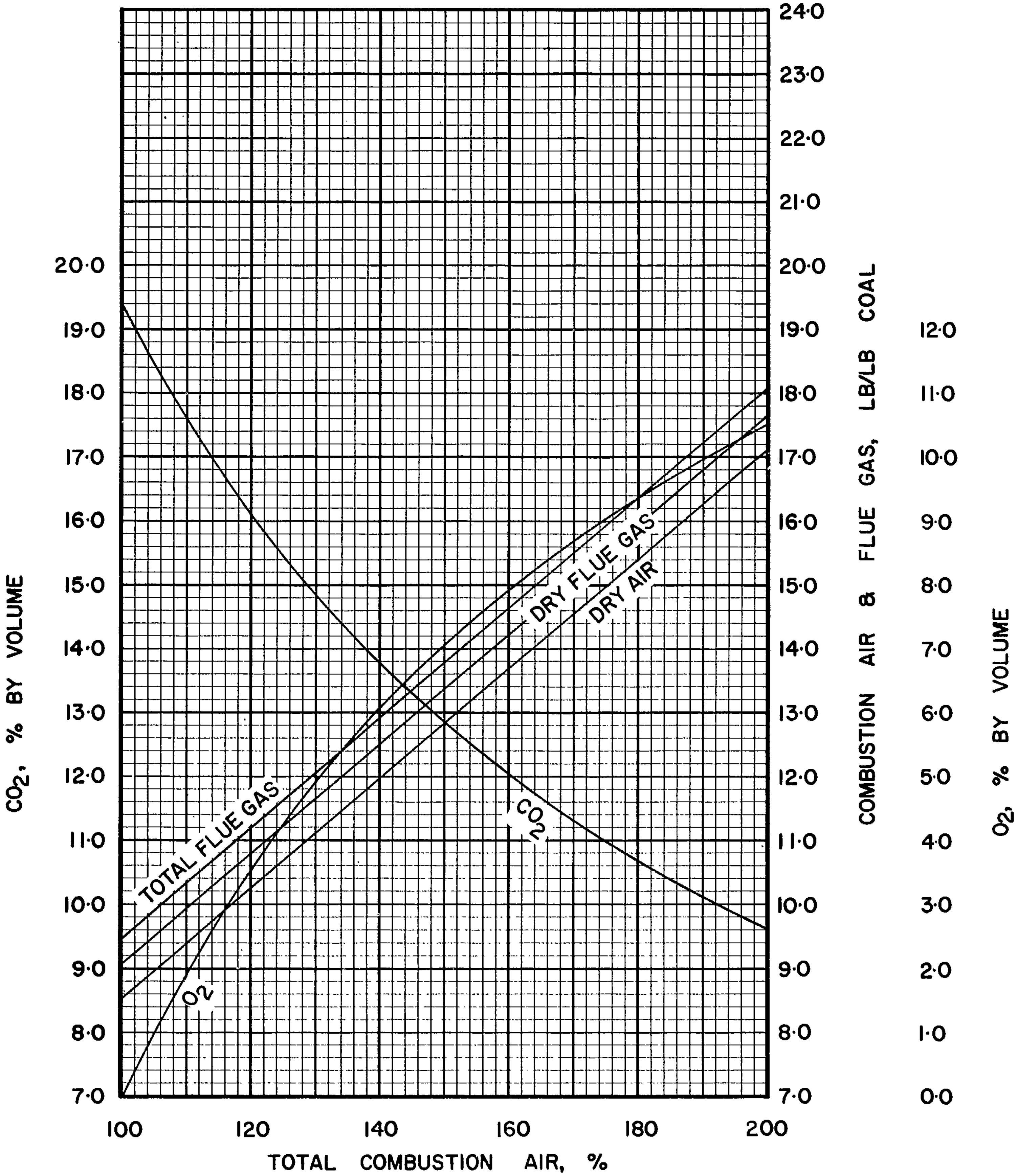


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

S·2·3

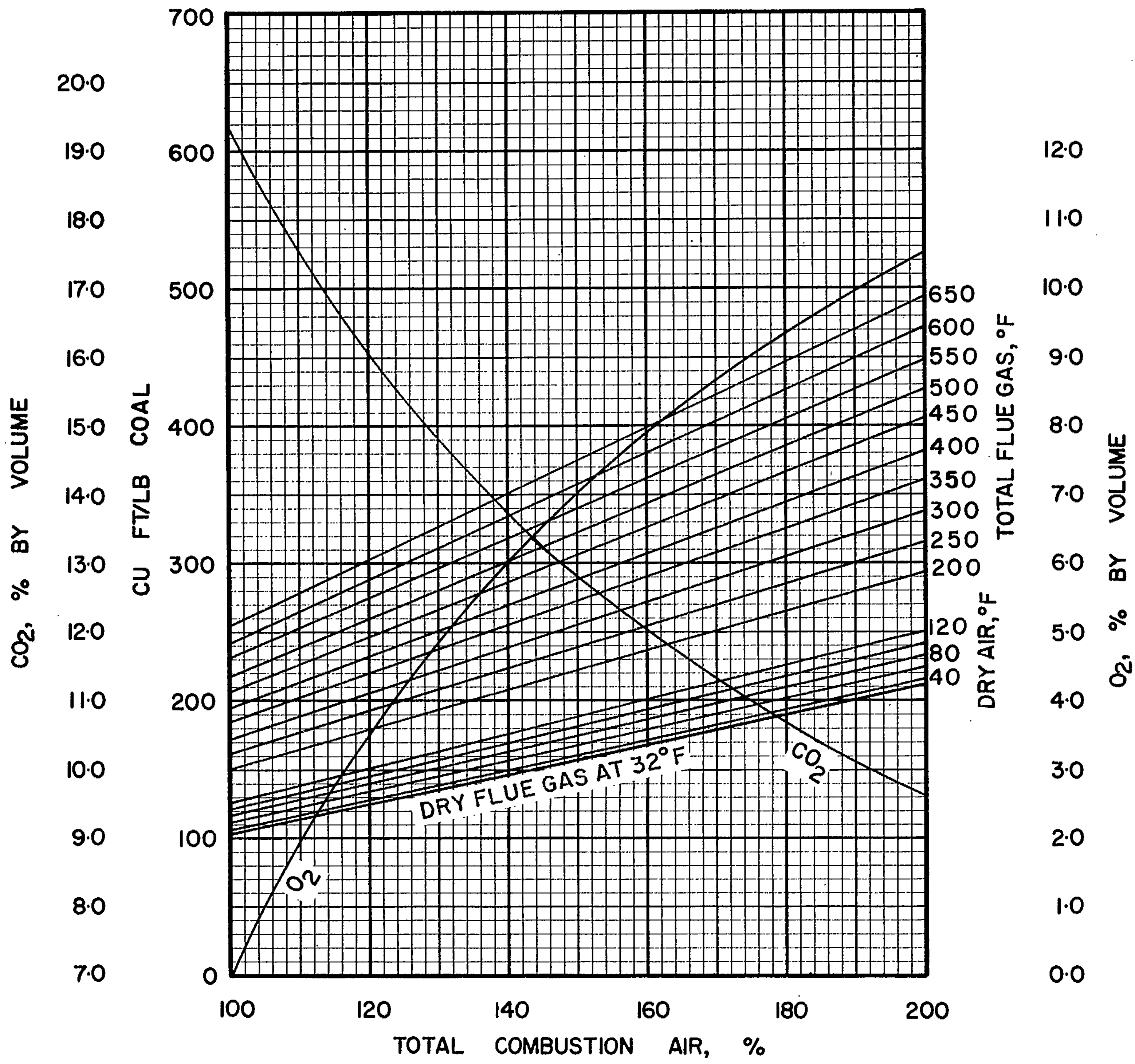


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·2·3

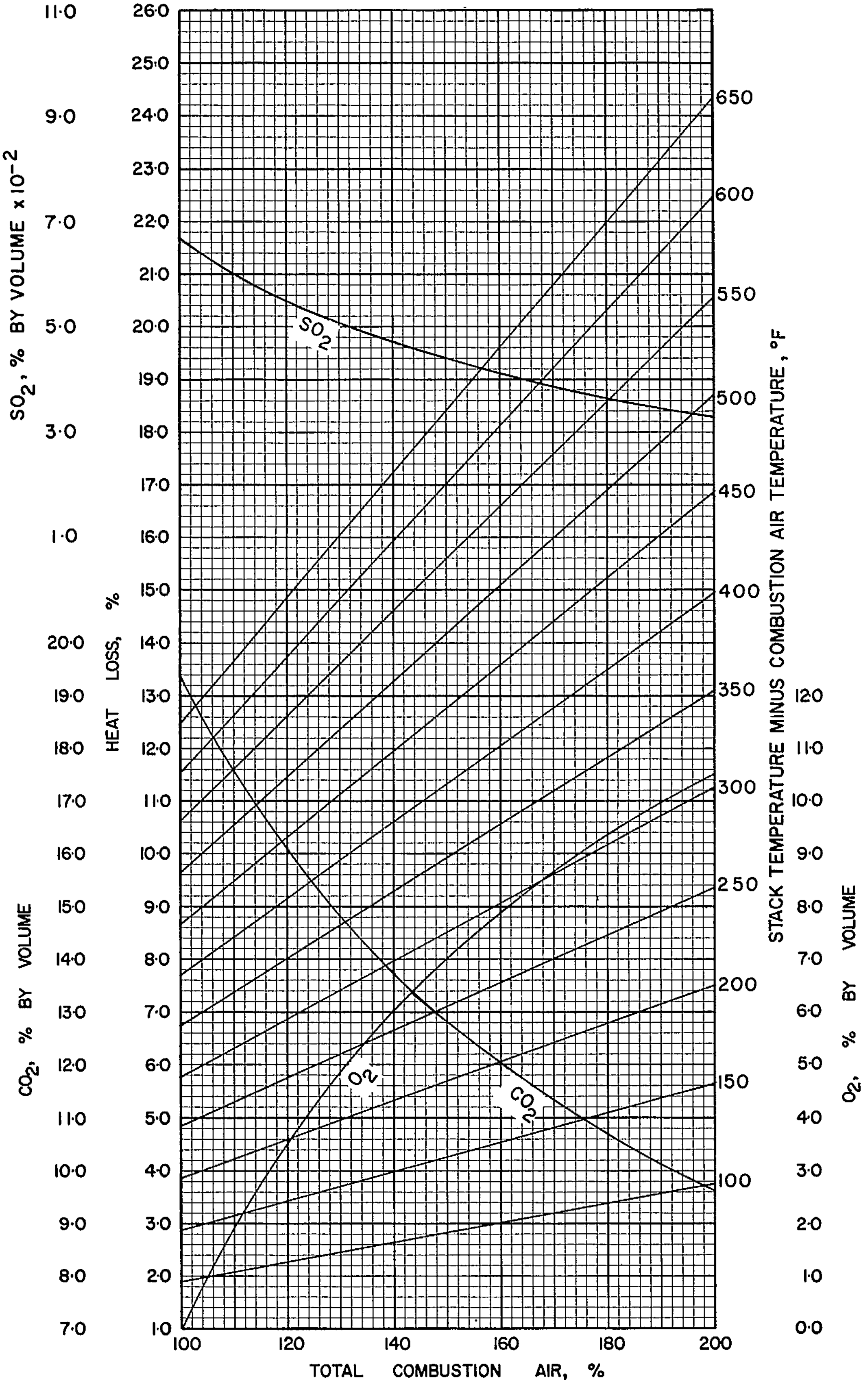


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·2·3

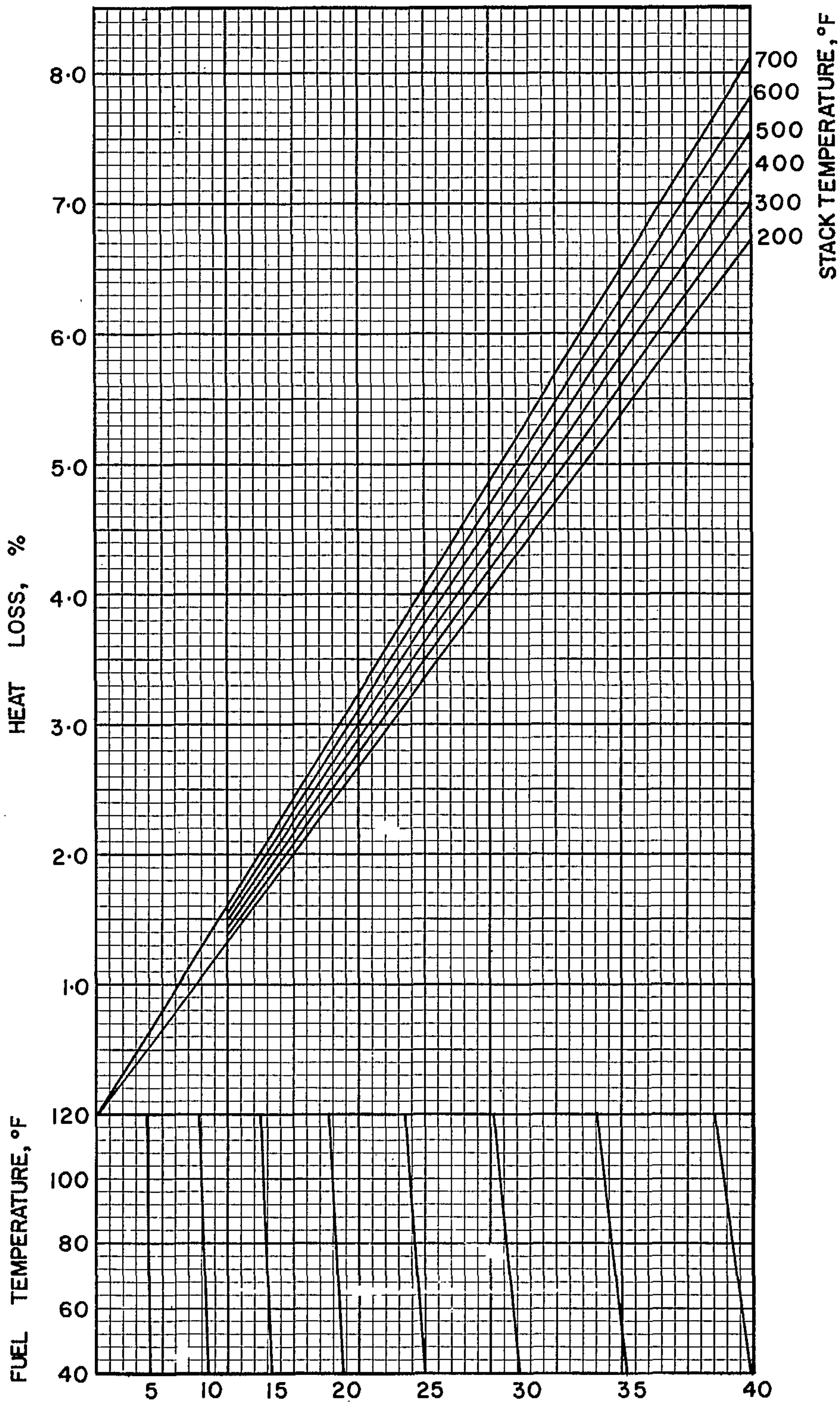


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·2·3

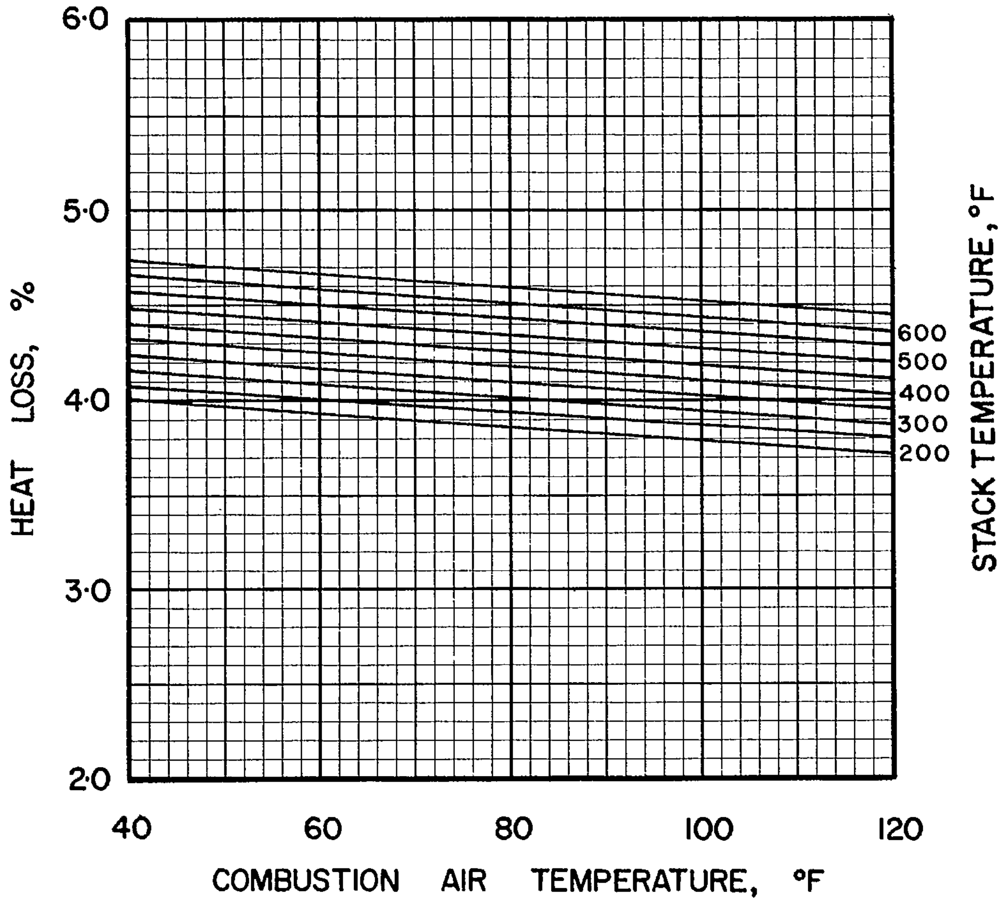


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·2·3

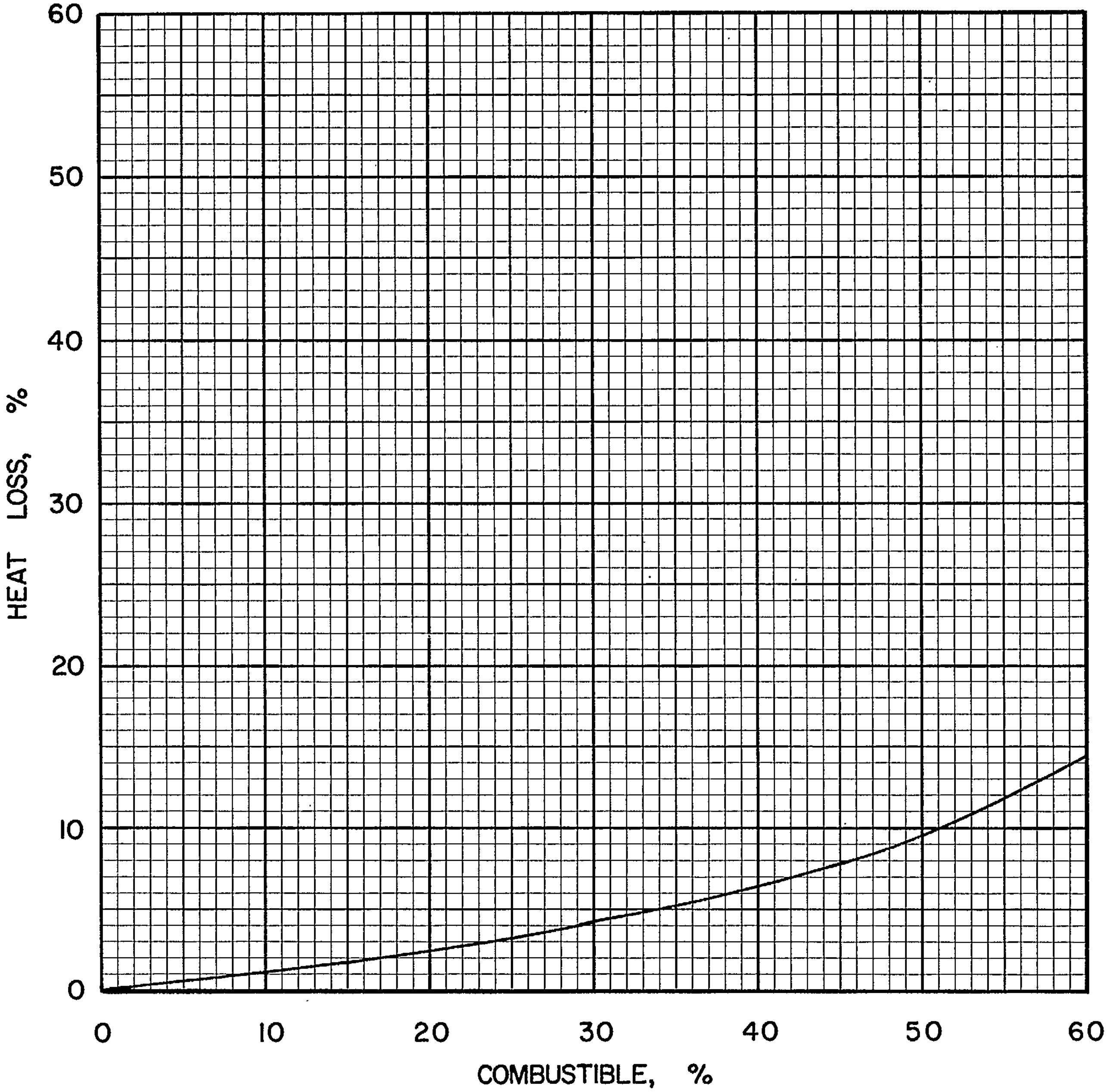


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·2·3

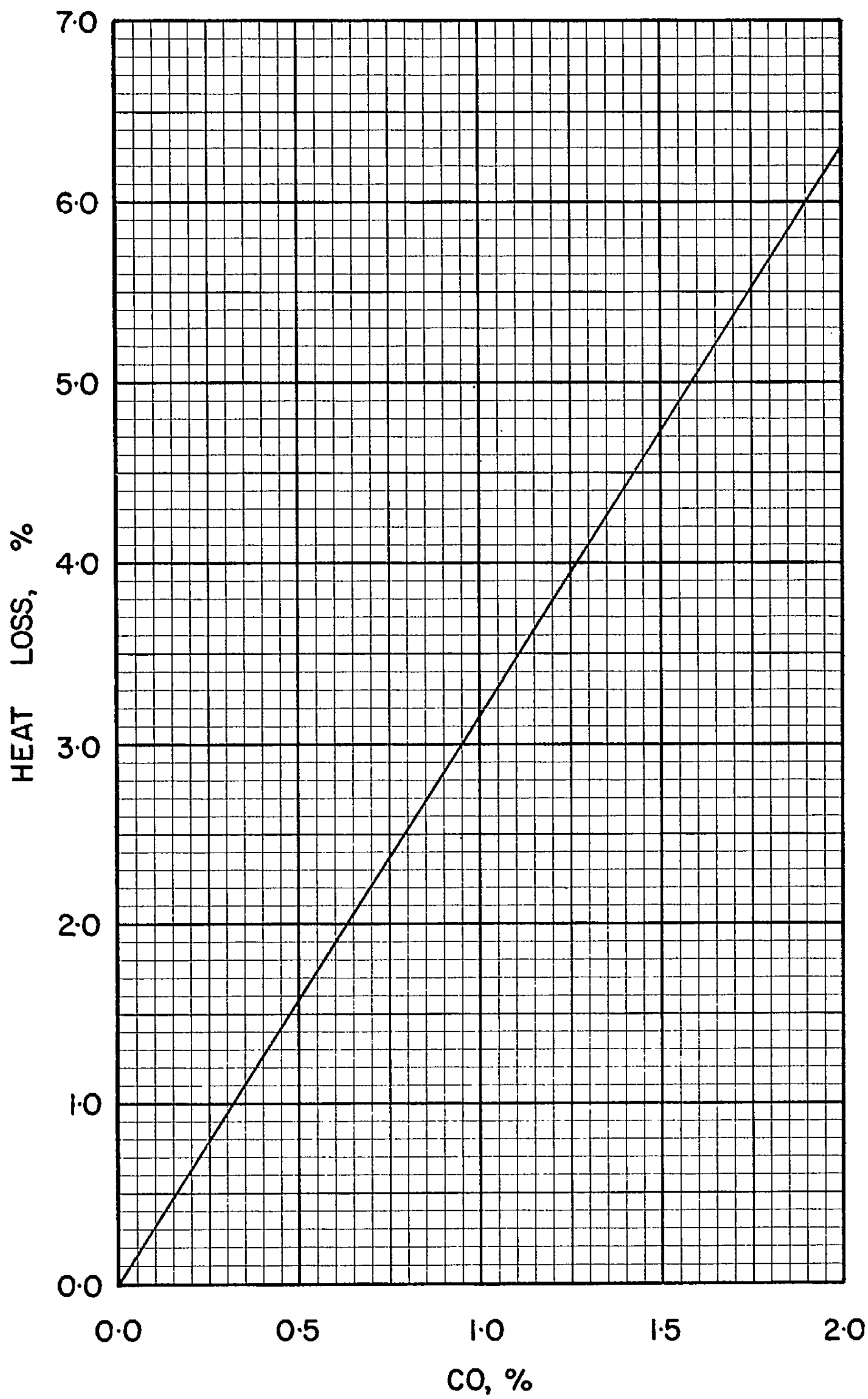


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·2·3

COAL S 2-4, MANITOBA AND SASKATCHEWAN COAL CO. LTD., BIENFAIT LIGNITE, 2 in. x 1 1/4 in.

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.0789
Volatile Matter	0.4155
Fixed Carbon	0.5056
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6873
Hydrogen (H)	0.0426
Sulphur (S)	0.0086
Nitrogen (N)	0.0116
Oxygen (O)	0.1710
Ash	0.0789
Total	1.0000

Gross Calorific Value

Btu/lb:	11370
Btu/short ton:	22.74×10^6
Btu/long ton:	25.47×10^6
MJ/kg:	26.44

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 87.95	lb	
10^6 Btu	= 0.04398	short tons	
10^6 Btu	= 0.03926	long tons	

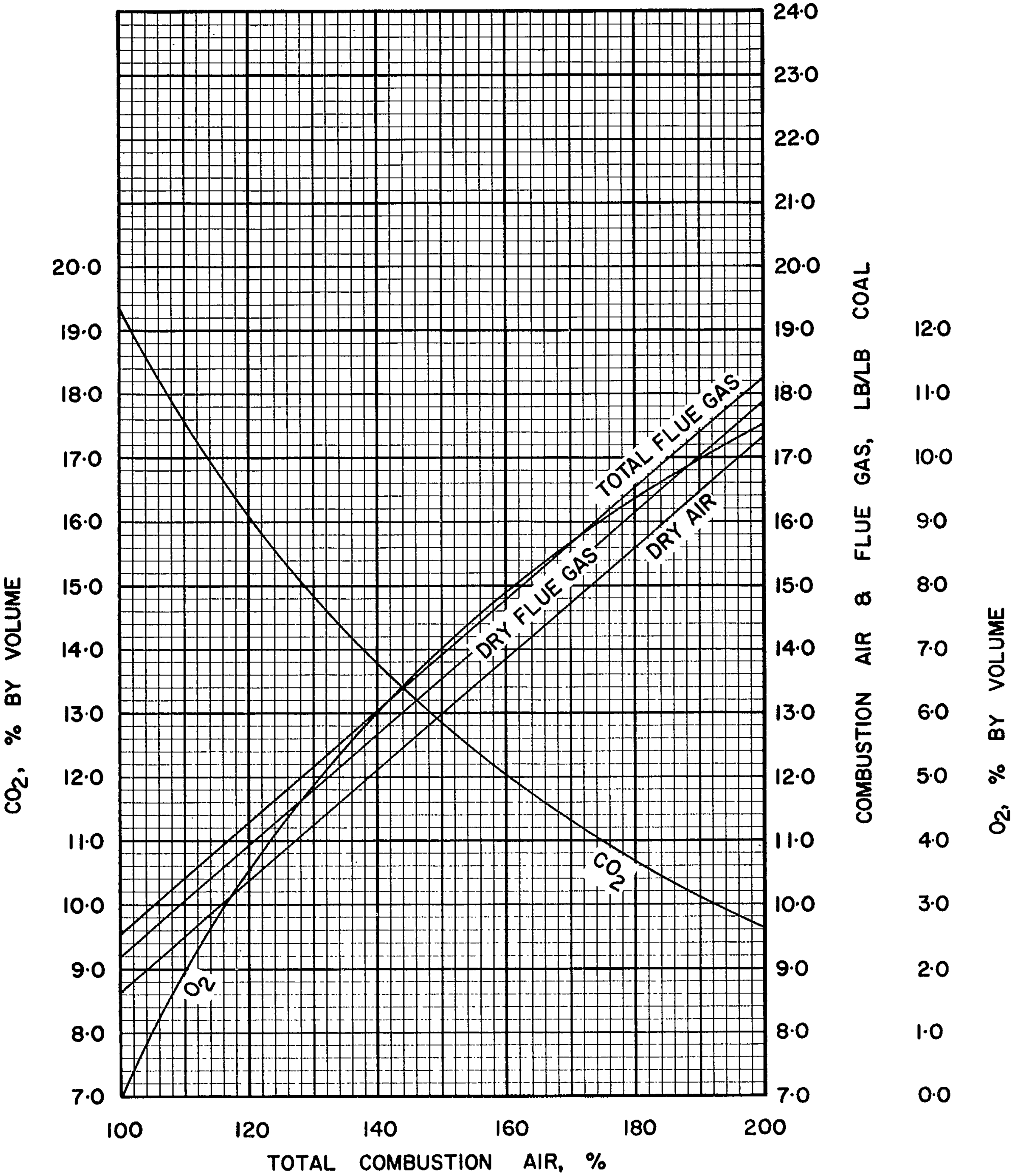


FIGURE I· COMBUSTION DATA, WEIGHT BASIS

S·2·4

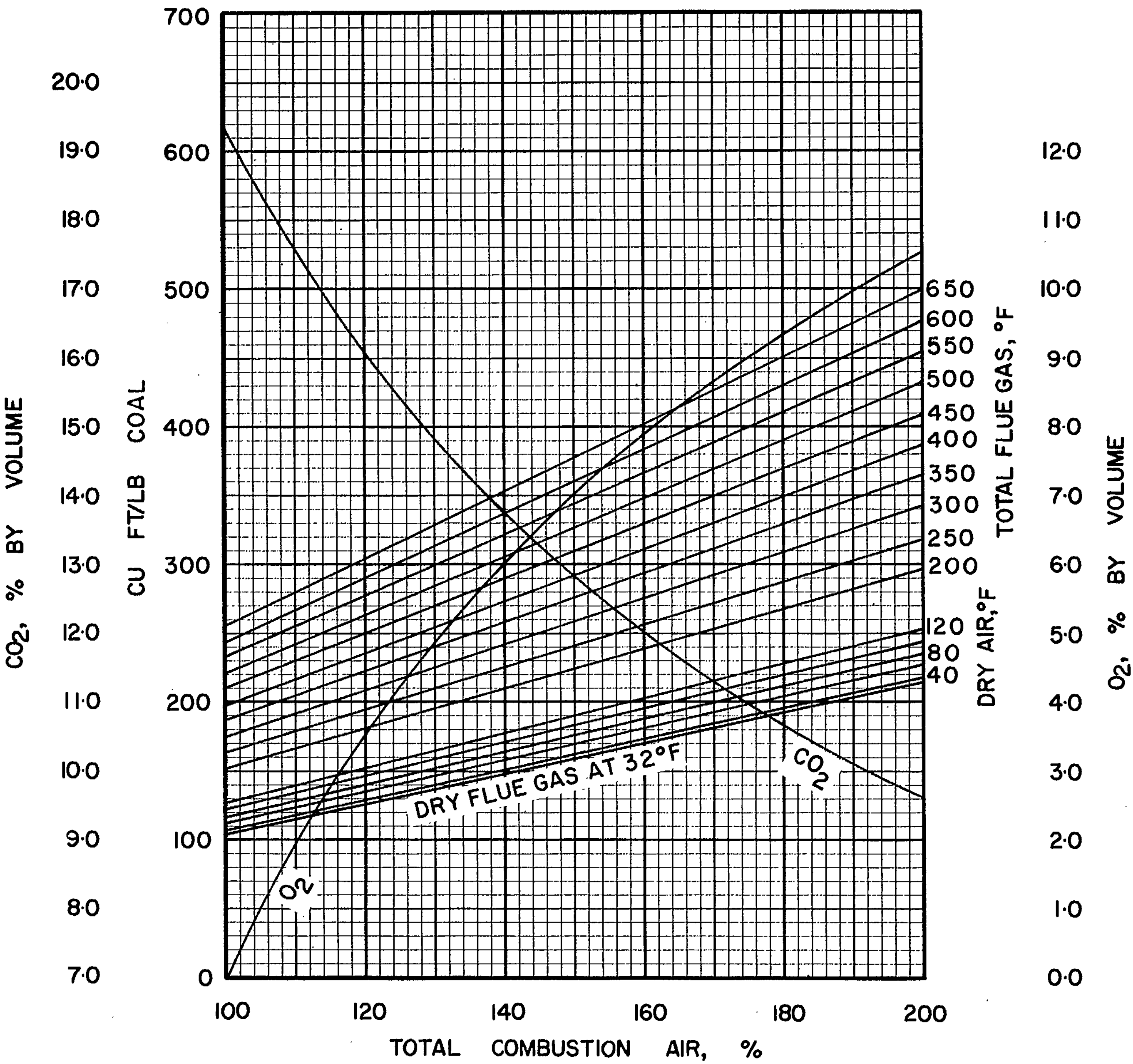


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·2·4

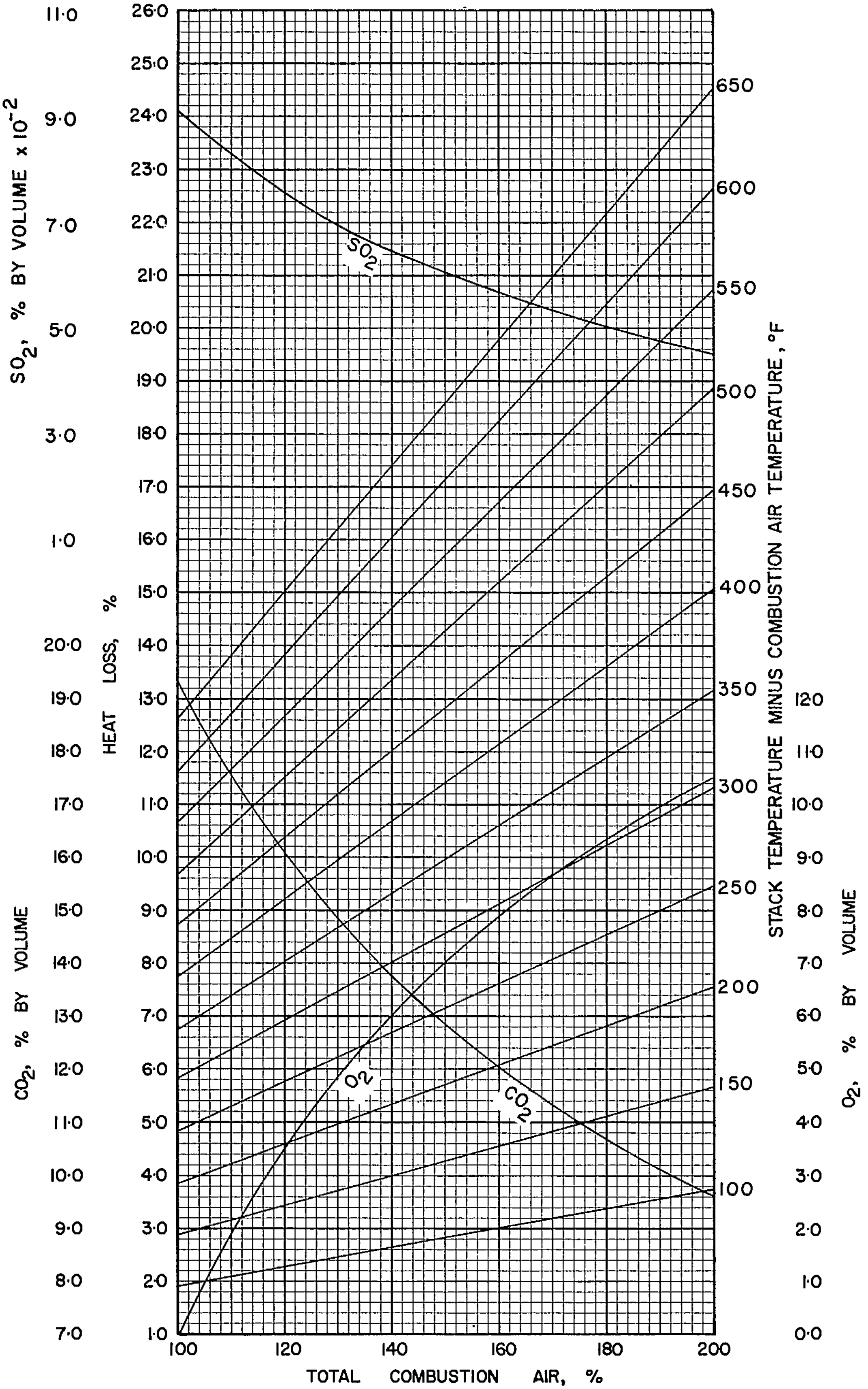


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·2·4

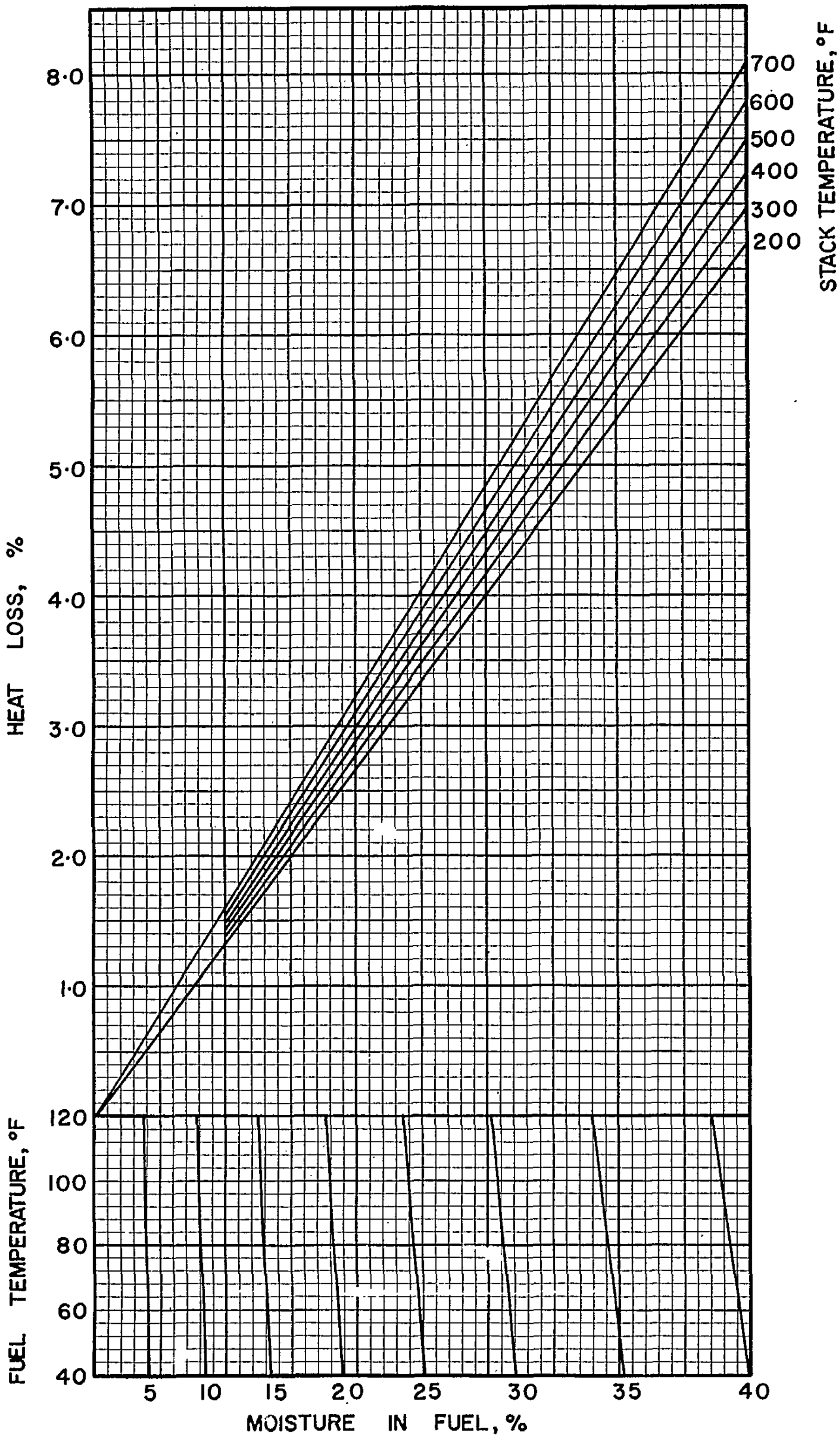


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·2·4

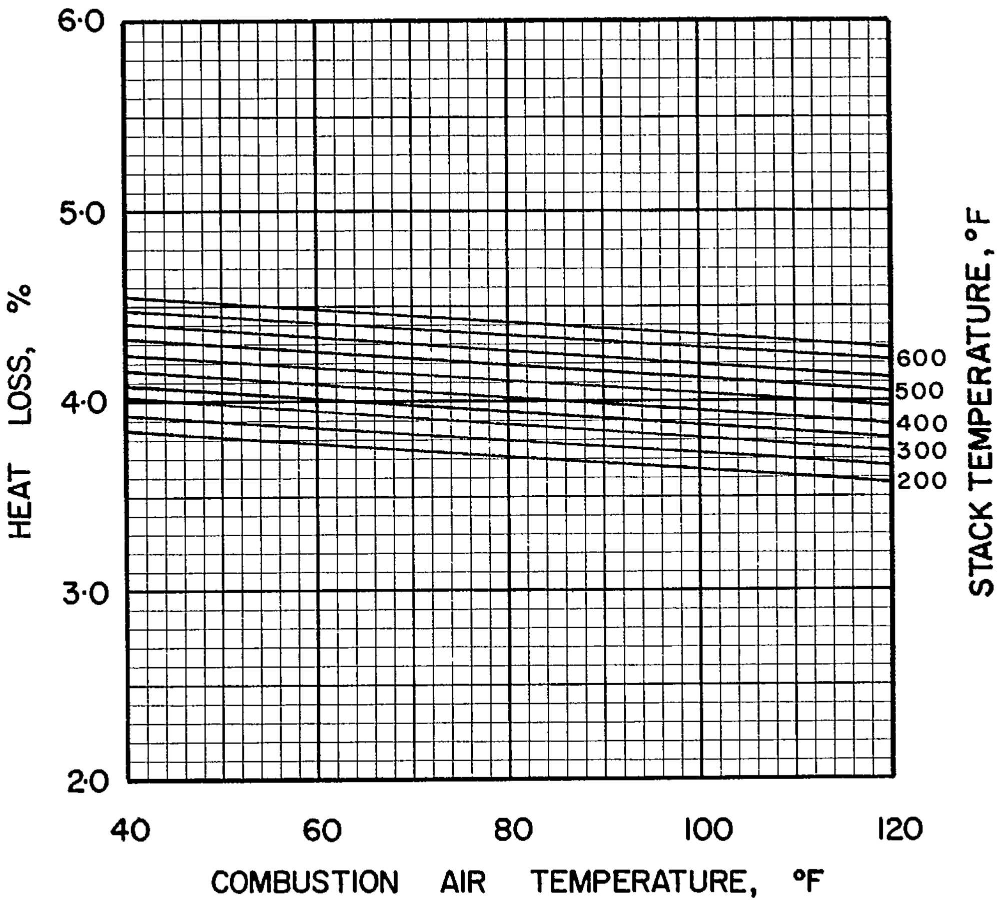


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·2·4

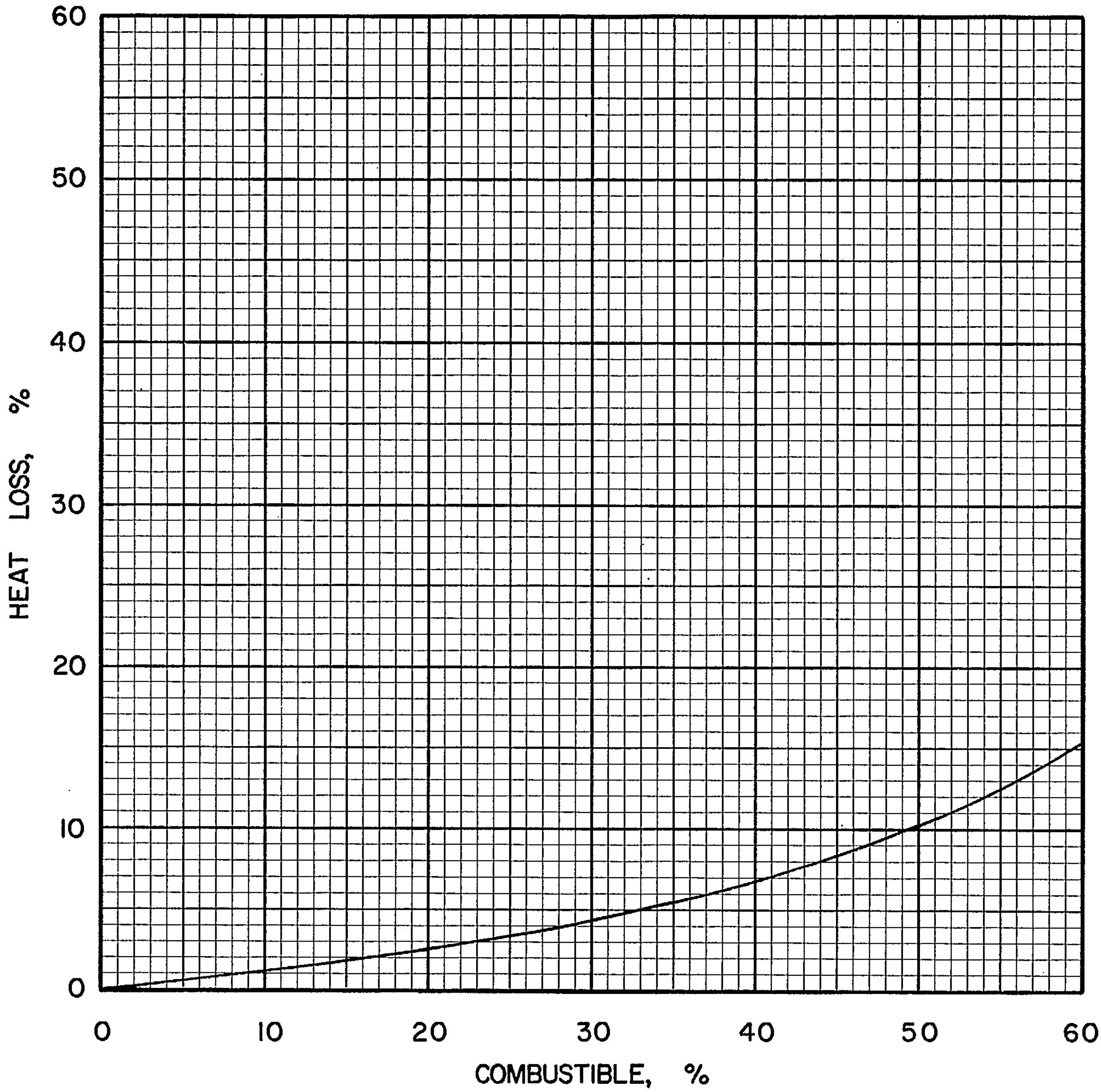


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·2·4

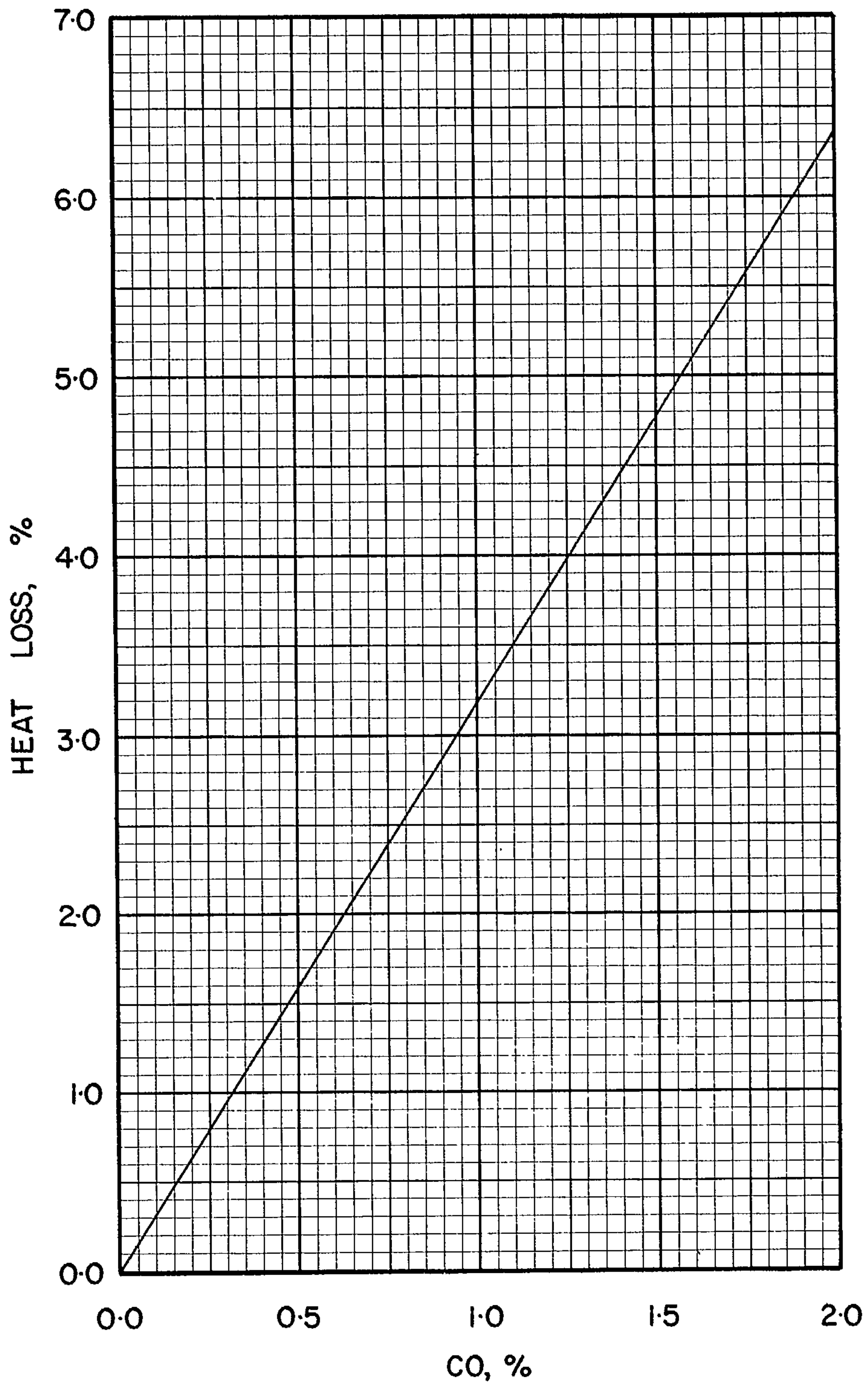


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·2·4

COAL S 3-1, UTILITY COAL LTD., ESTEVAN, MINE RUN

Typical Moisture Range: 25–40%

Proximate Analysis (lb/lb dry coal)

Ash	0.1336
Volatile Matter	0.3821
Fixed Carbon	0.4843
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6548
Hydrogen (H)	0.0361
Sulphur (S)	0.0060
Nitrogen (N)	0.0113
Oxygen (O)	0.1582
Ash	0.1336
Total	1.0000

Gross Calorific Value

Btu/lb:	10790
Btu/short ton:	21.58×10^6
Btu/long ton:	24.17×10^6
MJ/kg:	25.09

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	92.68	lb	
10^6 Btu	=	0.04634	short tons	
10^6 Btu	=	0.04137	long tons	

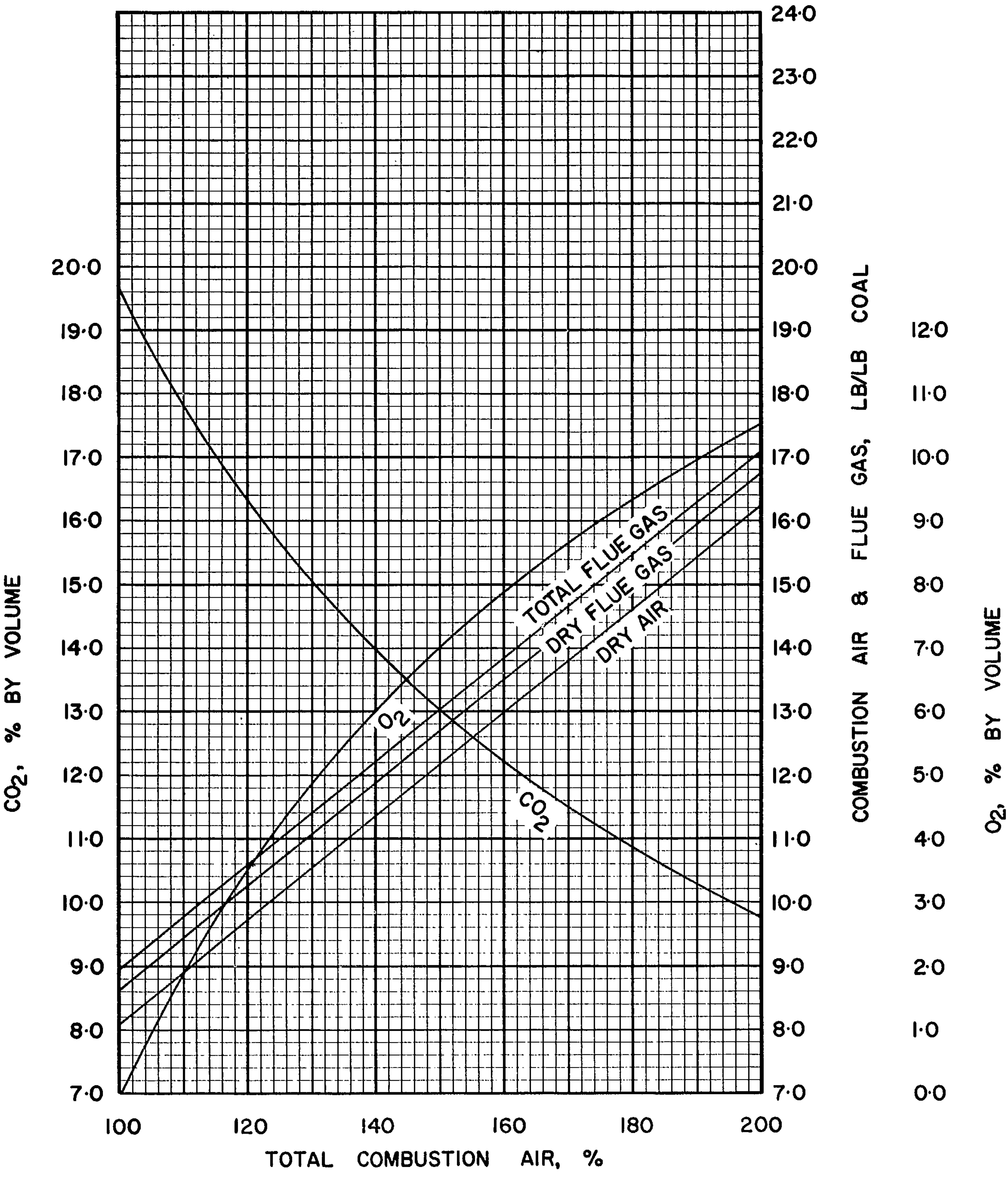


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

S·3·1

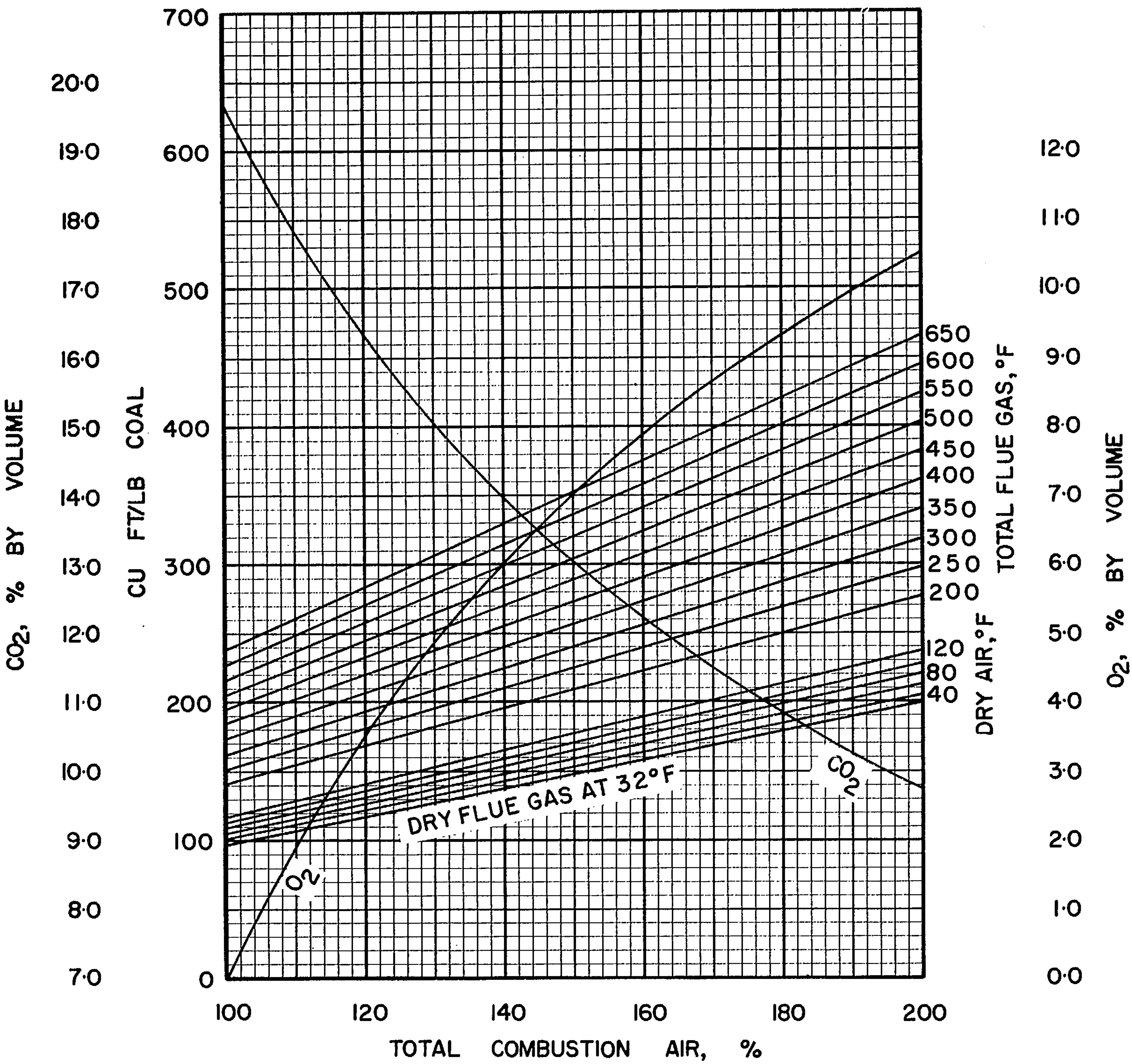


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

S·3·1

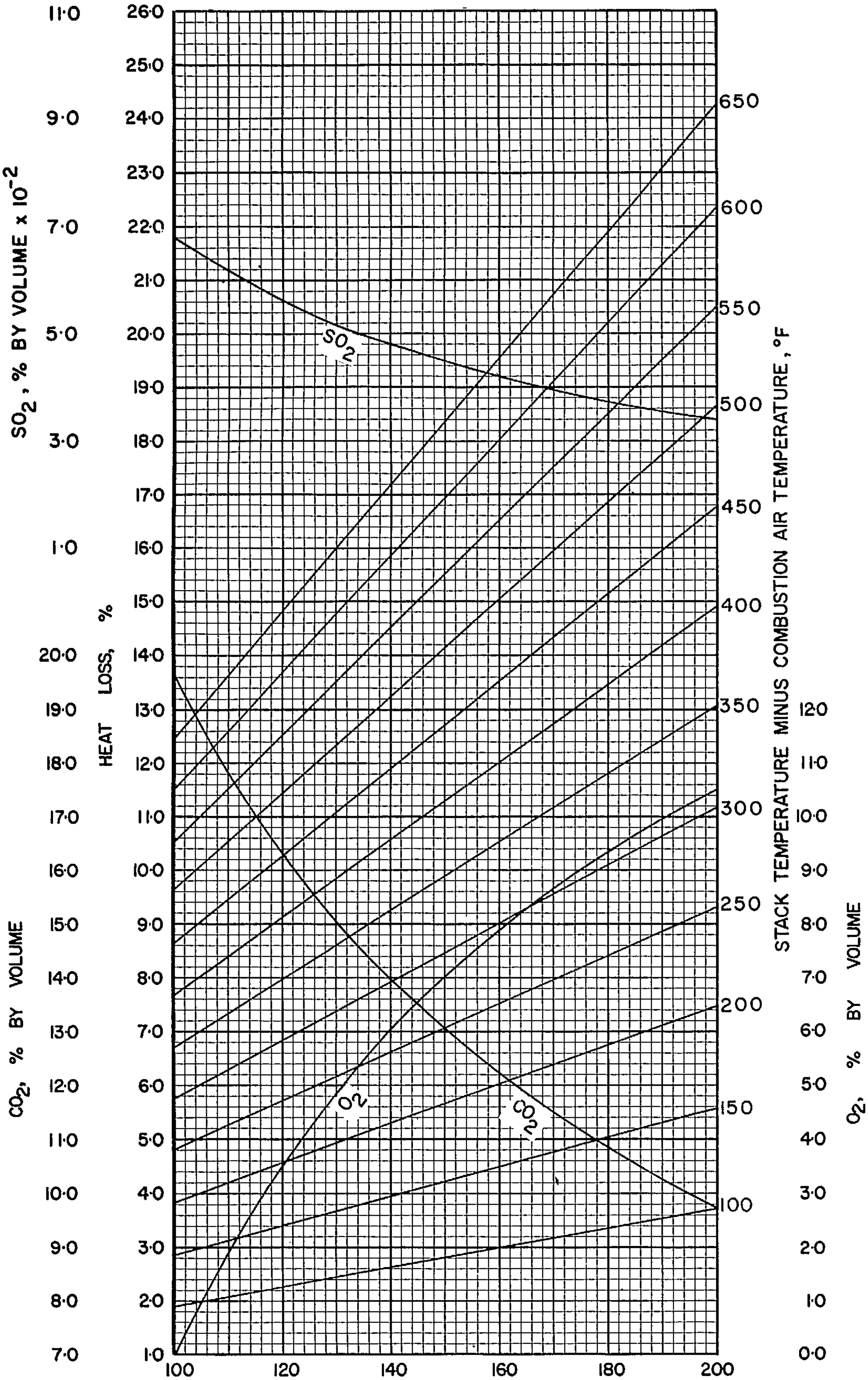


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

S·3·1

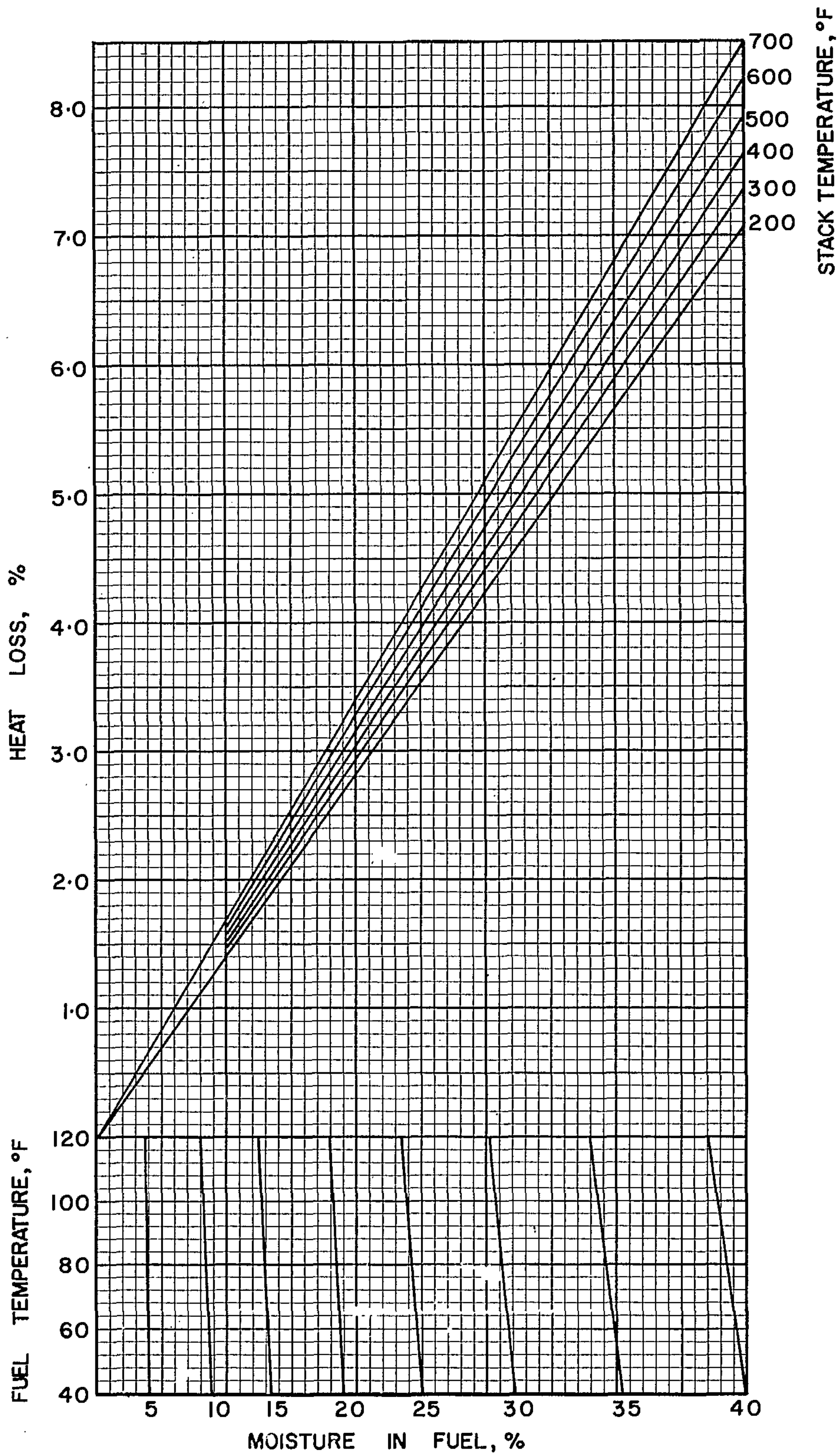


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

S·3·1

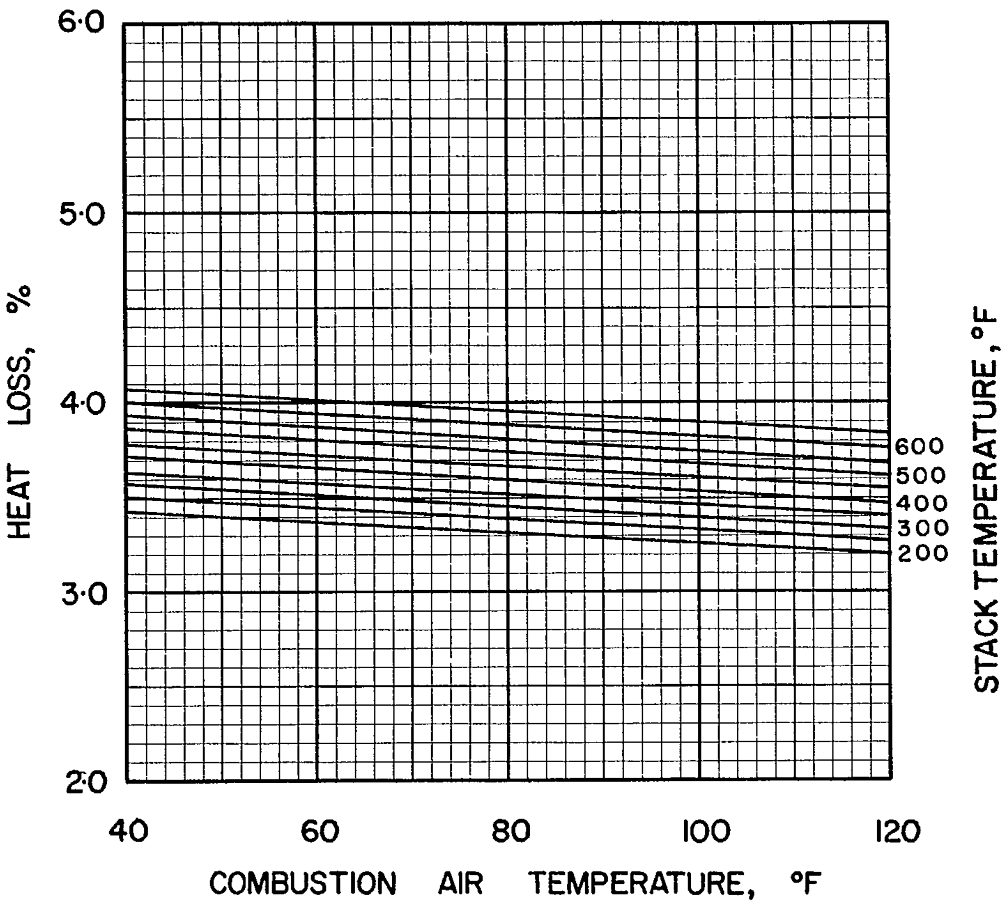


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

S·3·1

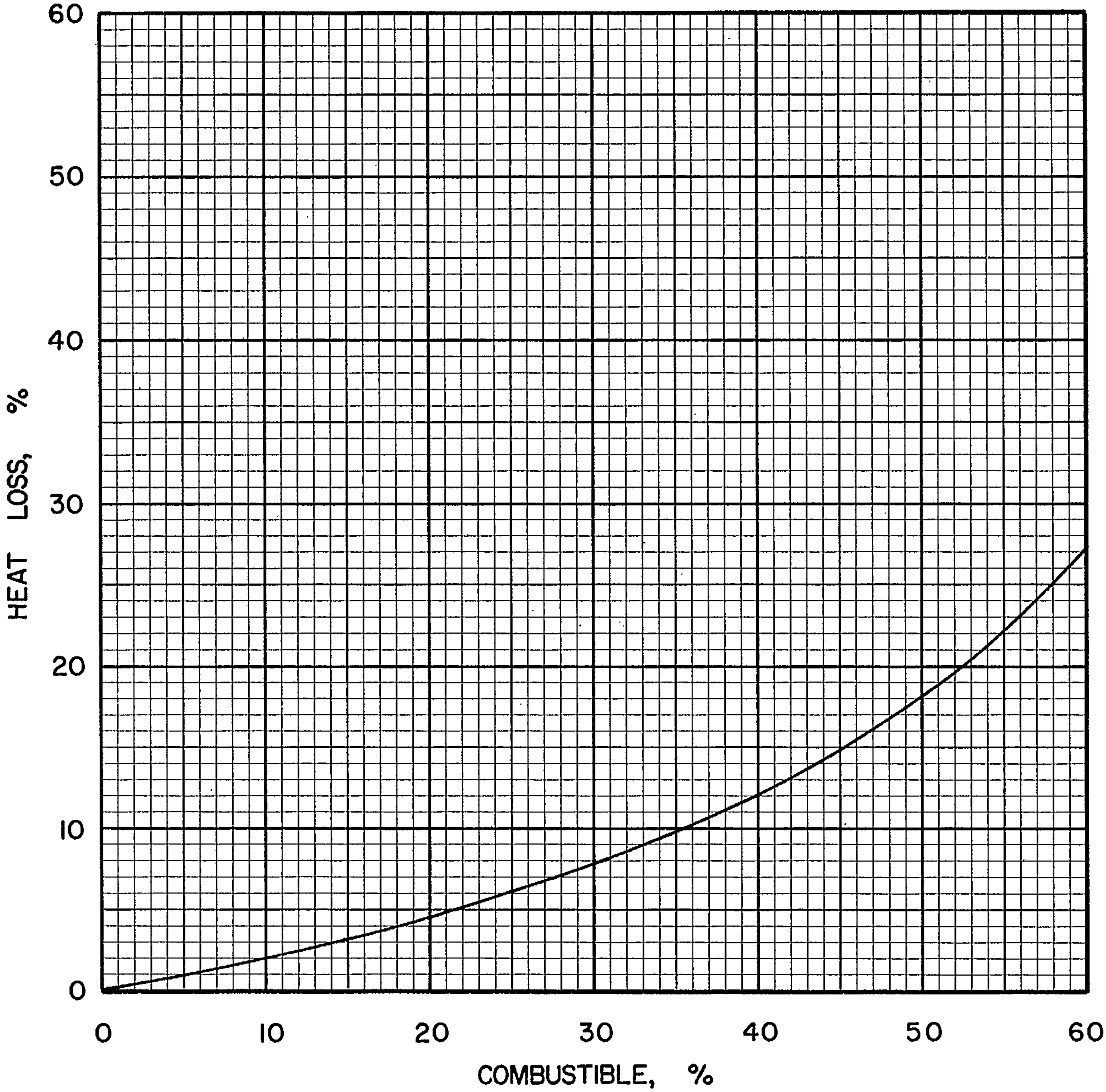


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

S·3·1

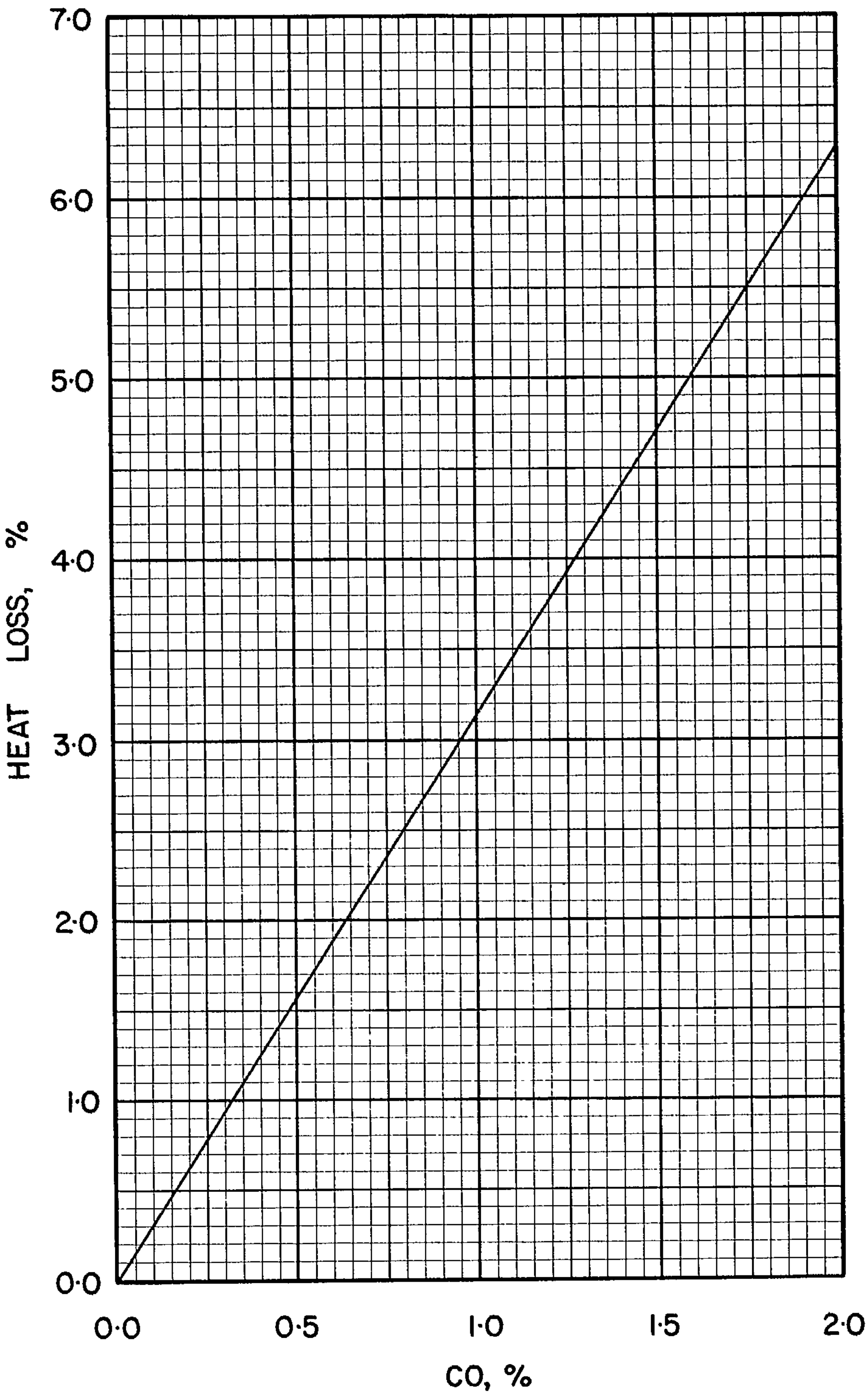


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

S·3·1

COAL ABC 1-1, CANMORE MINES LTD., CASCADE, 1 1/4 in. x 1/2 in.

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0753
Volatile Matter	0.1560
Fixed Carbon	0.7687
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8373
Hydrogen (H)	0.0421
Sulphur (S)	0.0069
Nitrogen (N)	0.0158
Oxygen (O)	0.0226
Ash	0.0753
Total	1.0000

Gross Calorific Value

Btu/lb:	14553
Btu/short ton:	29.11×10^6
Btu/long ton:	32.60×10^6
MJ/kg:	33.84

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 68.71	lb	
10^6 Btu	= 0.03436	short tons	
10^6 Btu	= 0.03068	long tons	

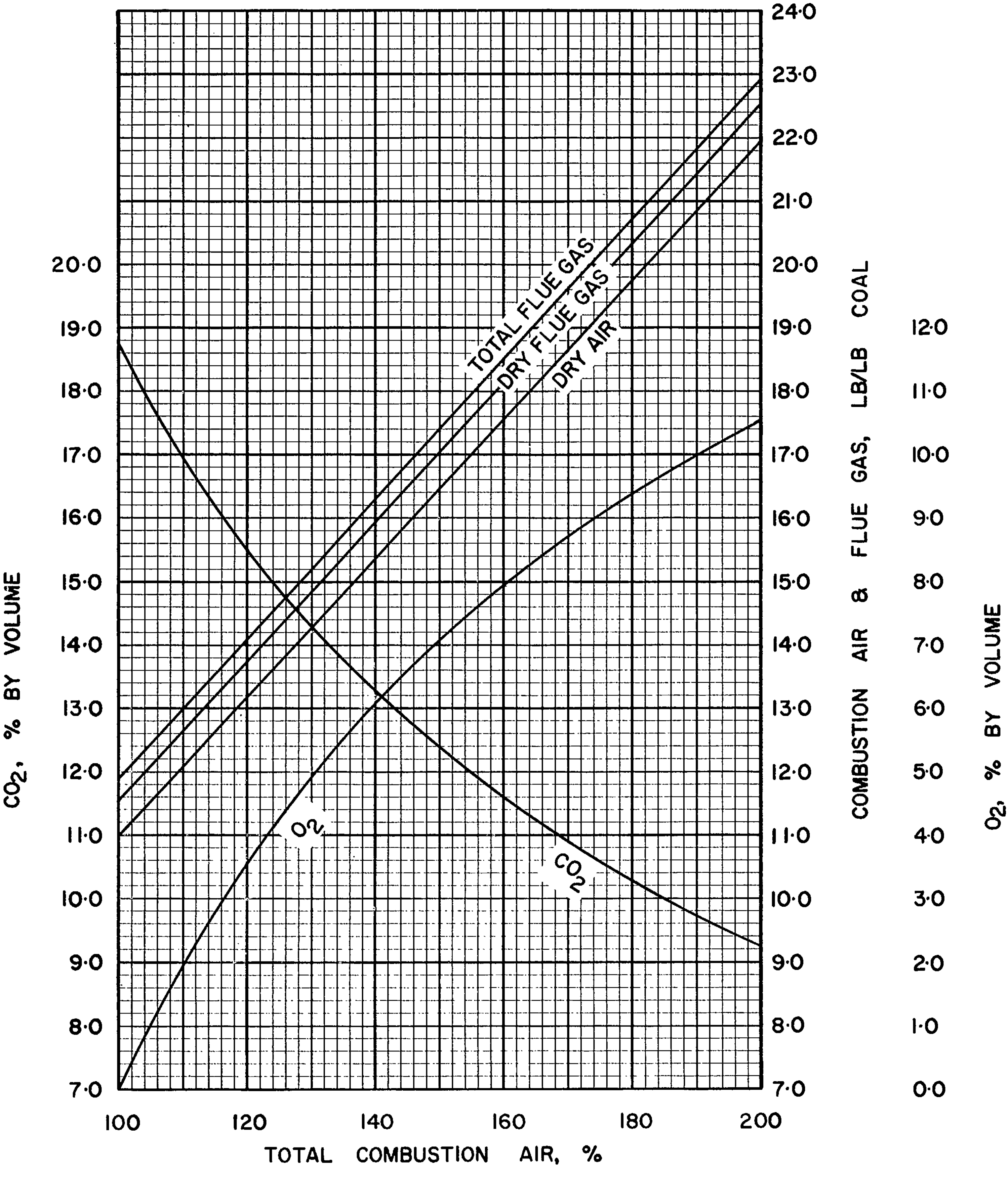


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC · 1·1

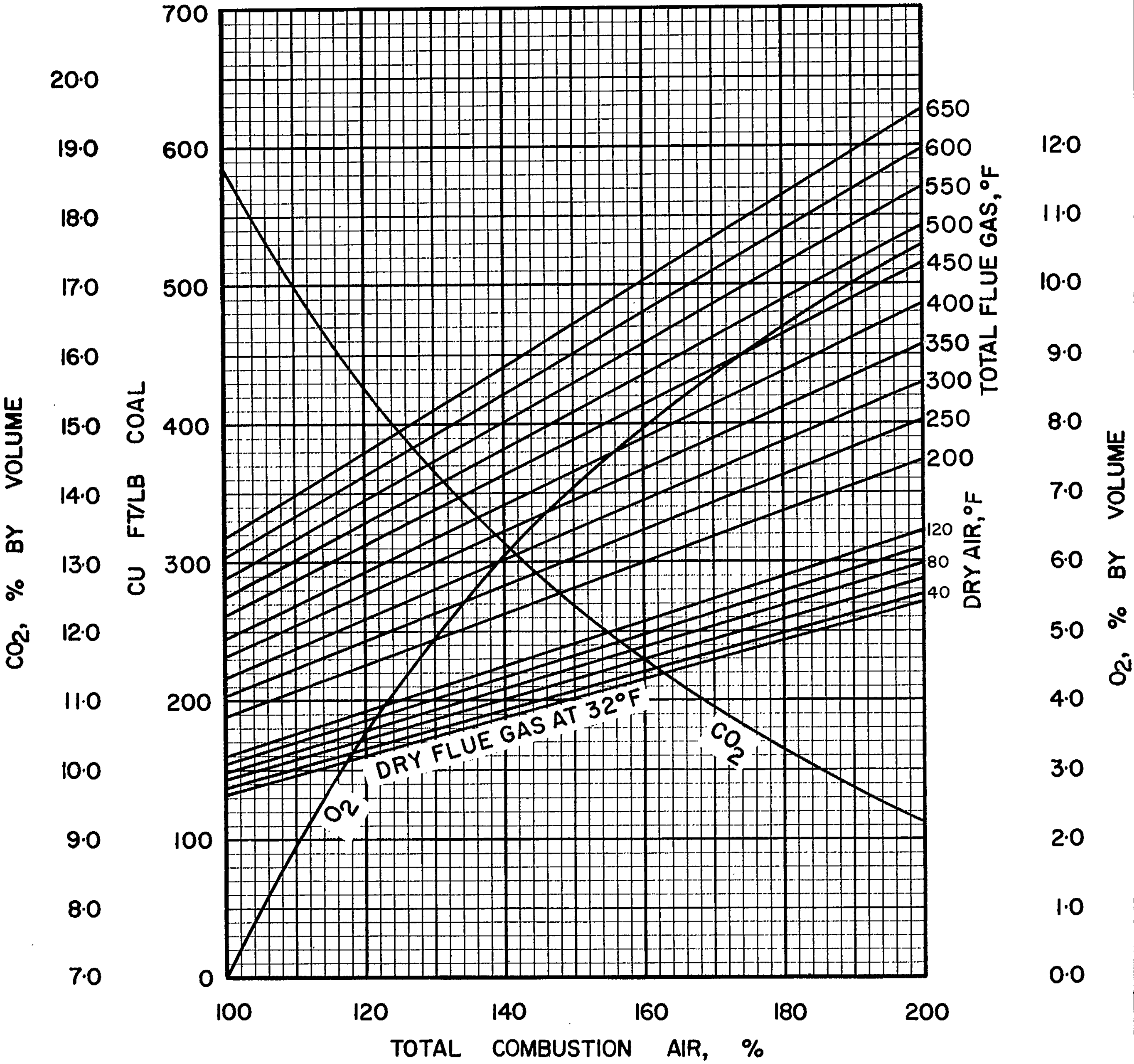


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC· 1·1

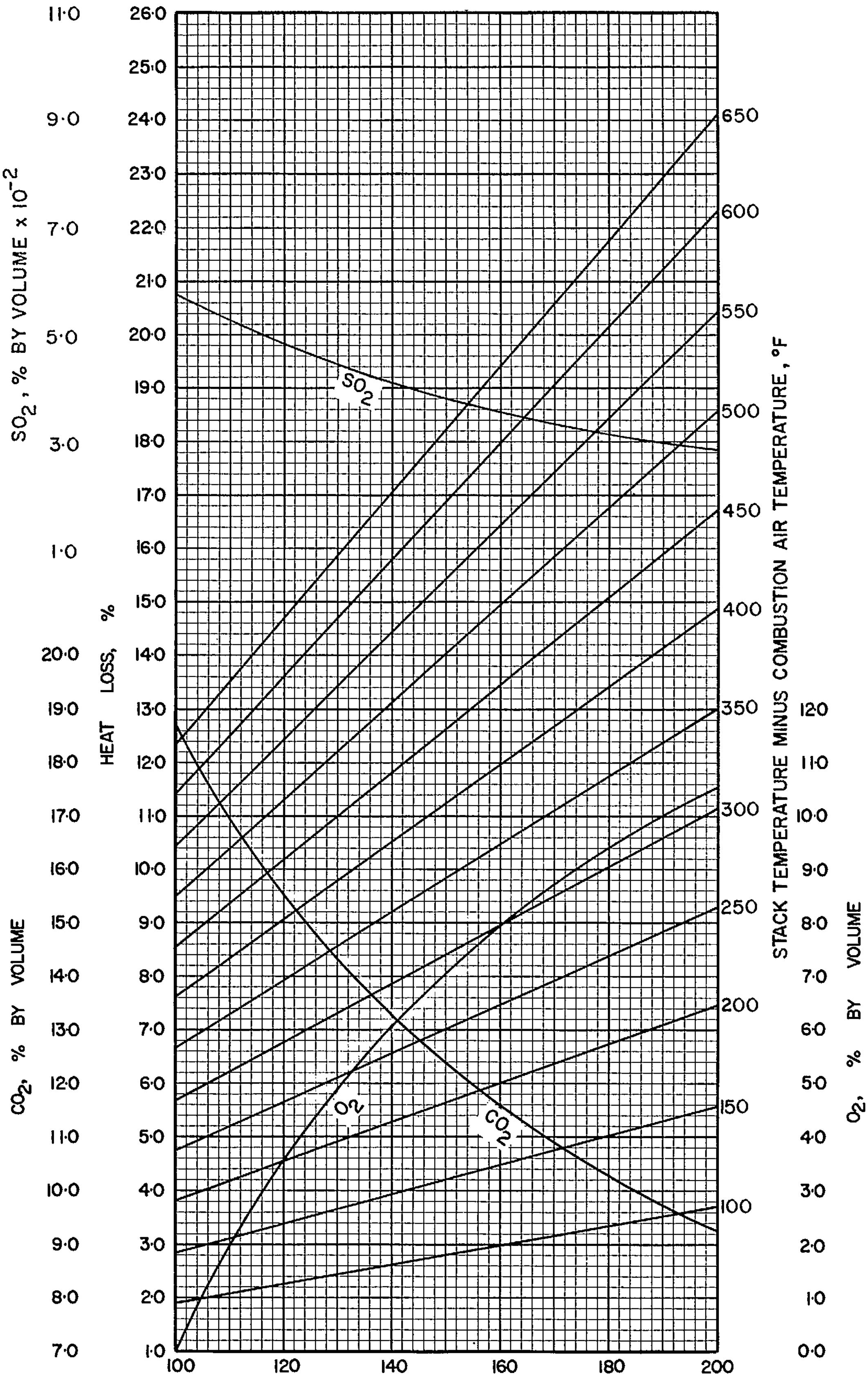


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC· 1·1

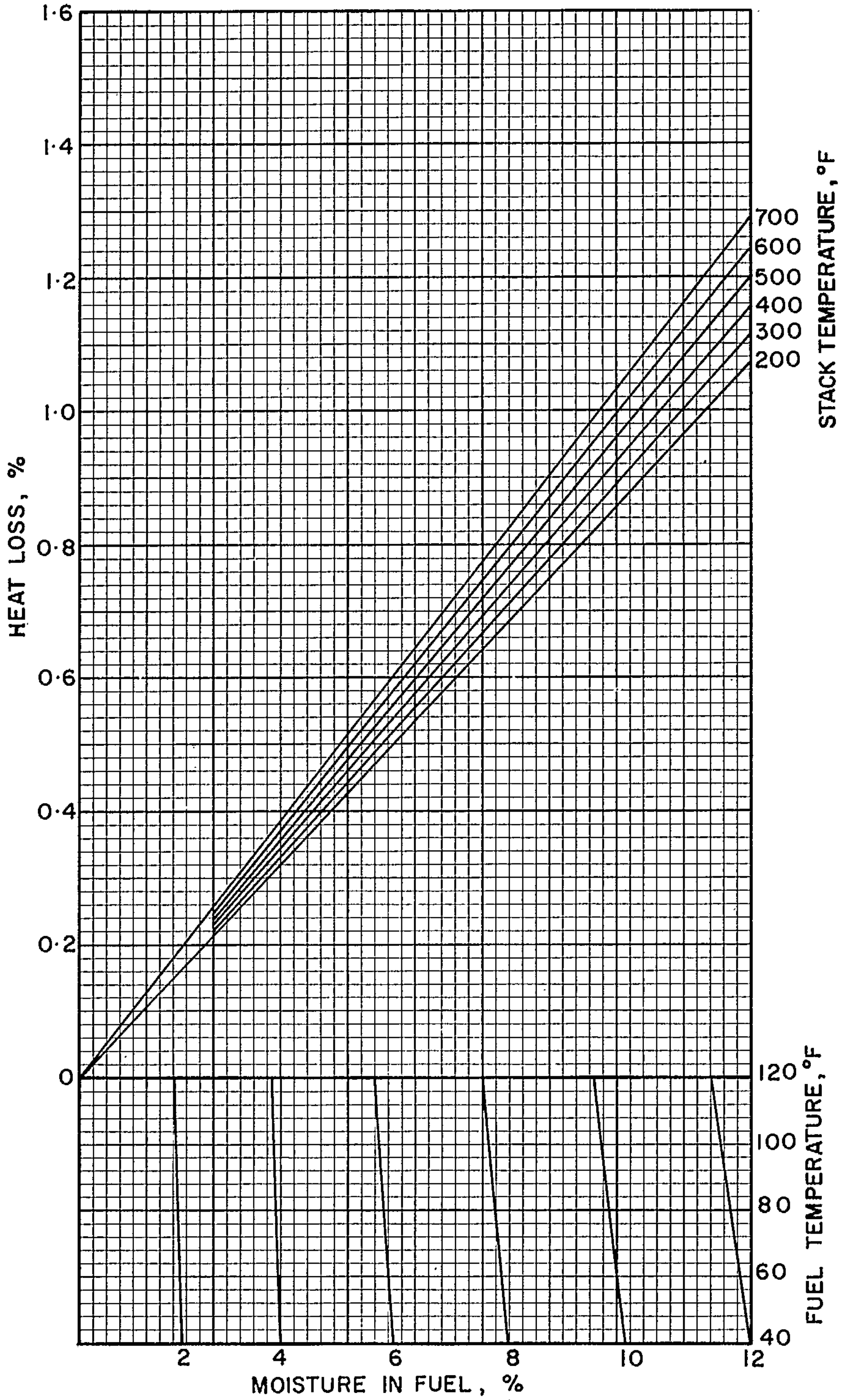


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC· 1·1

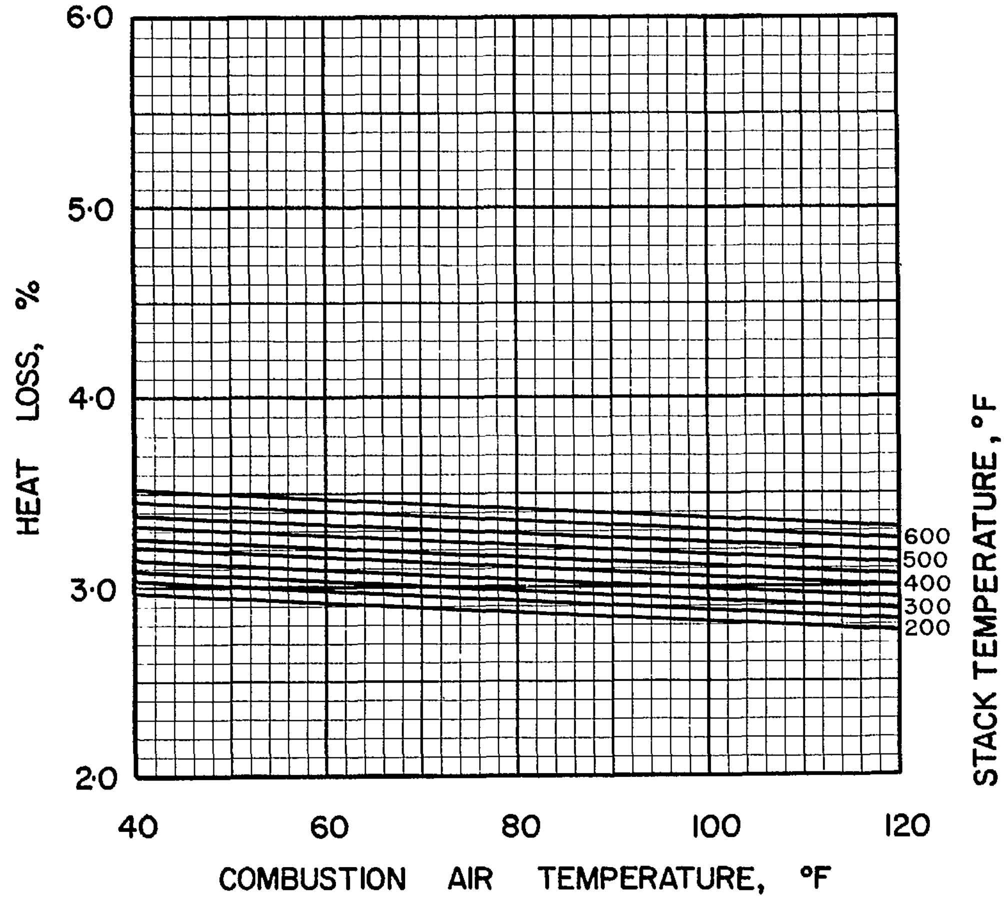


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC· 1·1

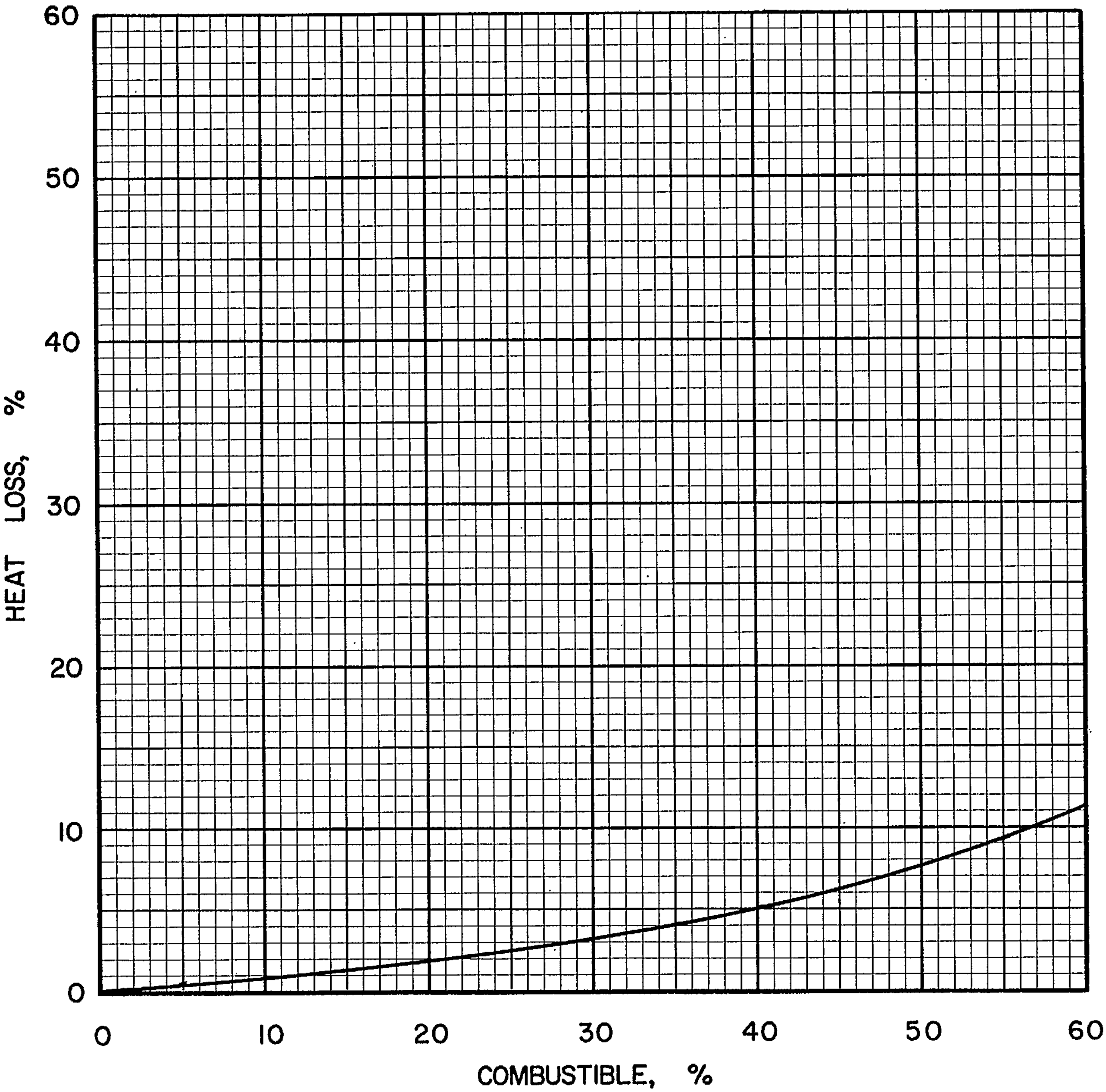


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC· 1·1

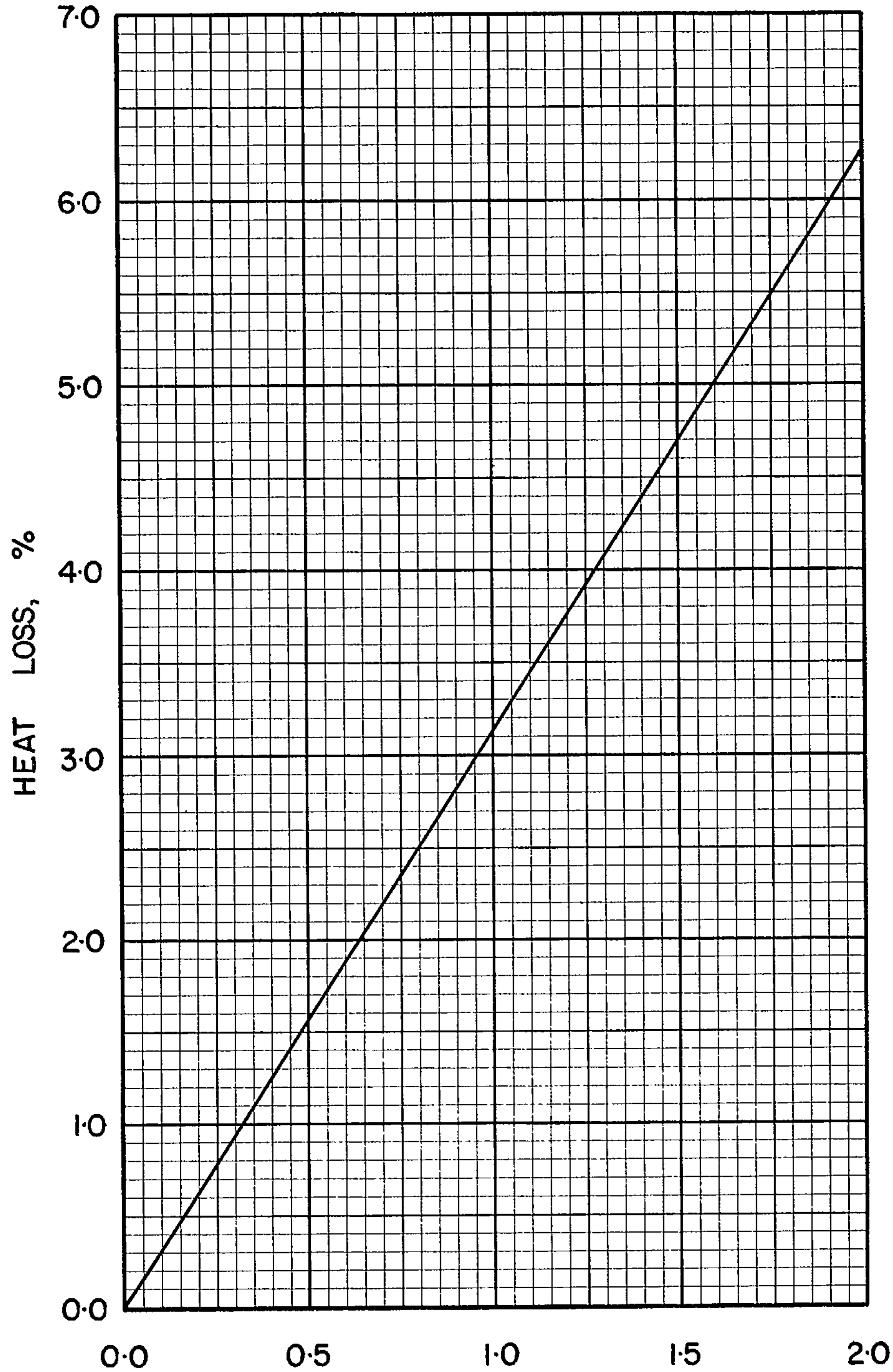


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC· 1·1

COAL ABC 1-2, CANMORE MINES LTD., CASCADE, – 3/16 in.

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0796
Volatile Matter	0.1500
Fixed Carbon	0.7704
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8366
Hydrogen (H)	0.0419
Sulphur (S)	0.0090
Nitrogen (N)	0.0164
Oxygen (O)	0.0165
Ash	0.0796
Total	1.0000

Gross Calorific Value

Btu/lb:	14193
Btu/short ton:	28.39×10^6
Btu/long ton:	31.79×10^6
MJ/kg:	33.01

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 70.46 lb
10^6 Btu = 0.03523 short tons
10^6 Btu = 0.03145 long tons

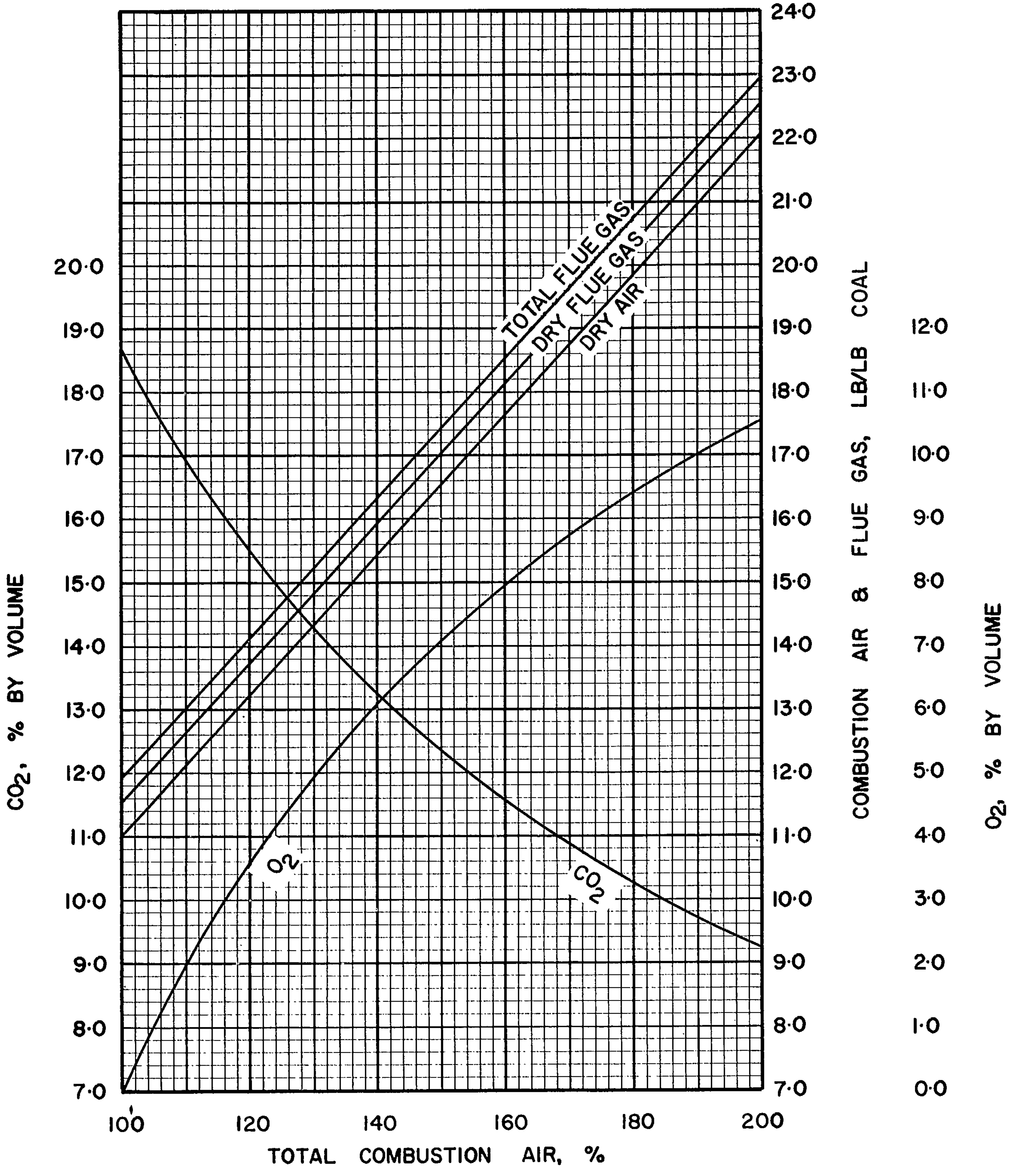


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC·1·2

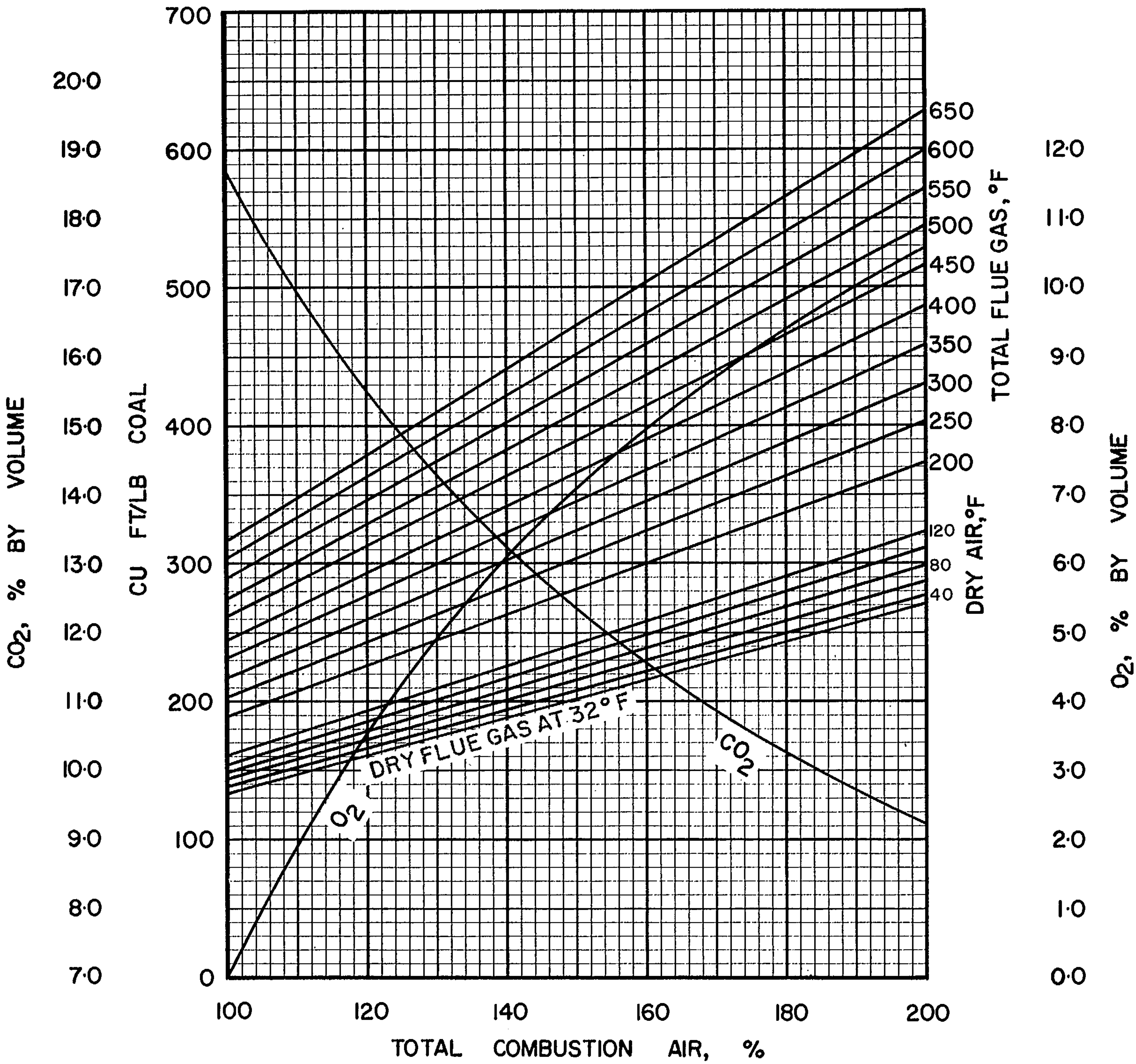


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 1 · 2

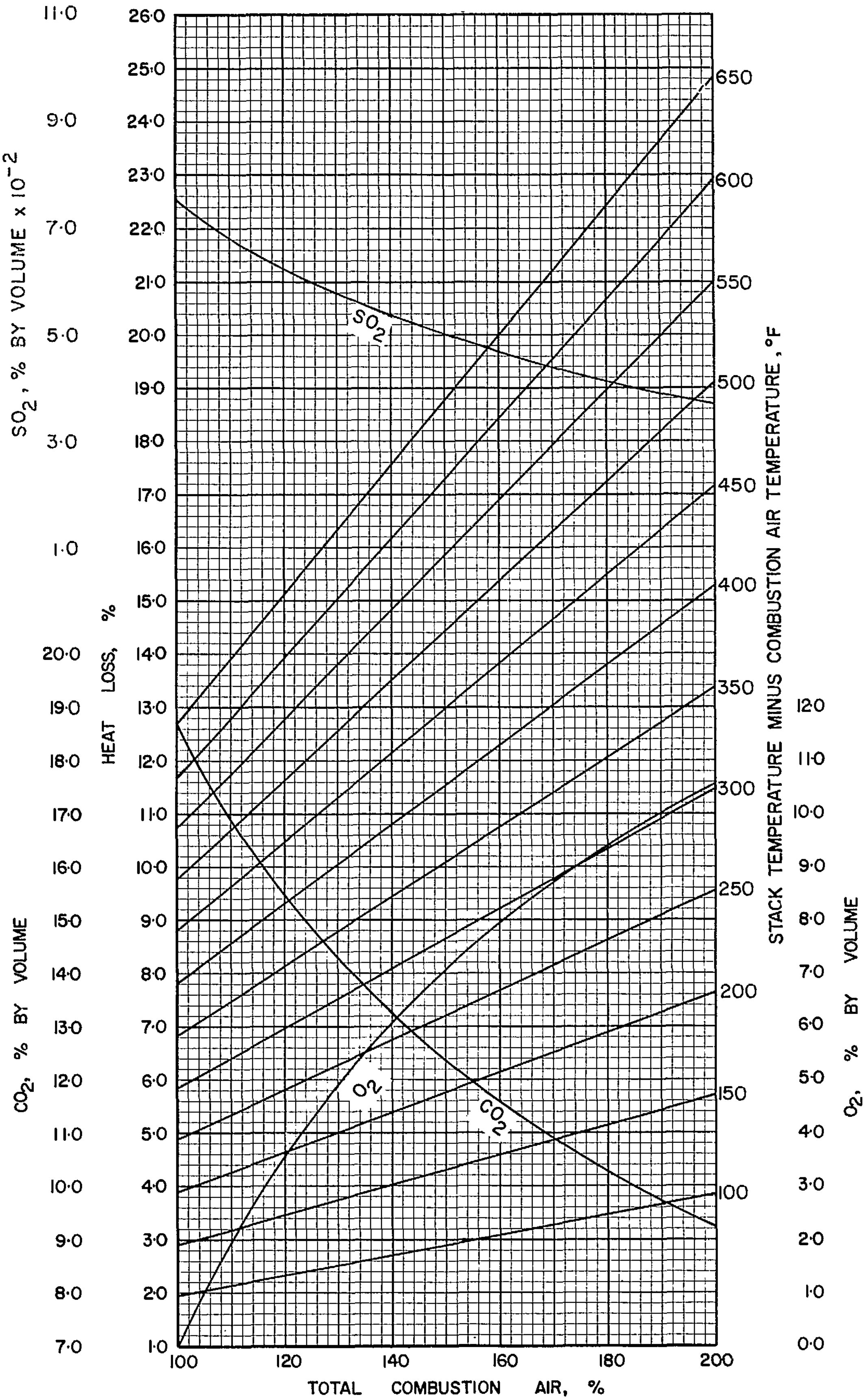


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·1·2

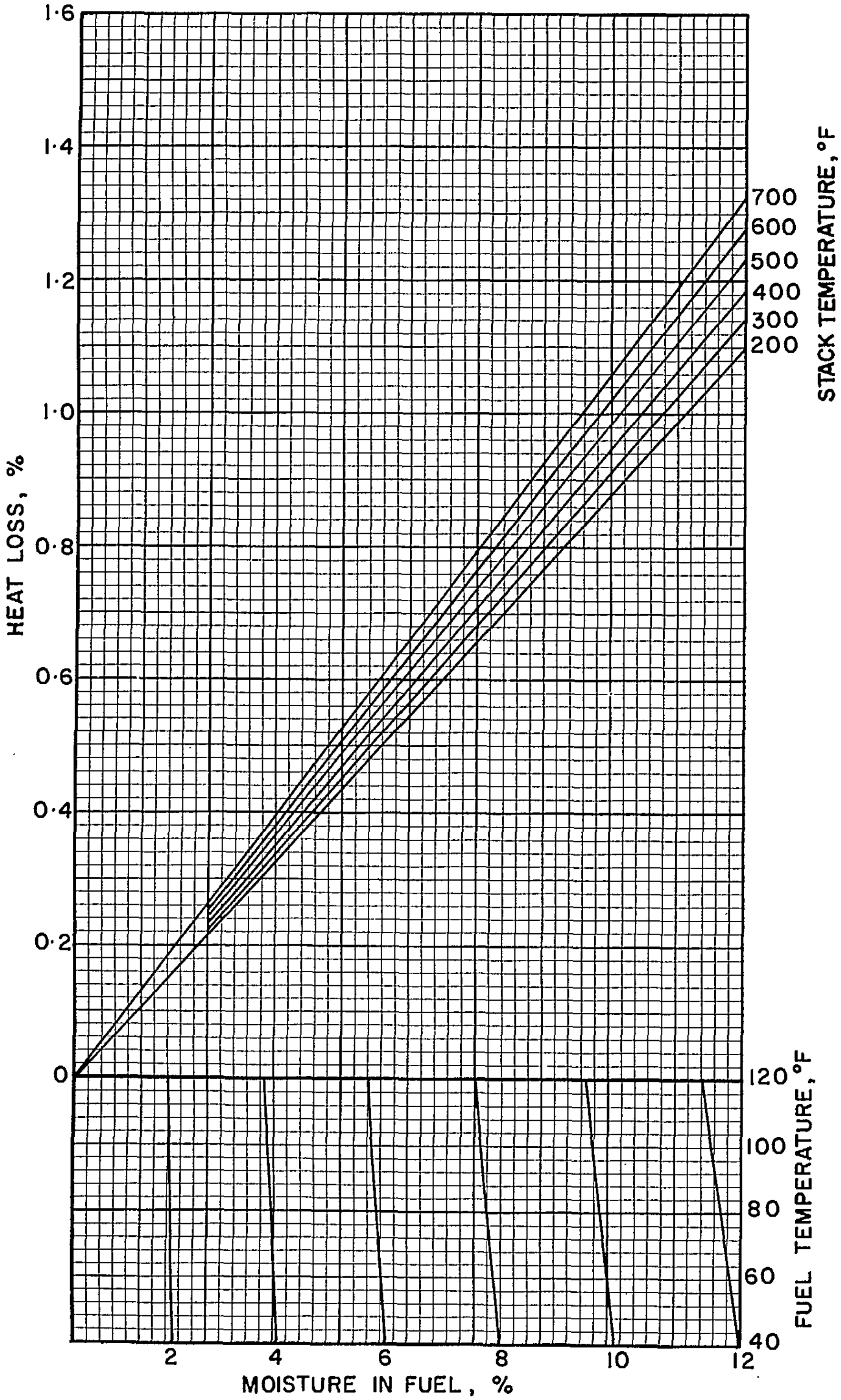


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC·1·2

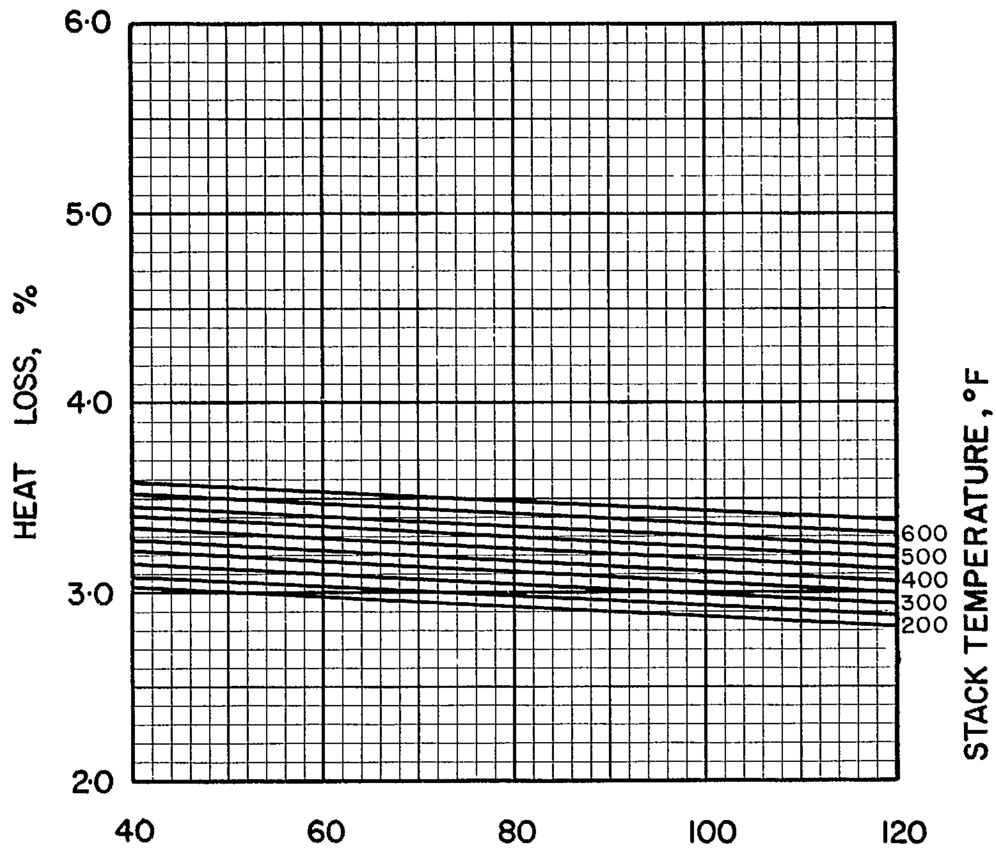


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·1·2

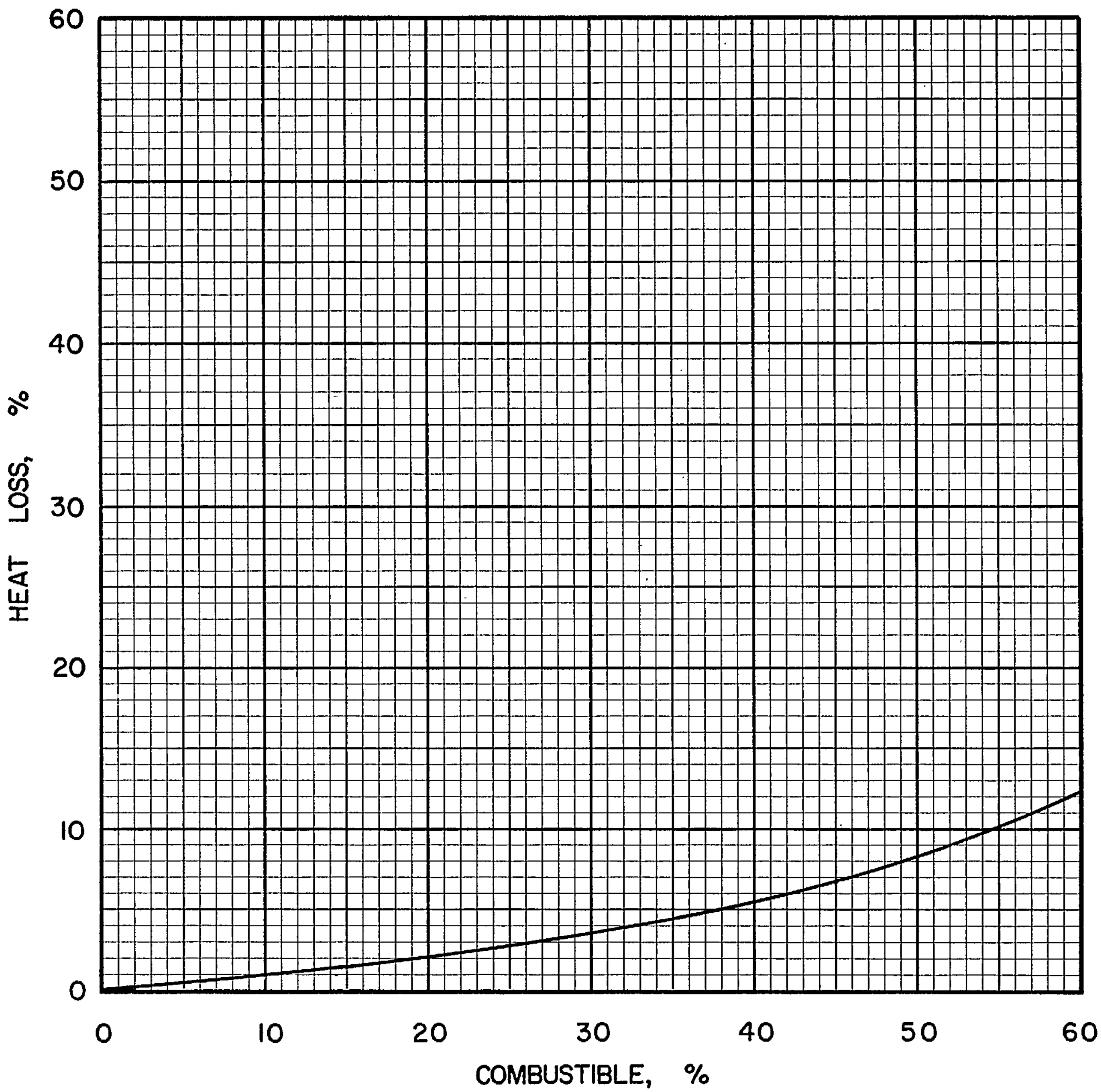


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·1·2

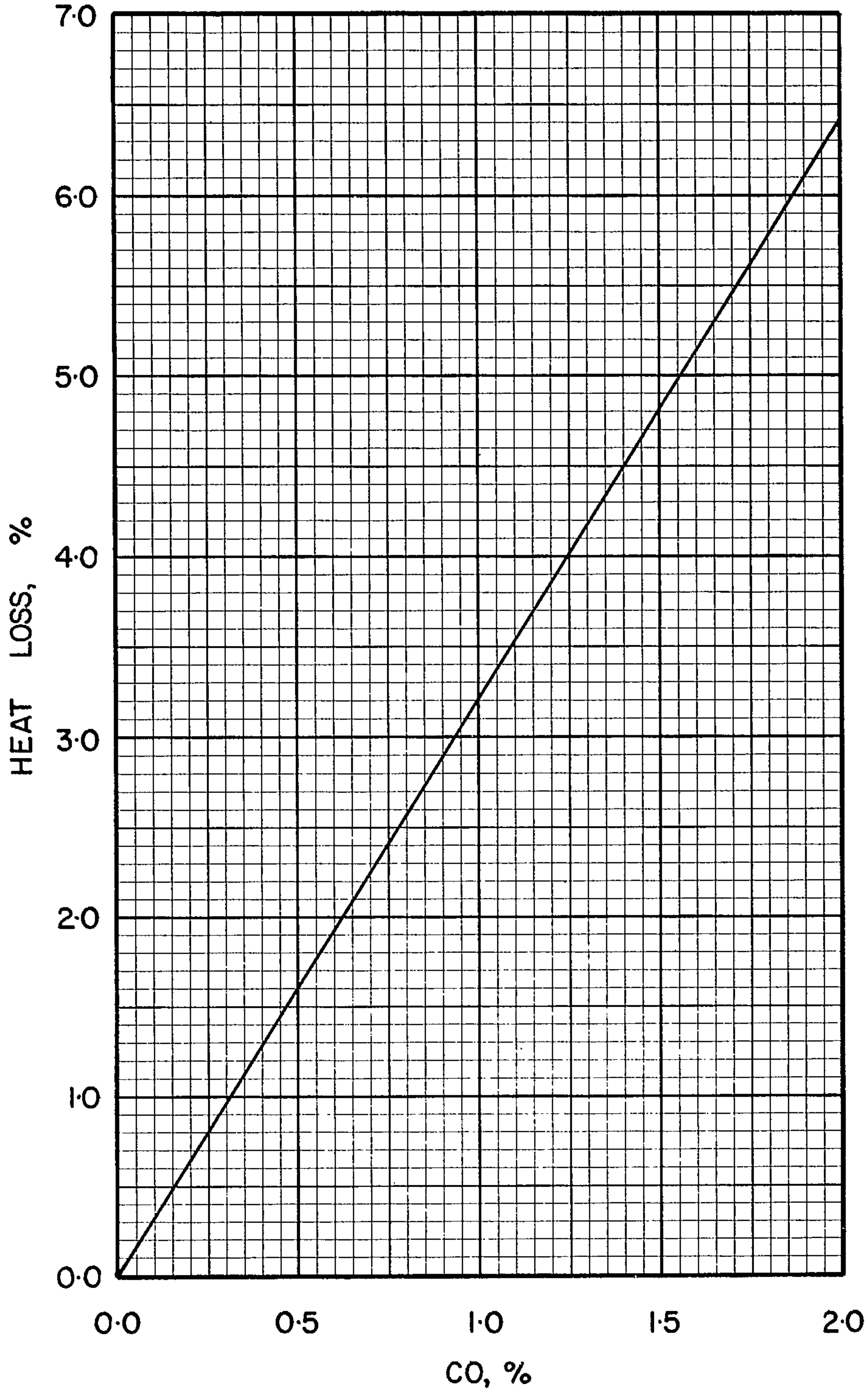


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 1 · 2

COAL ABC 2-1, CARDINAL RIVER COAL CO., MOUNTAIN PARK, No. 1768, MINE RUN

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0945
Volatile Matter	0.2190
Fixed Carbon	0.6865
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8152
Hydrogen (H)	0.0437
Sulphur (S)	0.0015
Nitrogen (N)	0.0109
Oxygen (O)	0.0342
Ash	0.0945
Total	1.0000

Gross Calorific Value

Btu/lb:	14038
Btu/short ton:	28.08×10^6
Btu/long ton:	31.45×10^6
MJ/kg:	32.64

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	71.24	lb	
10^6 Btu	=	0.03562	short tons	
10^6 Btu	=	0.03180	long tons	

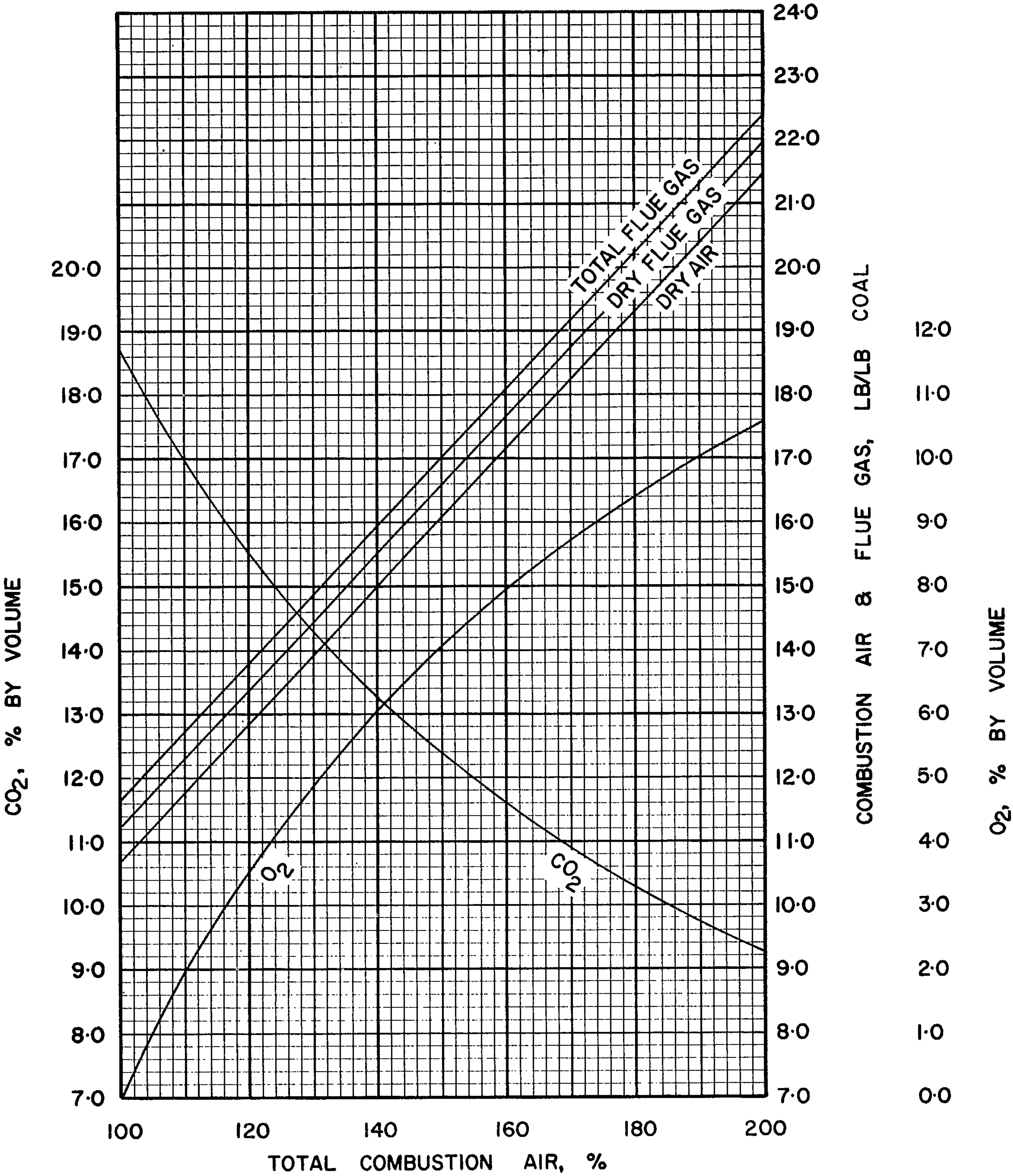


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC·2·1

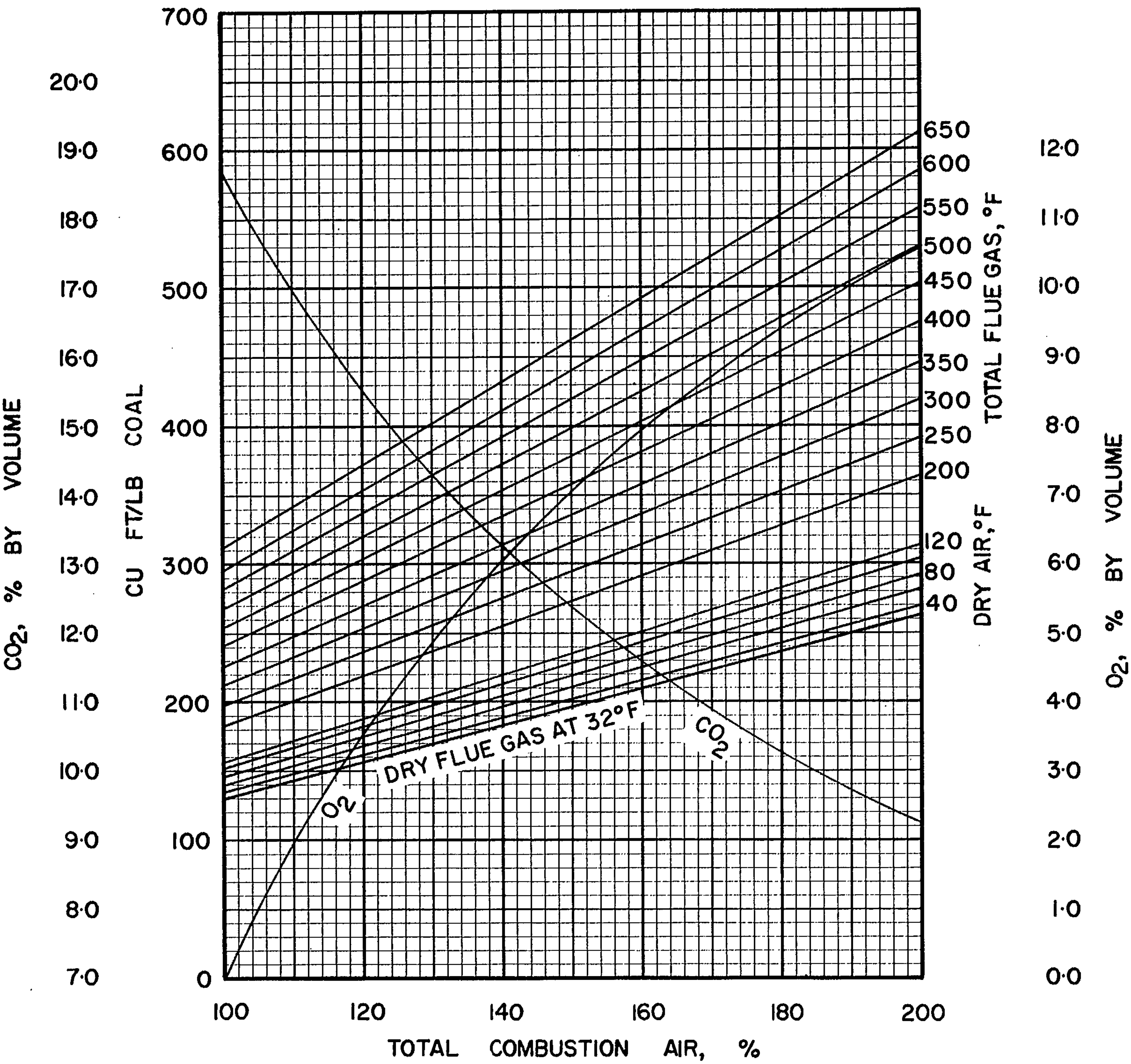


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·2·1

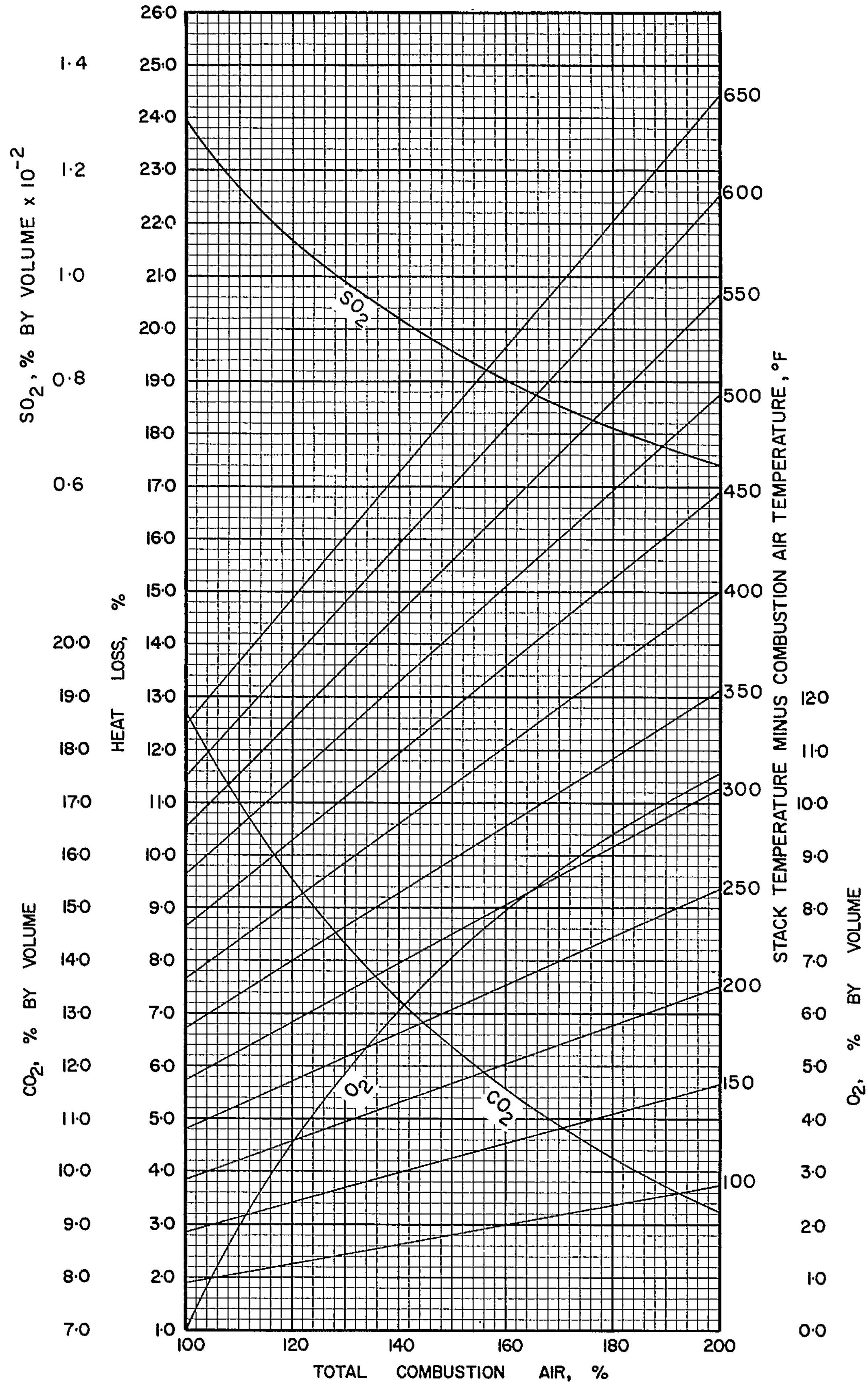


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·2·1

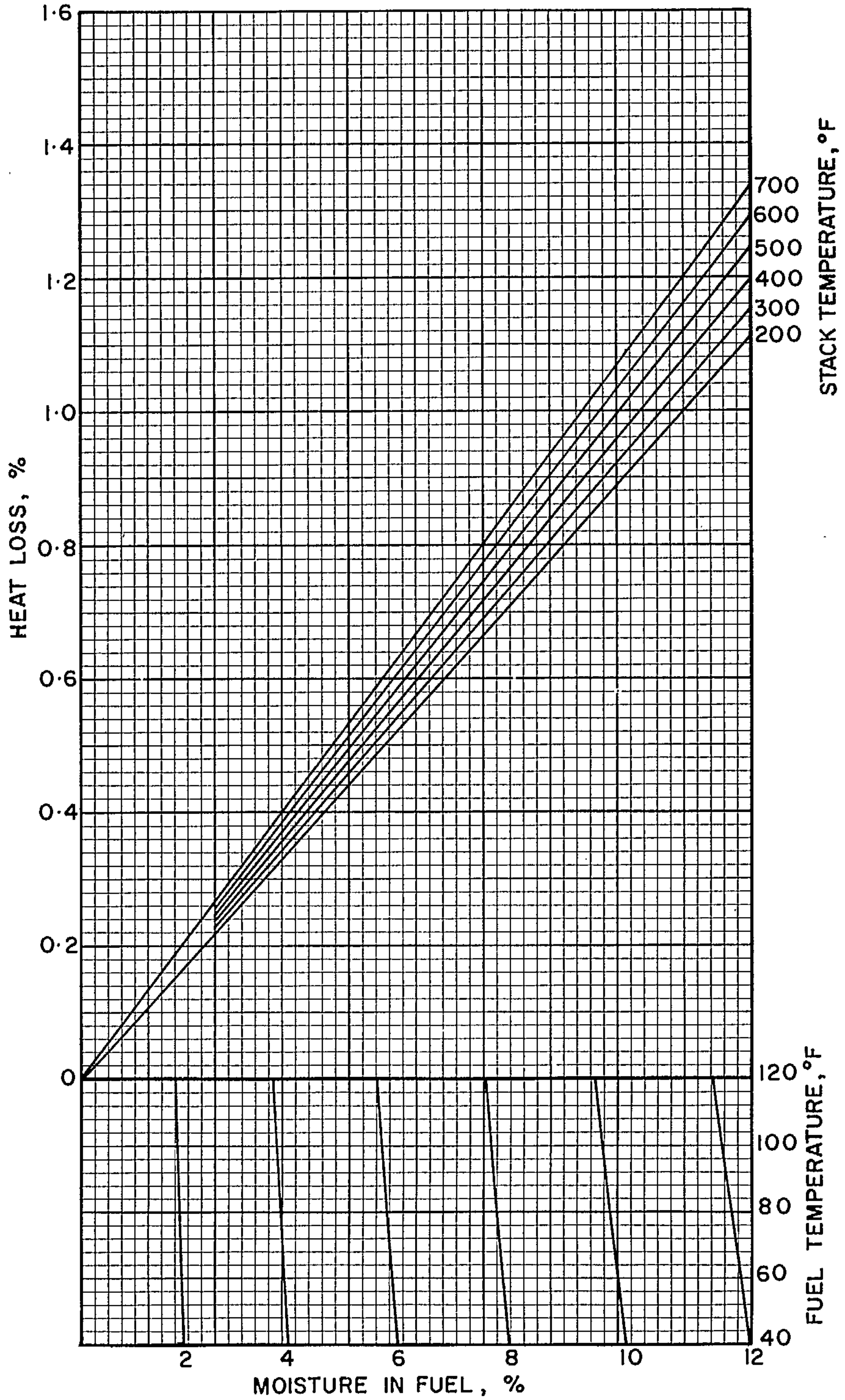


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·2·1

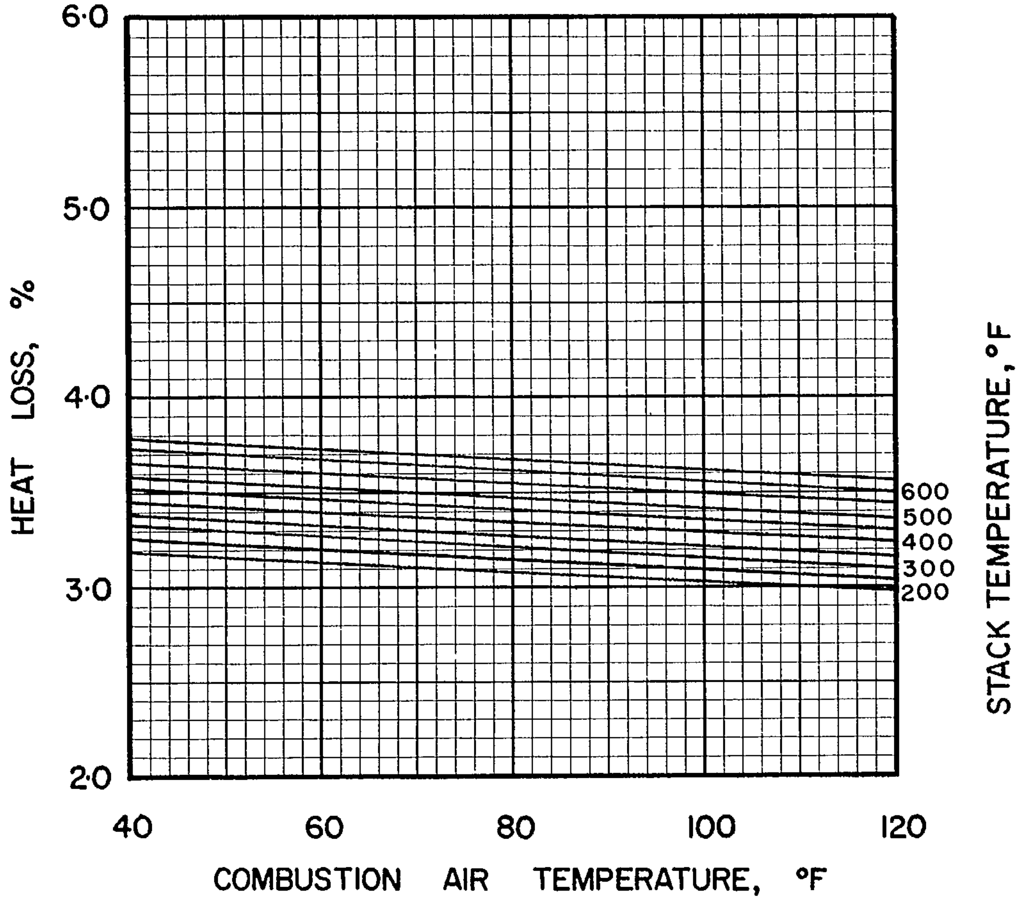


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 2 · I

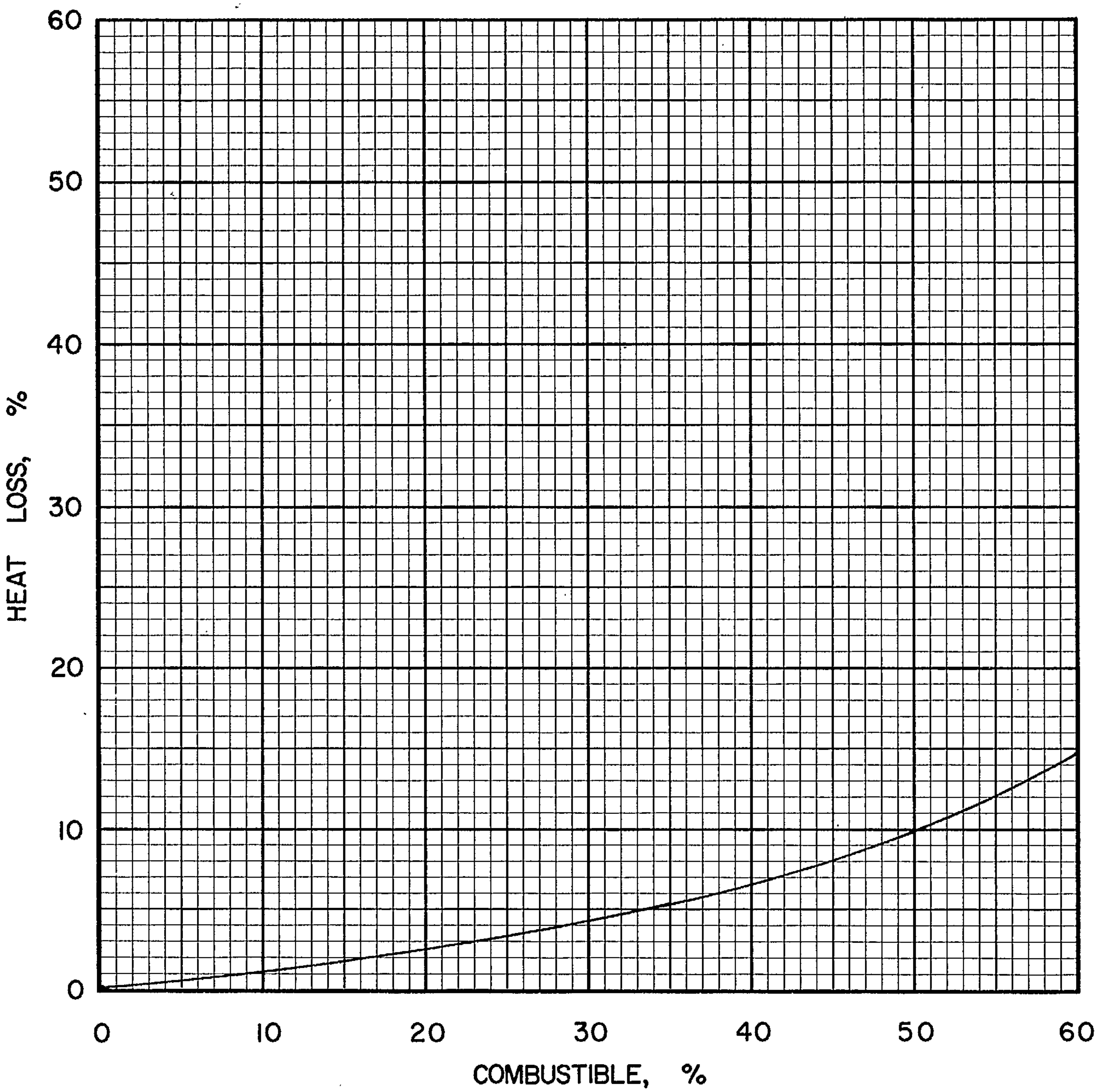


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·2·1

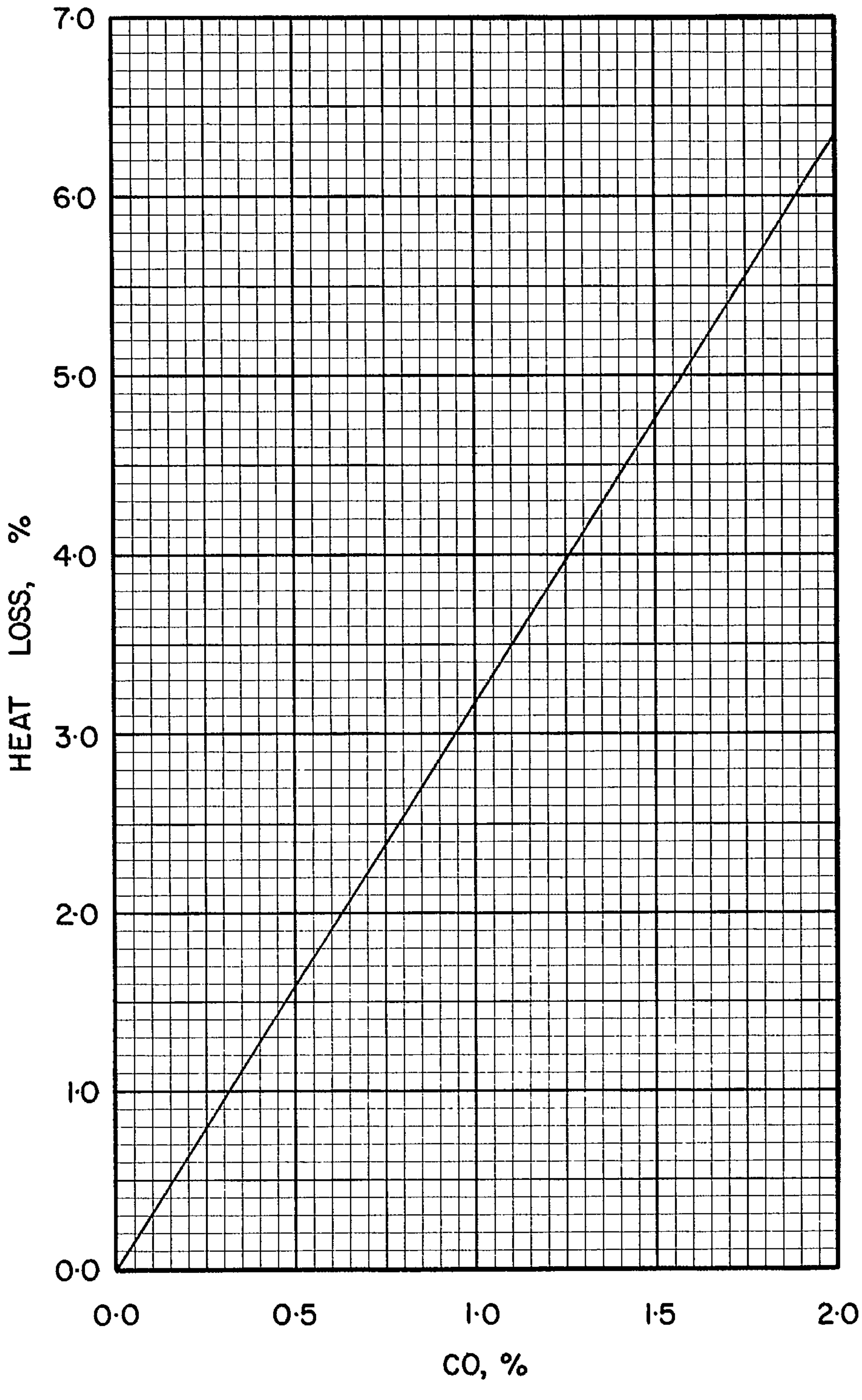


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·2·1

COAL ABC 3-1, COLEMAN EXPORT, CROWSNEST, 1 1/4 in. x 1/4 in.

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0849
Volatile Matter	0.2330
Fixed Carbon	0.6821
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8109
Hydrogen (H)	0.0447
Sulphur (S)	0.0075
Nitrogen (N)	0.0111
Oxygen (O)	0.0409
Ash	0.0849
Total	1.0000

Gross Calorific Value

Btu/lb:	14160
Btu/short ton:	28.32×10^6
Btu/long ton:	31.72×10^6
MJ/kg:	32.93

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	70.62	lb	
10^6 Btu	=	0.03531	short tons	
10^6 Btu	=	0.03153	long tons	

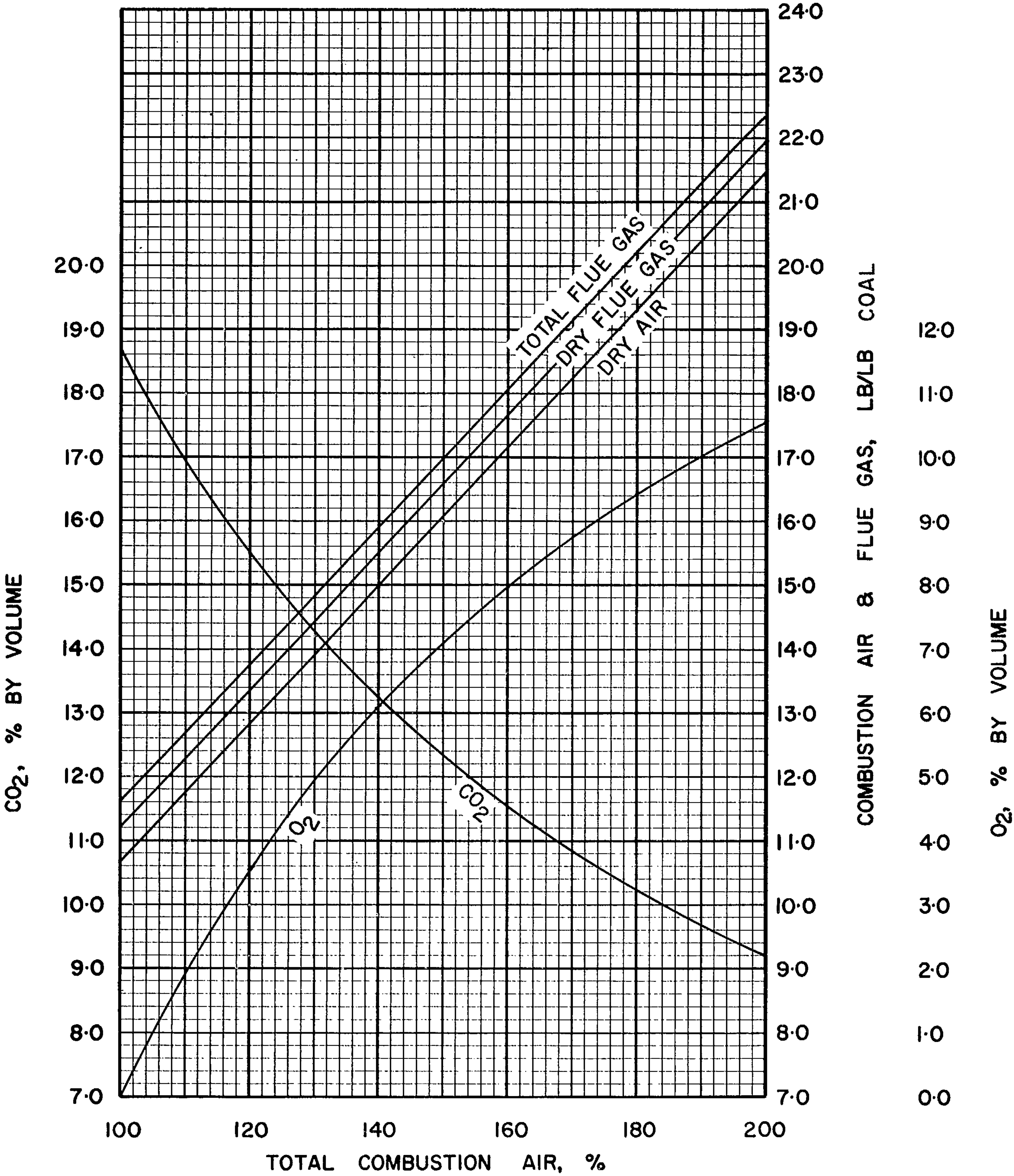


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC·3·1

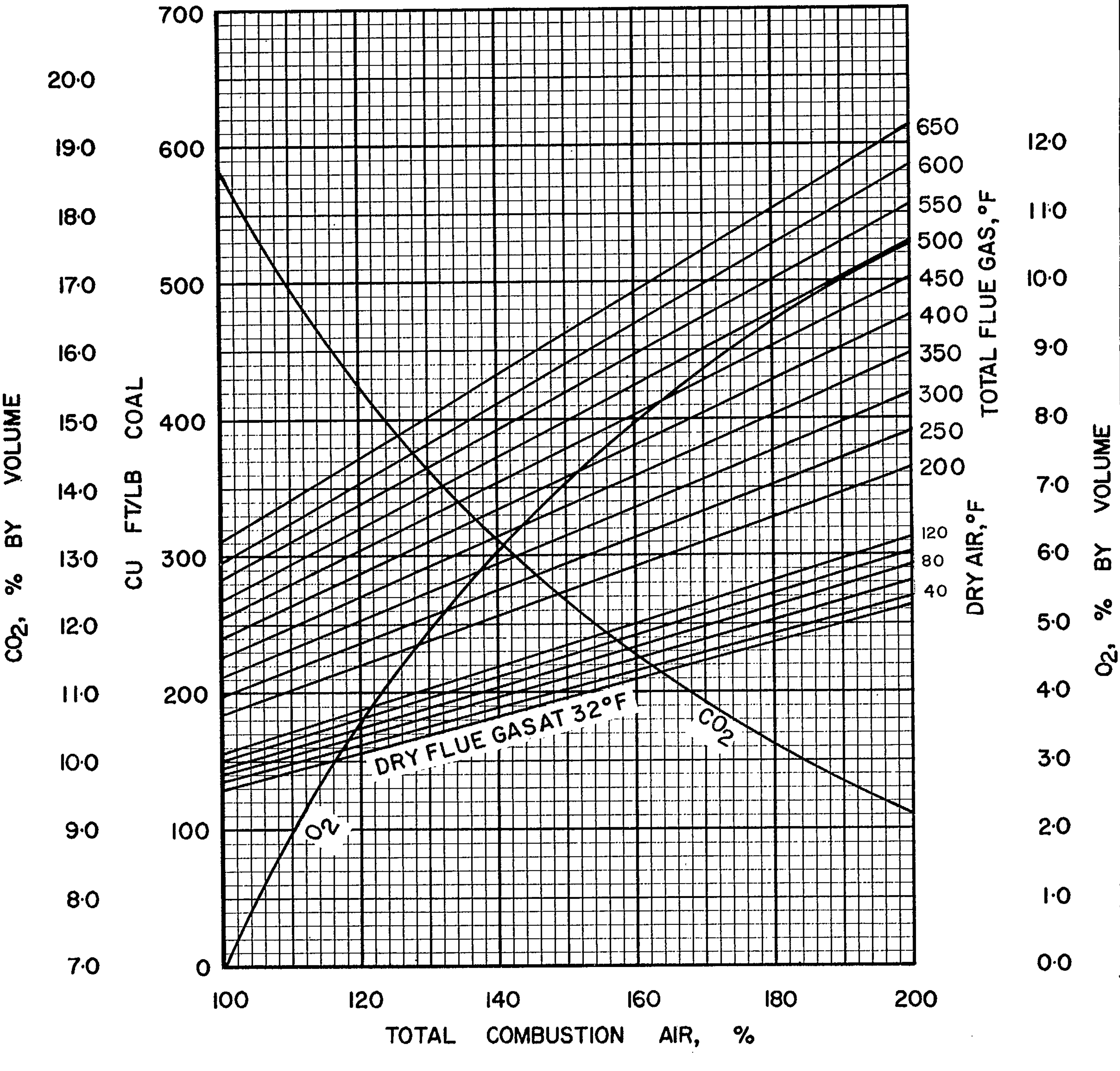


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·3·1

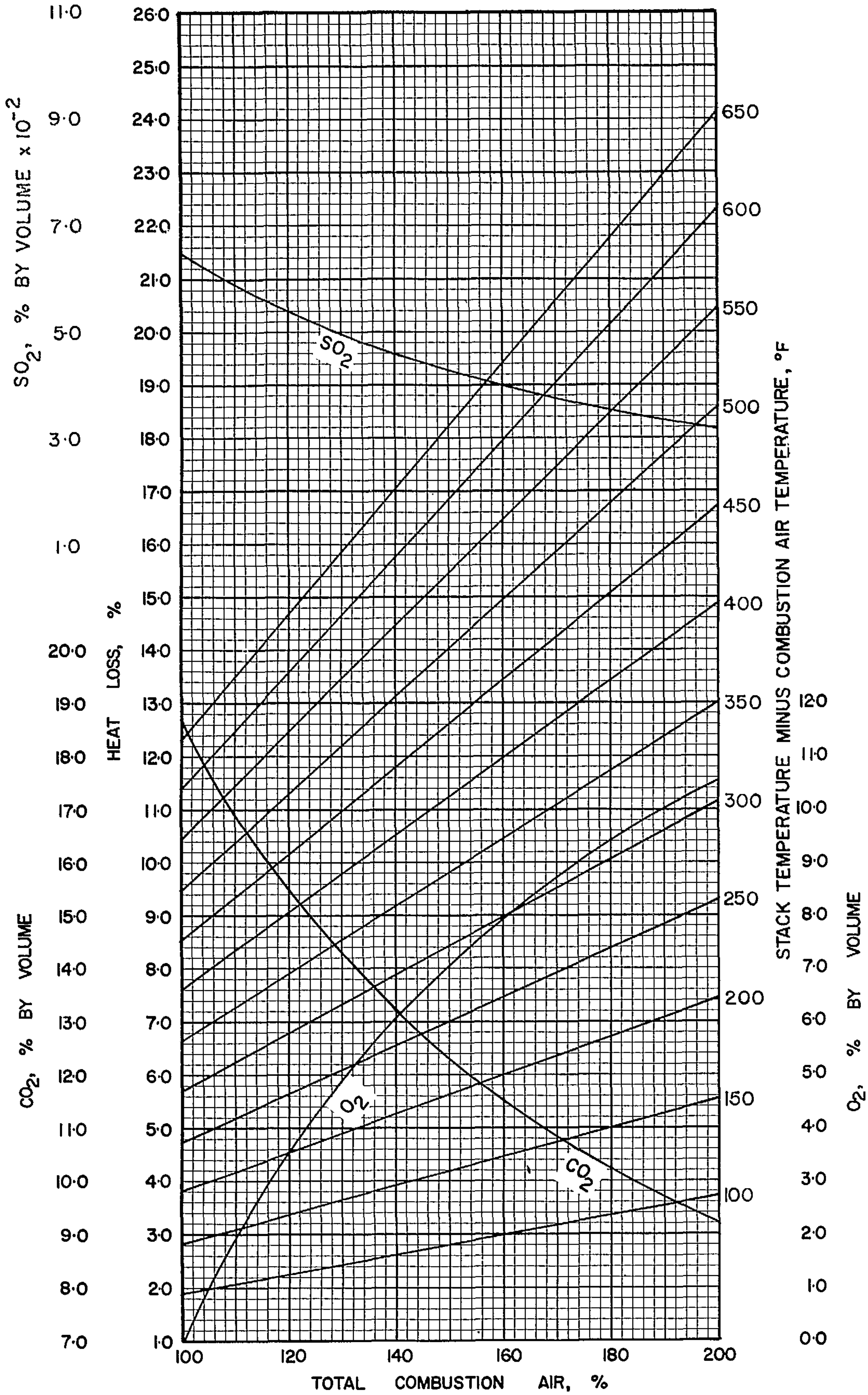


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·3·1

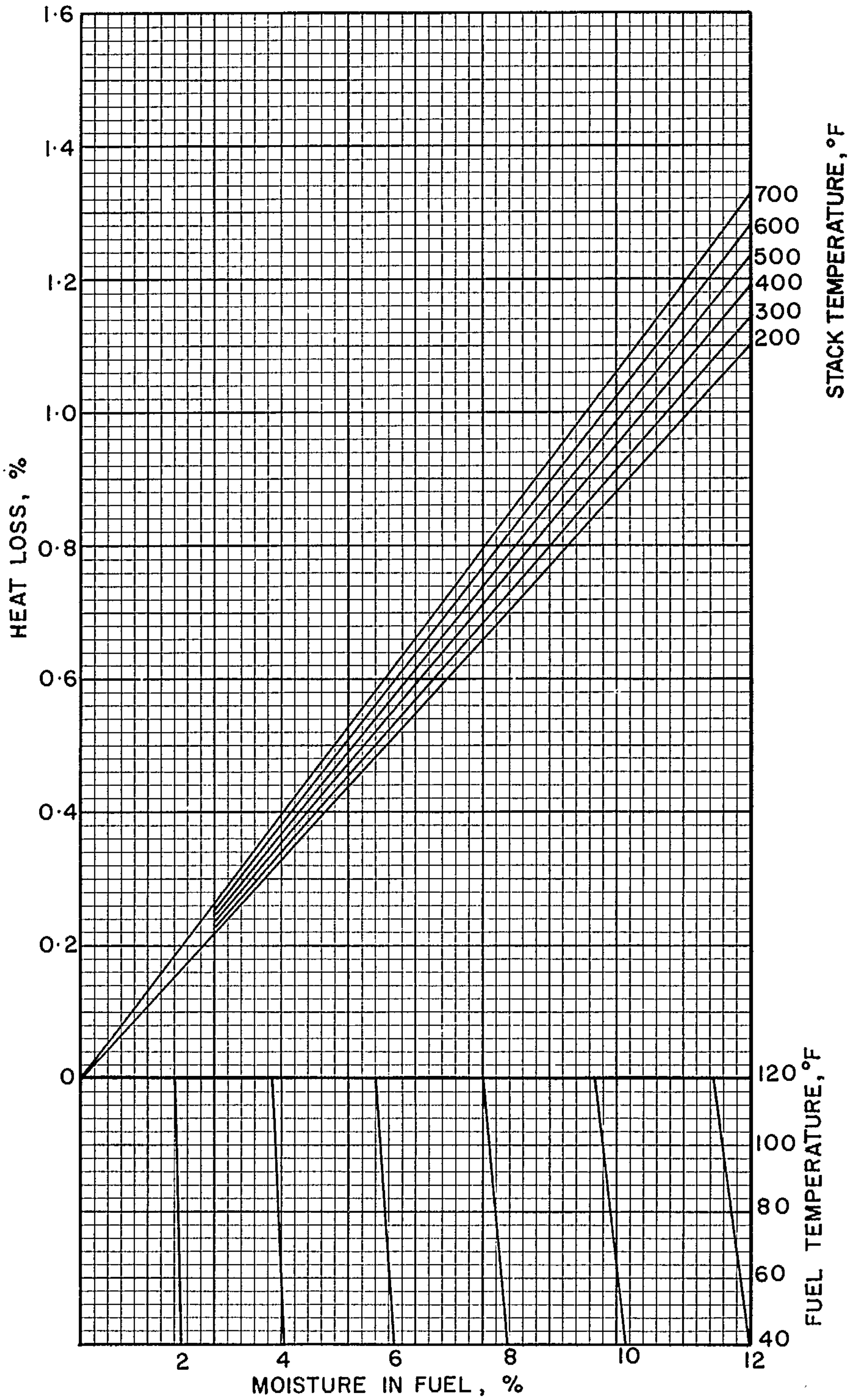


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·3·1

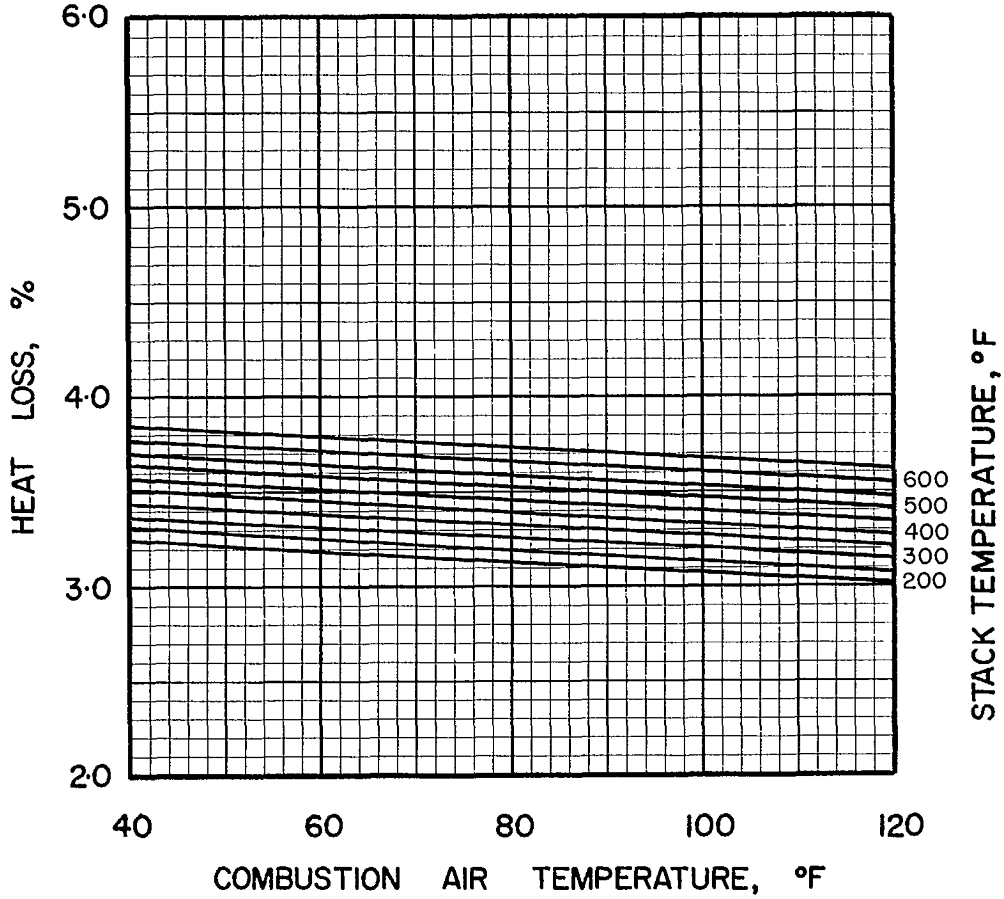


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 3 · 1

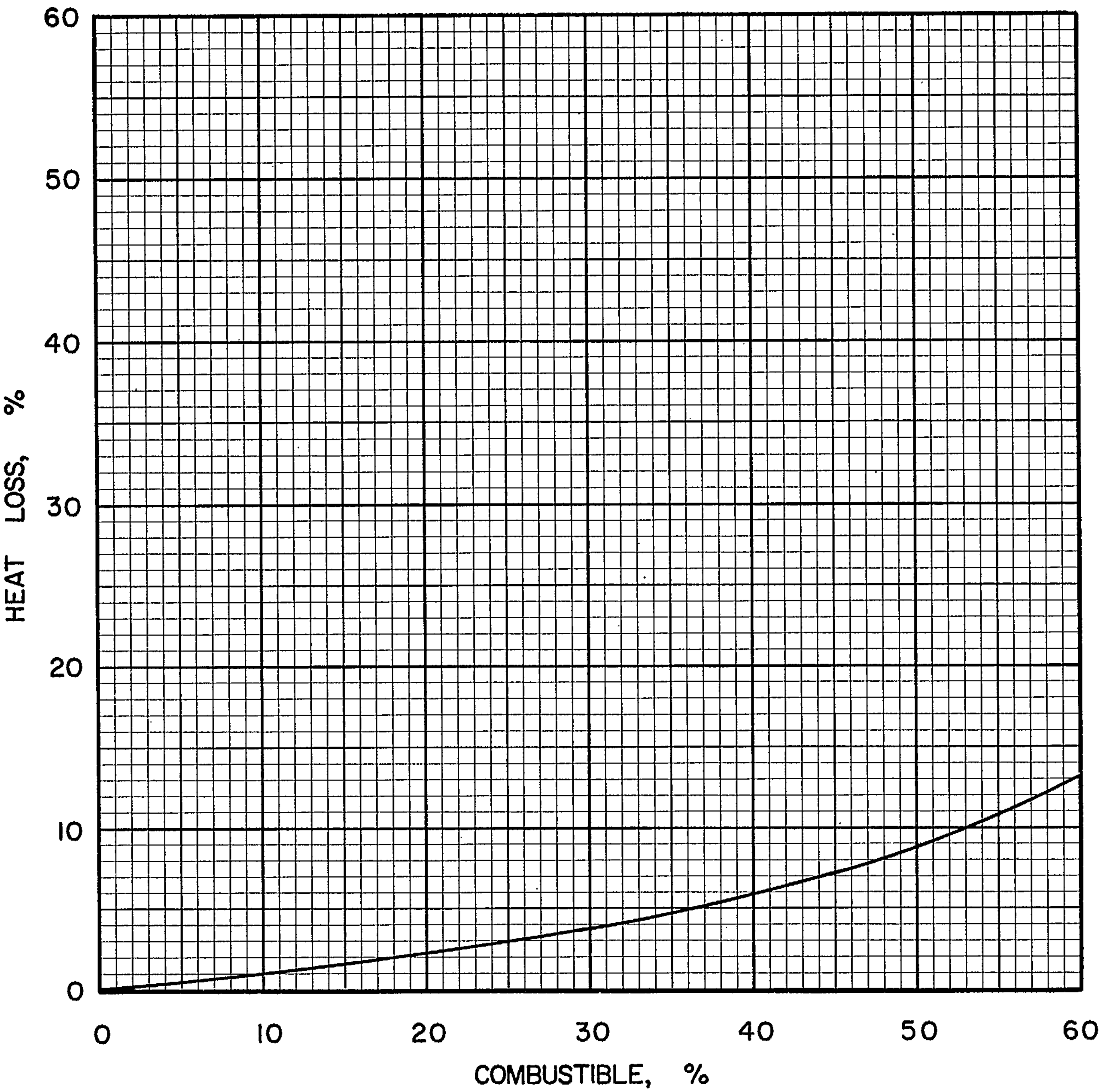


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·3·1

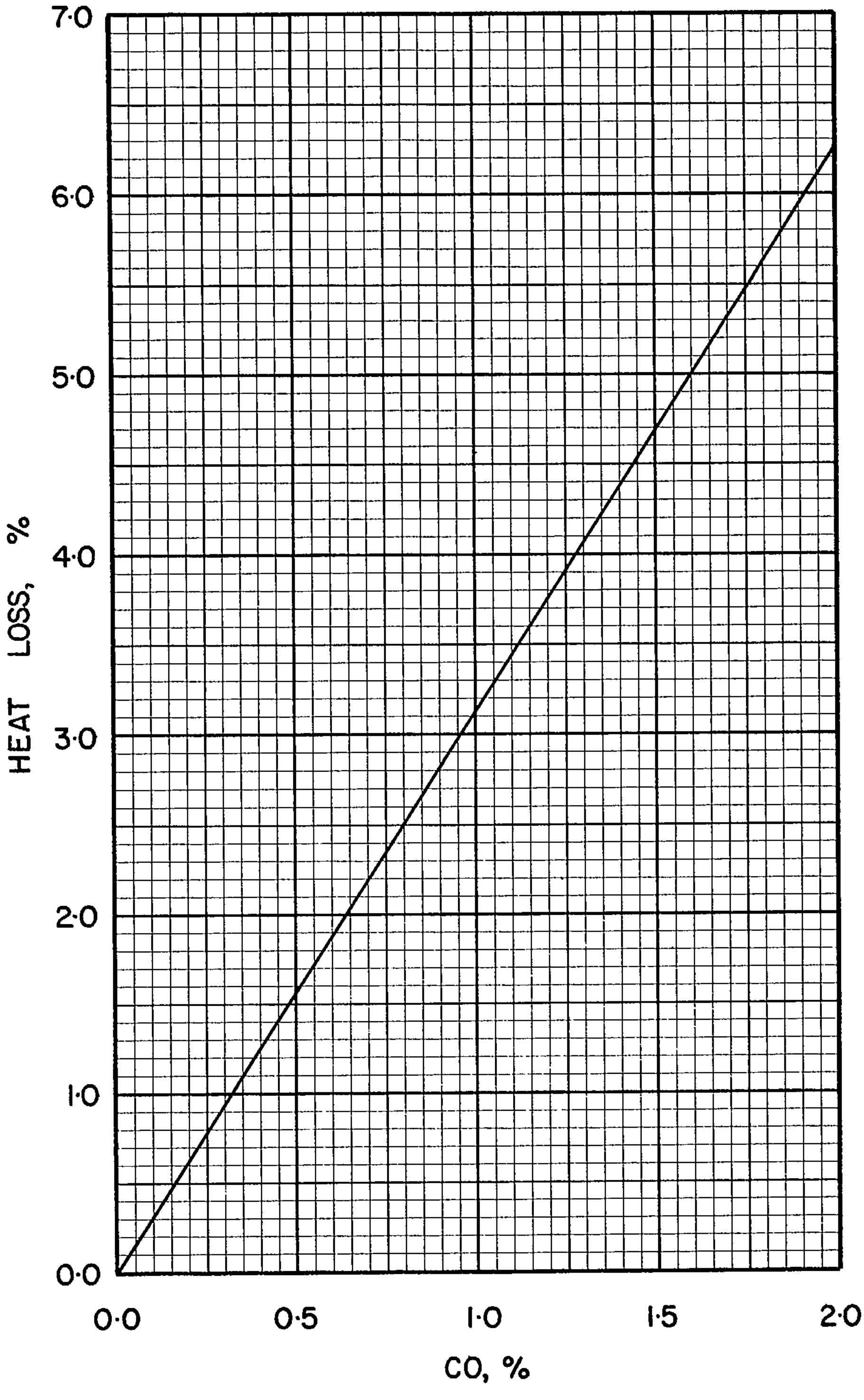


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 3 · 1

COAL ABC 3-2, COLEMAN EXPORT, CROWSNEST, 1/4 in. x 0

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0885
Volatile Matter	0.2289
Fixed Carbon	0.6826
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8117
Hydrogen (H)	0.0444
Sulphur (S)	0.0060
Nitrogen (N)	0.0112
Oxygen (O)	0.0382
Ash	0.0885
Total	1.0000

Gross Calorific Value

Btu/lb:	14040
Btu/short ton:	28.08×10^6
Btu/long ton:	31.45×10^6
MJ/kg:	32.65

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	71.23	lb	
10^6 Btu	=	0.03561	short tons	
10^6 Btu	=	0.03180	long tons	

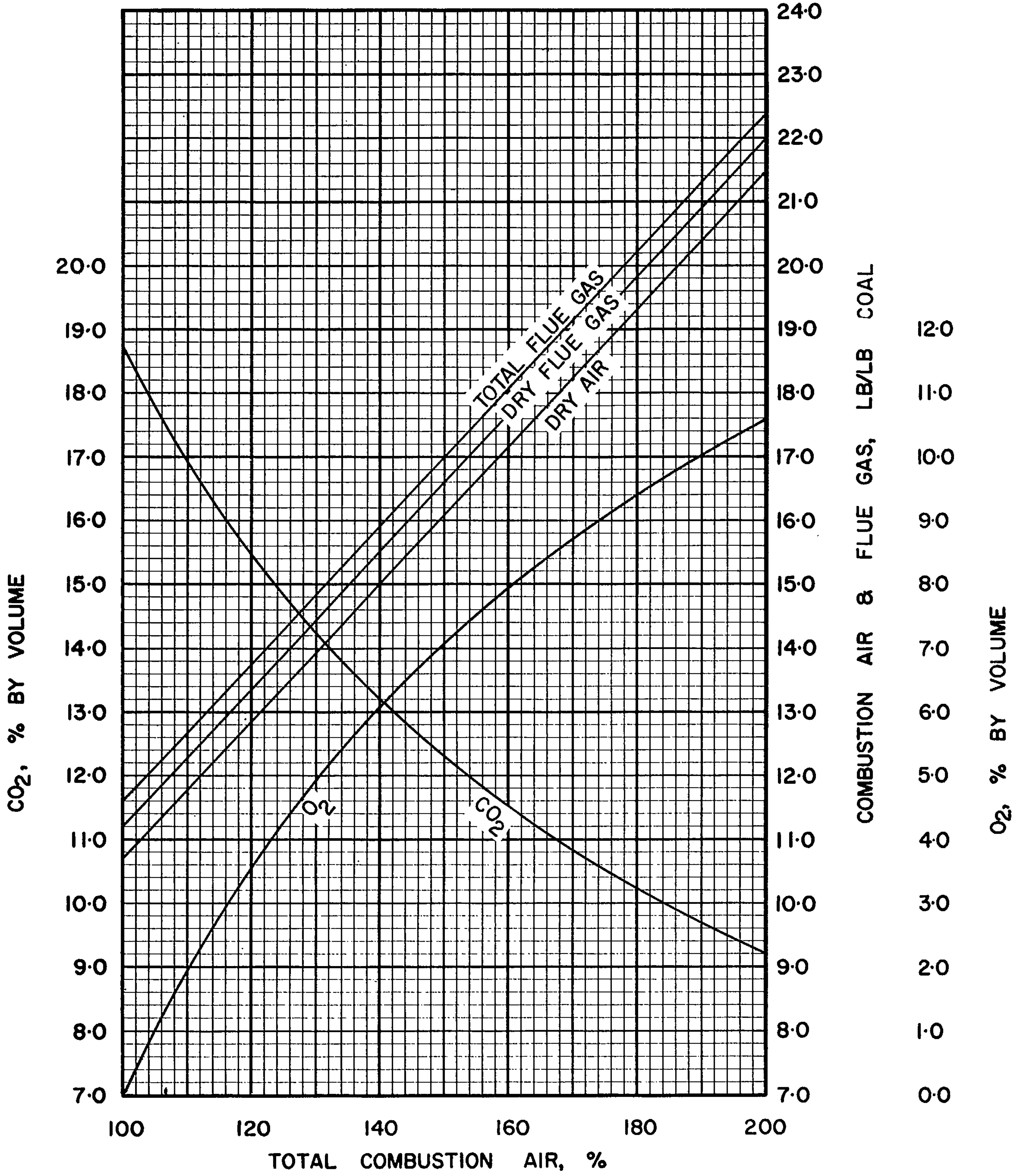


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC · 3 · 2

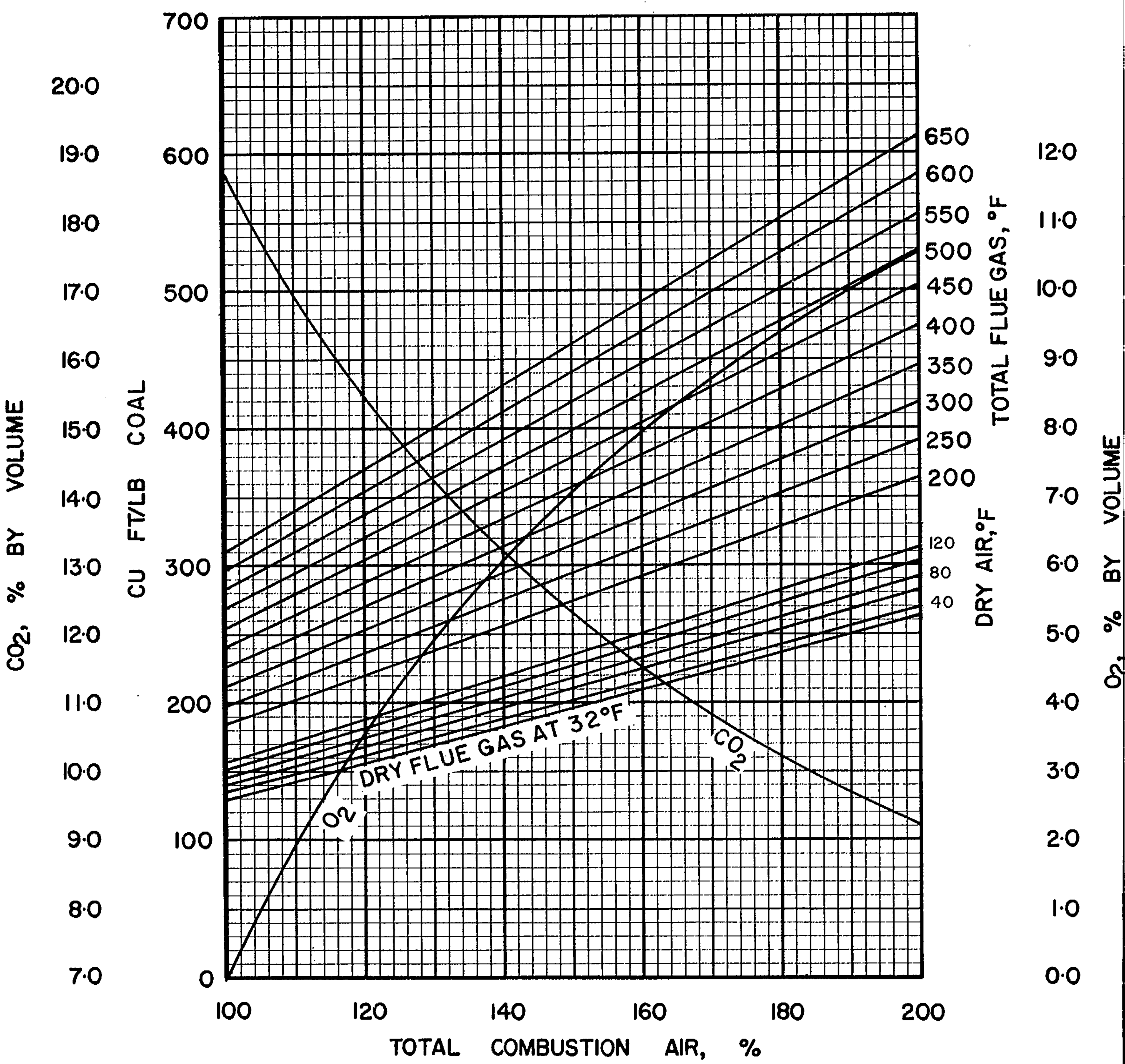


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 3 · 2

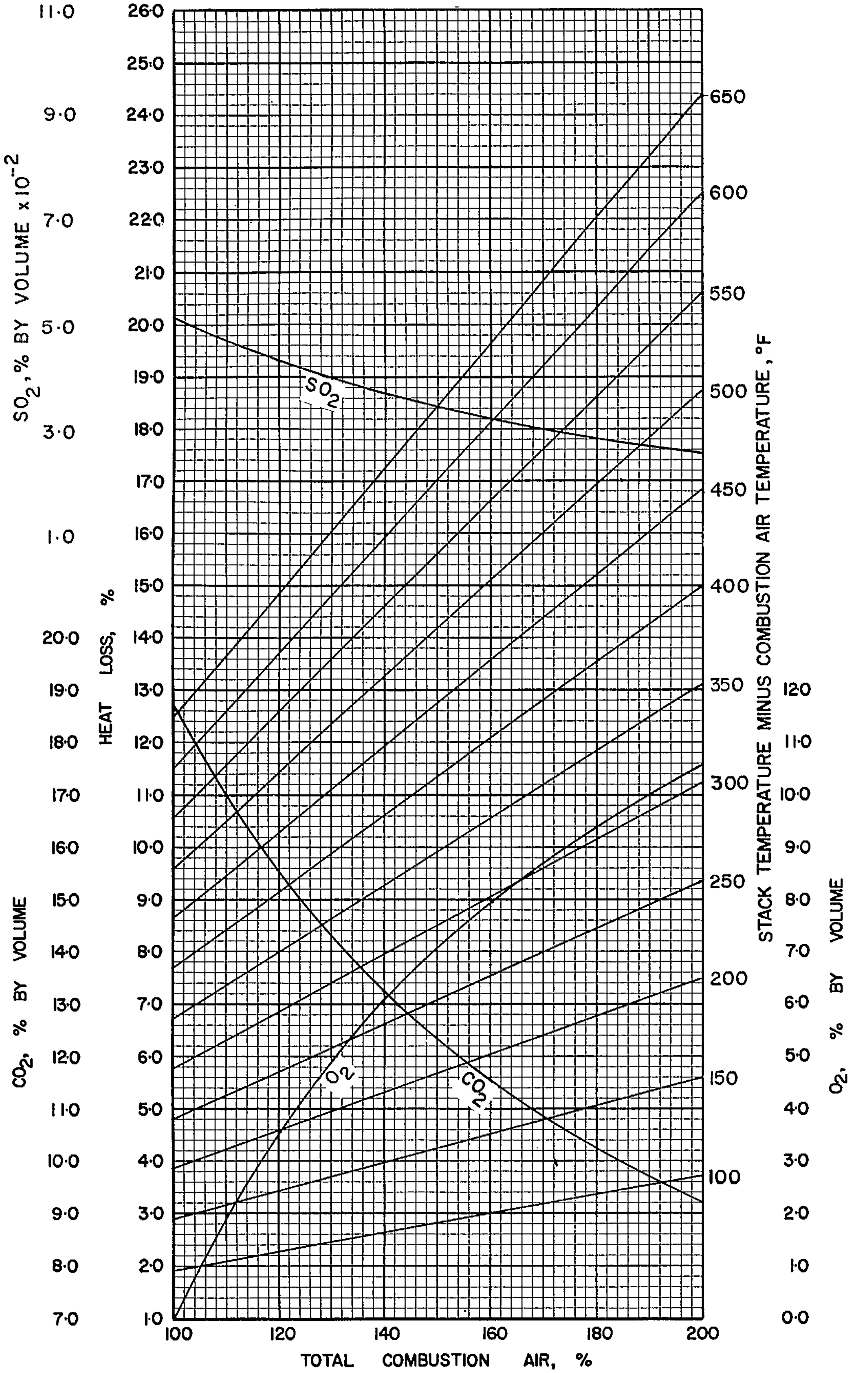


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·3·2

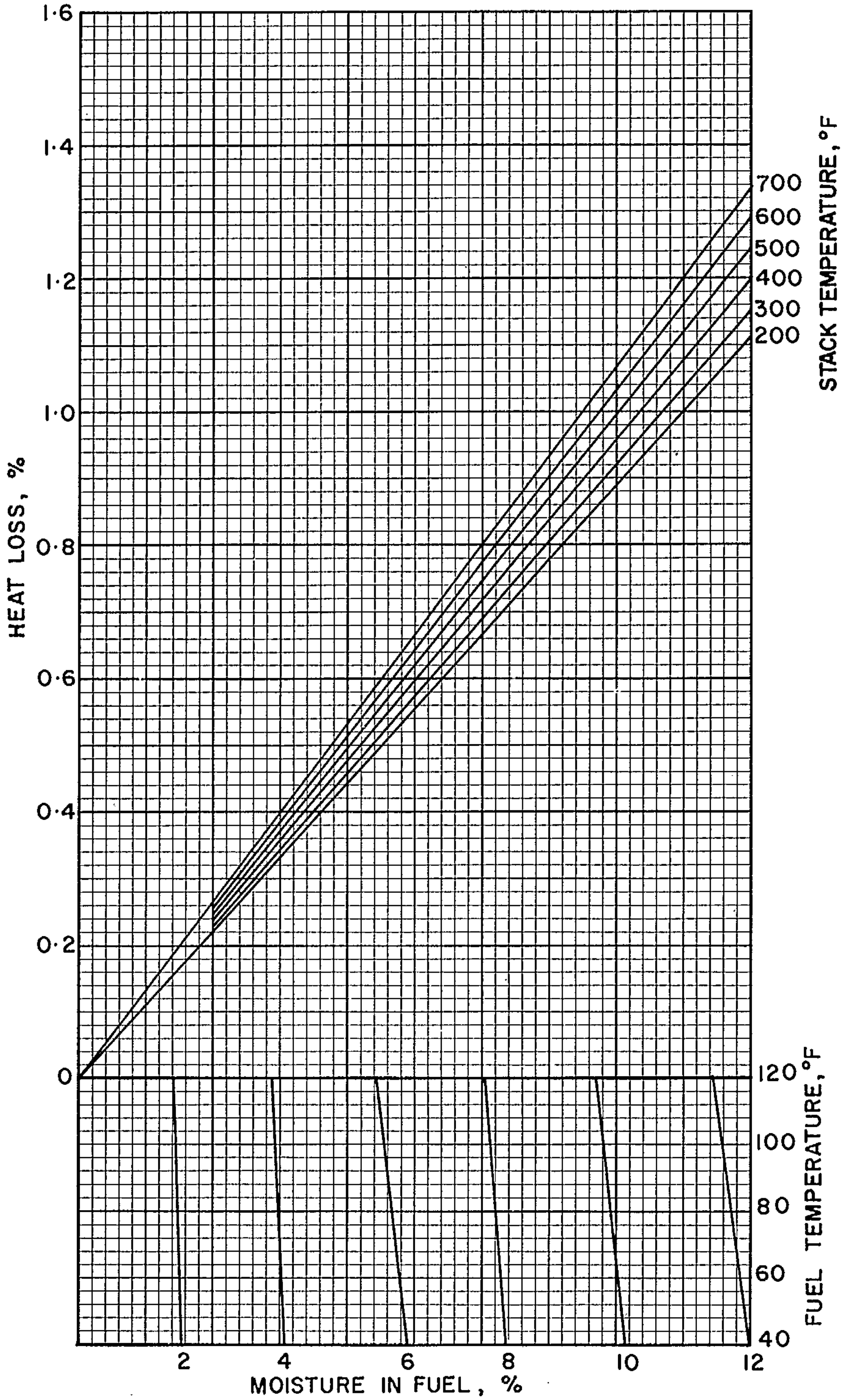


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·3·2

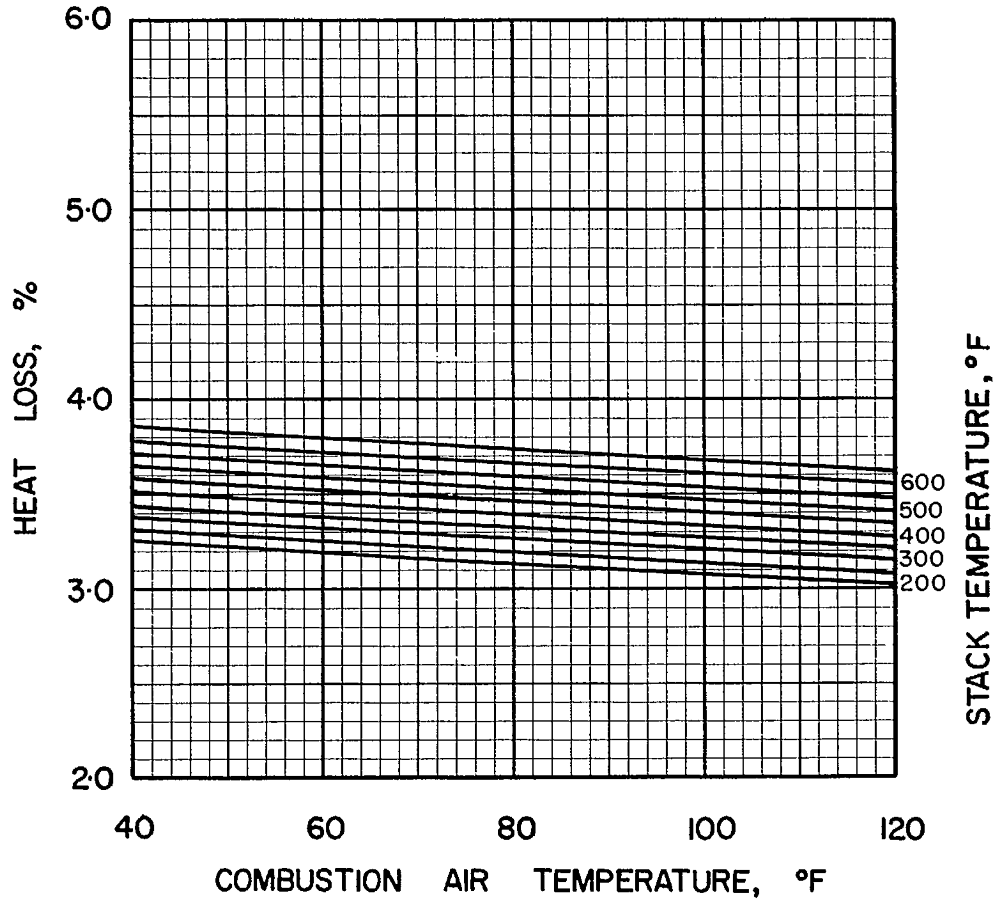


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·3·2

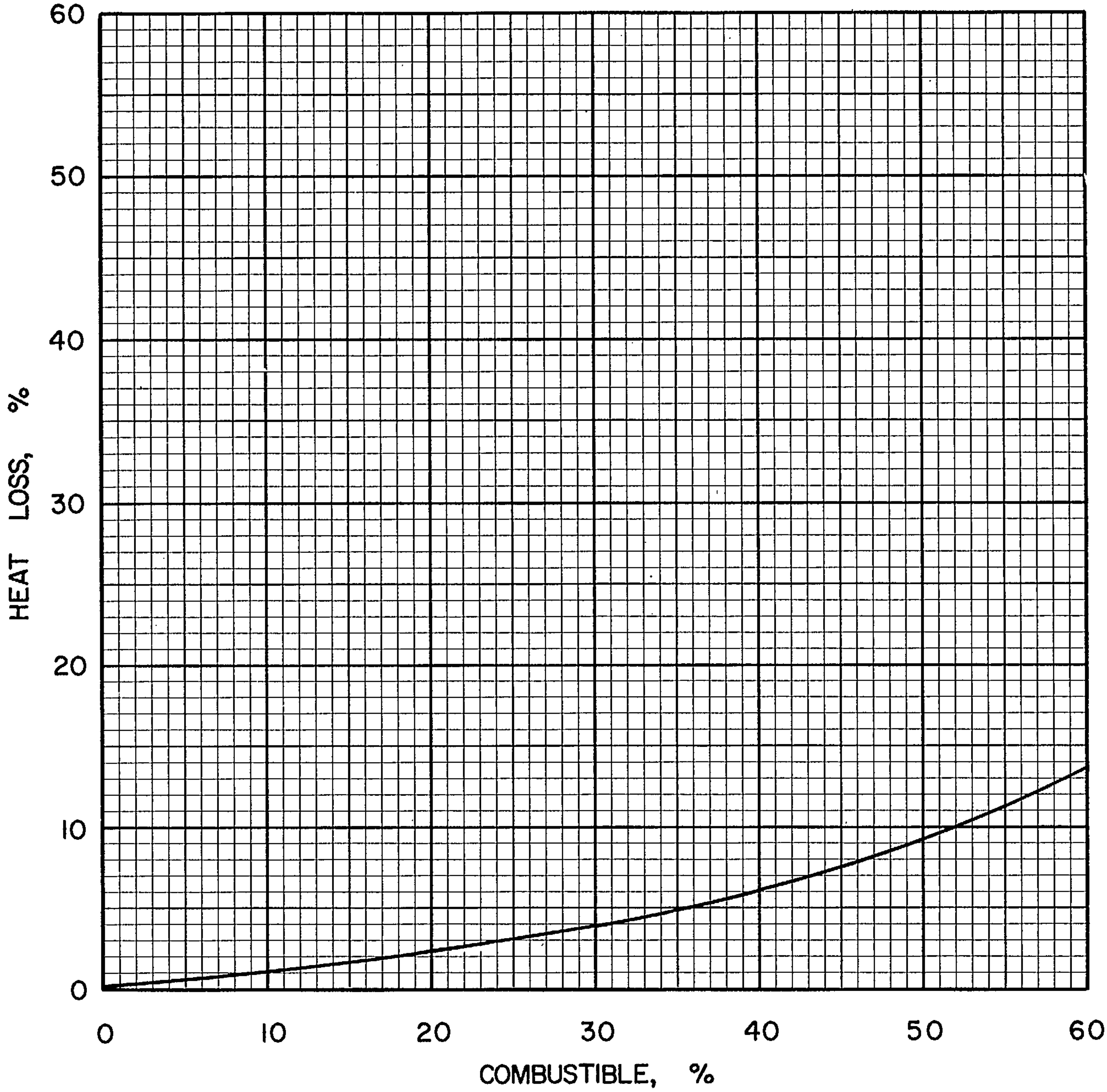


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·3·2

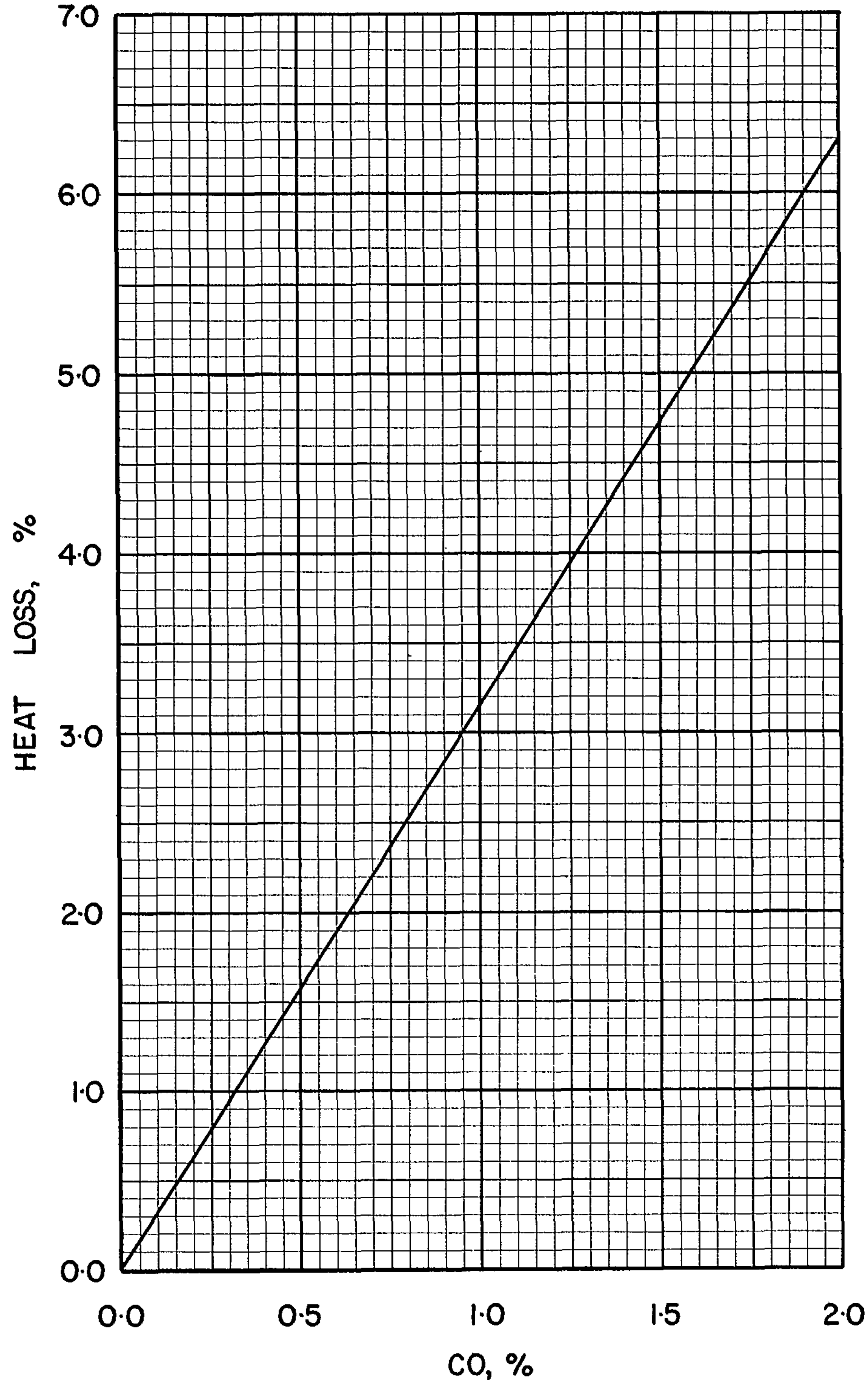


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC· 3 · 2

COAL ABC 3-3, COLEMAN TENT MOUNTAIN, CROWSNEST, 1 1/4 in. x 1/4 in.

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0985
Volatile Matter	0.2353
Fixed Carbon	0.6662
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8002
Hydrogen (H)	0.0443
Sulphur (S)	0.0068
Nitrogen (N)	0.0112
Oxygen (O)	0.0390
Ash	0.0985
Total	1.0000

Gross Calorific Value

Btu/lb:	13920
Btu/short ton:	27.84×10^6
Btu/long ton:	31.18×10^6
MJ/kg:	32.37

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 71.84	lb	
10^6 Btu	= 0.03592	short tons	
10^6 Btu	= 0.03207	long tons	

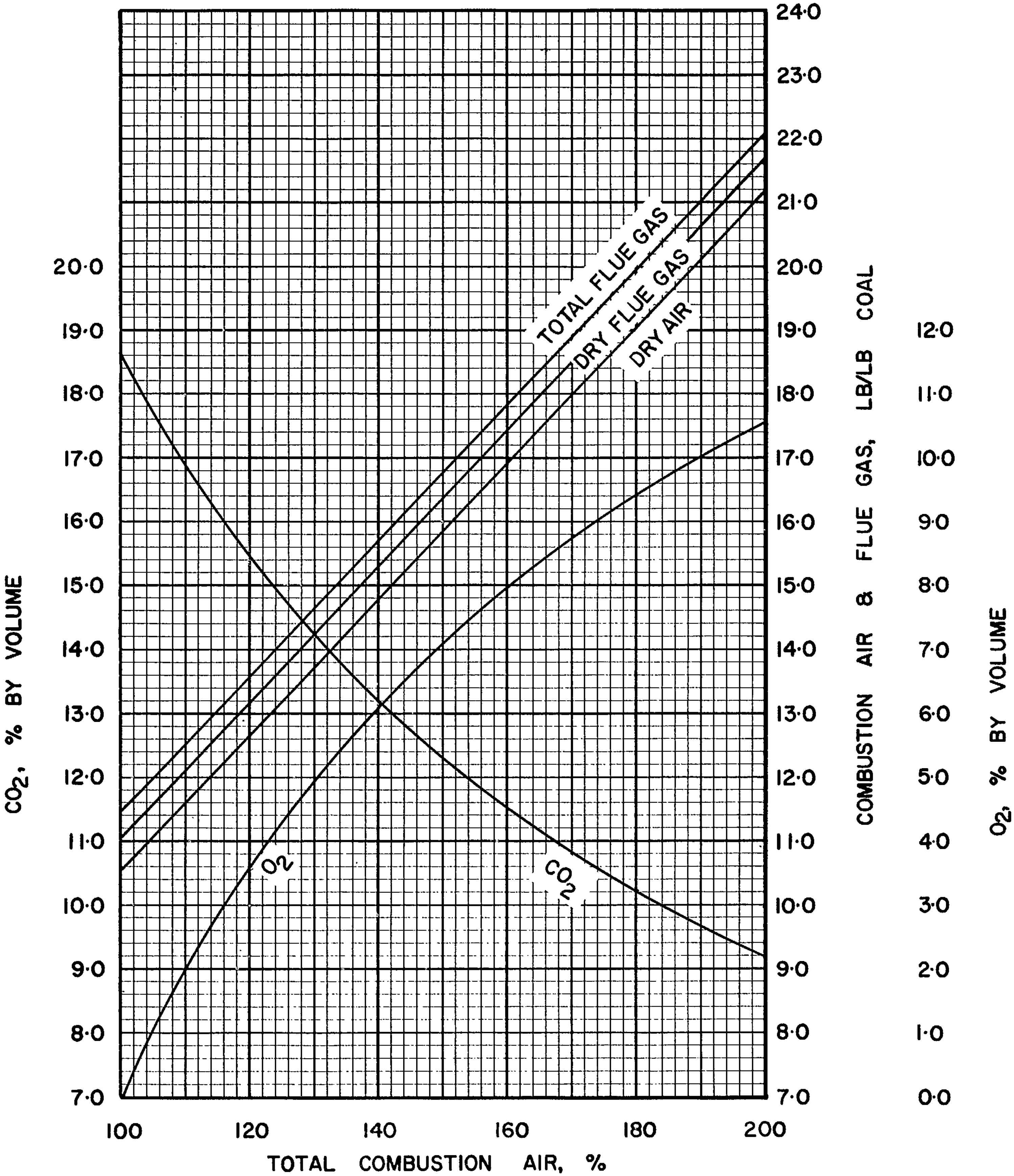


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS　　ABC· 3· 3

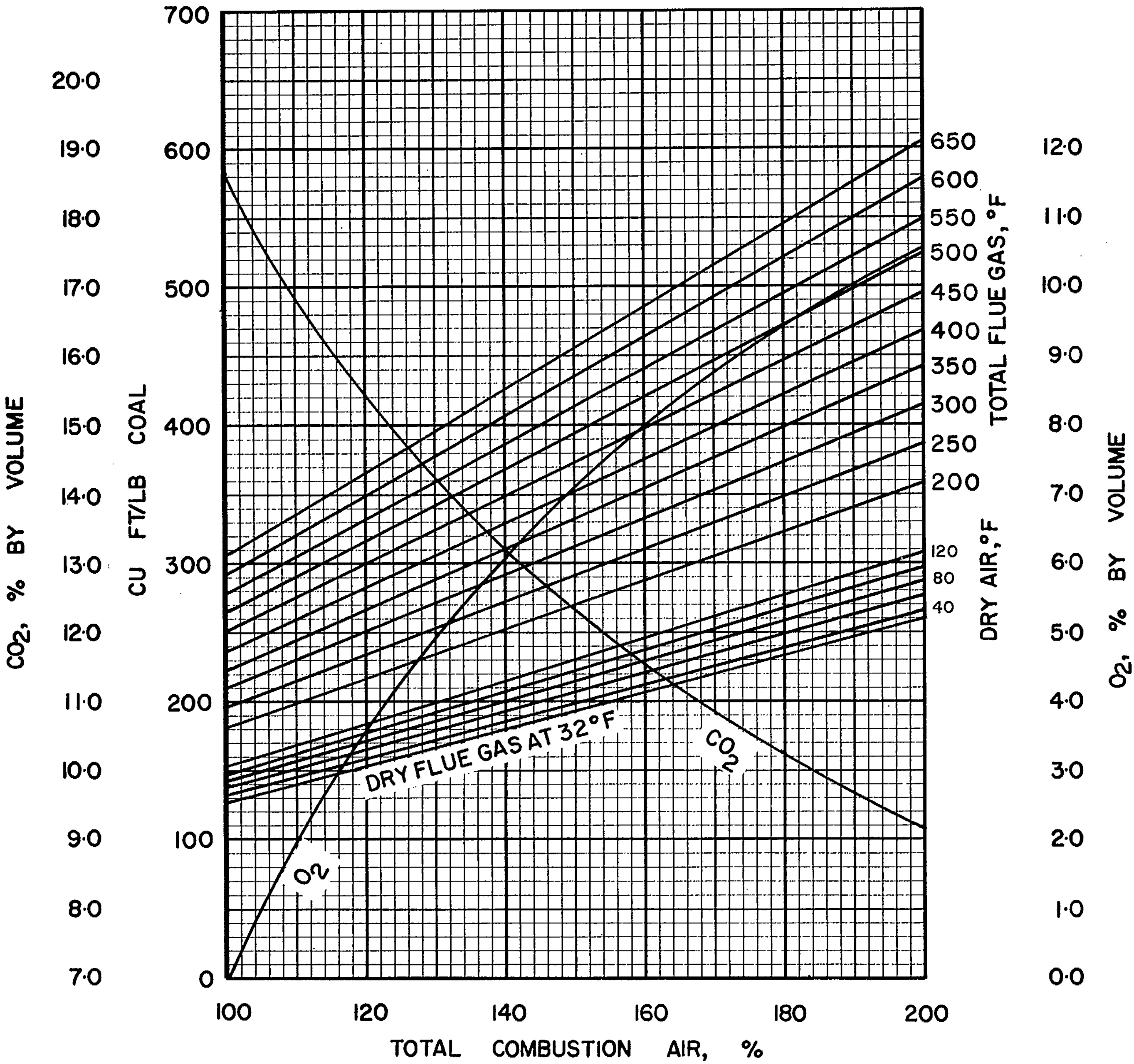


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·3·3

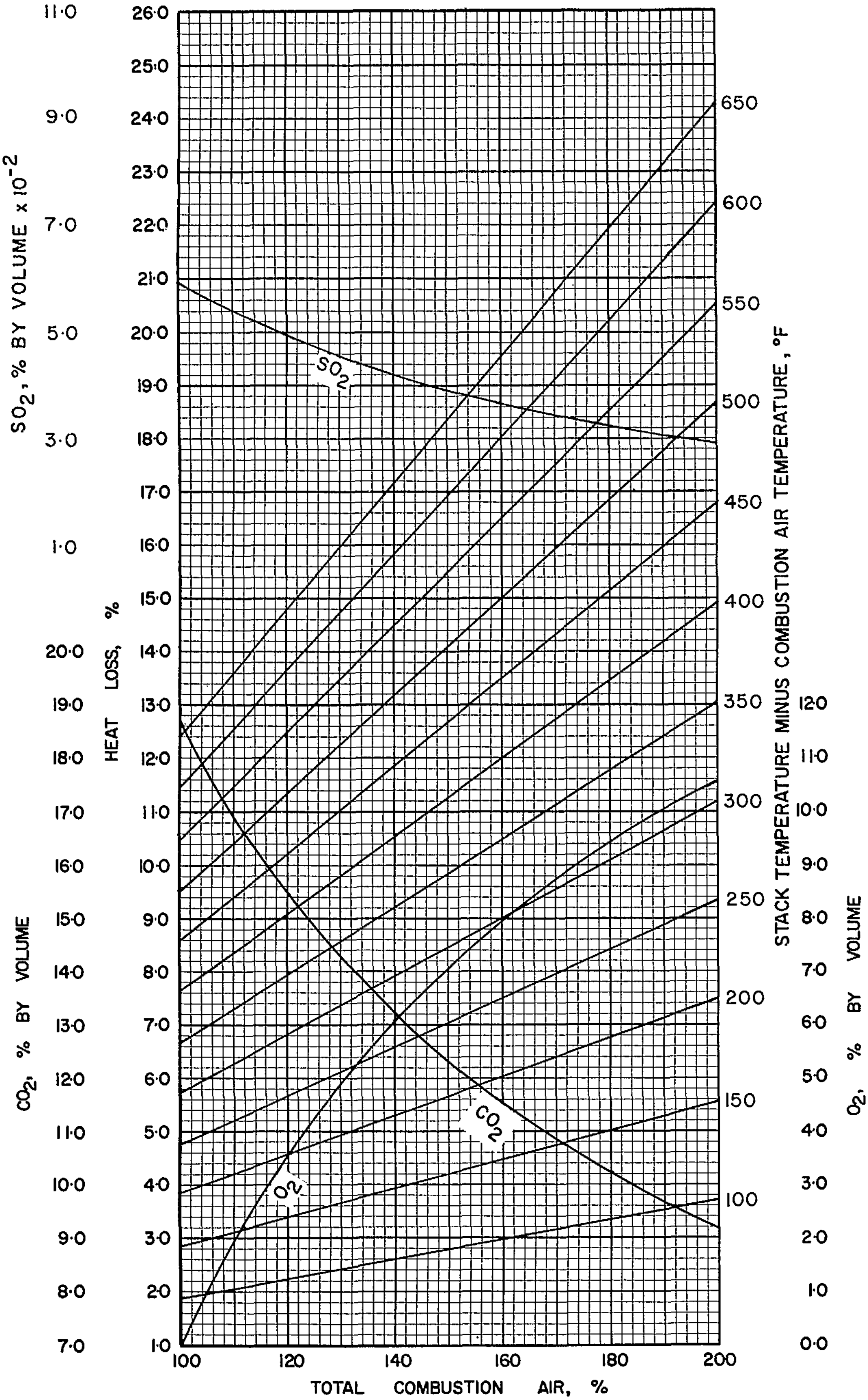


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·3·3

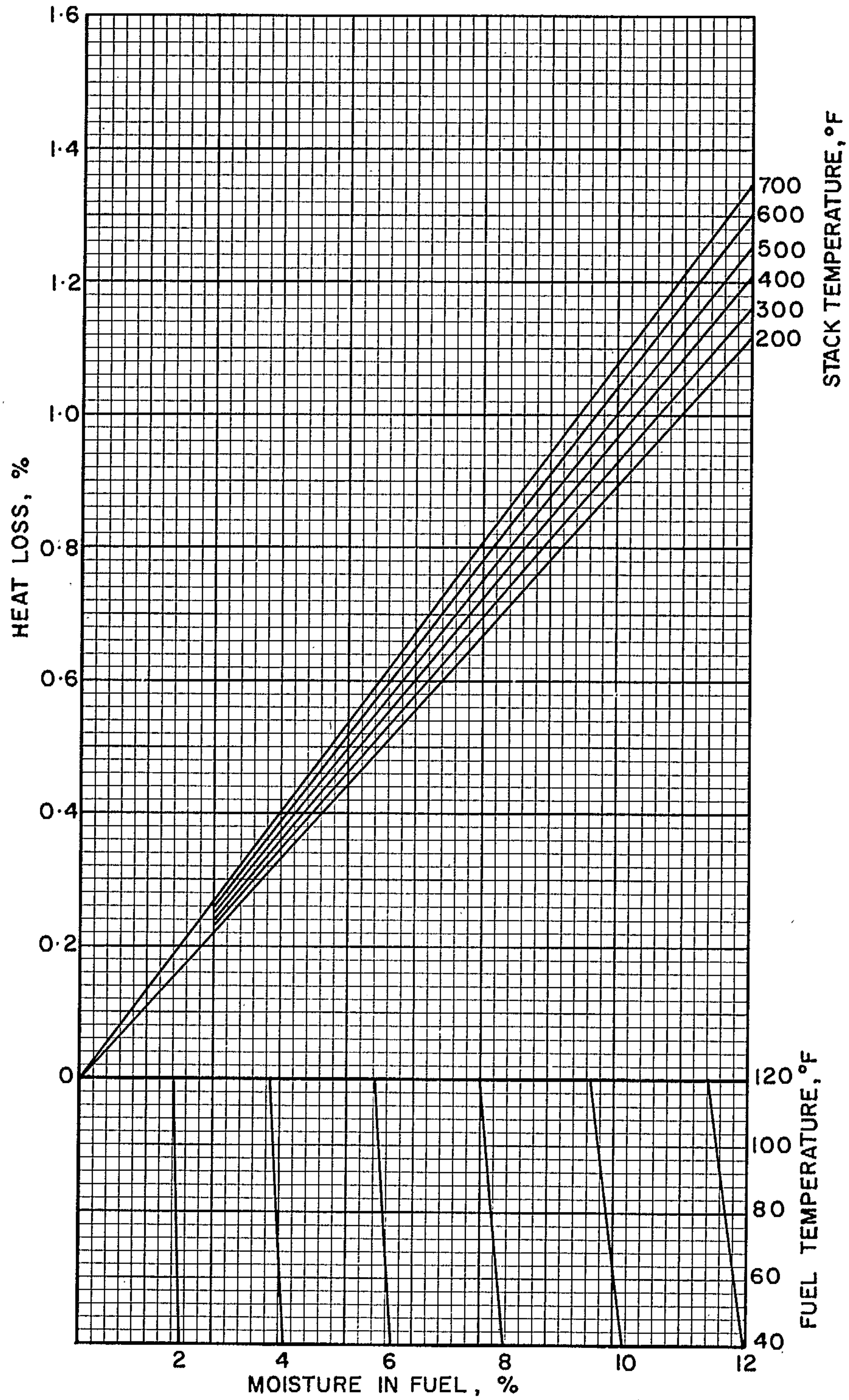


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC · 3 · 3

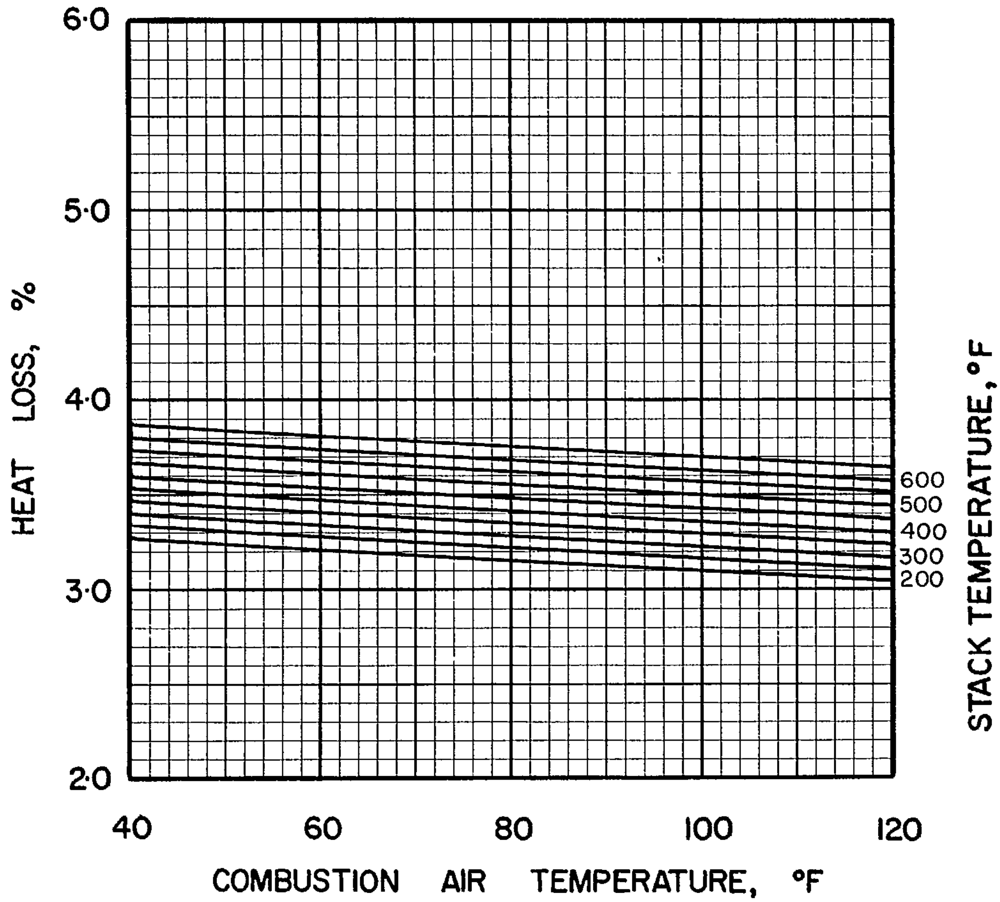


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 3 · 3

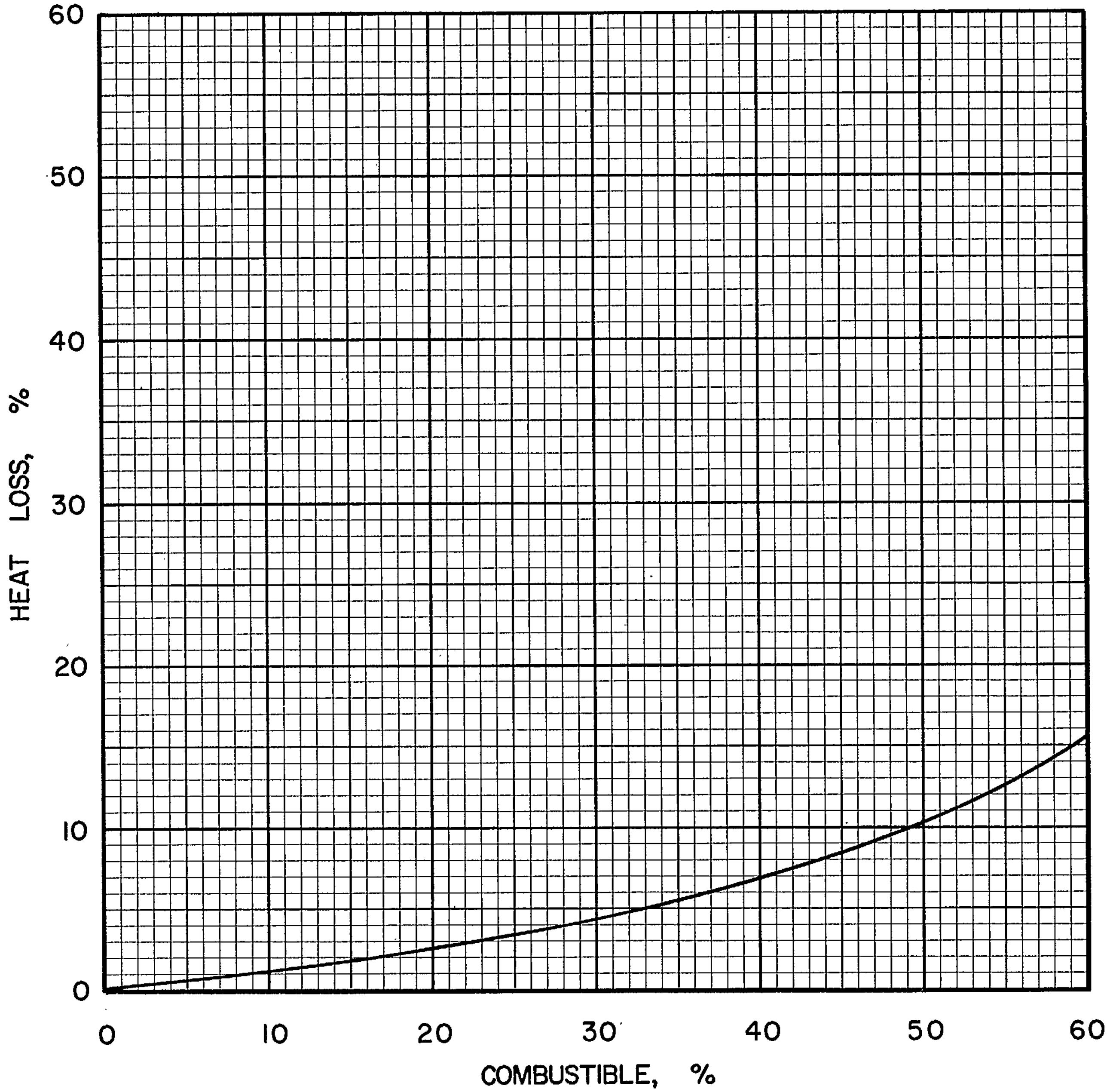


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·3·3

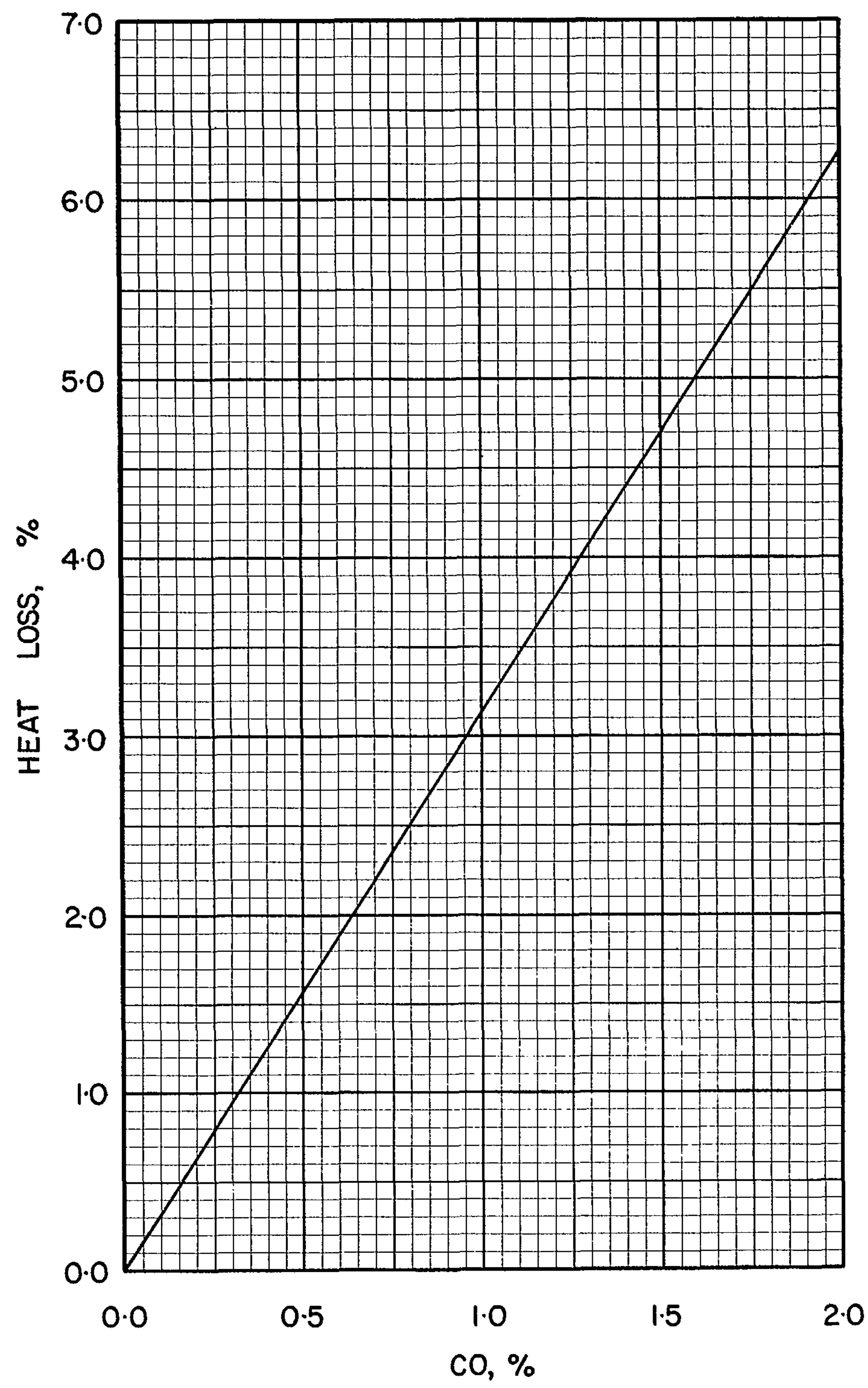


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 3 · 3

COAL ABC 4-1, CROWSNEST INDUSTRIES LTD., A SEAM, EAST KOOTENAY, 2 in. x 0

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0810
Volatile Matter	0.2530
Fixed Carbon	0.6660
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8130
Hydrogen (H)	0.0464
Sulphur (S)	0.0057
Nitrogen (N)	0.0136
Oxygen (O)	0.0403
Ash	0.0810
Total	1.0000

Gross Calorific Value

Btu/lb:	14210
Btu/short ton:	28.42×10^6
Btu/long ton:	31.83×10^6
MJ/kg:	33.04

Conversion Factors

1 short ton	=	0.8929	long tons = 2000 lb
10^6 Btu	=	70.37	lb
10^6 Btu	=	0.03519	short tons
10^6 Btu	=	0.03142	long tons

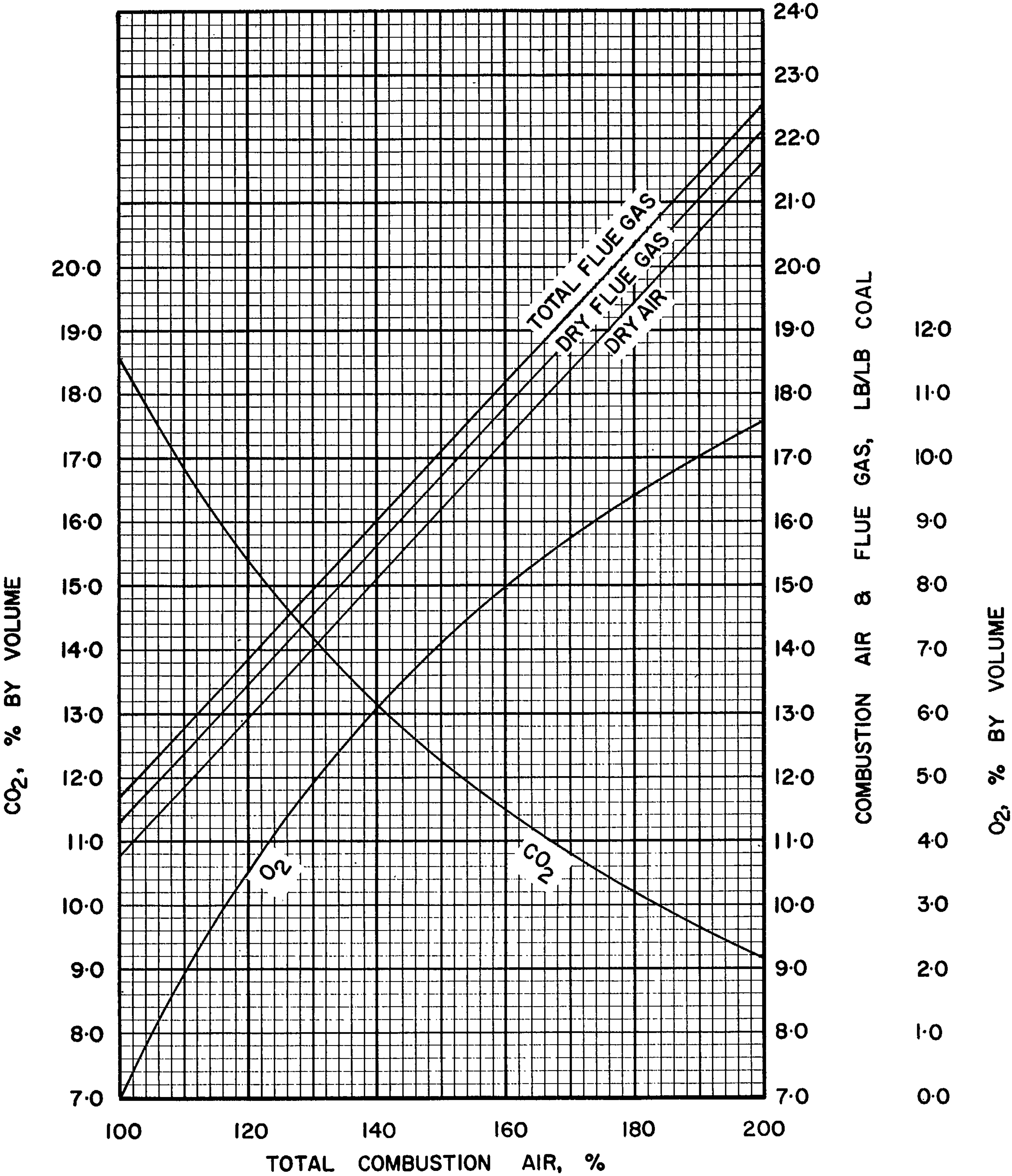


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC·4·1

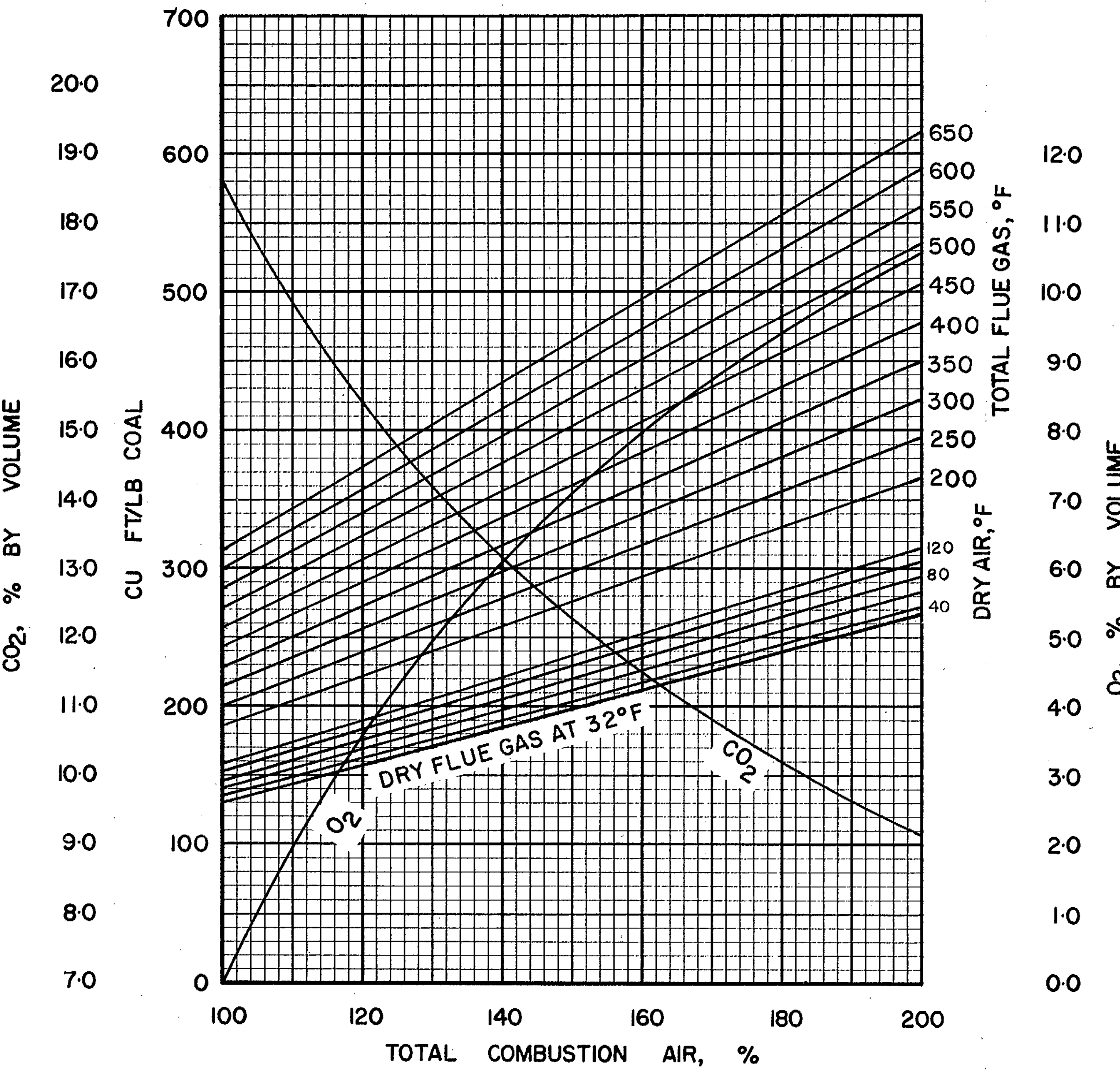


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·4·1

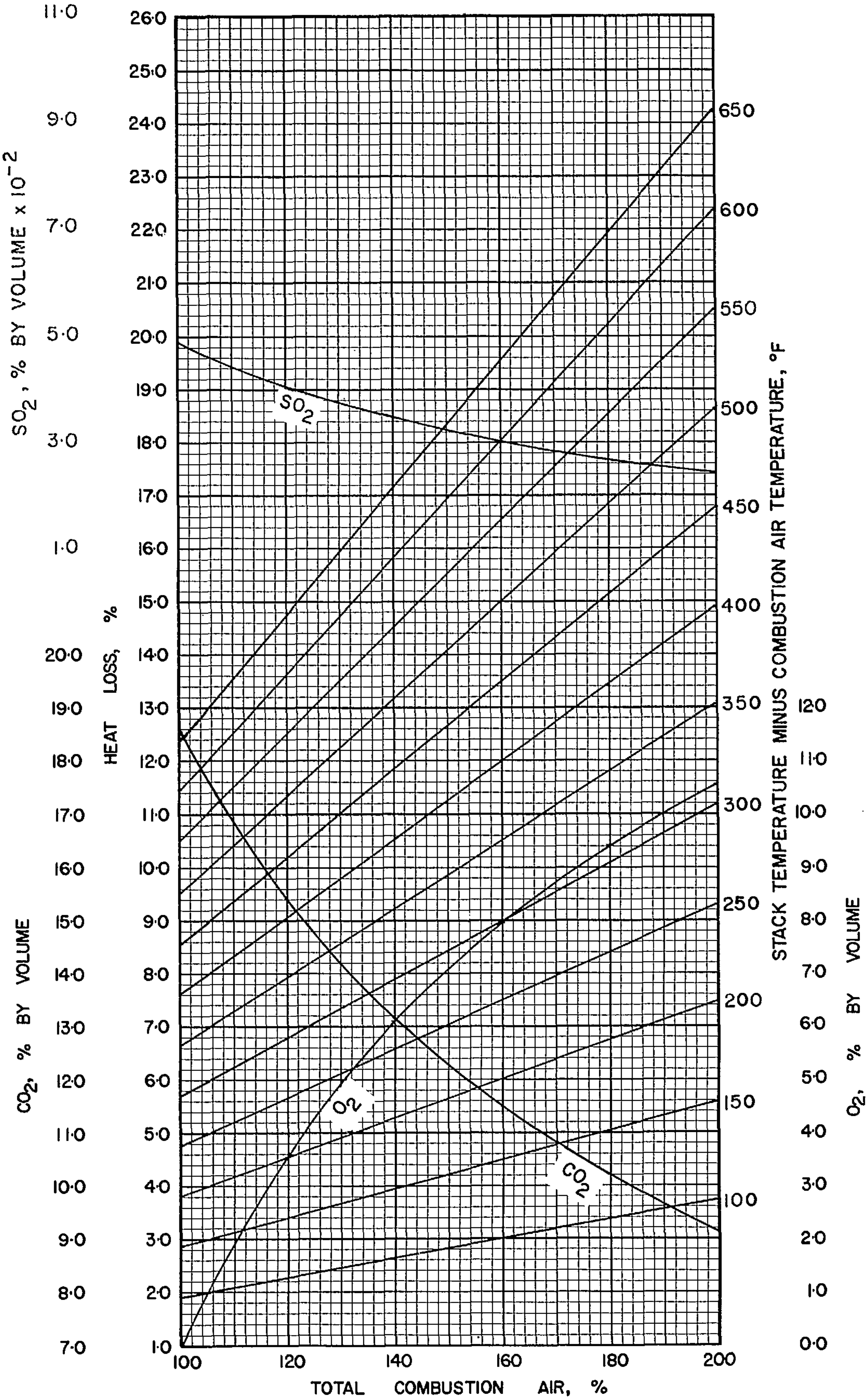


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS ABC·4·1

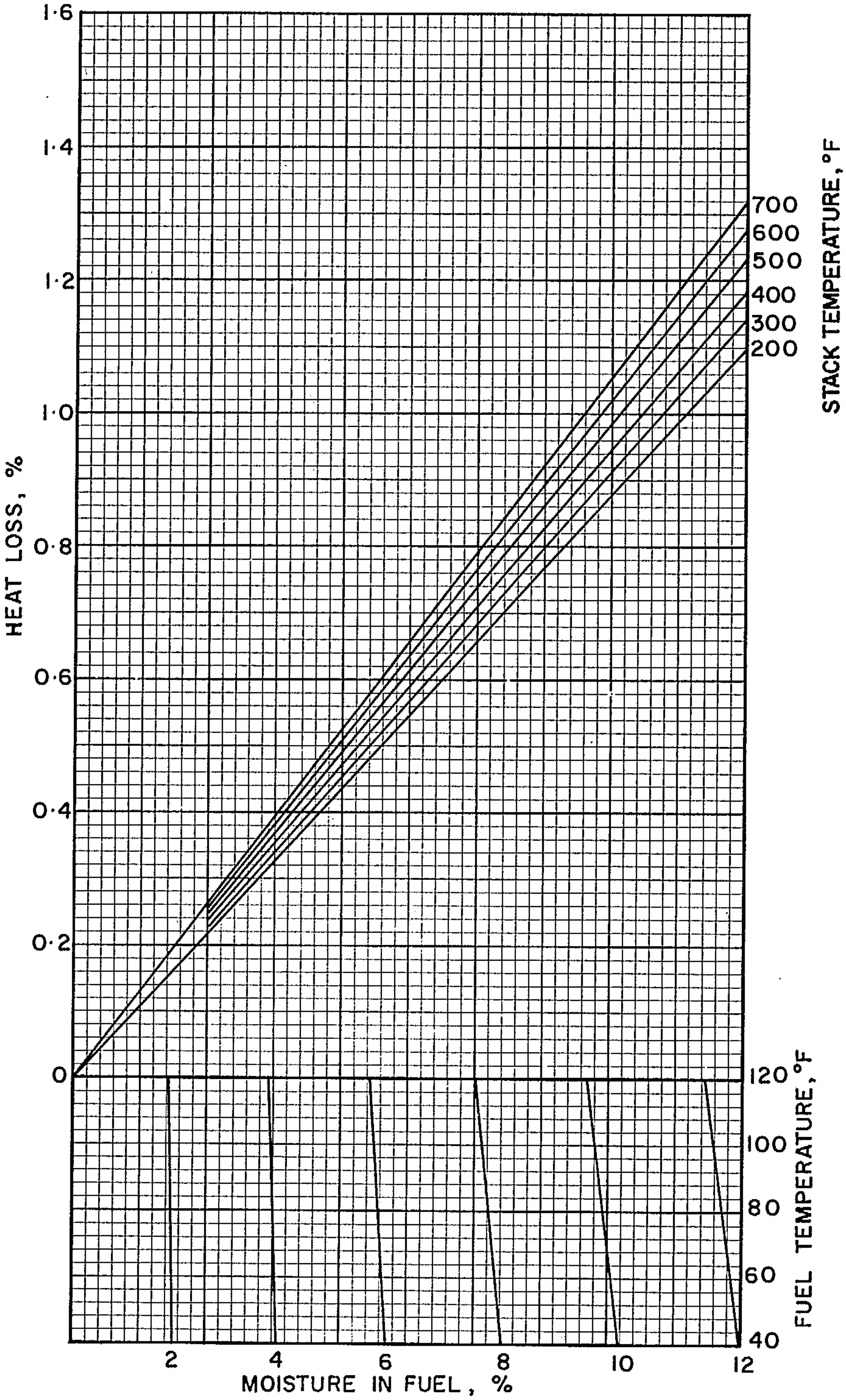


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC· 4 · 1

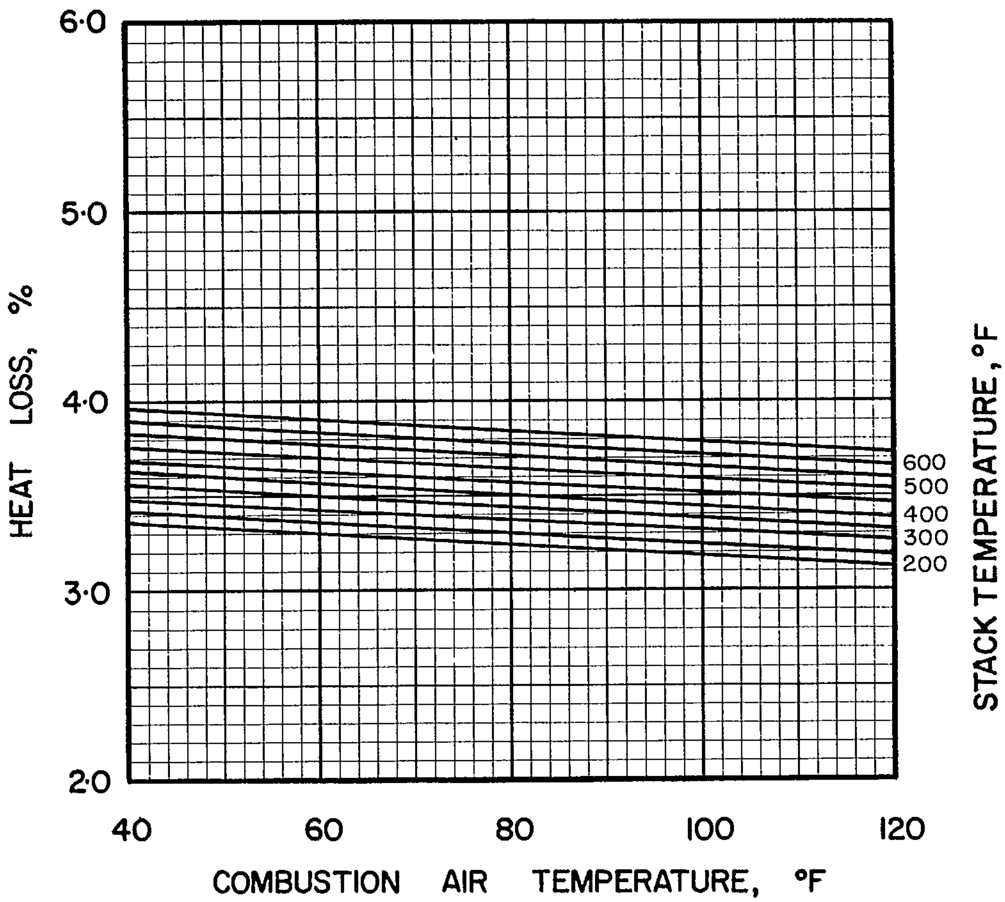


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·4·1

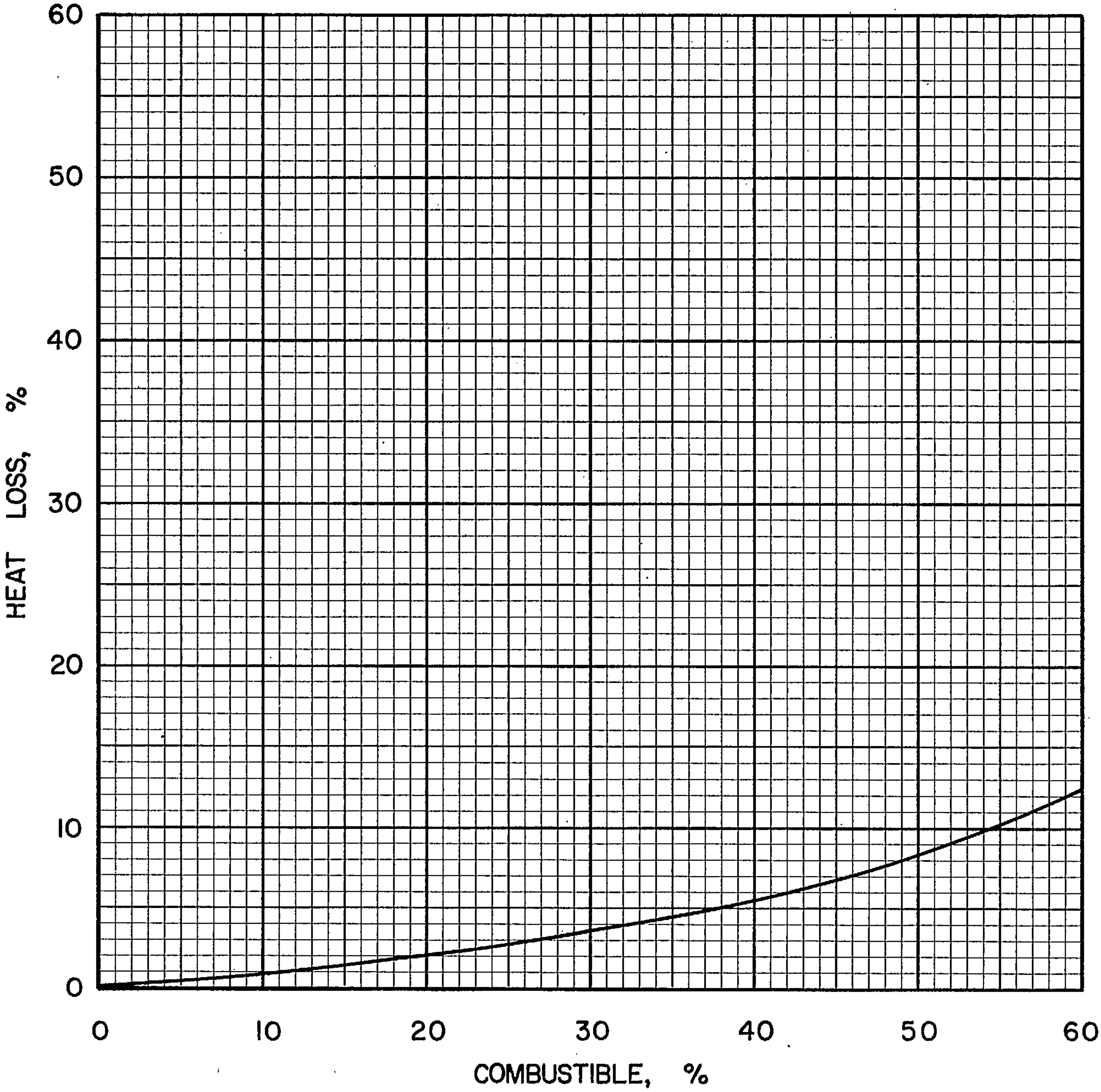


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·4·1

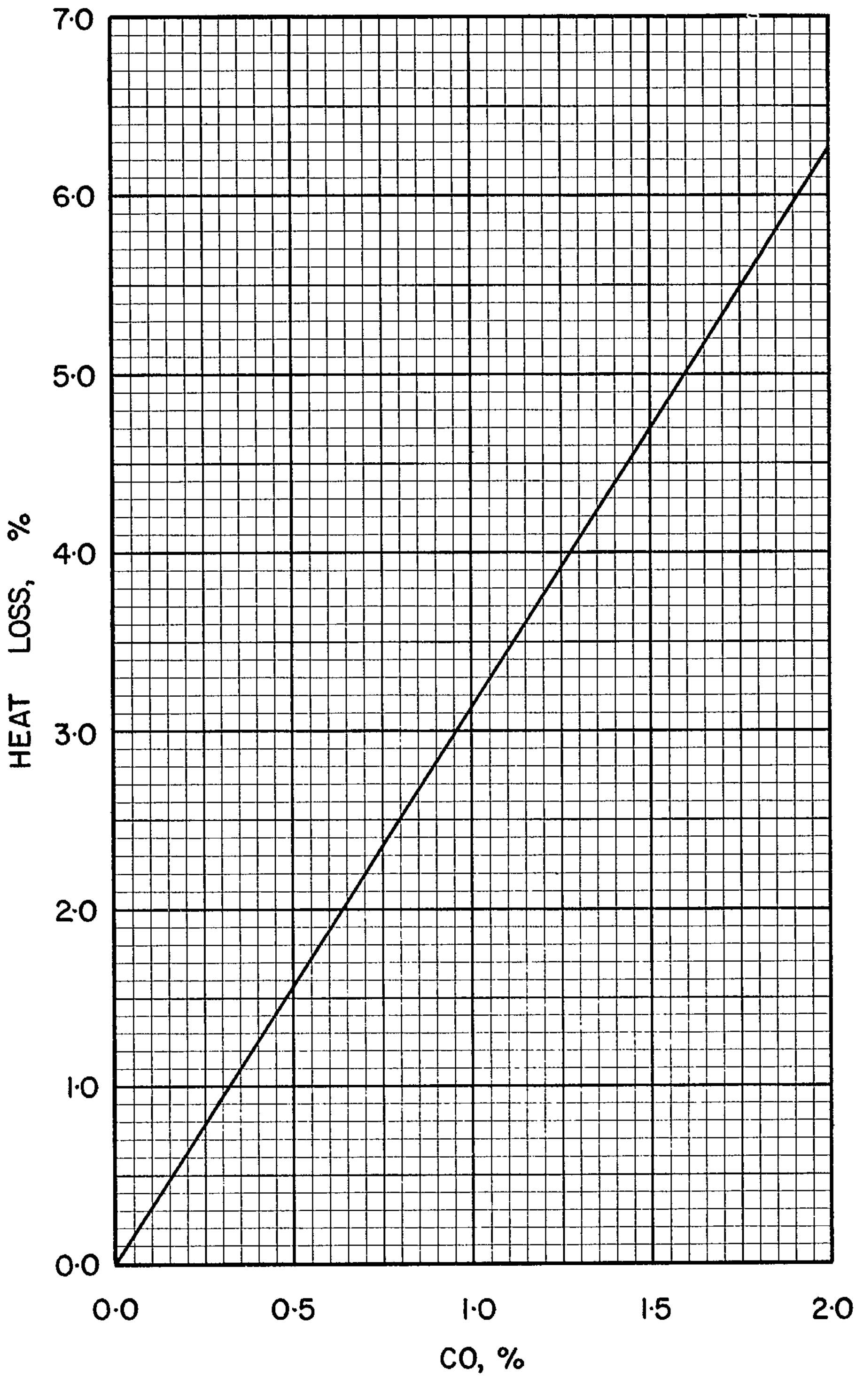


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 4 · 1

COAL ABC 4-2, CROWSNEST INDUSTRIES LTD., BALMER SEAM, EAST KOOTENAY, 2 in. x 0

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0919
Volatile Matter	0.2030
Fixed Carbon	0.7051
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8202
Hydrogen (H)	0.0430
Sulphur (S)	0.0042
Nitrogen (N)	0.0114
Oxygen (O)	0.0293
Ash	0.0919
Total	1.0000

Gross Calorific Value

Btu/lb:	14140
Btu/short ton:	28.28×10^6
Btu/long ton:	31.67×10^6
MJ/kg:	32.88

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 70.72 lb
10^6 Btu = 0.03536 short tons
10^6 Btu = 0.03157 long tons

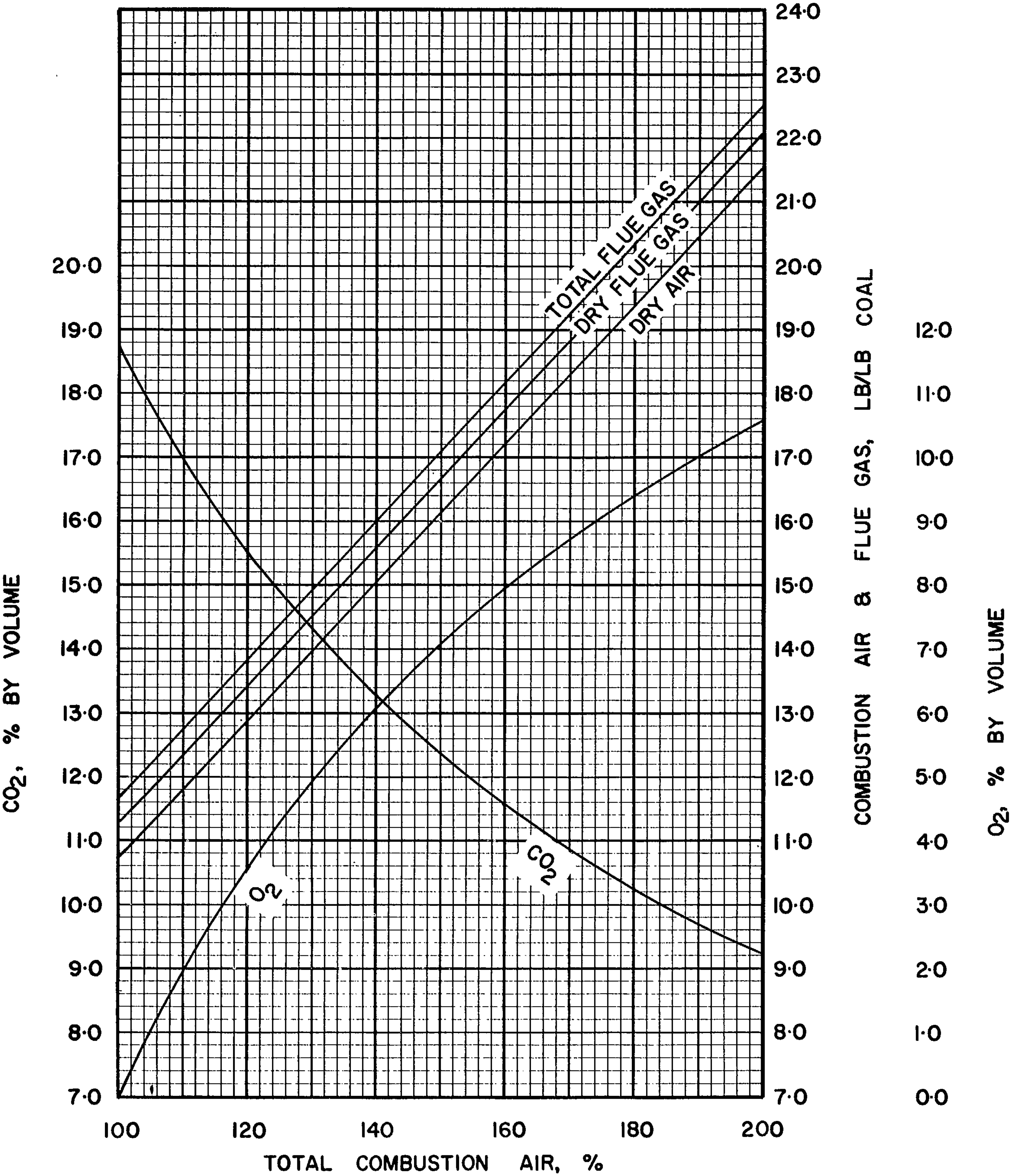


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC·4·2

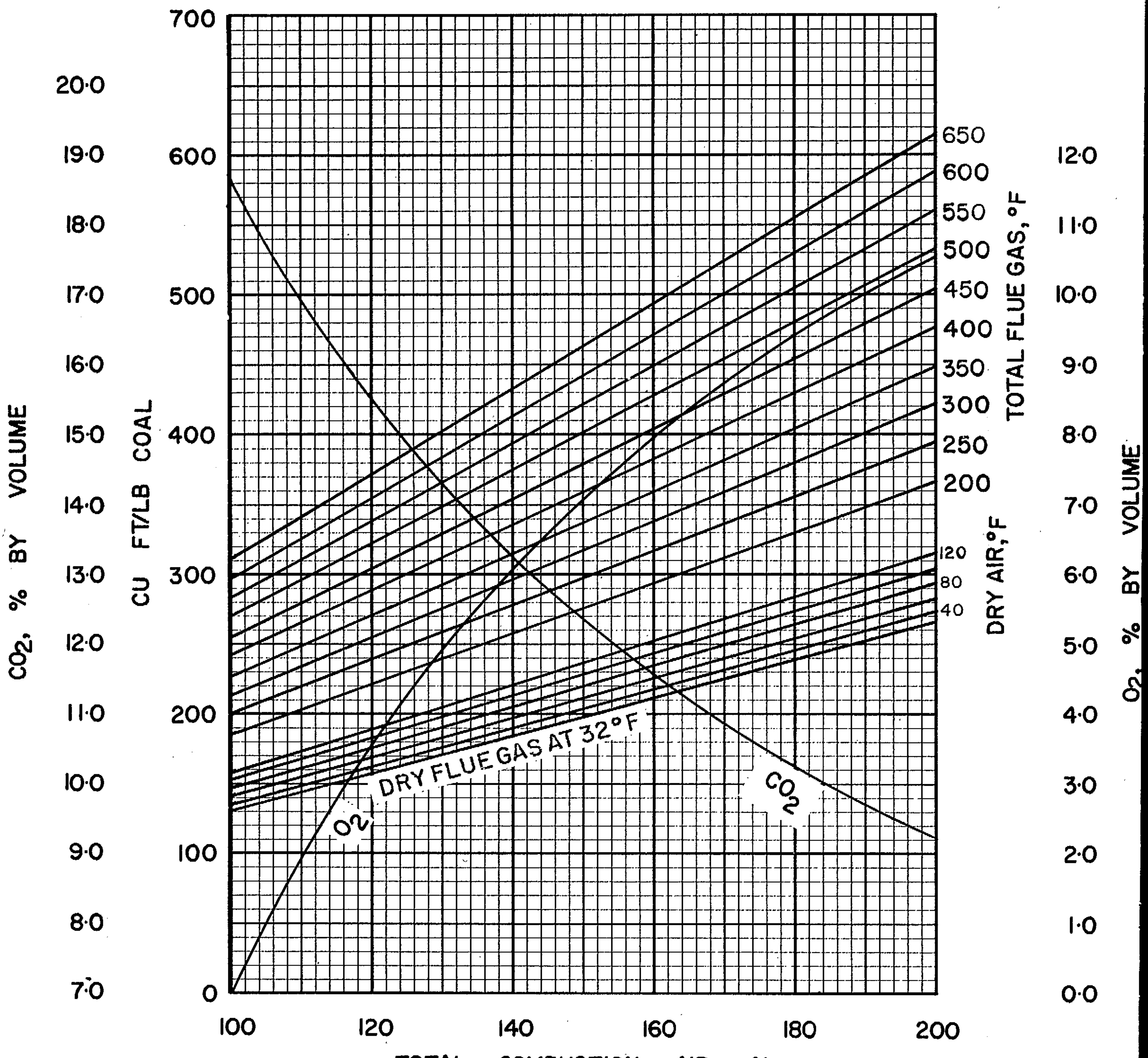


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 4 · 2

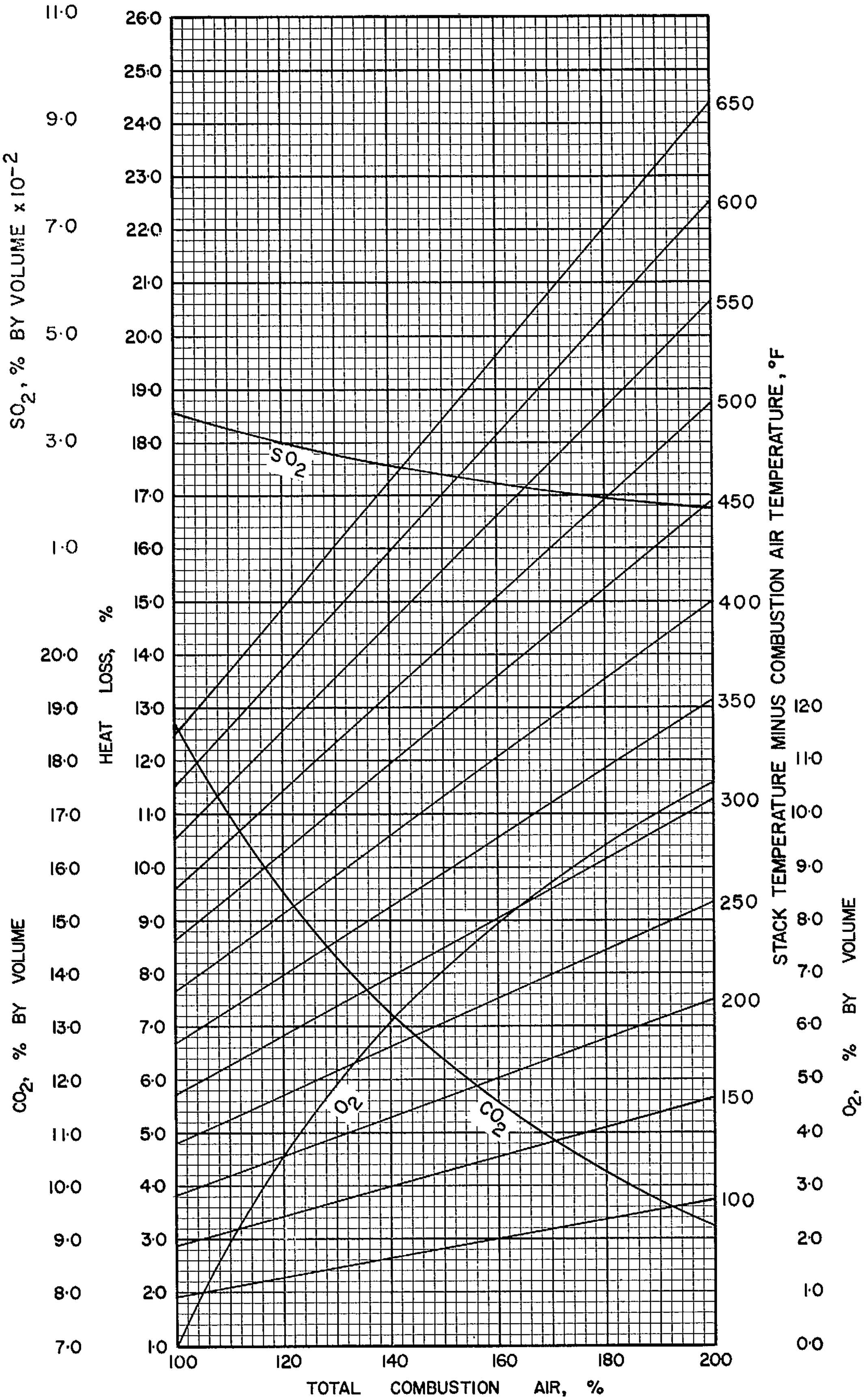


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·4·2

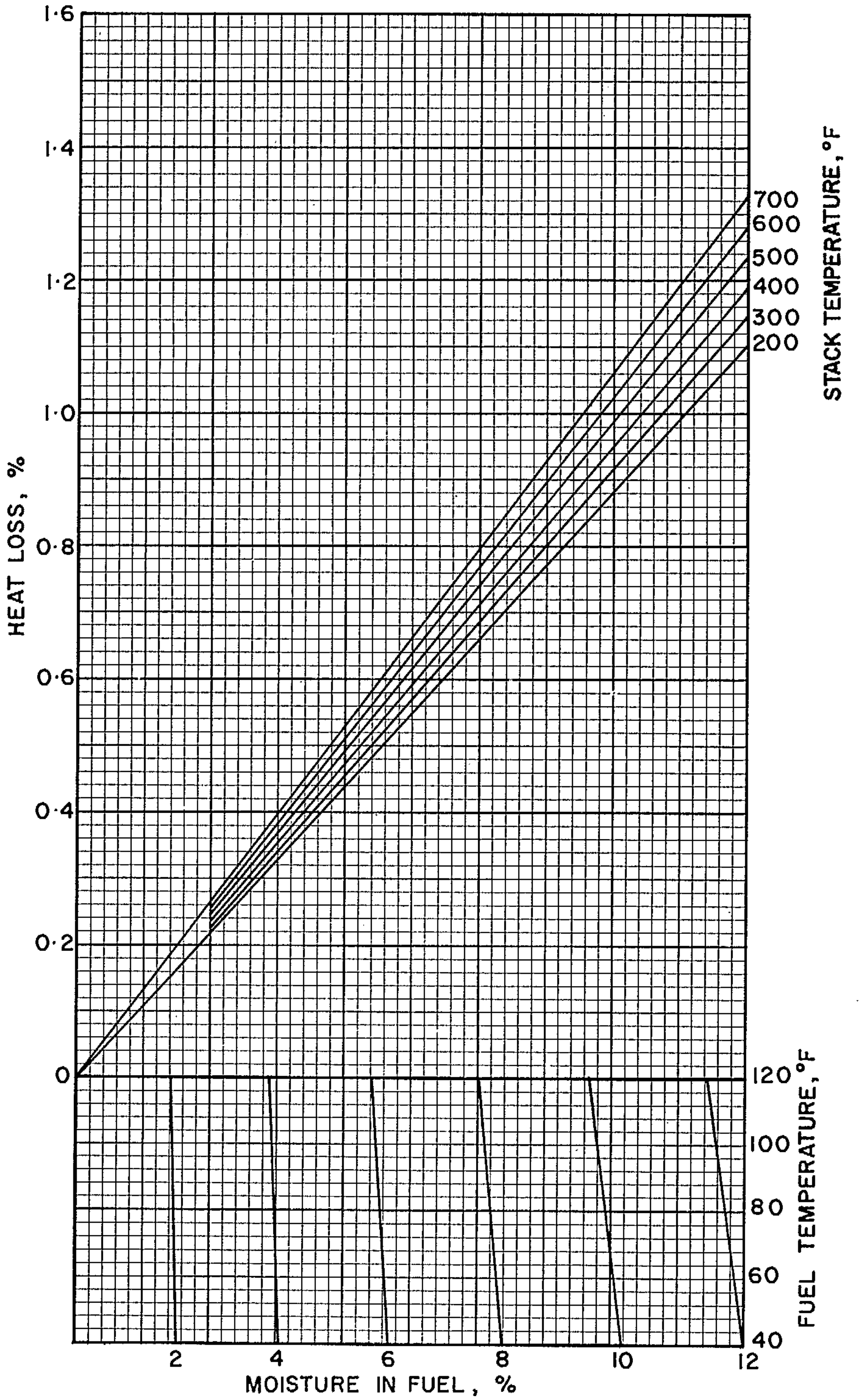


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC·4·2

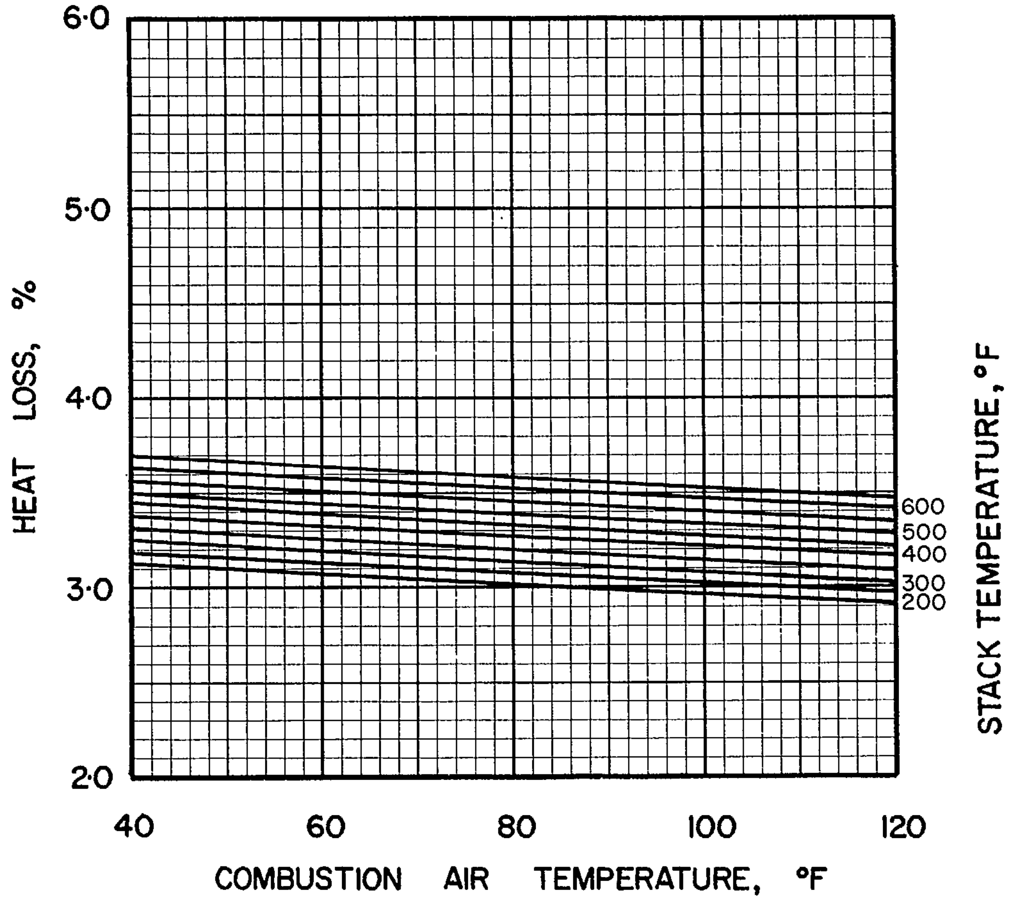


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·4·2

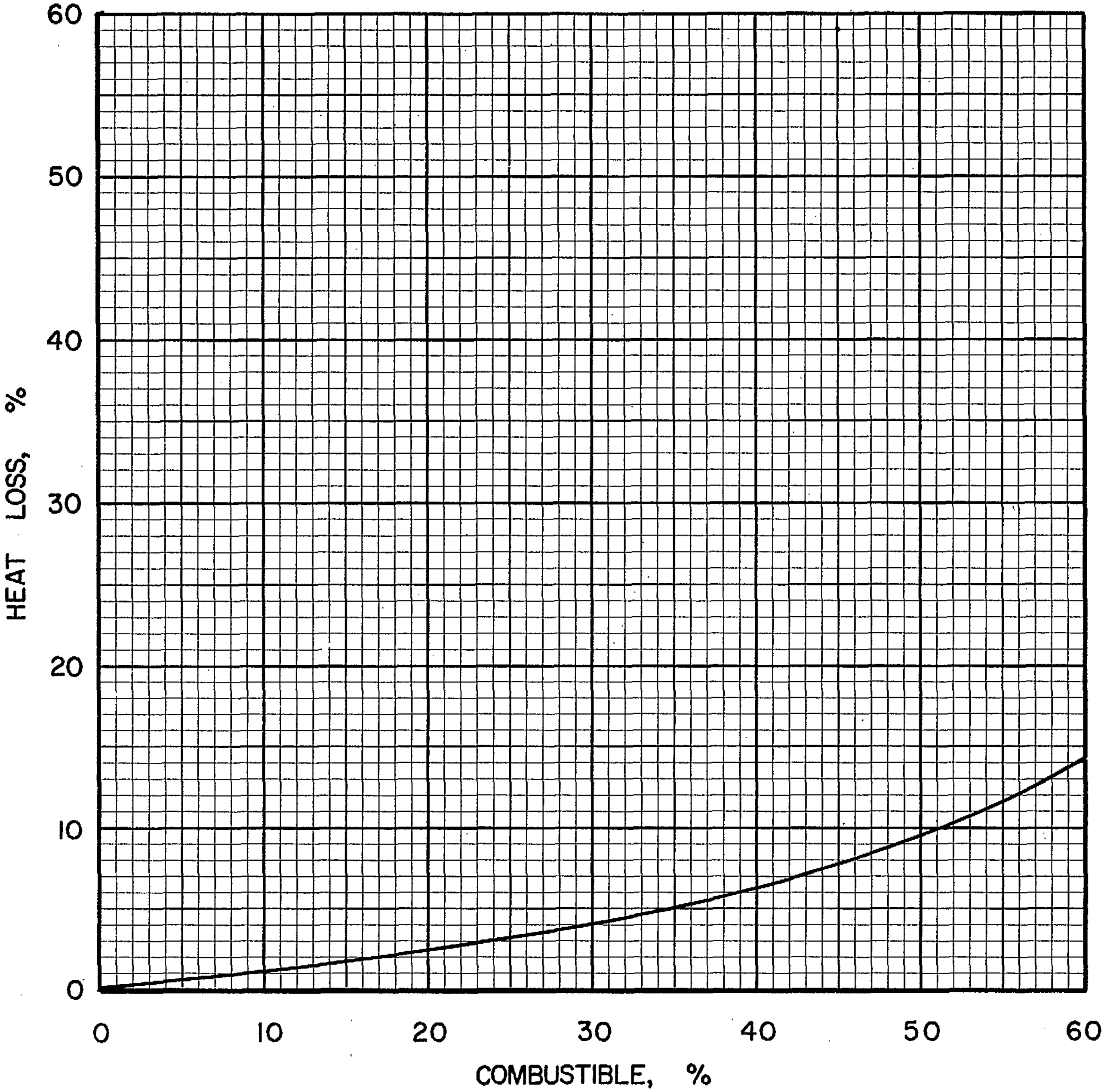


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·4·2

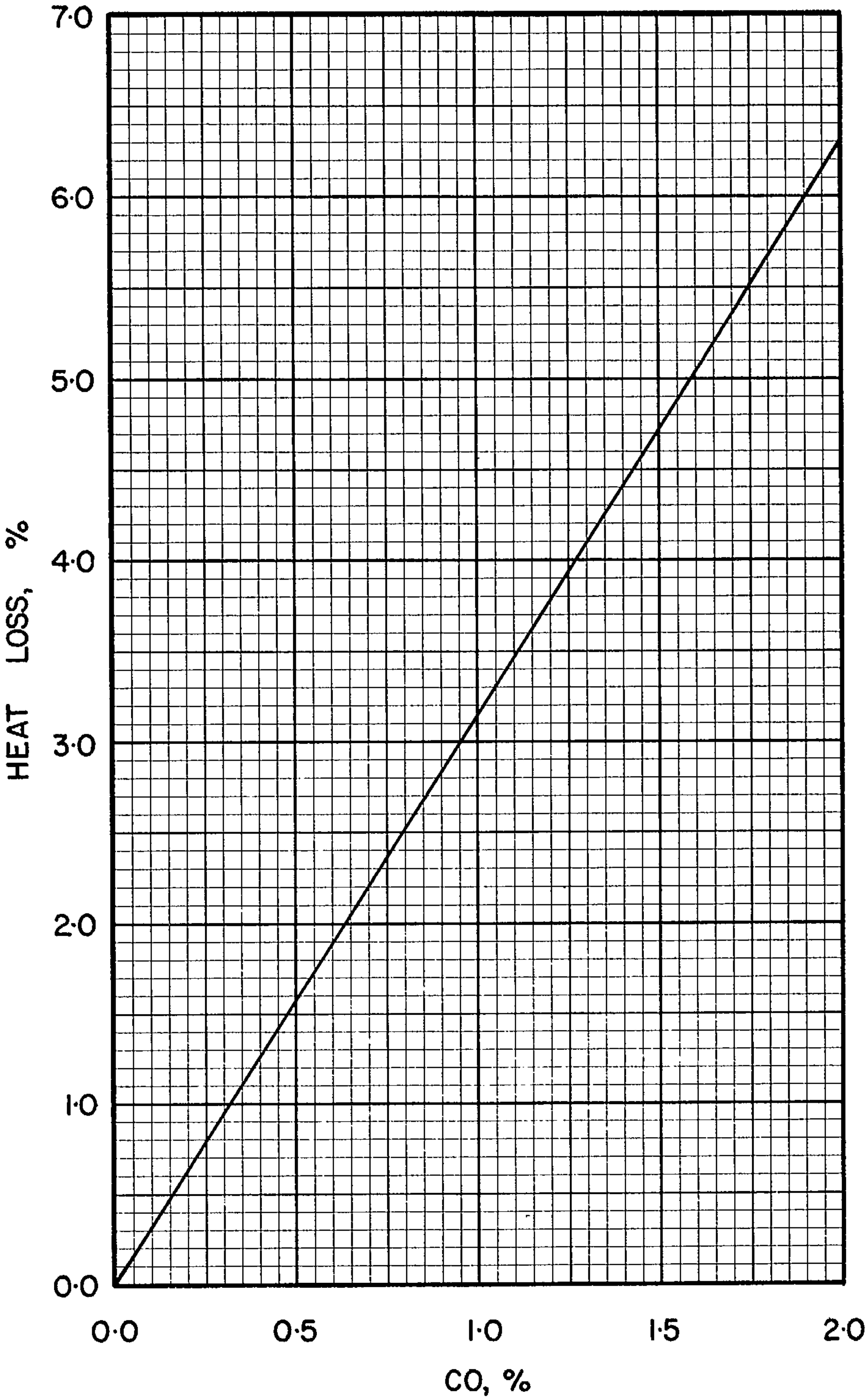


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 4 · 2

COAL ABC 5-1, GREAT CANADIAN OIL SANDS, FORT MCMURRAY, COKE

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0442
Volatile Matter	0.1295
Fixed Carbon	0.8263
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8315
Hydrogen (H)	0.0354
Sulphur (S)	0.0565
Nitrogen (N)	0.0142
Oxygen (O)	0.0182
Ash	0.0442
Total	1.0000

Gross Calorific Value

Btu/lb:	14410
Btu/short ton:	28.82×10^6
Btu/long ton:	32.28×10^6
MJ/kg:	33.51

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 69.40 lb
10^6 Btu = 0.03470 short tons
10^6 Btu = 0.03098 long tons

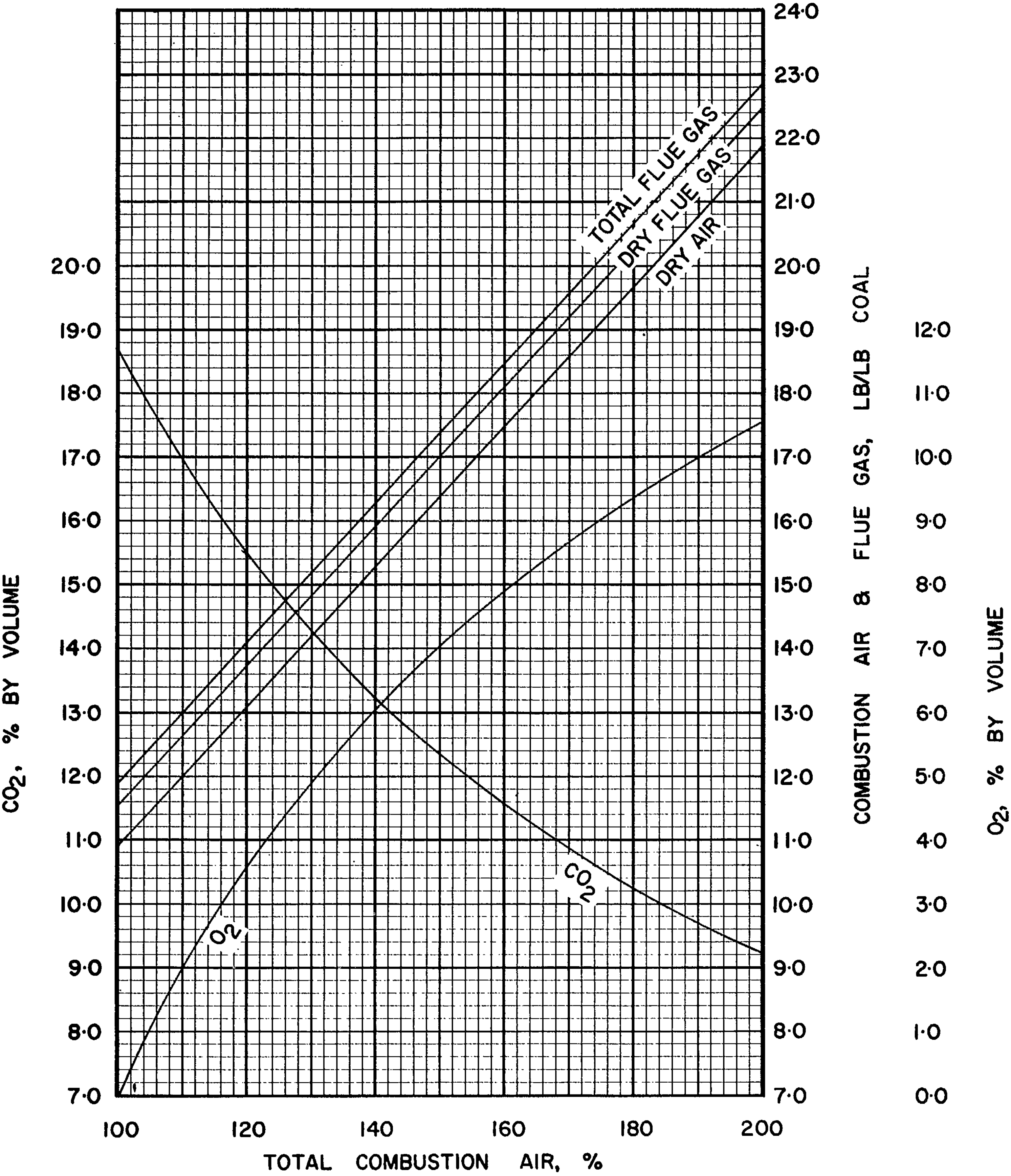


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC · 5 · 1

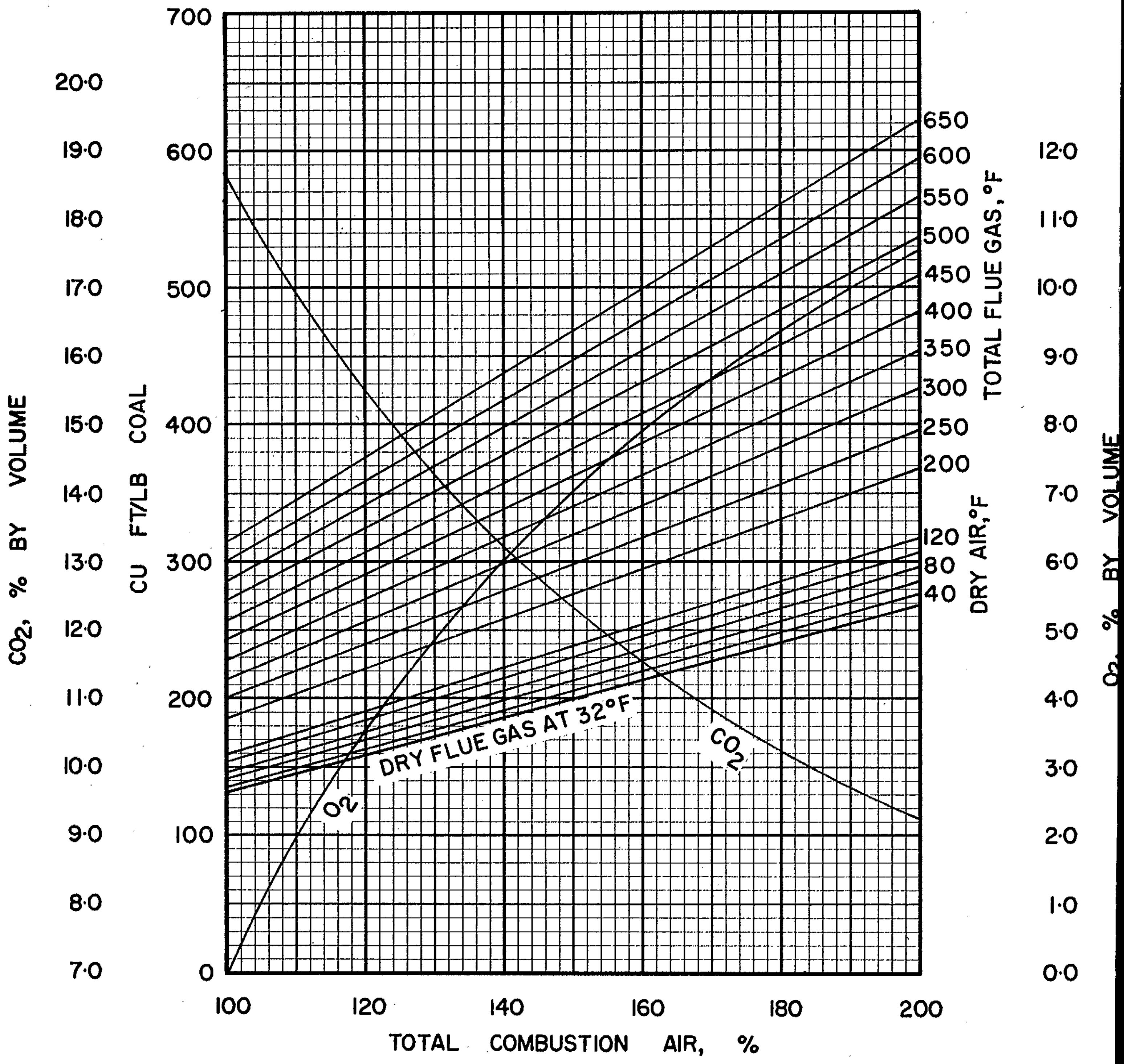


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC·5·1

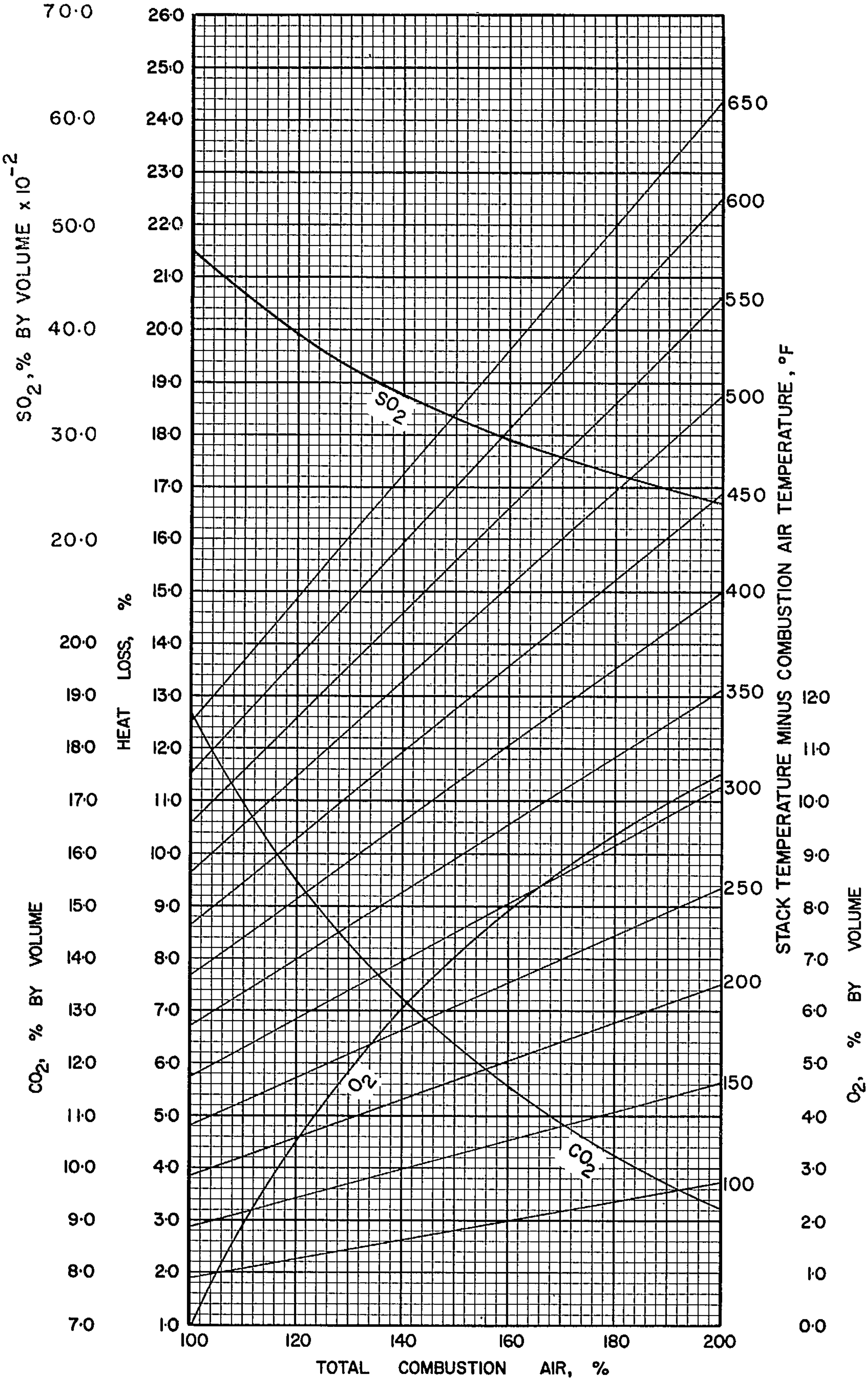


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·5·1

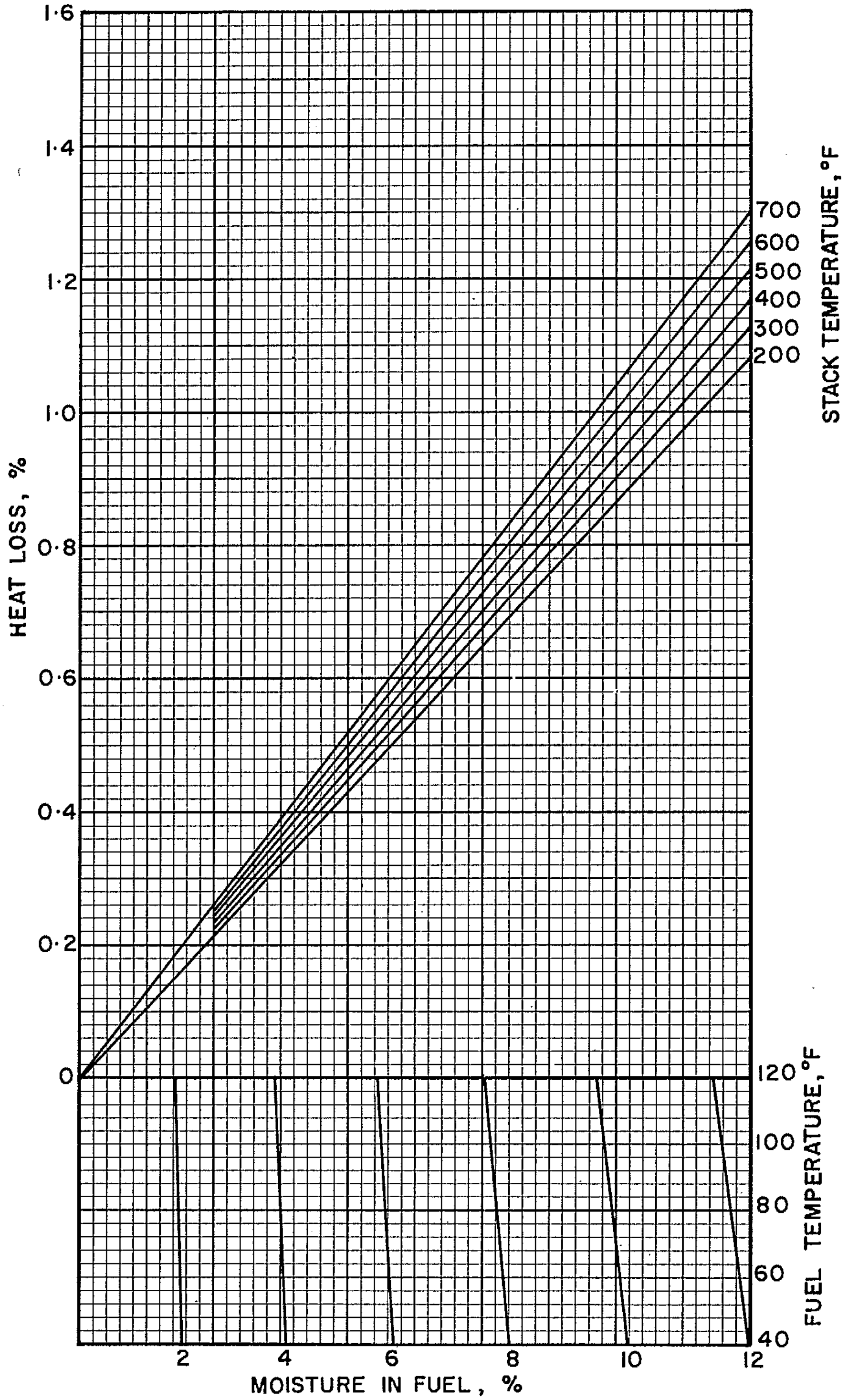


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·5·1

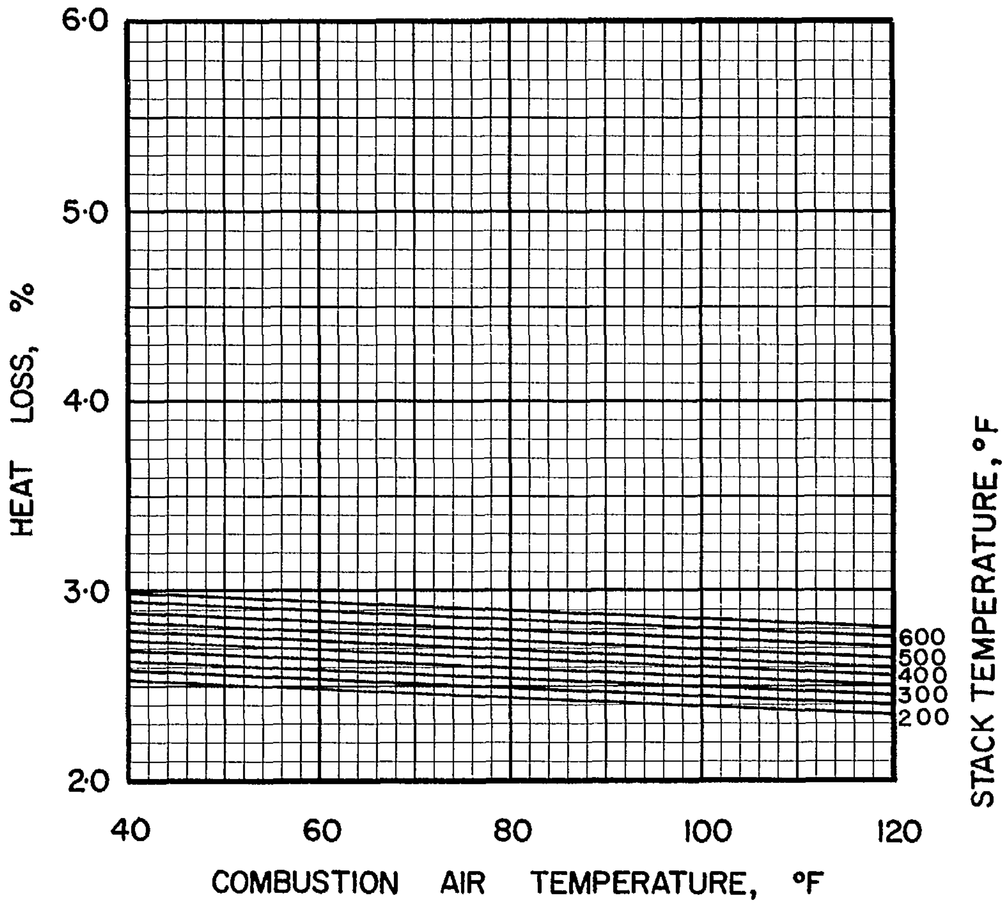


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 5 · 1

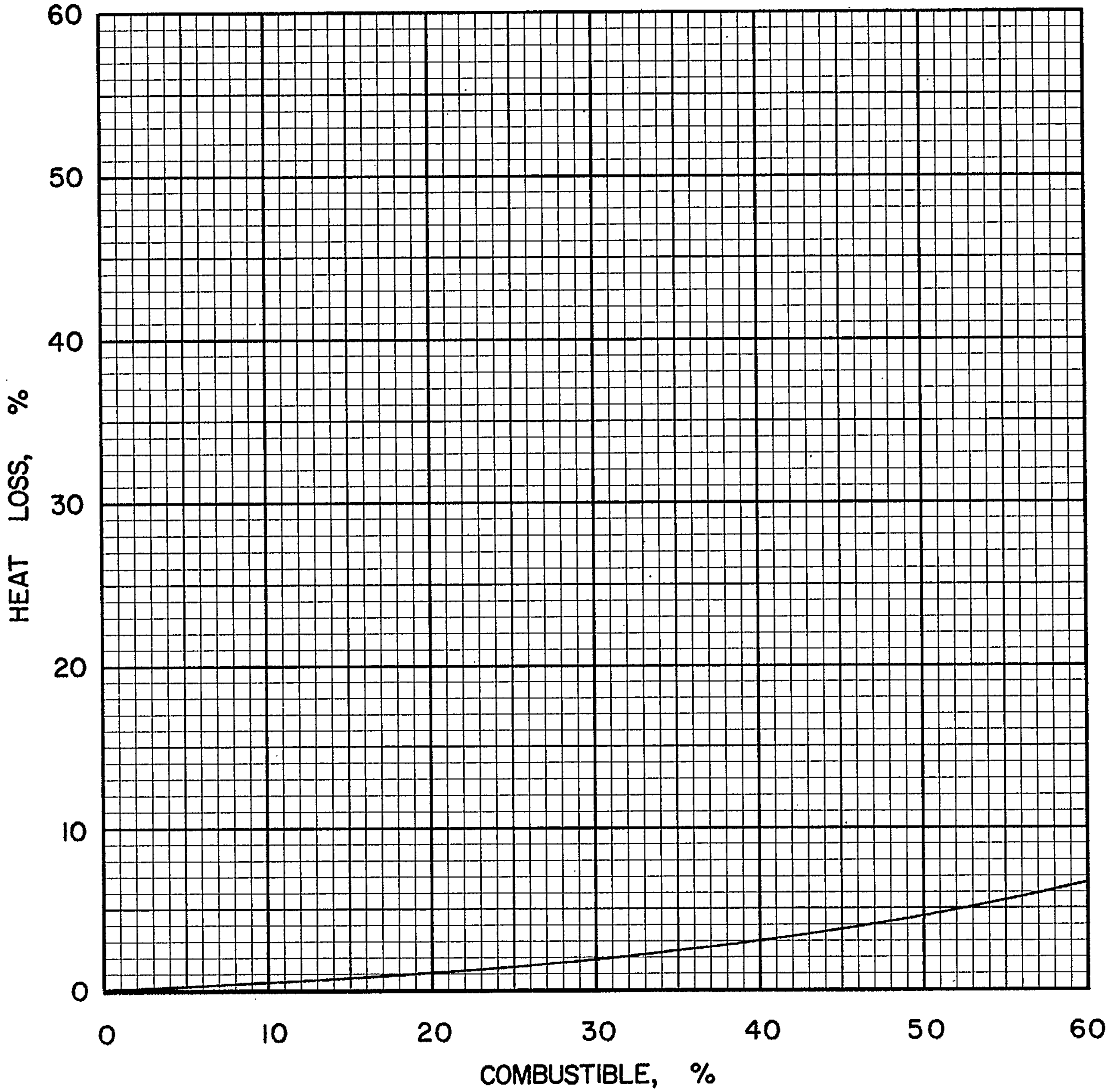


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·5·1

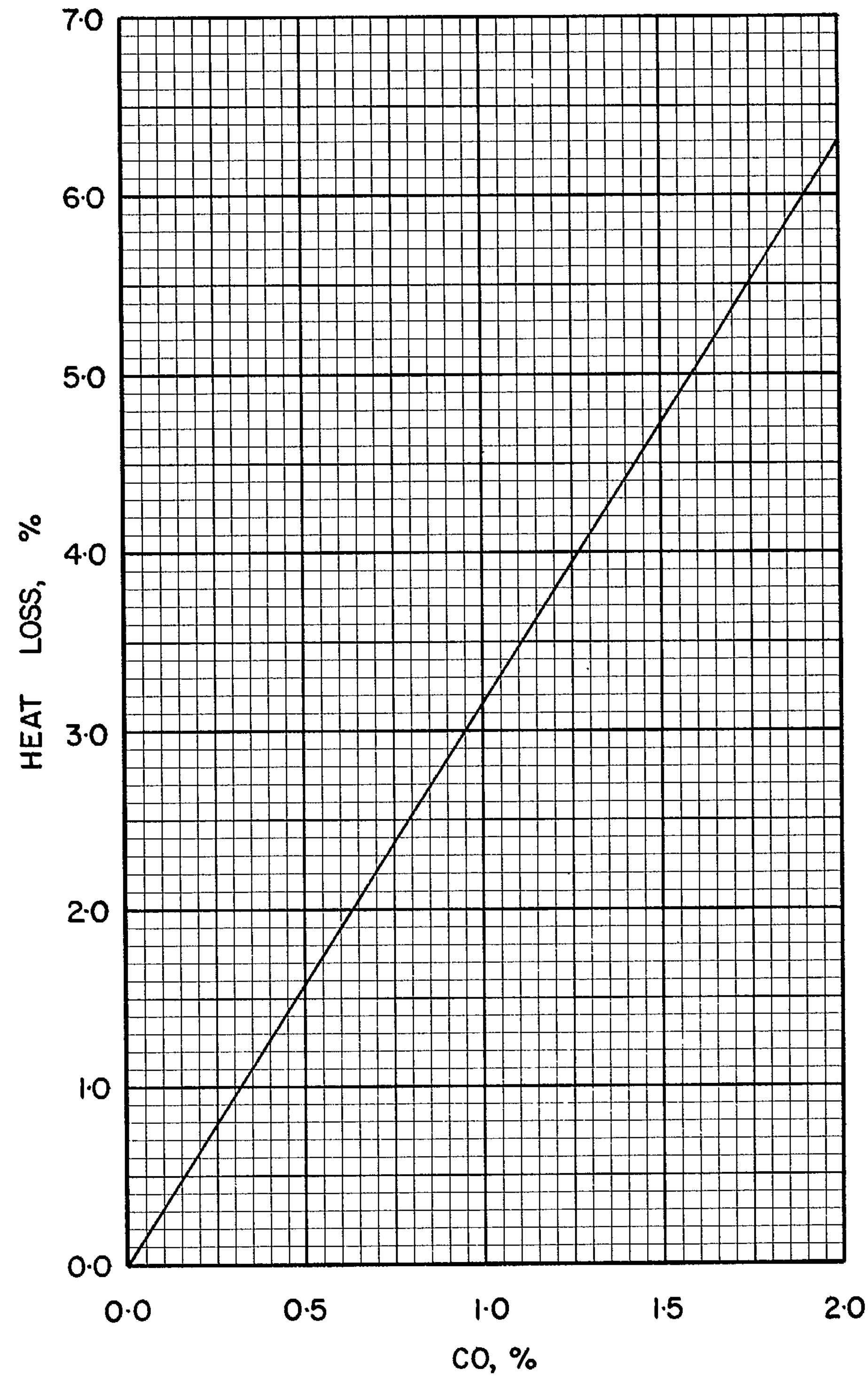


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 5 · 1

COAL ABC 6-1, MACINTYRE PORCUPINE COAL MINES, SMOKEY RIVER, No. 1765, MINE RUN

Typical Moisture Range: 0–4%

Proximate Analysis (lb/lb dry coal)

Ash	0.0628
Volatile Matter	0.1990
Fixed Carbon	0.7382
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.8411
Hydrogen (H)	0.0451
Sulphur (S)	0.0042
Nitrogen (N)	0.0119
Oxygen (O)	0.0349
Ash	0.0628
Total	1.0000

Gross Calorific Value

Btu/lb:	14636
Btu/short ton:	29.27×10^6
Btu/long ton:	32.78×10^6
MJ/kg:	34.04

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 68.32 lb
10^6 Btu = 0.03416 short tons
10^6 Btu = 0.03050 long tons

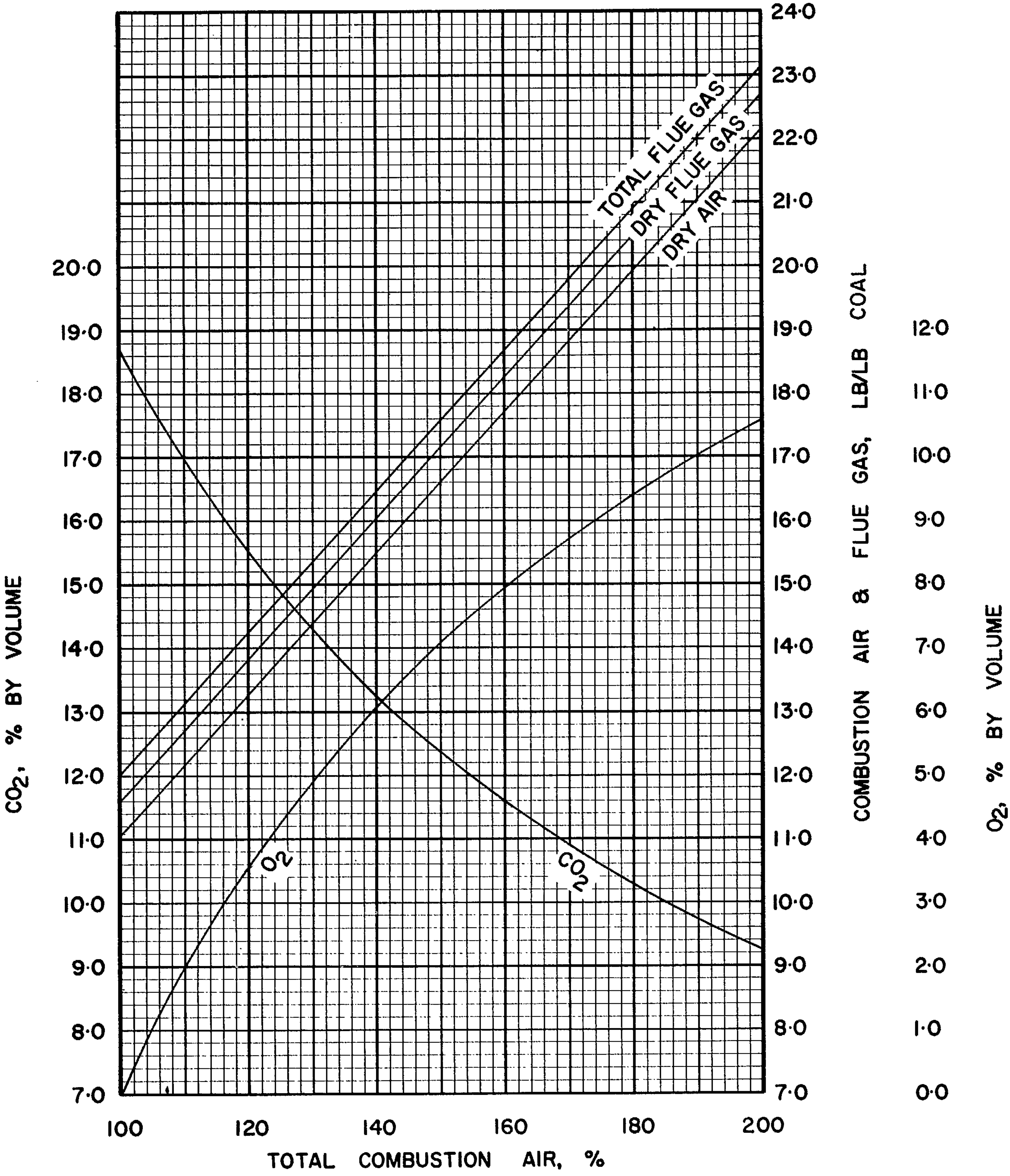


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC-6·1

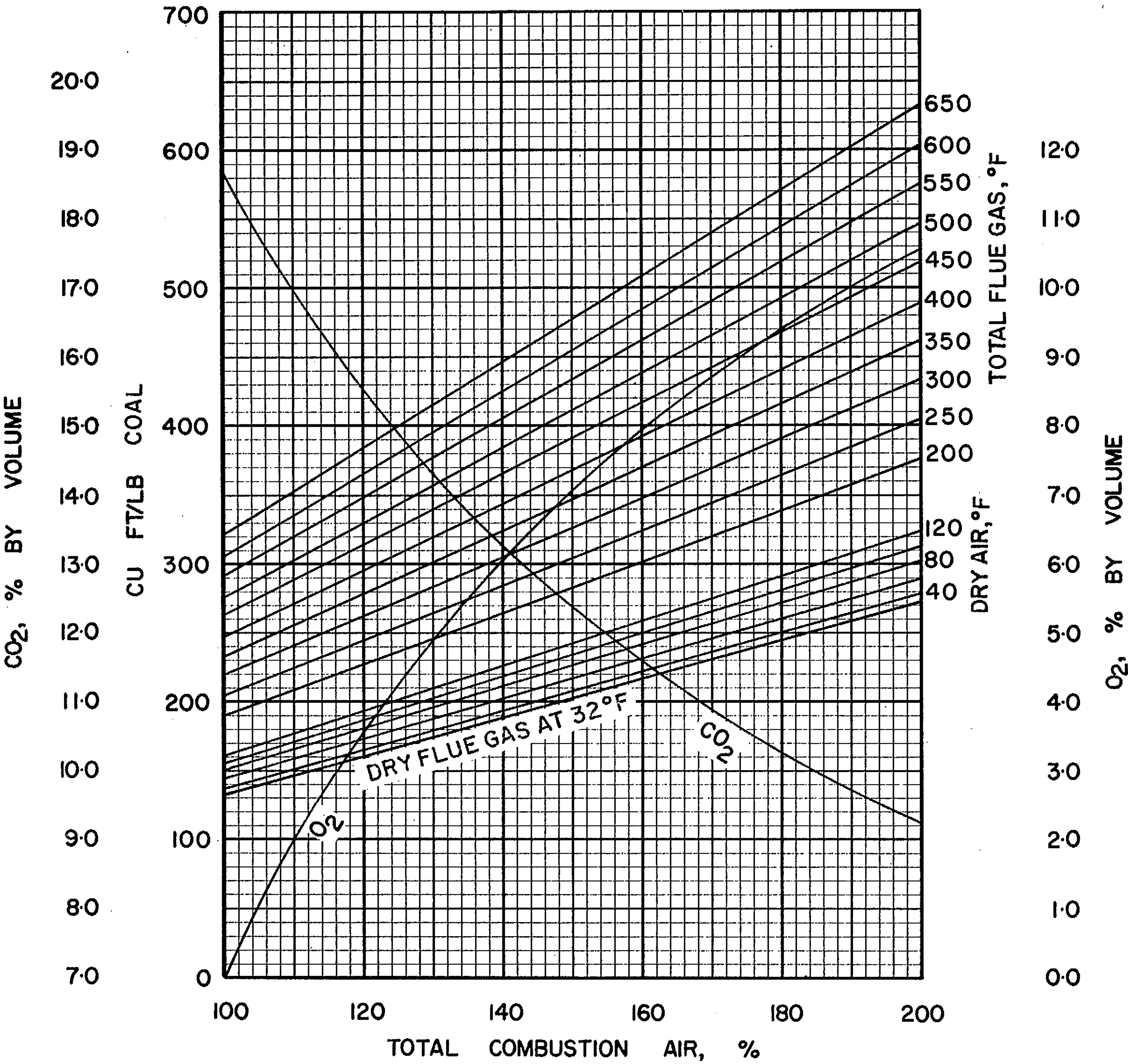


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 6 · 1

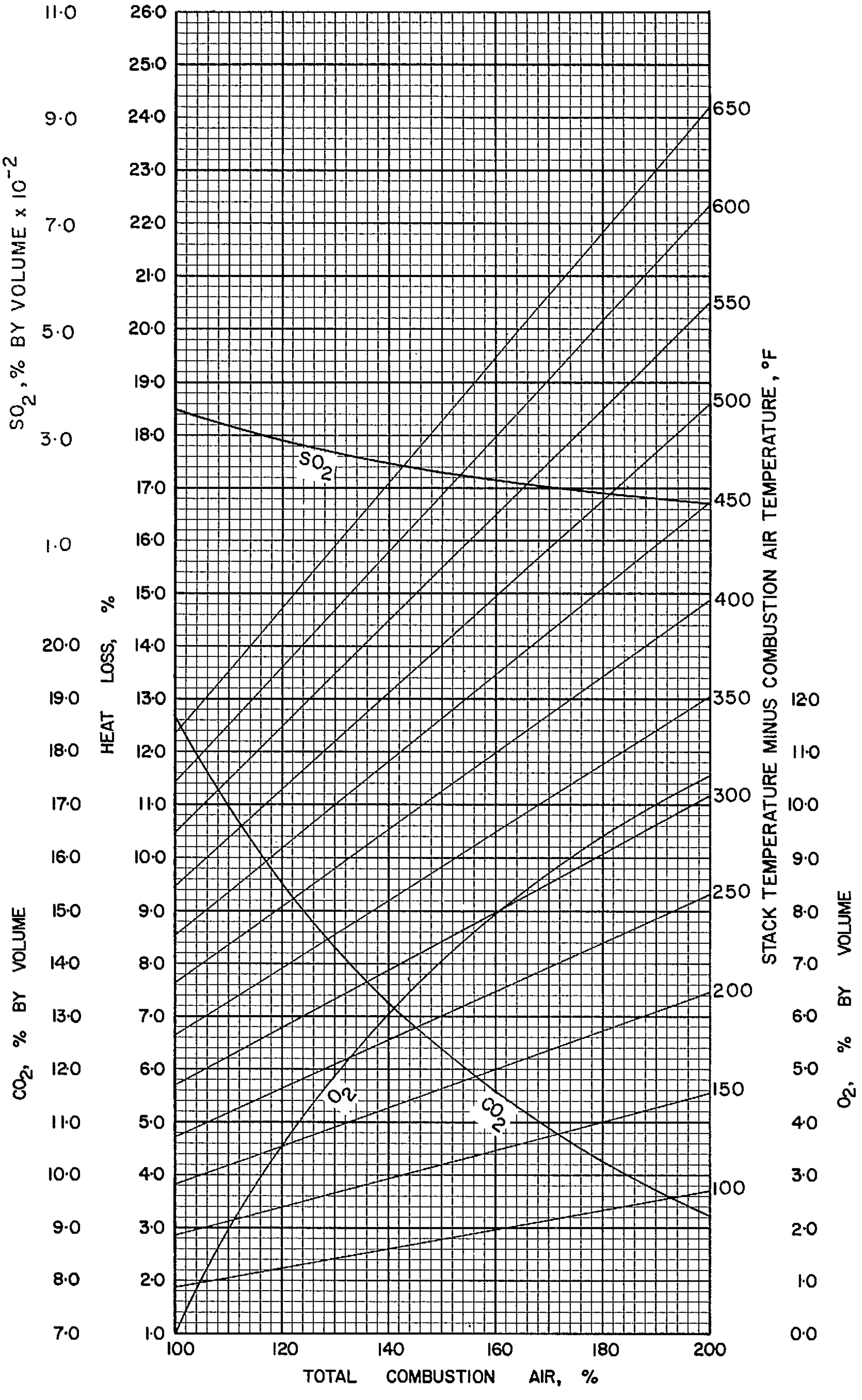


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·6·1

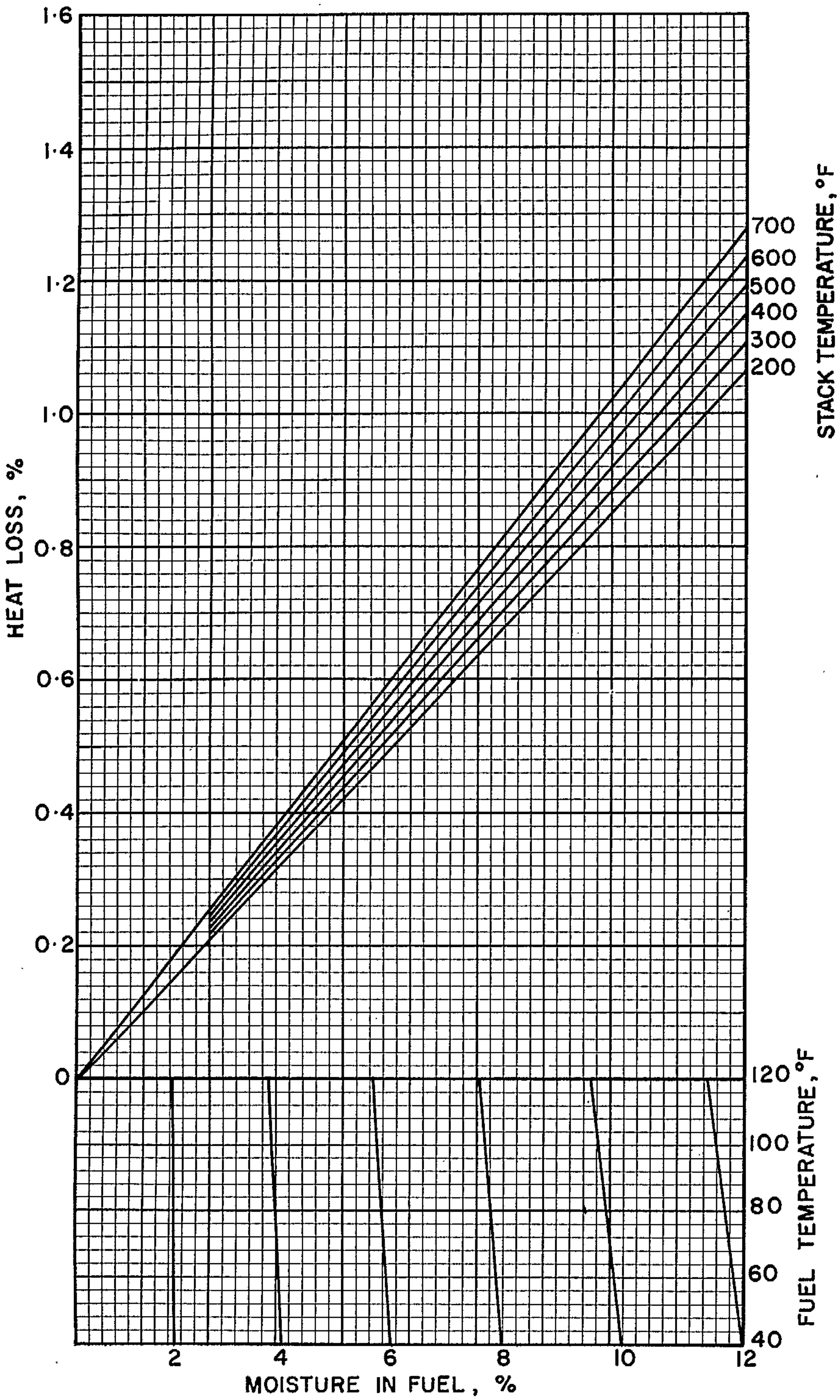


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·6·1

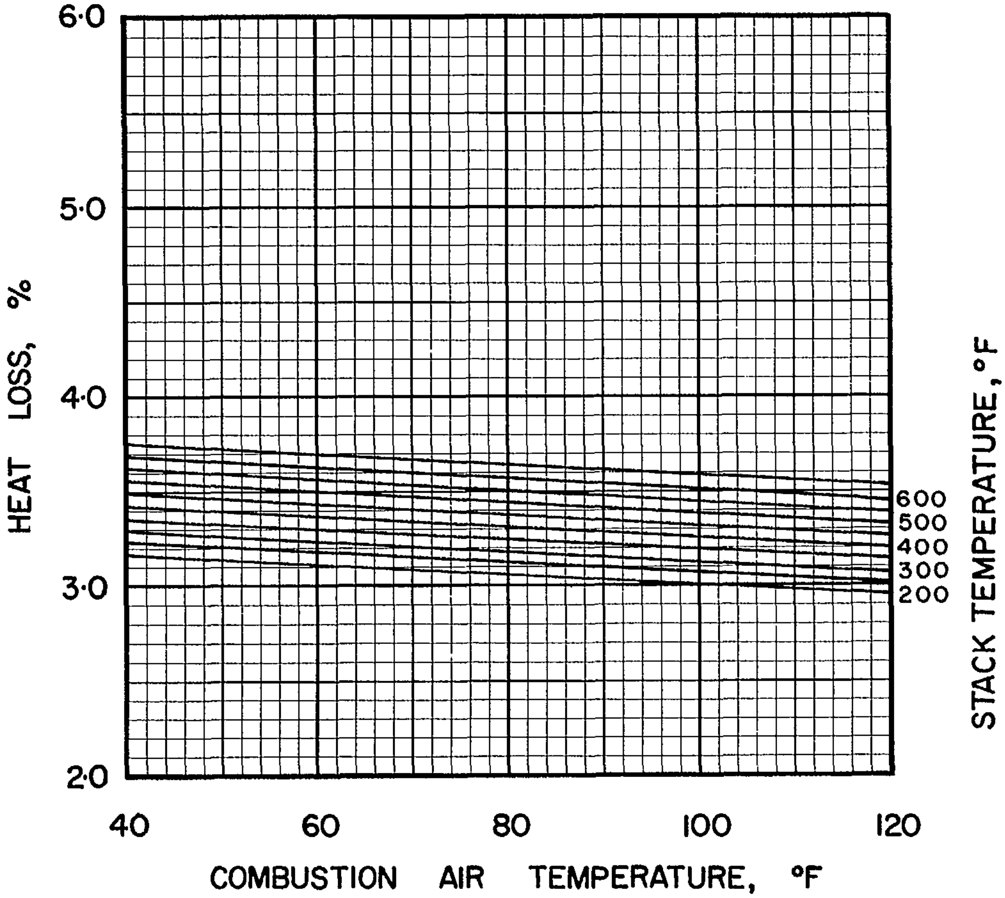


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·6·1

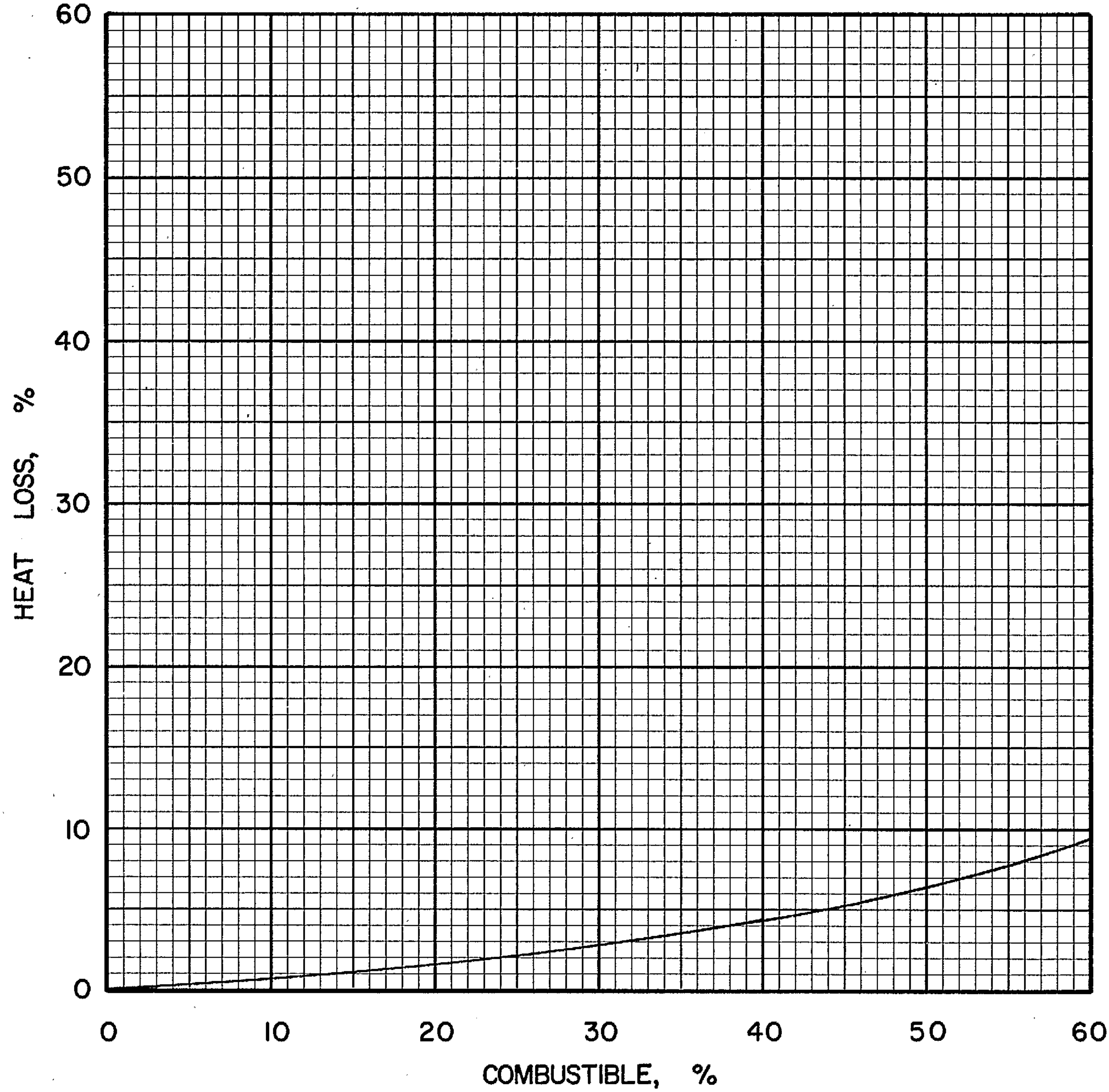


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·6·1

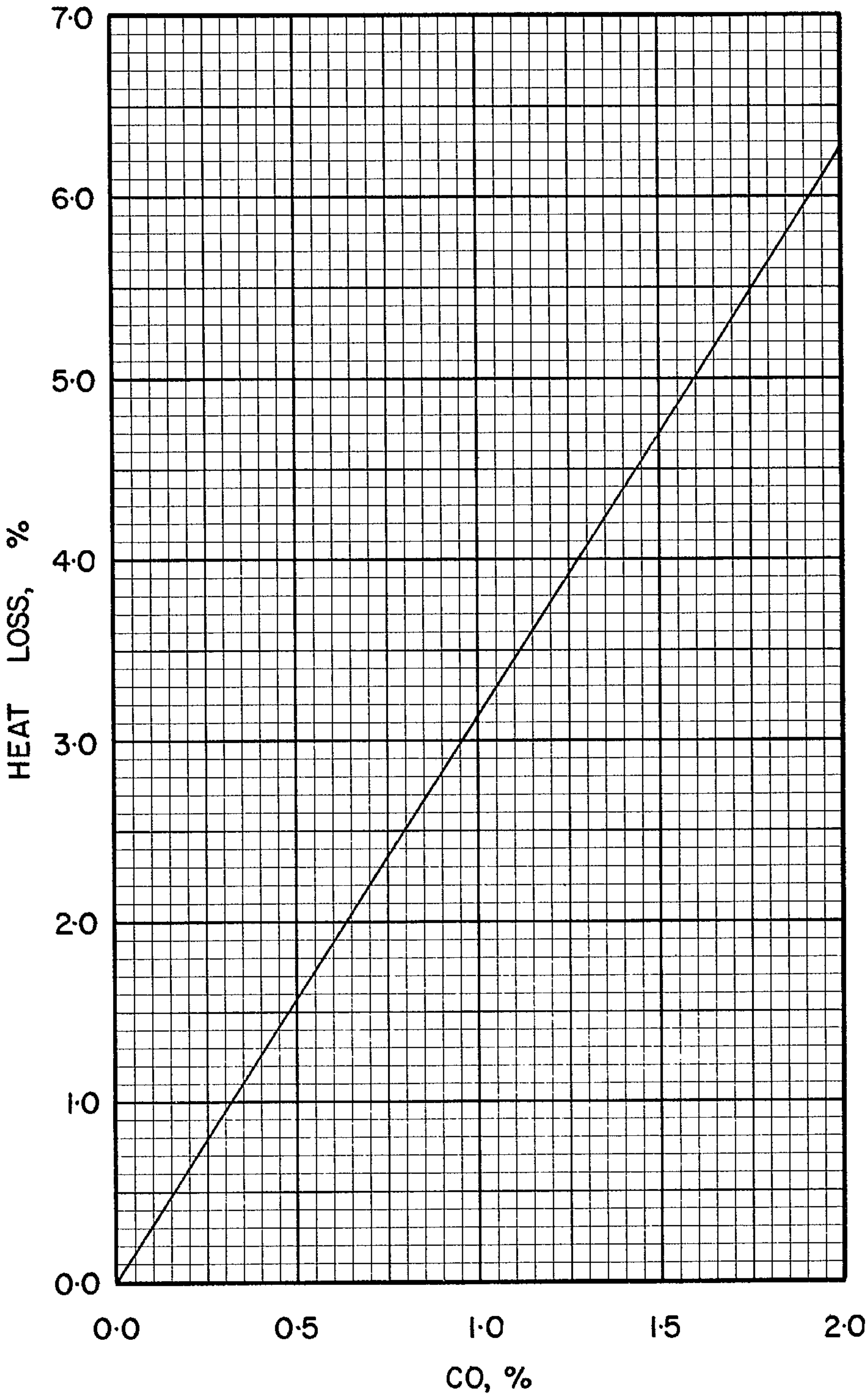


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 6 · 1

COAL ABC 7-1, AMALGAMATED COALS LTD., DRUMHELLER, 1 1/8 in. x 5/8 in.

Typical Moisture Range: 10–25%

Proximate Analysis (lb/lb dry coal)

Ash	0.1228
Volatile Matter	0.3702
Fixed Carbon	0.5070
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6521
Hydrogen (H)	0.0449
Sulphur (S)	0.0075
Nitrogen (N)	0.0145
Oxygen (O)	0.1582
Ash	0.1228
Total	1.0000

Gross Calorific Value

Btu/lb:	11130
Btu/short ton:	22.26×10^6
Btu/long ton:	24.93×10^6
MJ/kg:	25.88

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 89.85	lb	
10^6 Btu	= 0.04492	short tons	
10^6 Btu	= 0.04011	long tons	

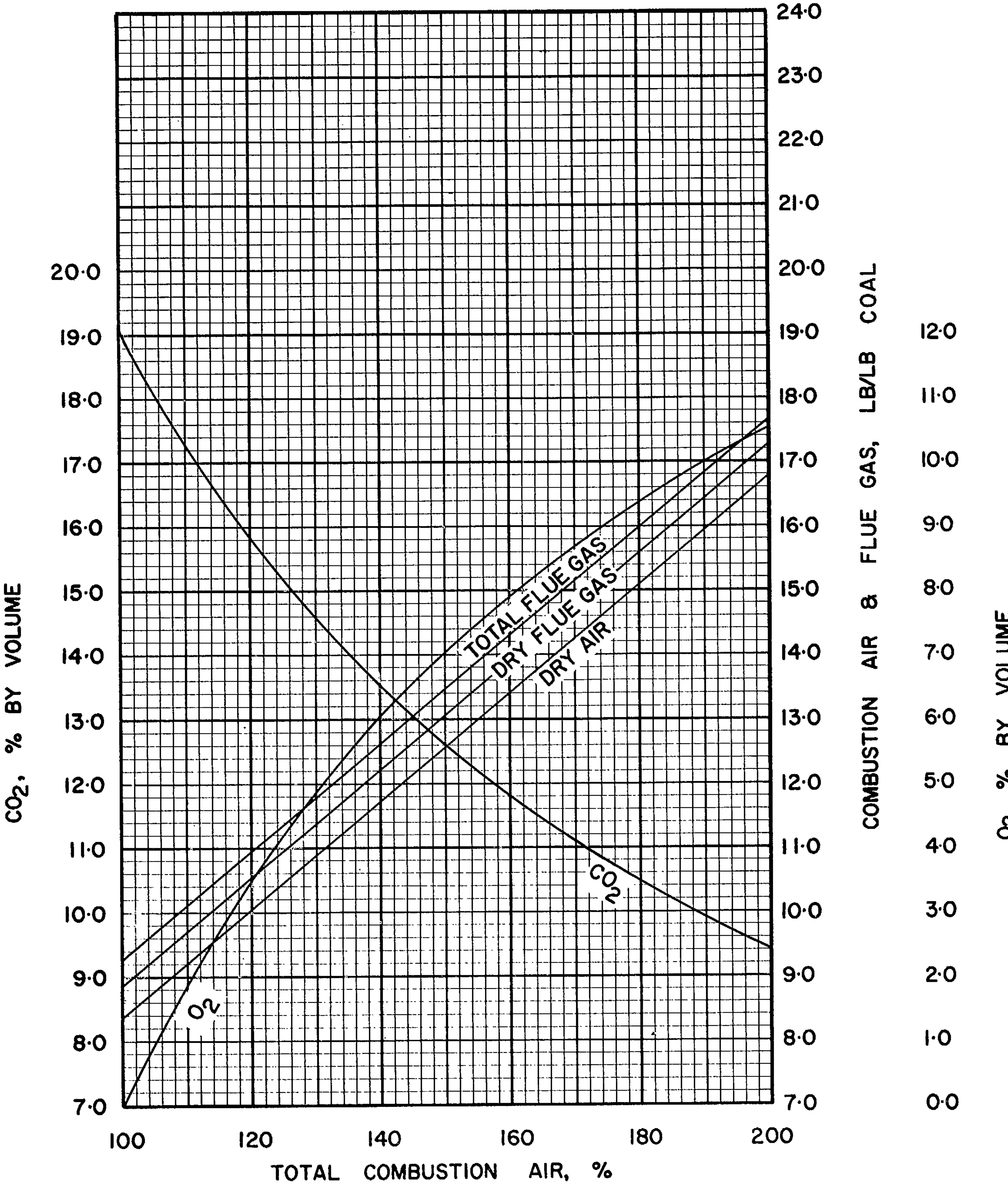


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC· 7·1

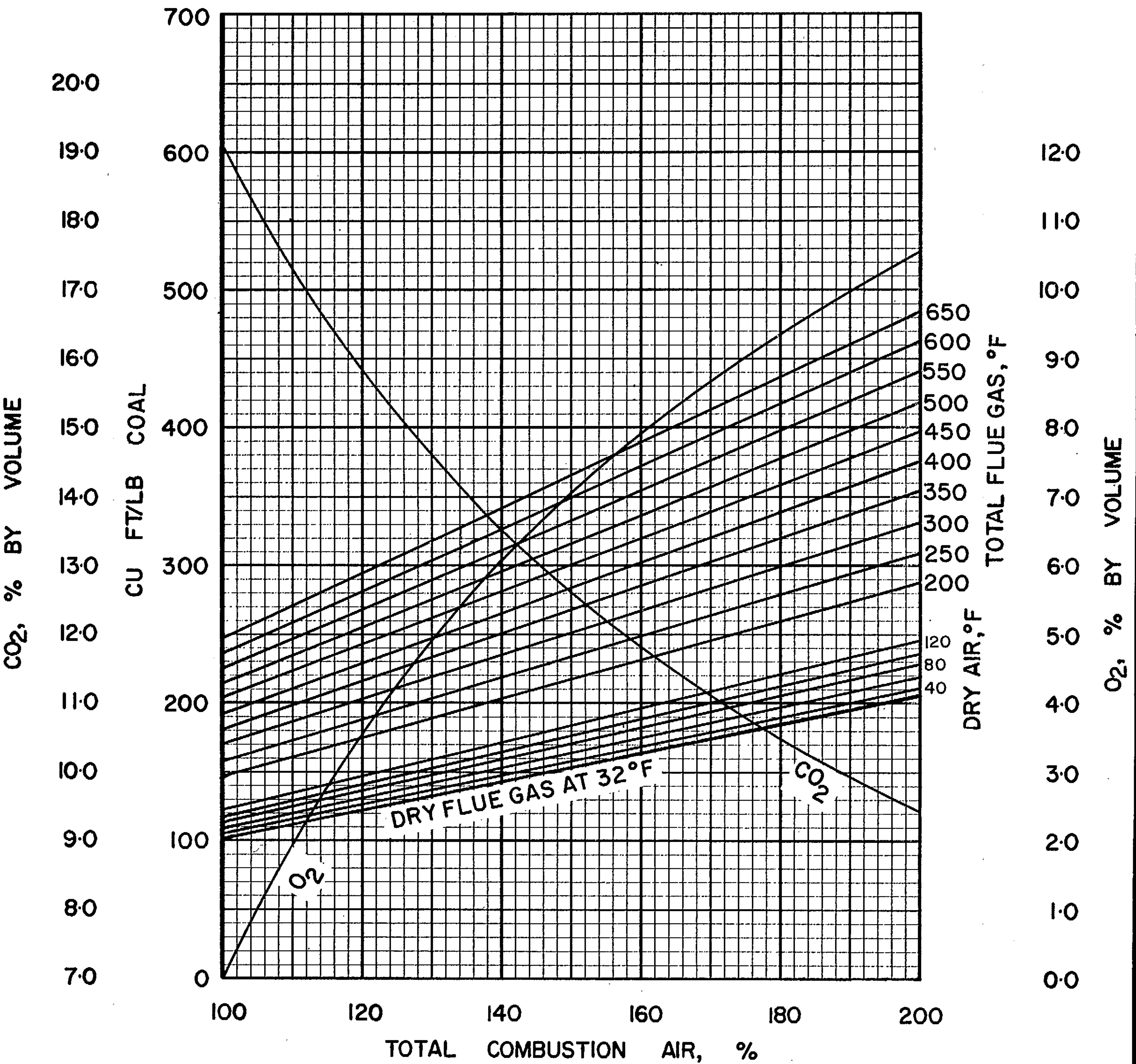


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 7 · 1

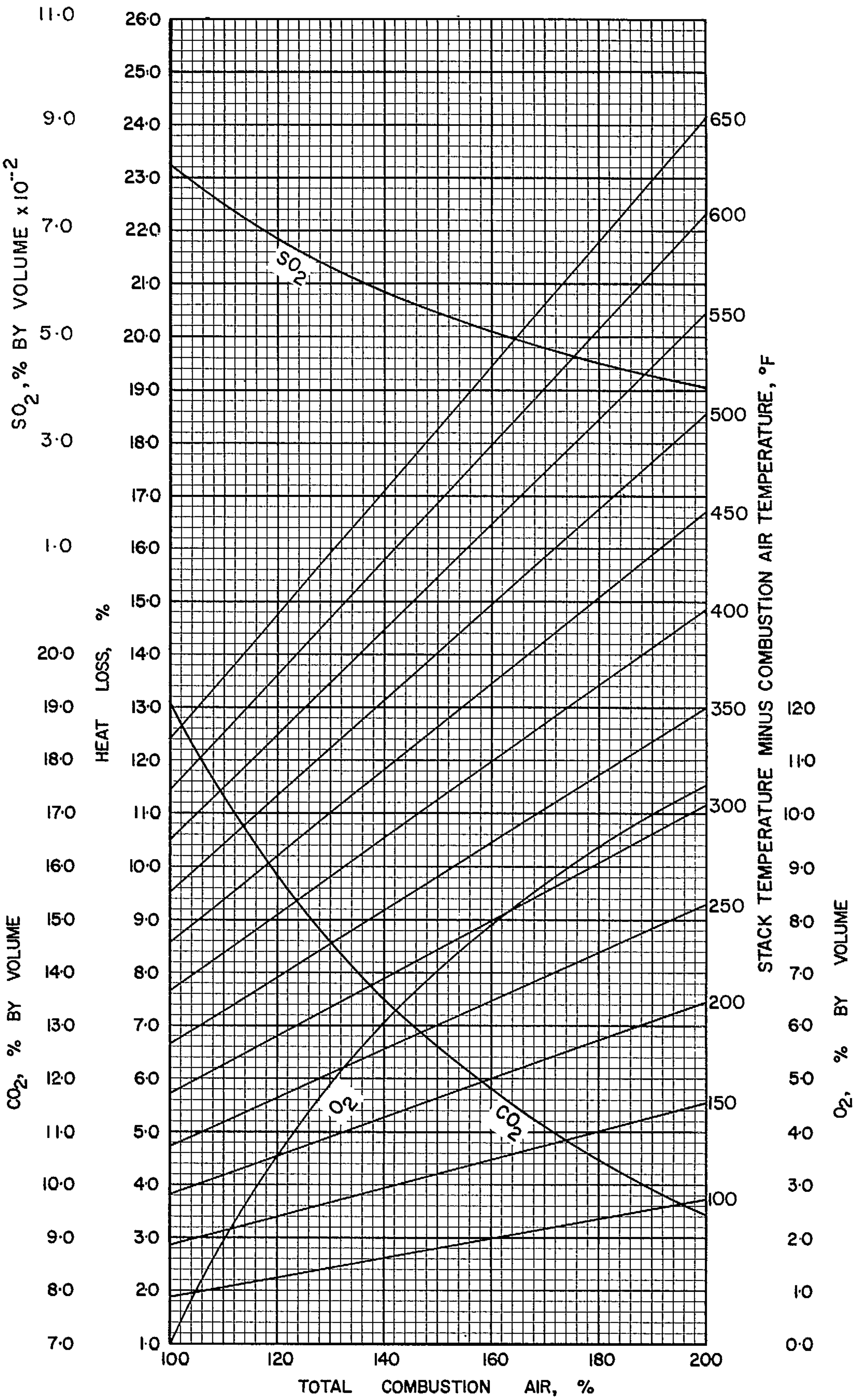


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·7·1

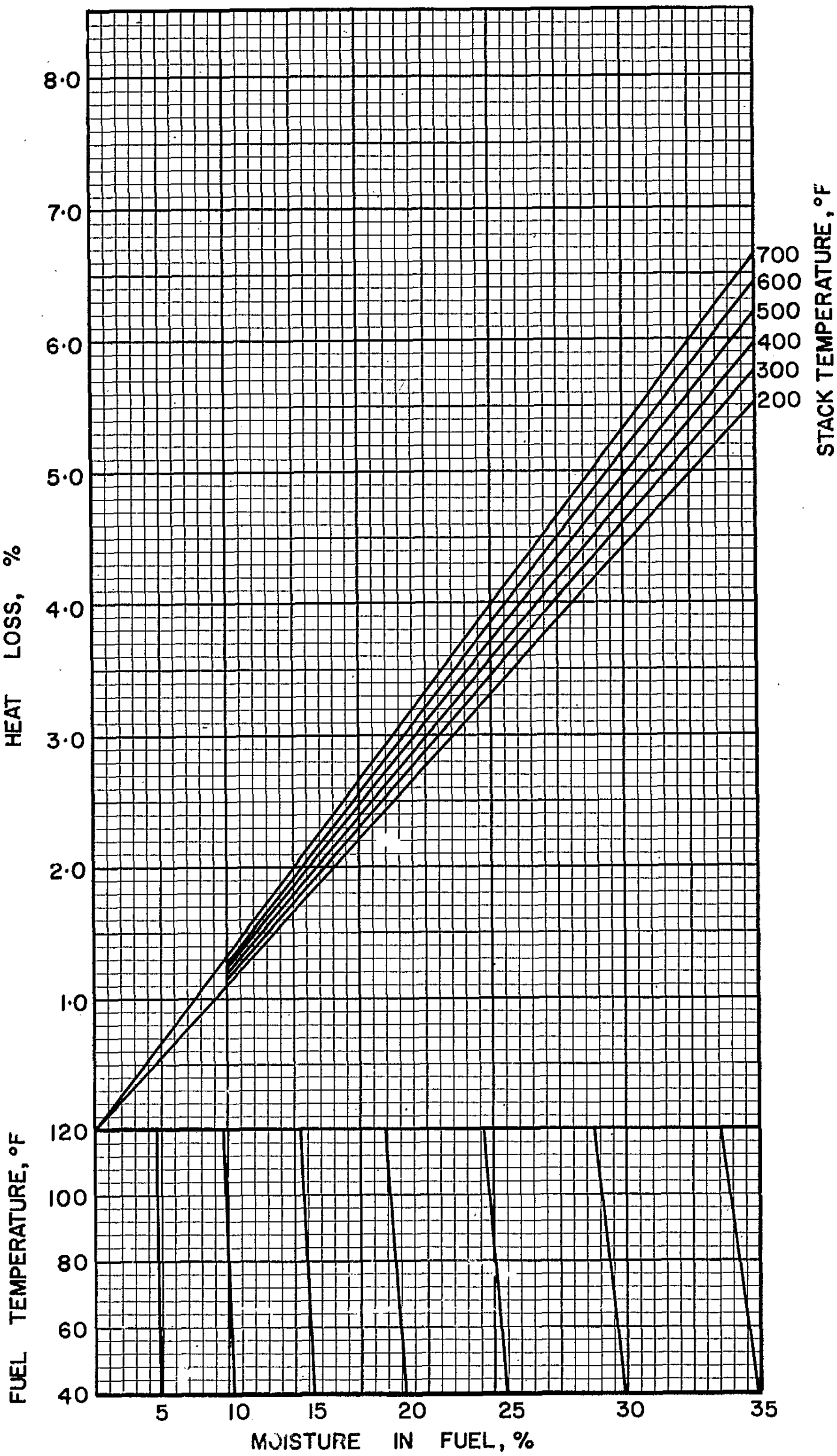


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·7·1

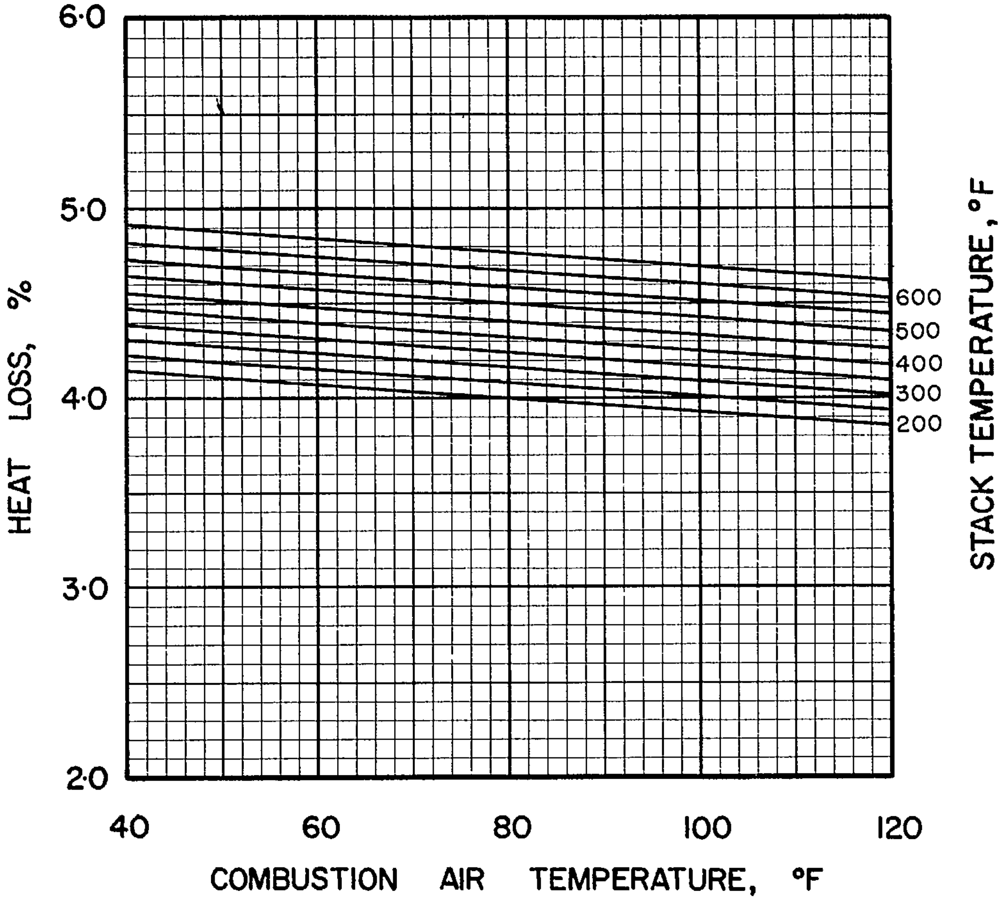


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·7·1

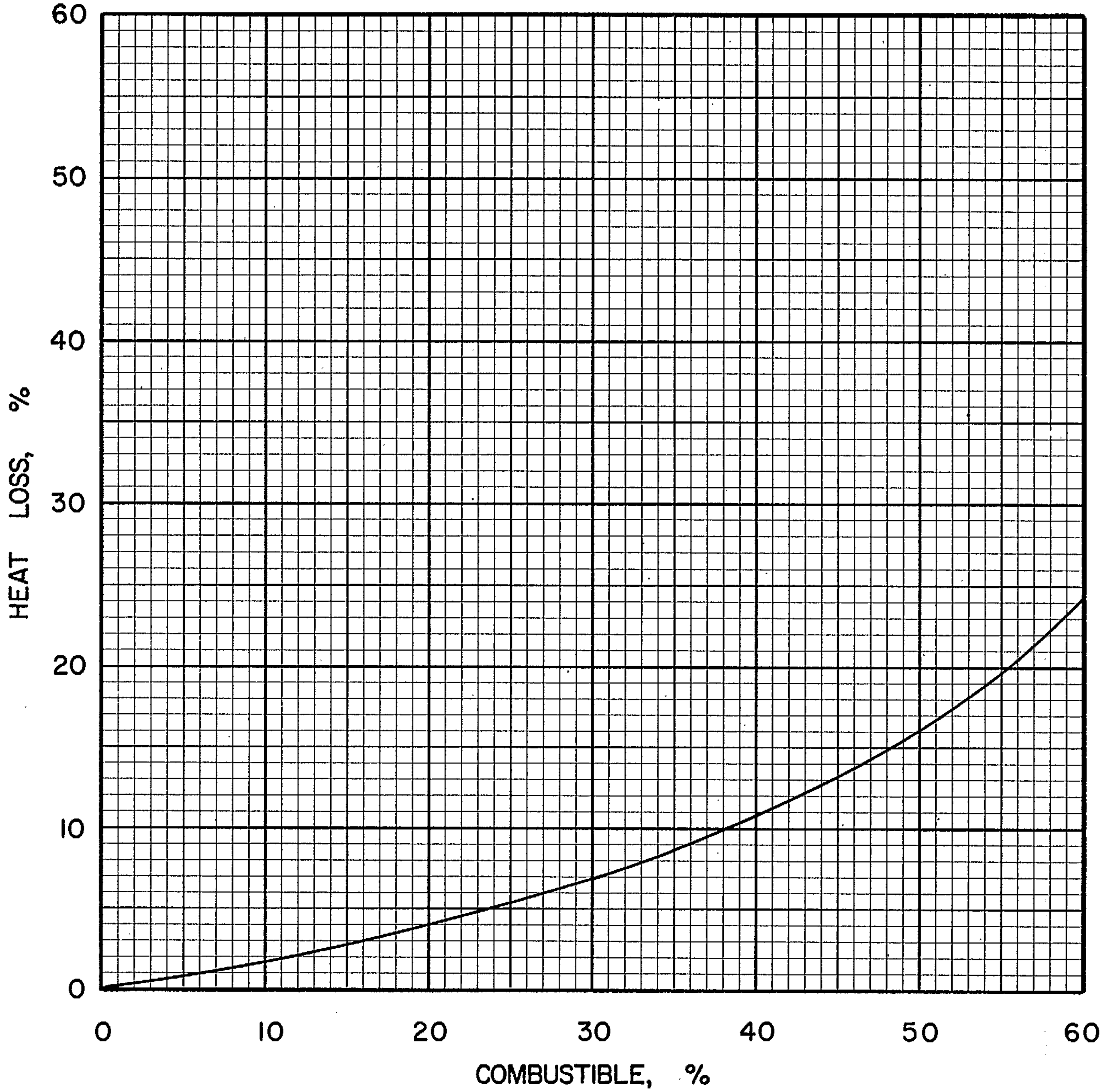


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC-7-1

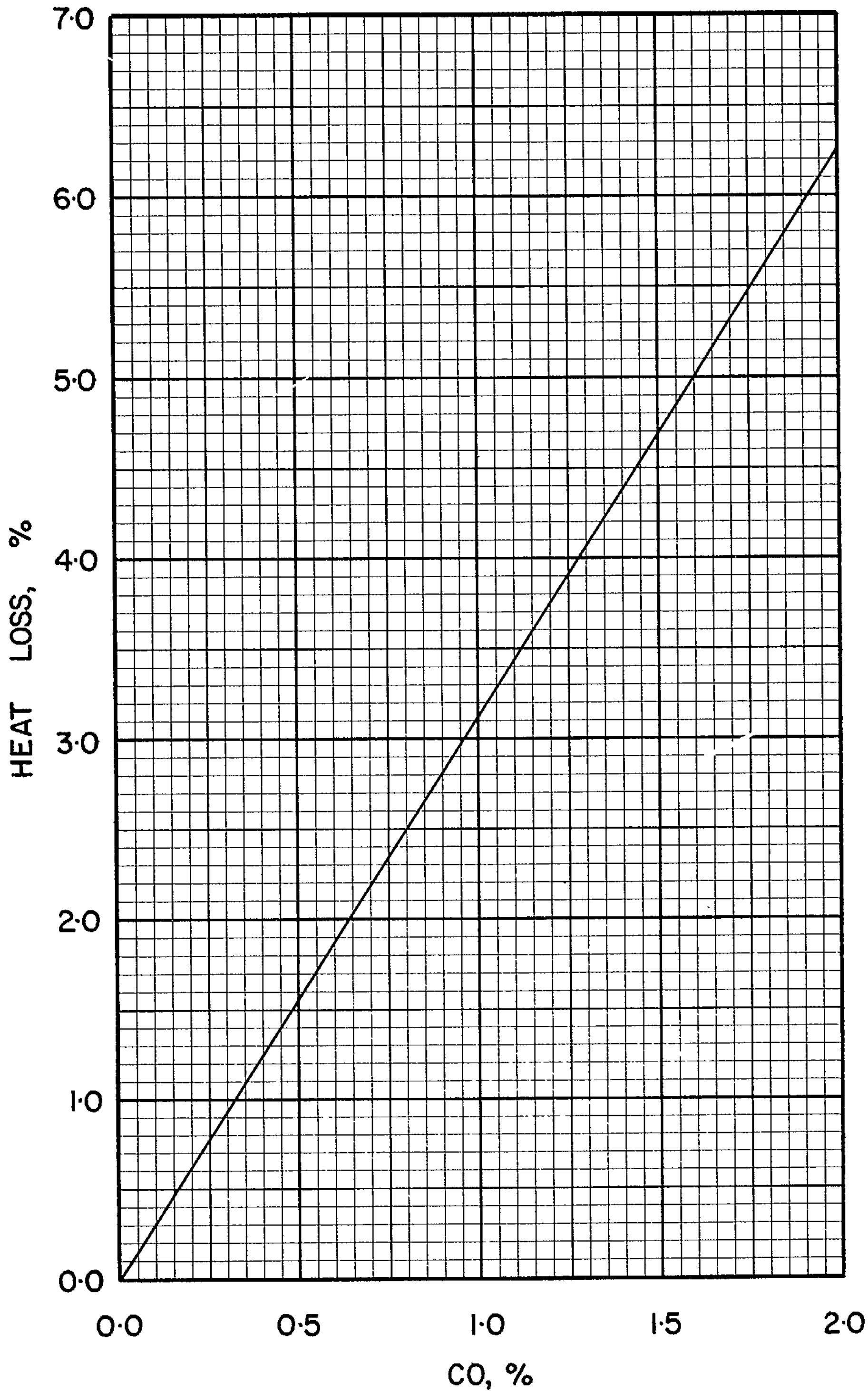


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 7 · 1

COAL ABC 7-2, AMALGAMATED COALS LTD., DRUMHELLER, 5/8 in. x 0

Typical Moisture Range: 10–25%

Proximate Analysis (lb/lb dry coal)

Ash	0.1224
Volatile Matter	0.3679
Fixed Carbon	0.5097
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6538
Hydrogen (H)	0.0439
Sulphur (S)	0.0072
Nitrogen (N)	0.0143
Oxygen (O)	0.1584
Ash	0.1224
Total	1.0000

Gross Calorific Value

Btu/lb:	11080
Btu/short ton:	22.16×10^6
Btu/long ton:	24.82×10^6
MJ/kg:	25.77

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	90.25	lb	
10^6 Btu	=	0.04513	short tons	
10^6 Btu	=	0.04029	long tons	

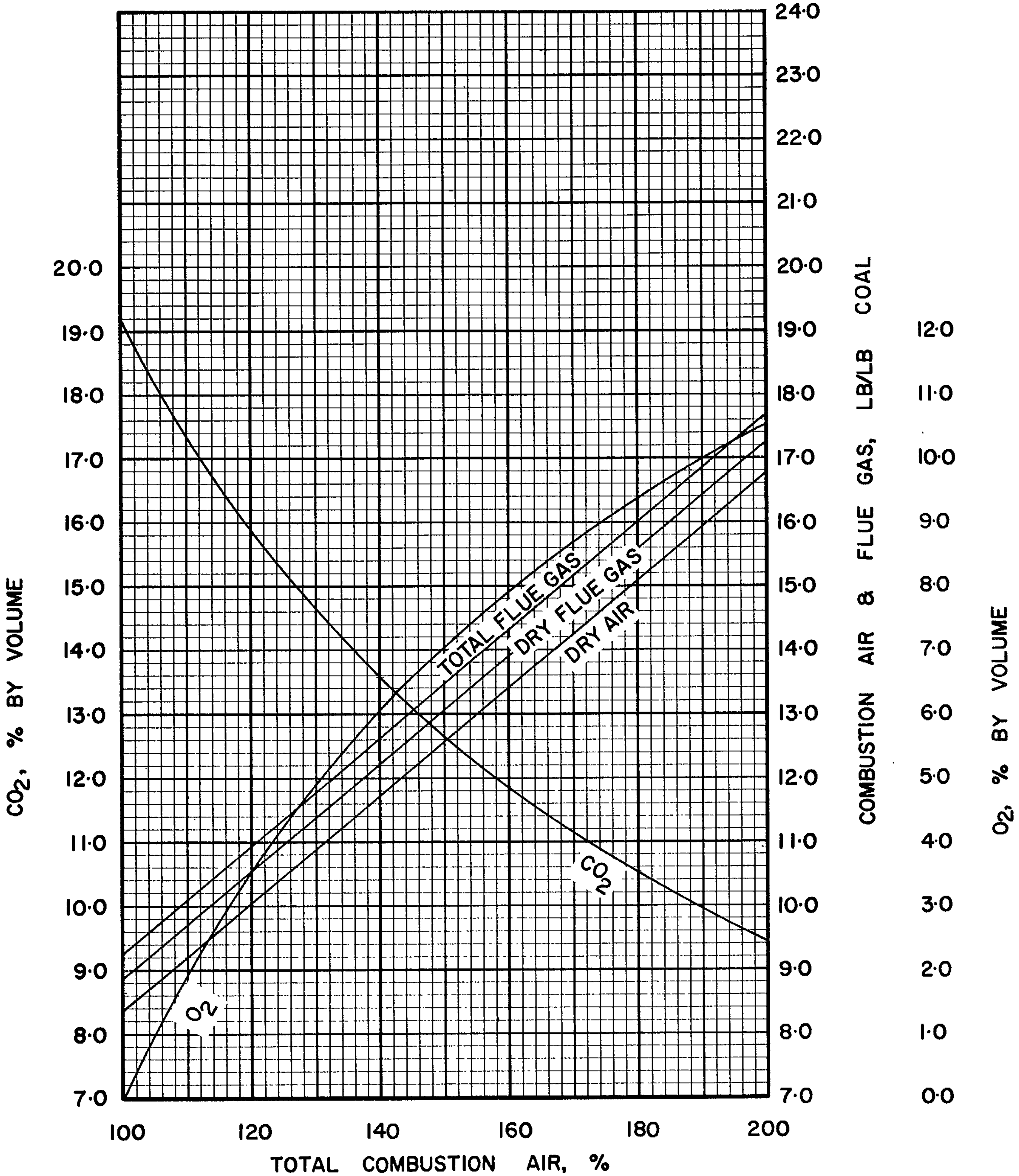


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC·7·2

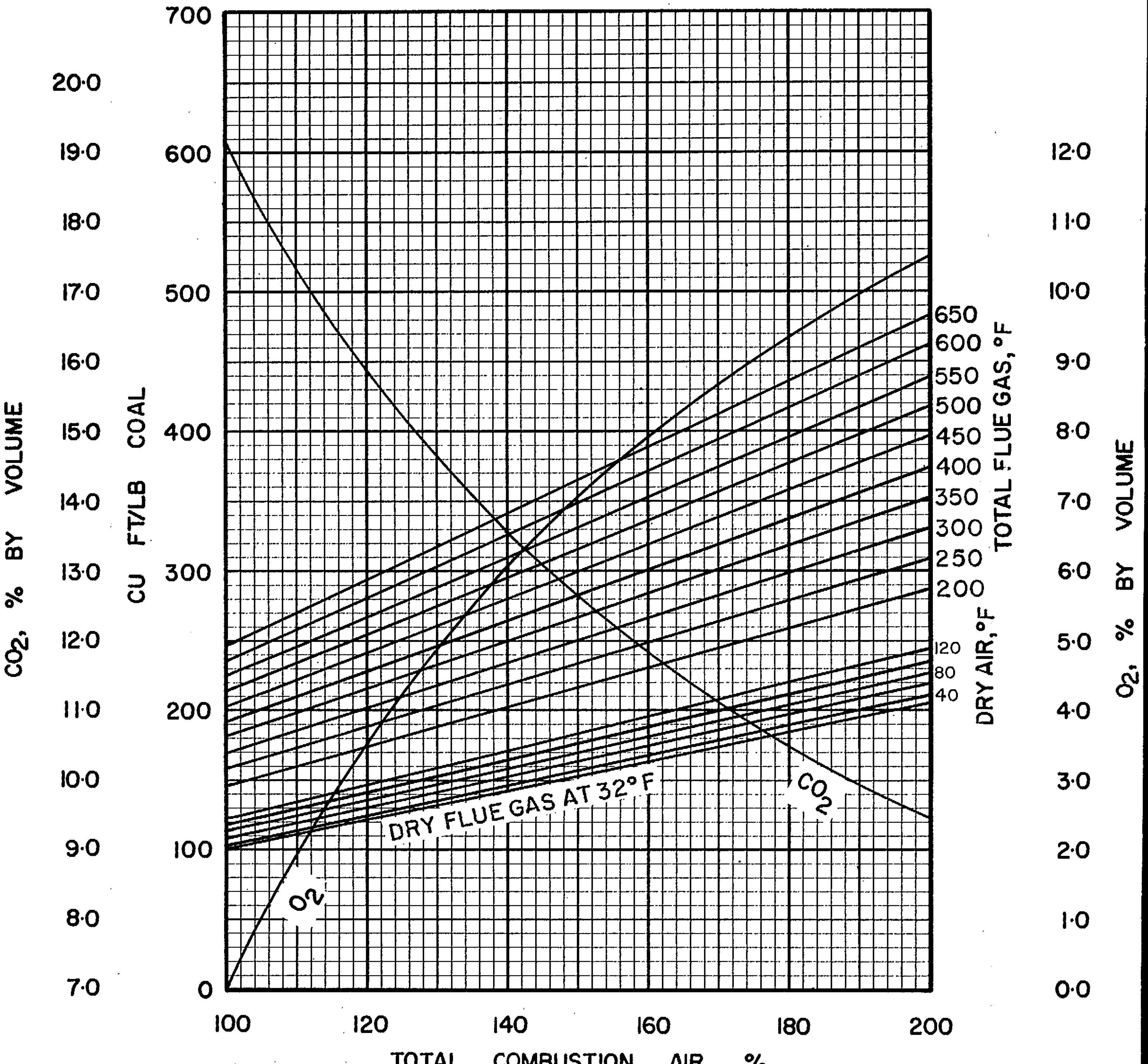


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 7 · 2

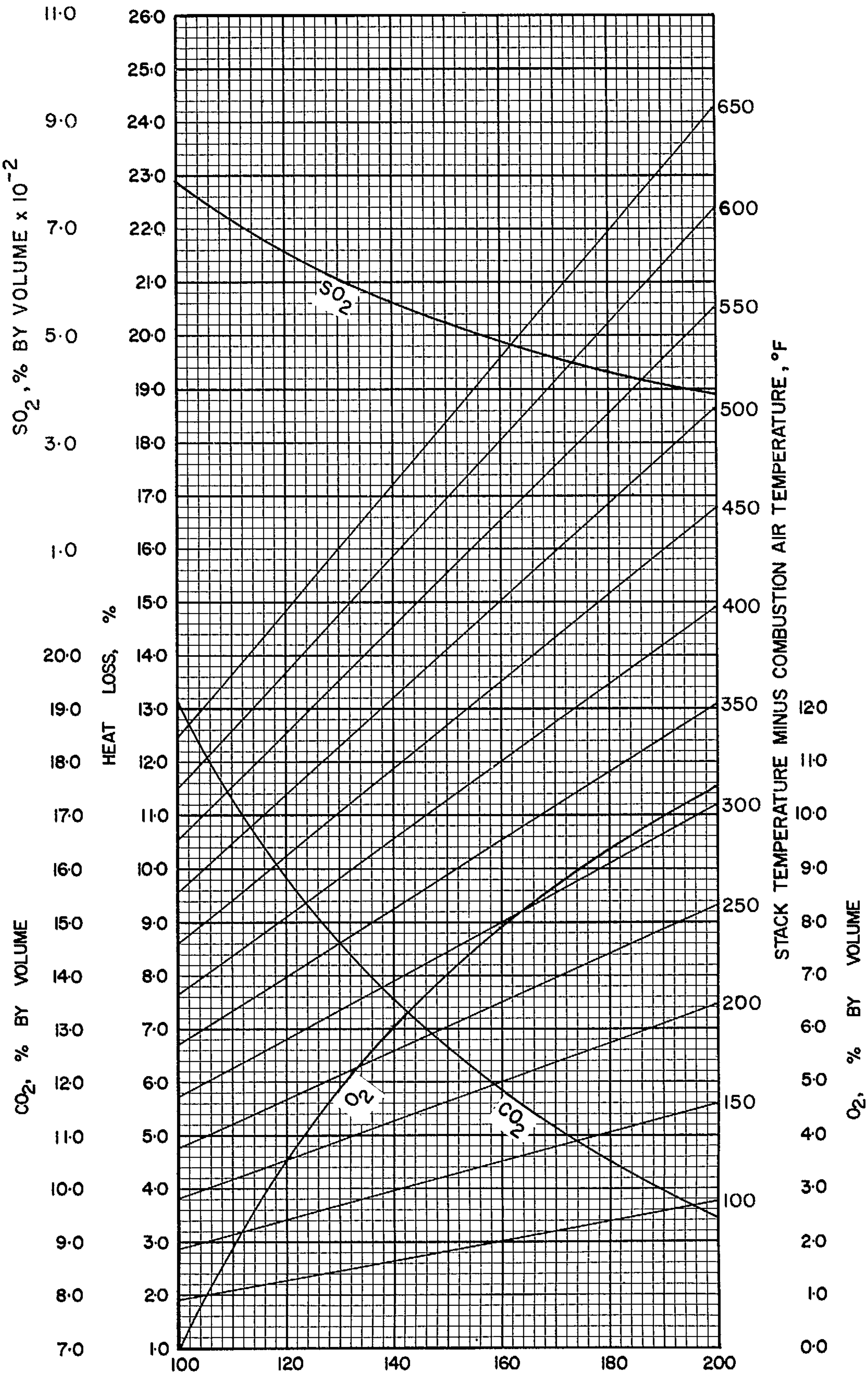


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·7·2

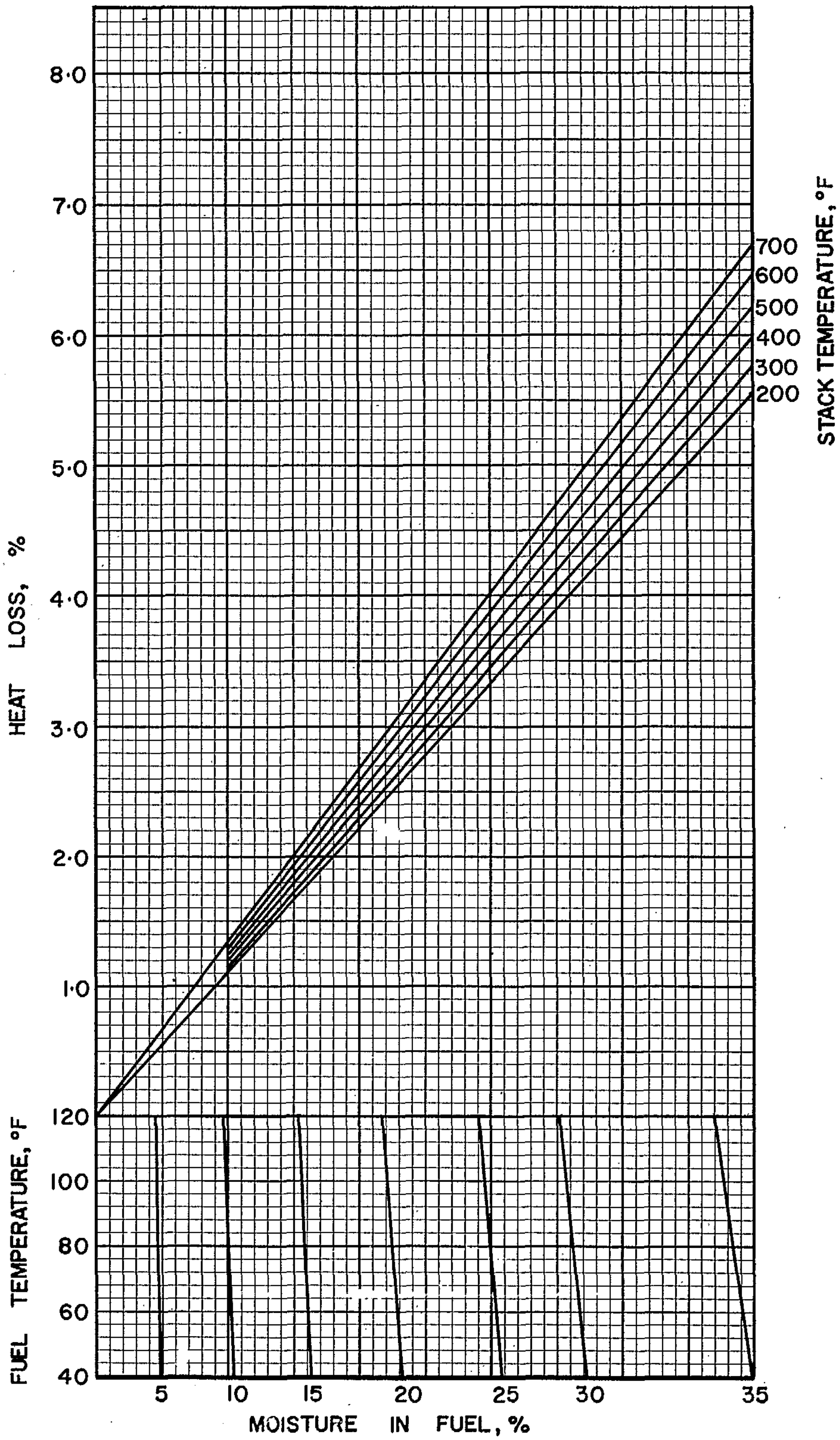


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·7·2

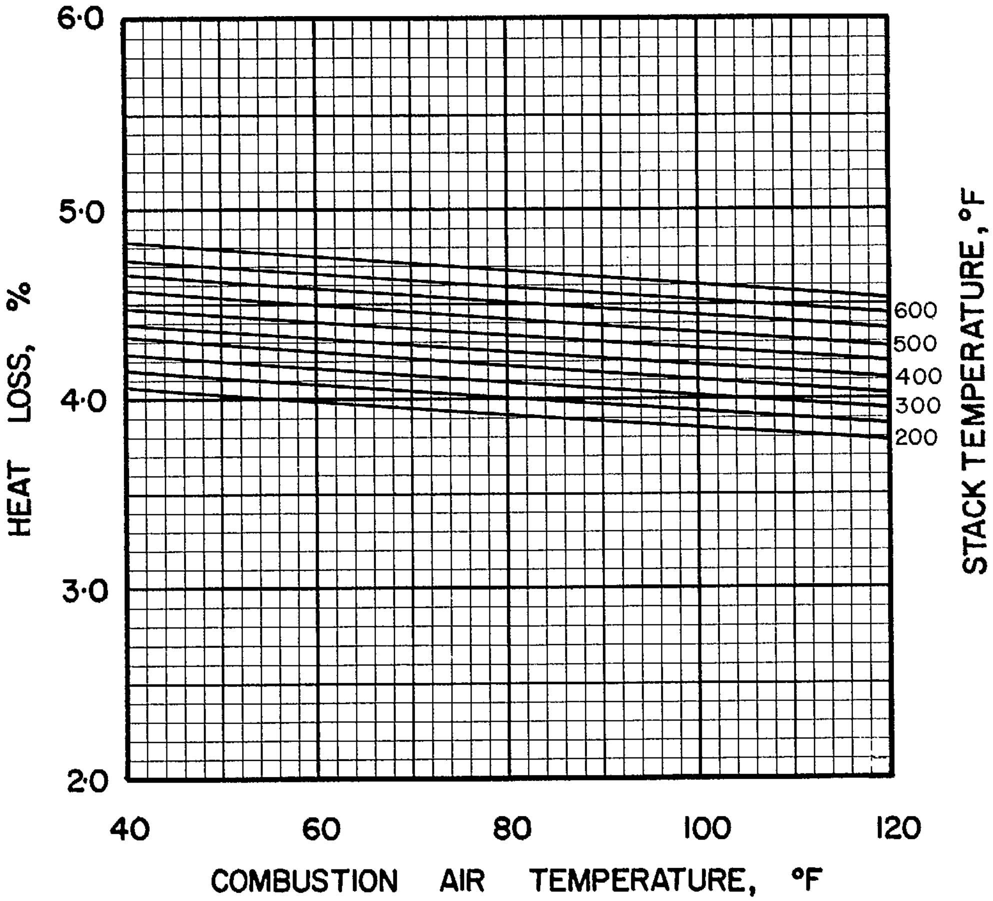


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·7·2

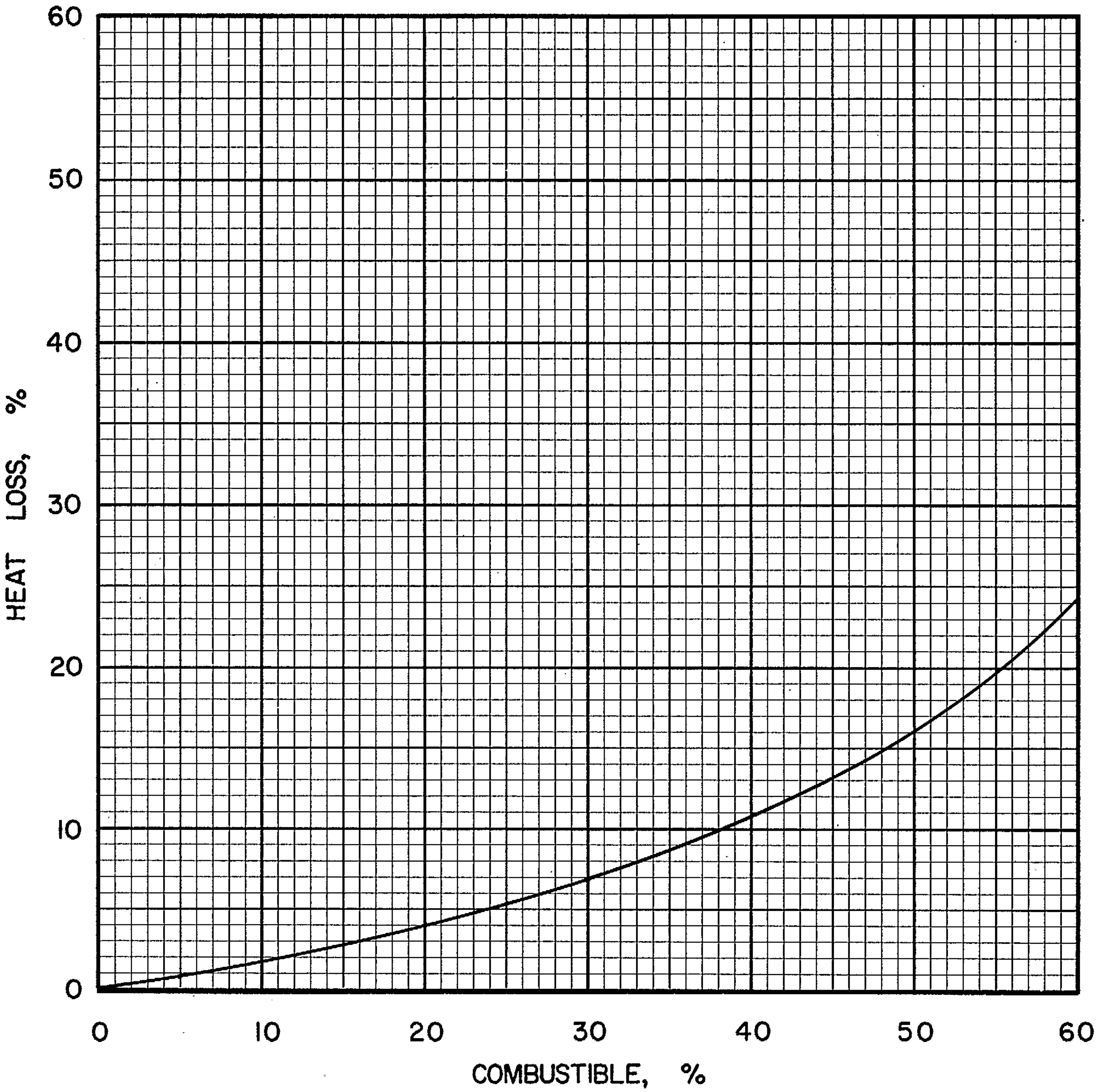


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC · 7 · 2

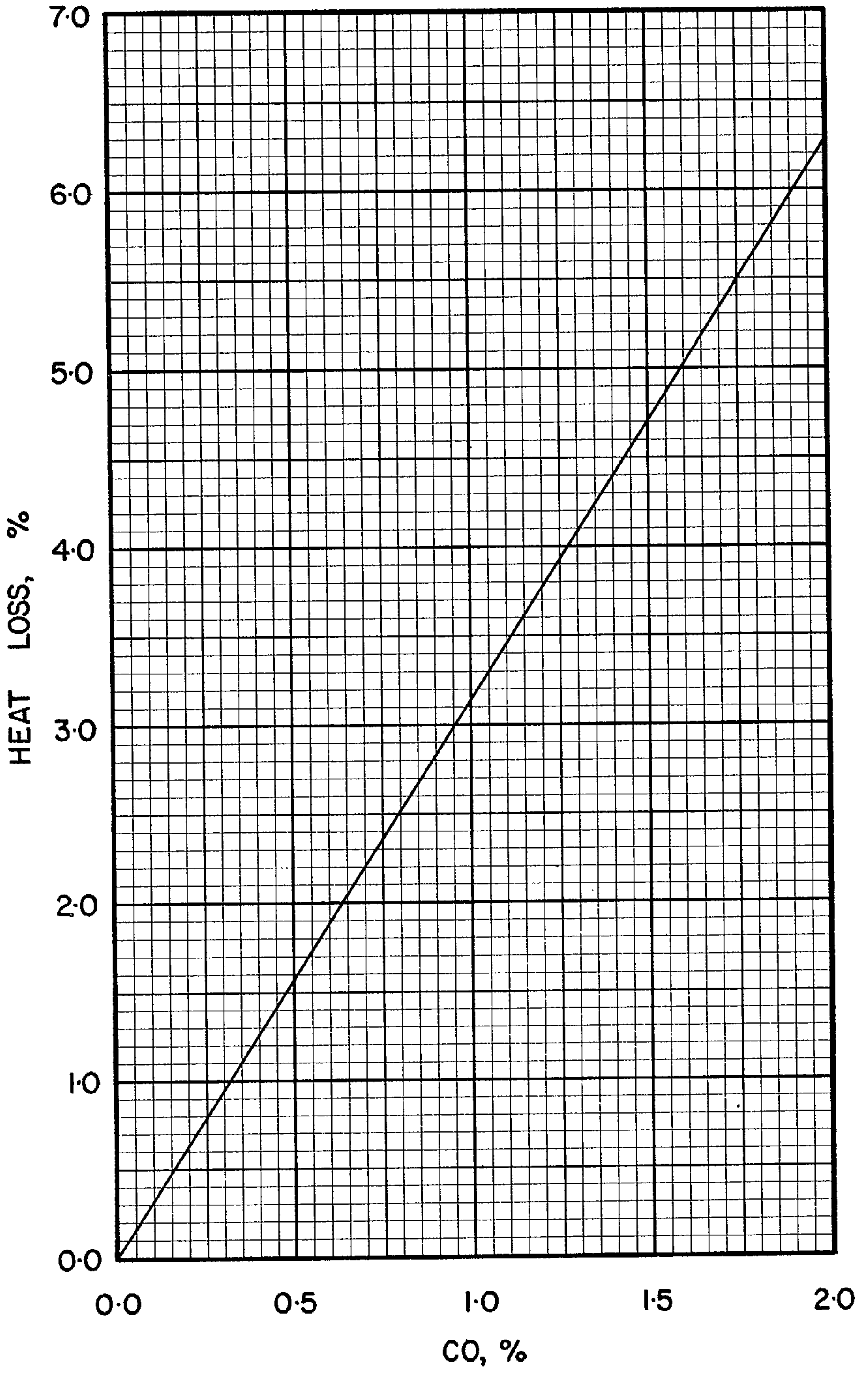


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 7 · 2

COAL ABC 8-1, BATTLE RIVER COAL CO. LTD., SHEERNESS, No. 1046, 2 in. x 1 1/4 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.0999
Volatile Matter	0.3616
Fixed Carbon	0.5385
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6784
Hydrogen (H)	0.0466
Sulphur (S)	0.0103
Nitrogen (N)	0.0146
Oxygen (O)	0.1502
Ash	0.0999
Total	1.0000

Gross Calorific Value

Btu/lb:	11420
Btu/short ton:	22.84×10^6
Btu/long ton:	25.58×10^6
MJ/kg:	26.56

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	87.57	lb	
10^6 Btu	=	0.04378	short tons	
10^6 Btu	=	0.03909	long tons	

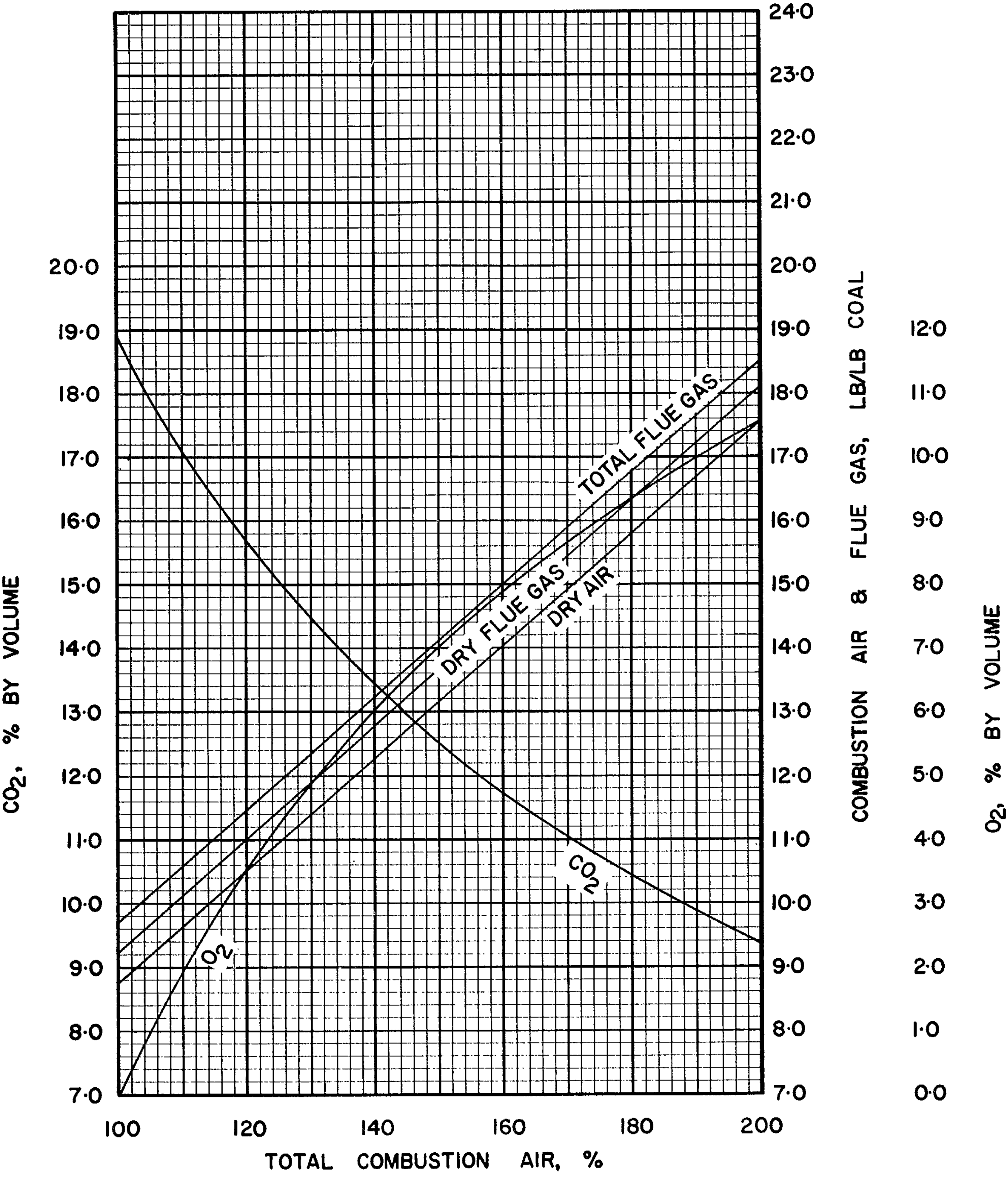


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC · 8 · 1

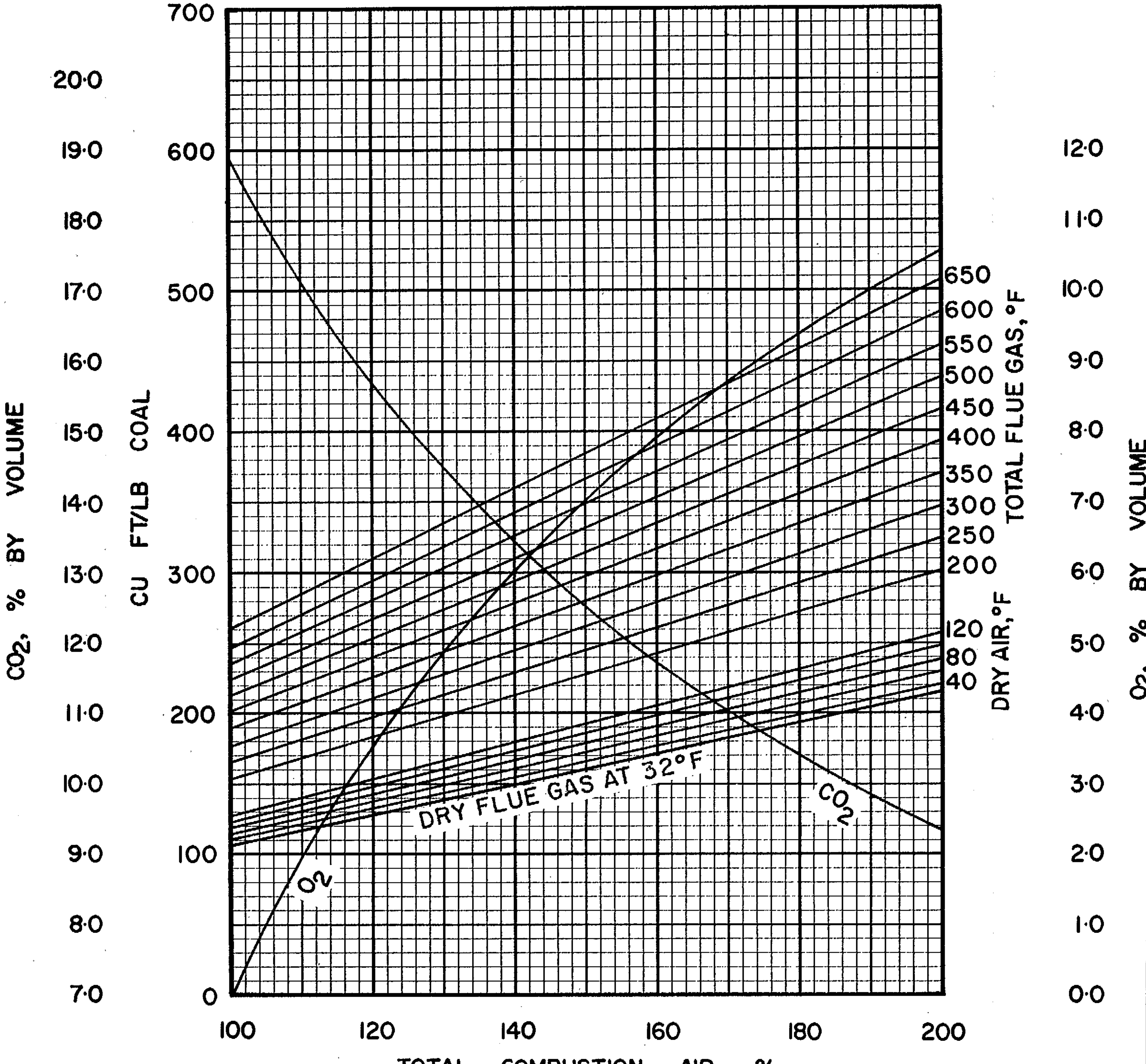


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 8 · 1

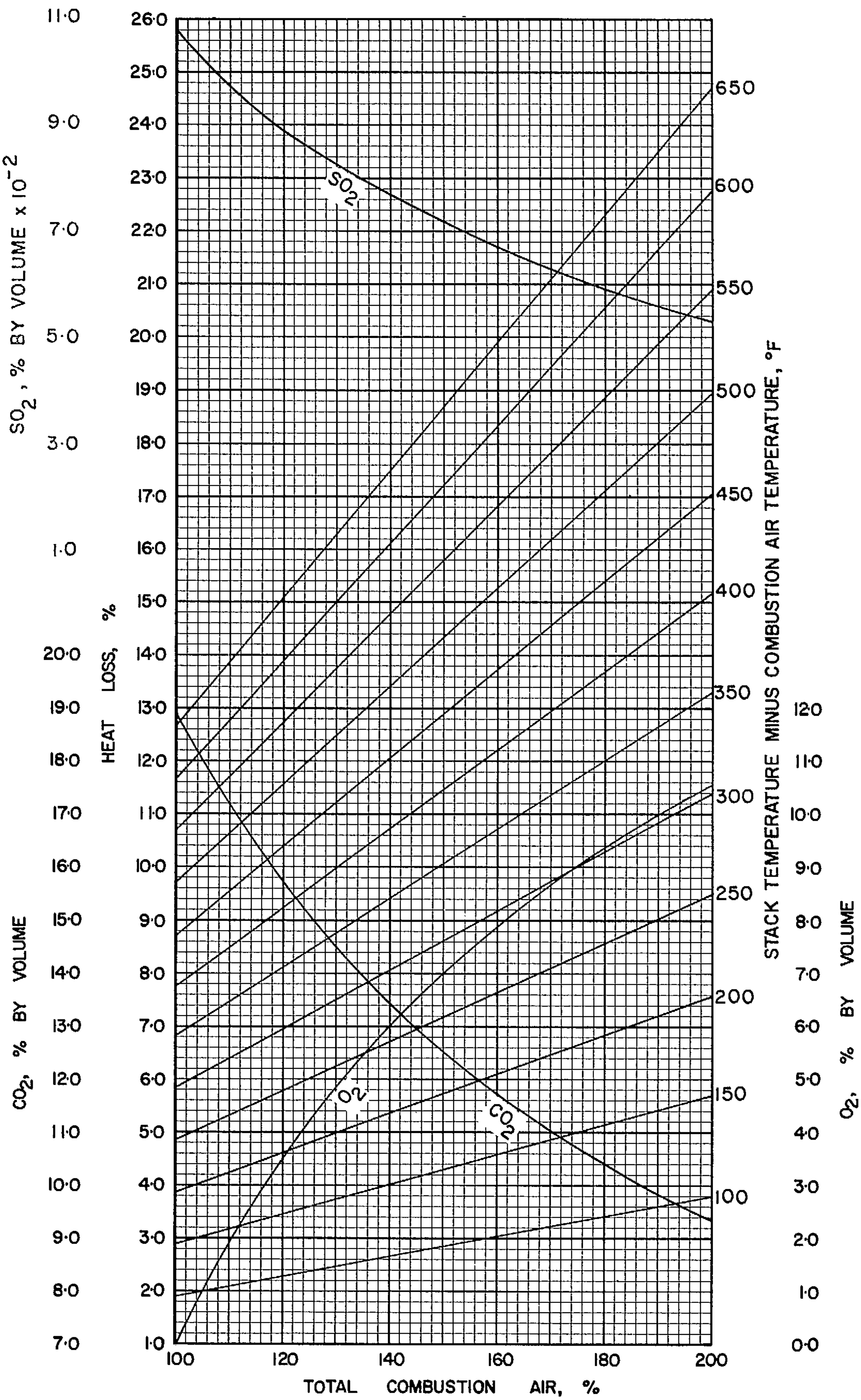


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·8·1

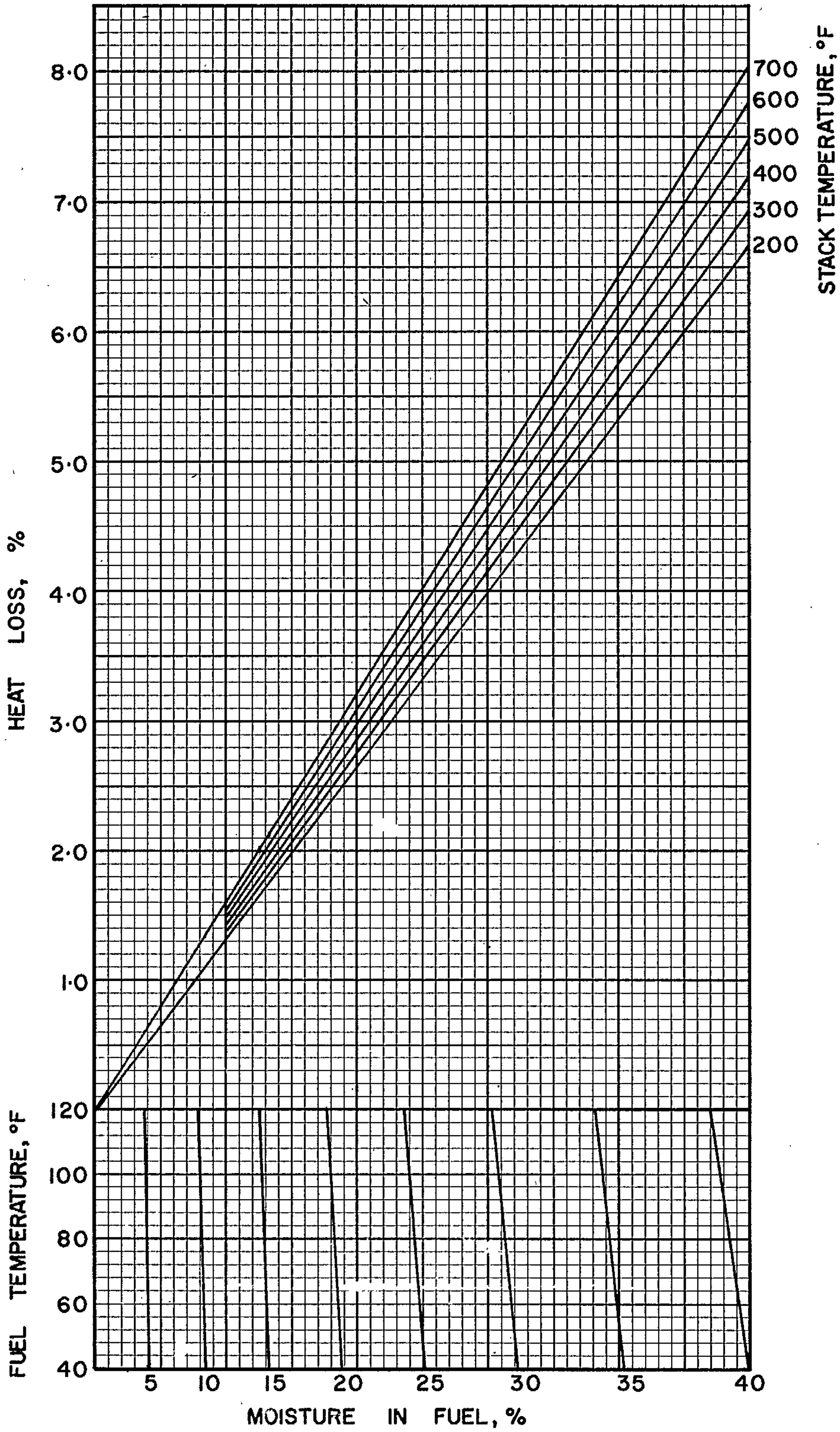


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·8·1

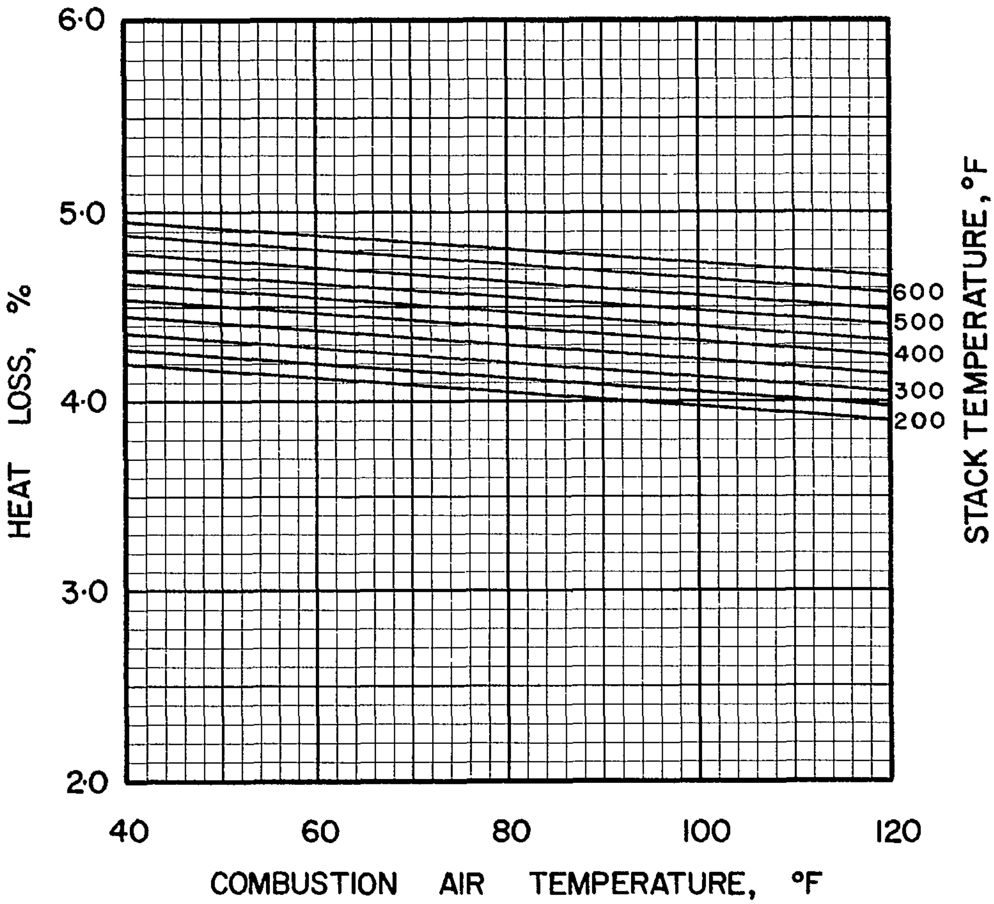


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 8 · I

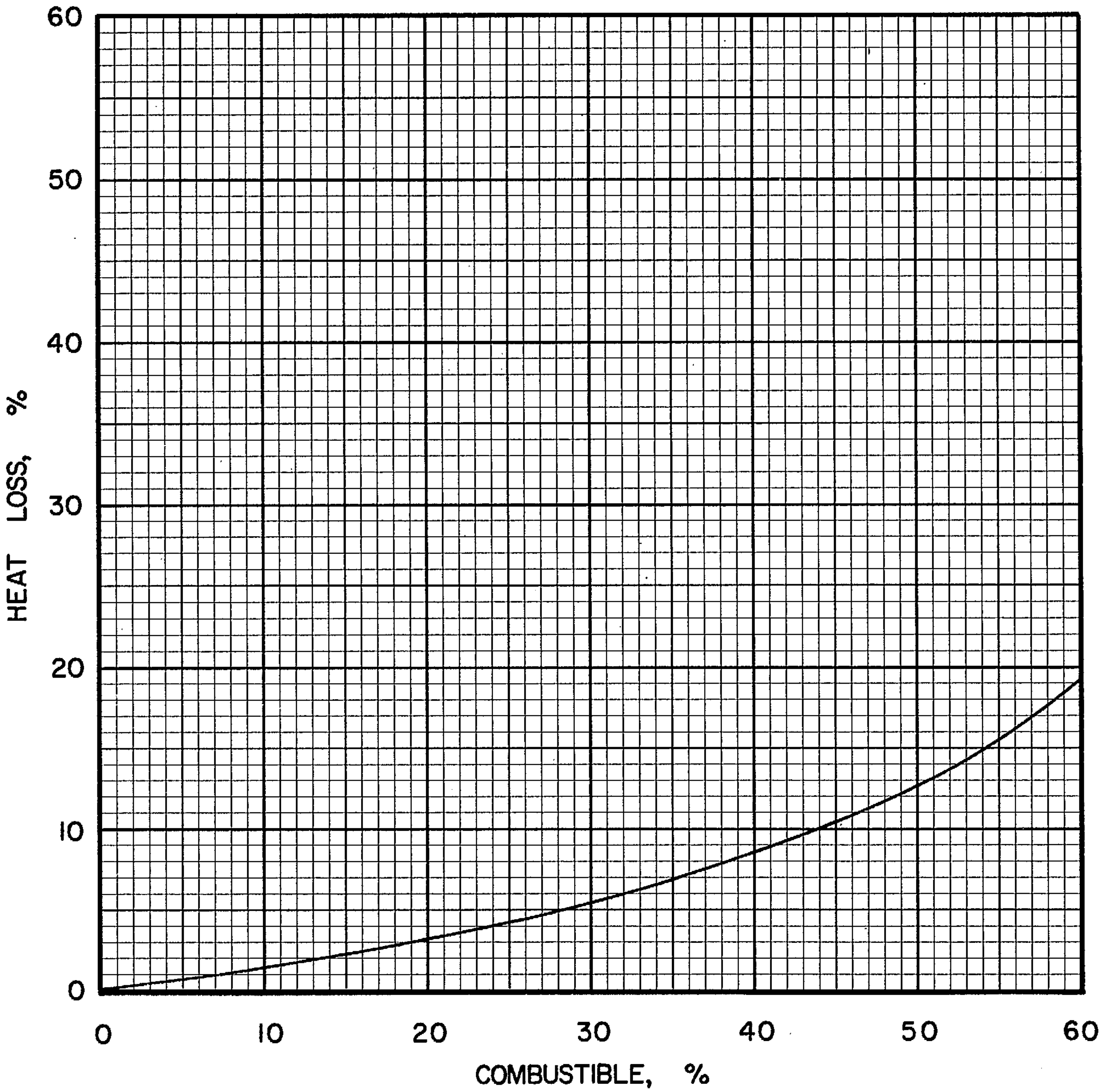


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·8·1

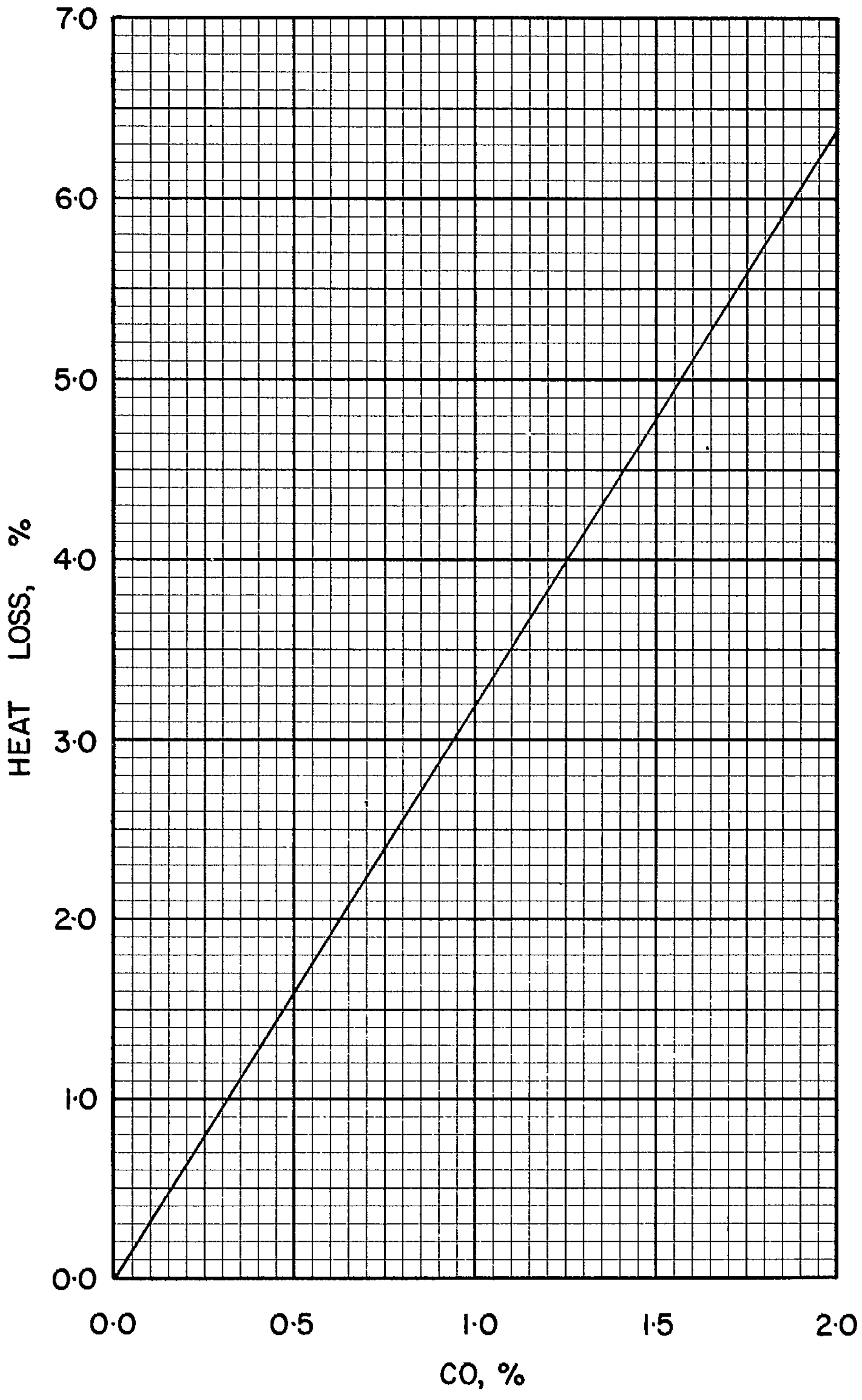


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·8·1

COAL ABC 8-2, BATTLE RIVER COAL CO. LTD.,
SHEERNESS, No. 1046, 1 1/4 in. x 3/4 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.0952
Volatile Matter	0.3933
Fixed Carbon	0.5115
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6842
Hydrogen (H)	0.0450
Sulphur (S)	0.0059
Nitrogen (N)	0.0149
Oxygen (O)	0.1548
Ash	0.0952
Total	1.0000

Gross Calorific Value

Btu/lb:	11570
Btu/short ton:	23.14×10^6
Btu/long ton:	25.92×10^6
MJ/kg:	26.91

Conversion Factors

1 short ton	= 0.8929	long tons	=	2000 lb
10^6 Btu	= 86.43	lb		
10^6 Btu	= 0.04322	short tons		
10^6 Btu	= 0.03859	long tons		

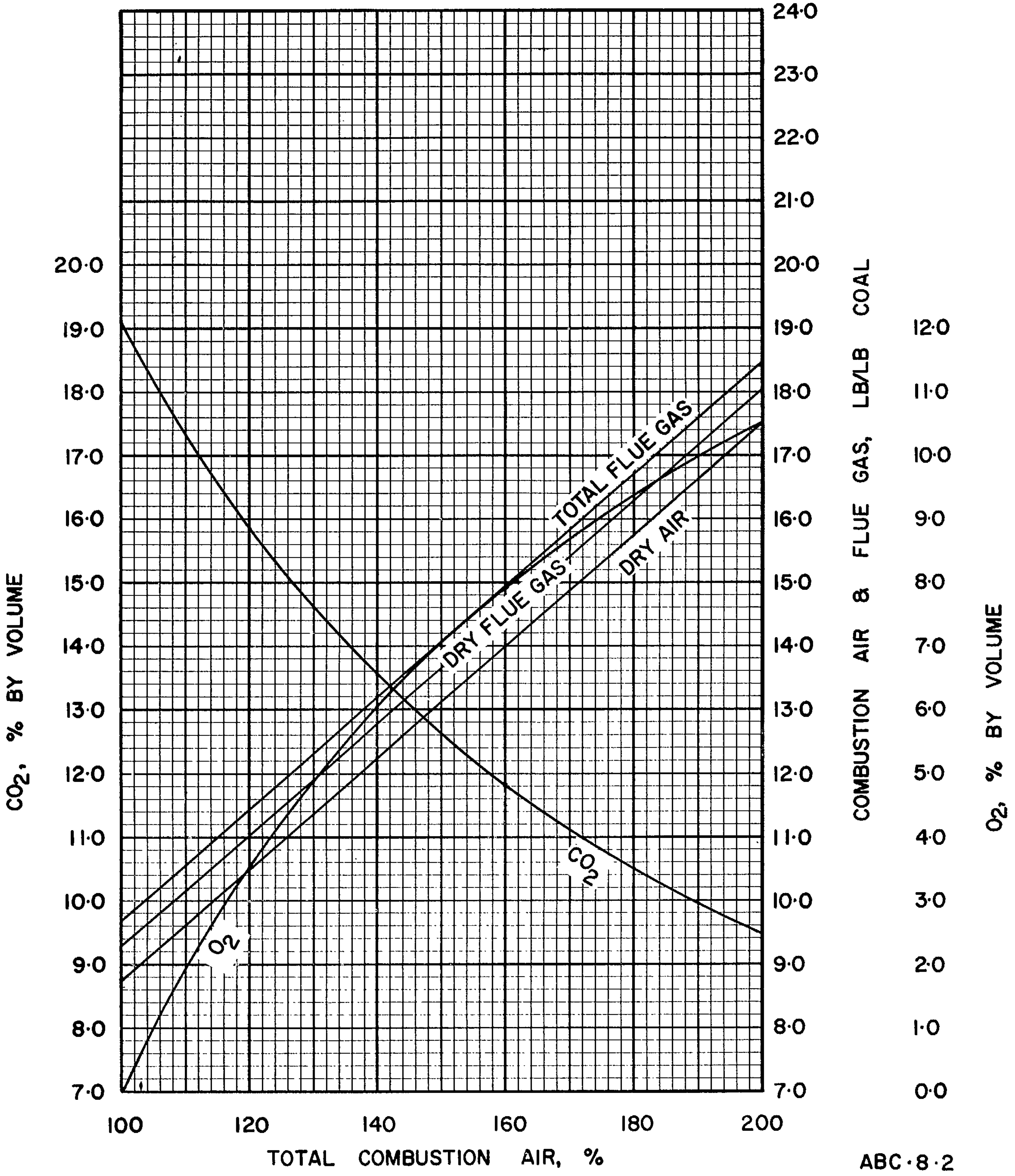


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

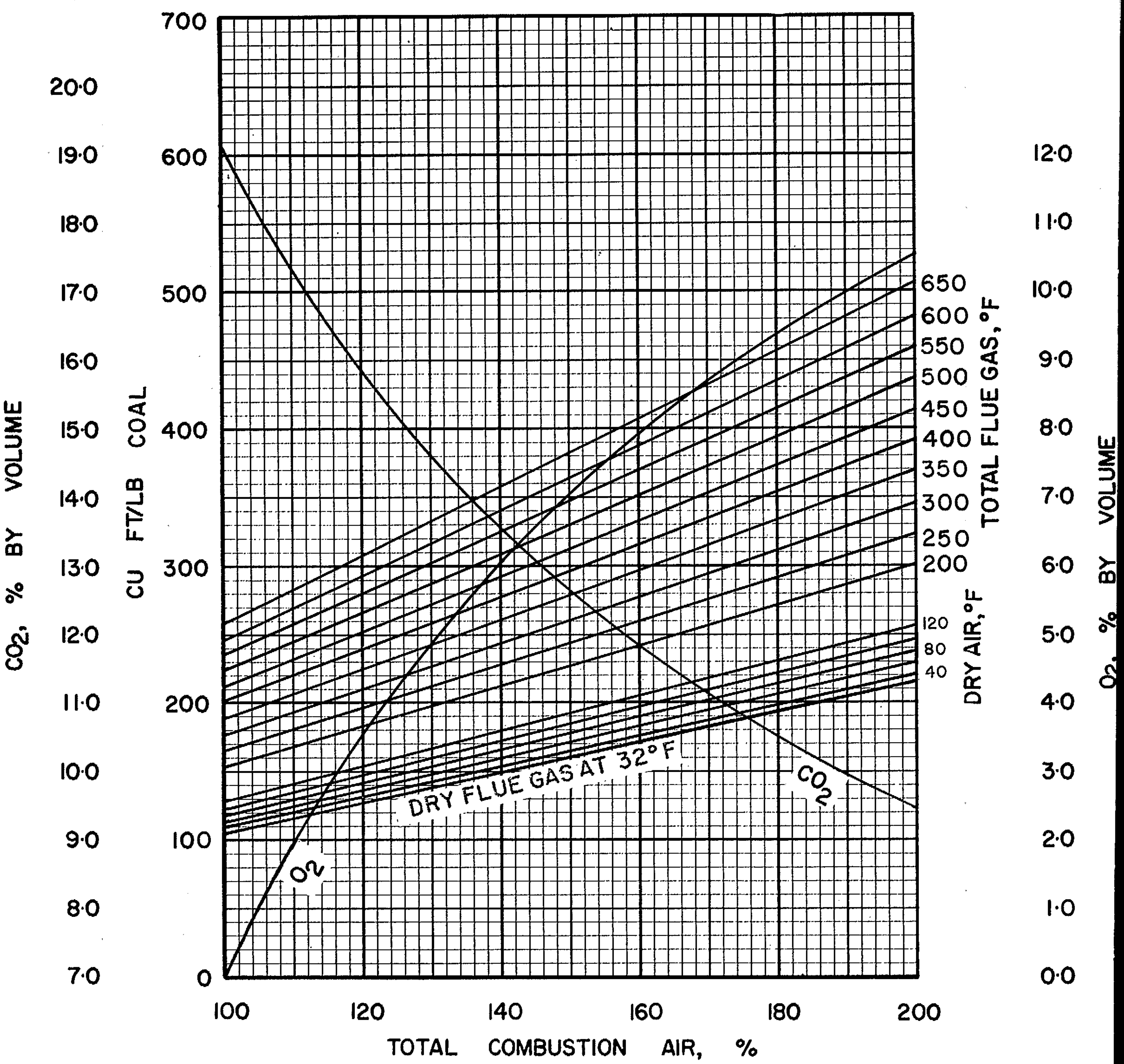


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 8 · 2

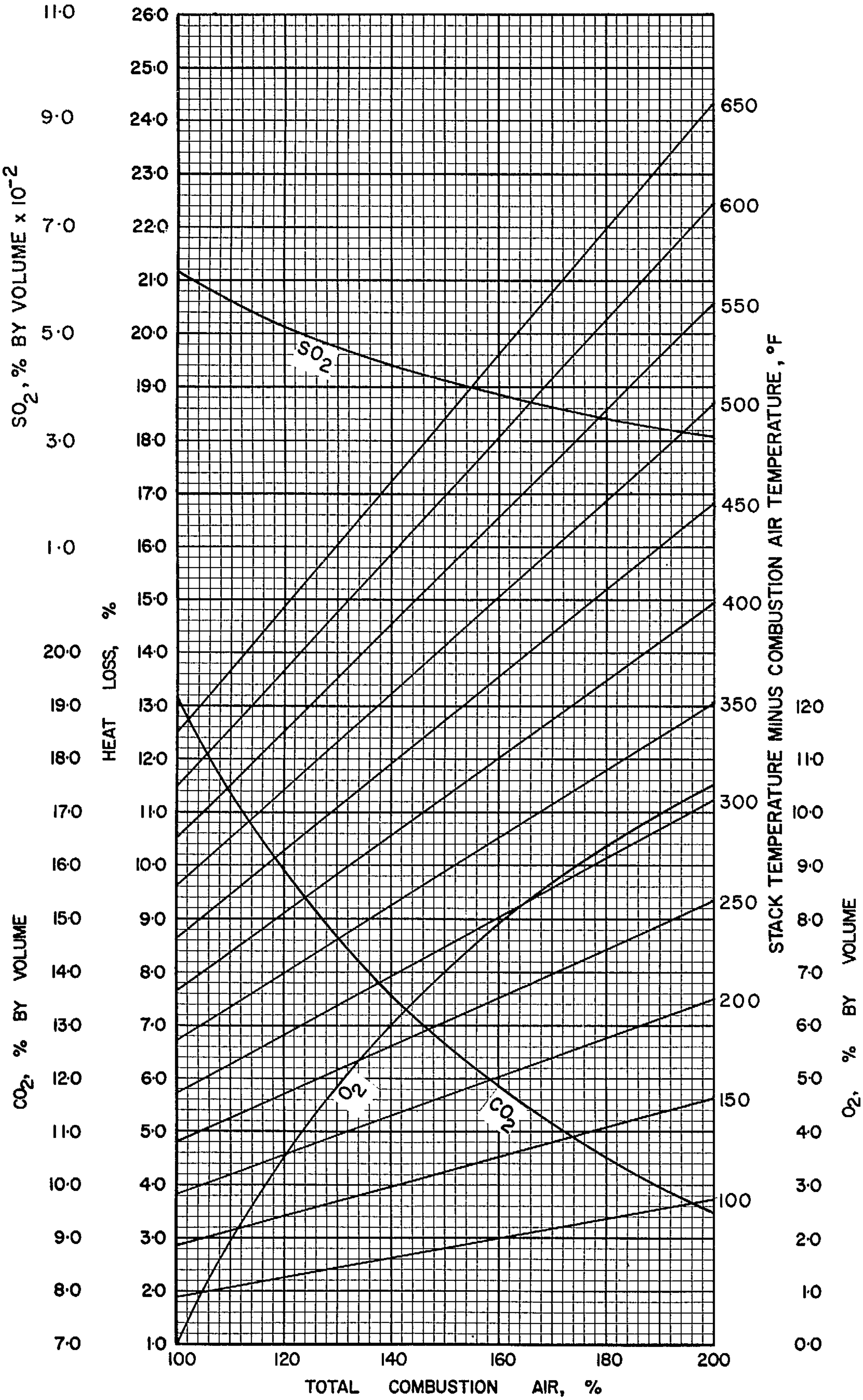


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·8·2

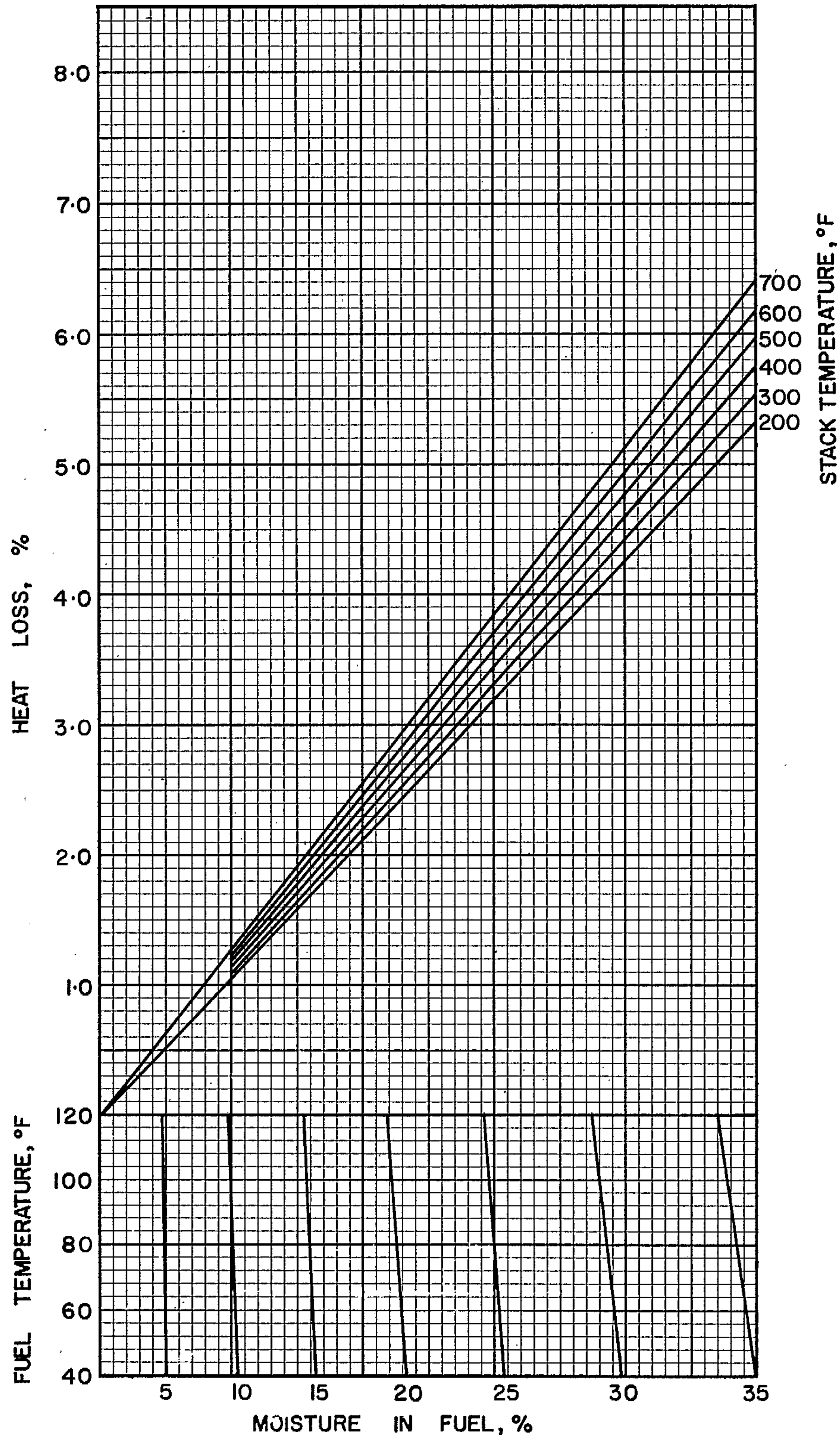


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·8·2

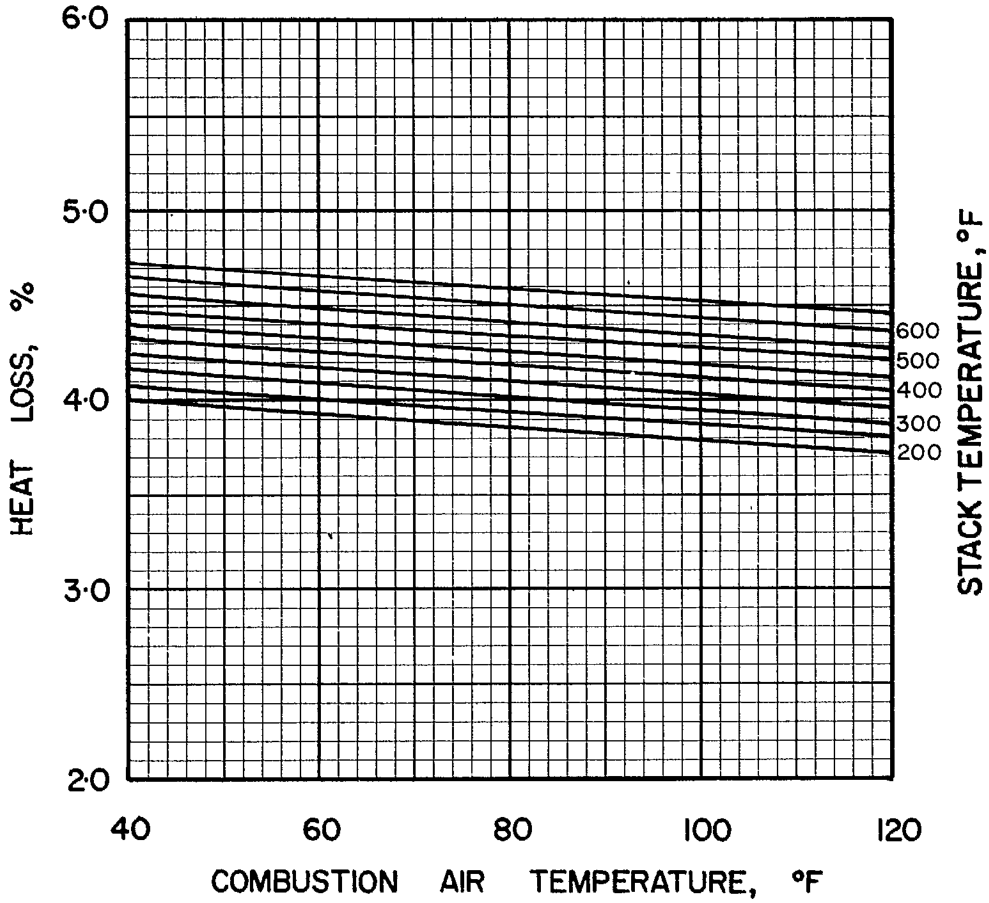


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 8 · 2

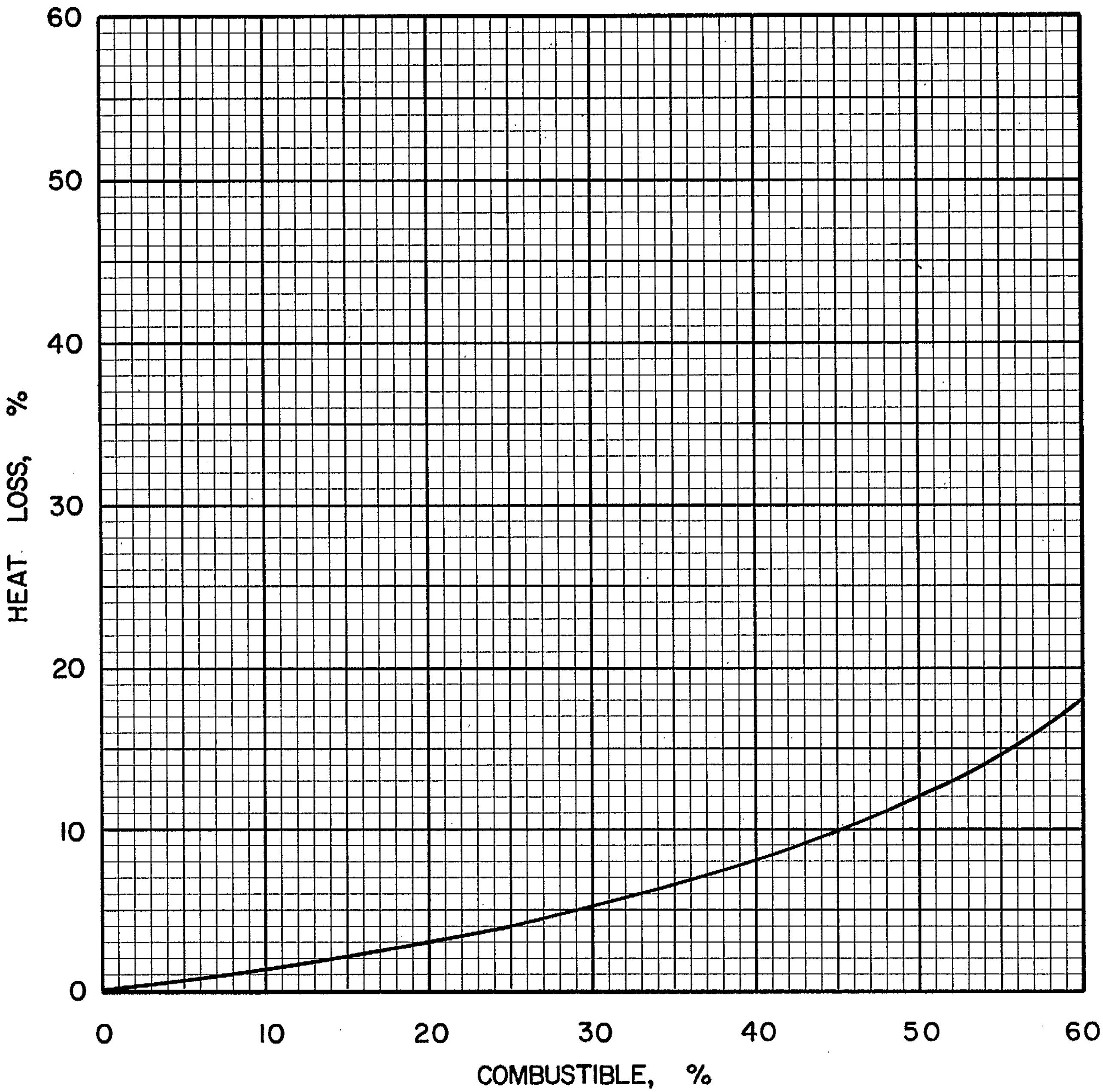


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·8·2

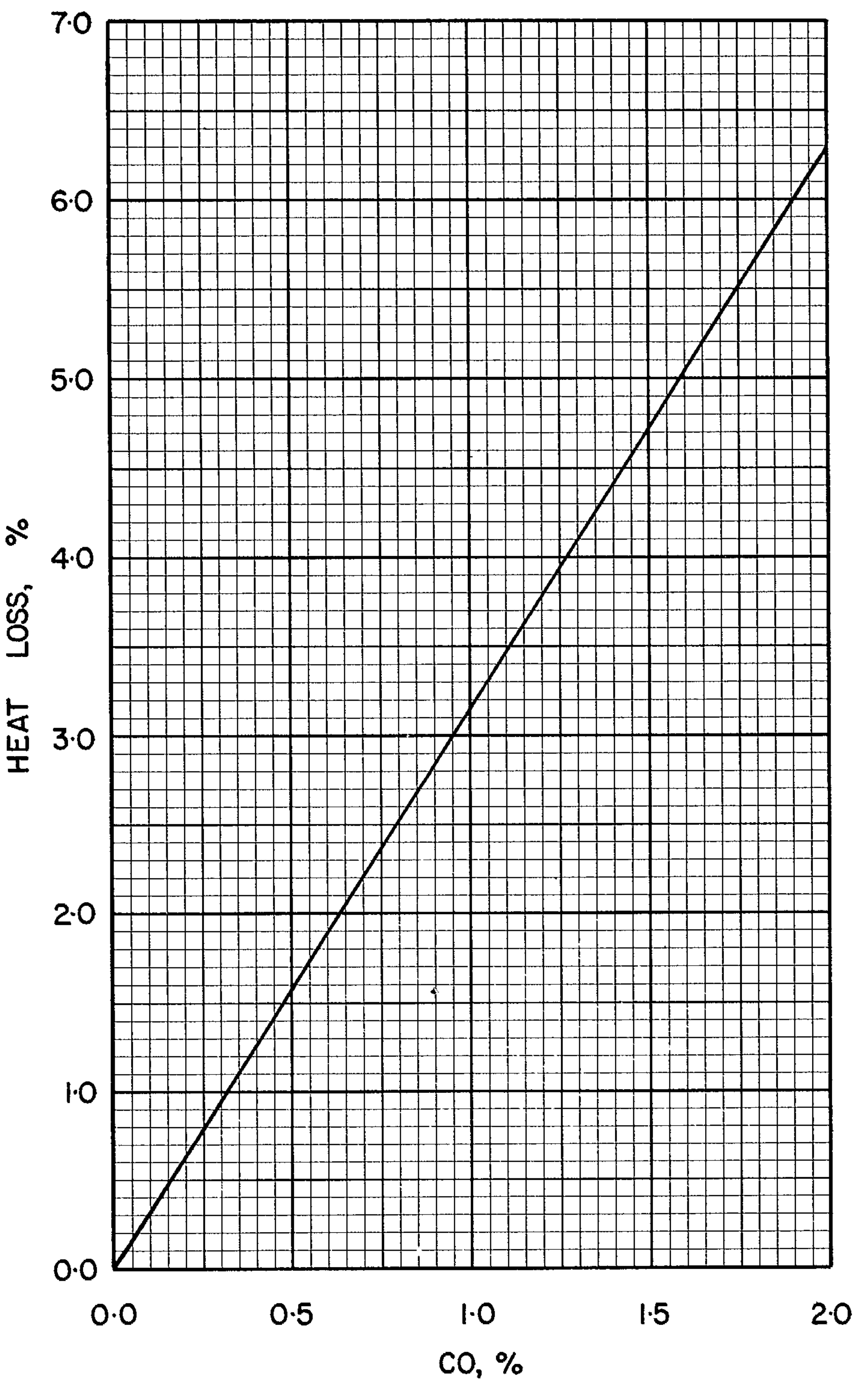


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 8 · 2

COAL ABC 8-3, BATTLE RIVER COAL CO. LTD., SHEERNESS, No. 1046, – 3/4 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.0877
Volatile Matter	0.4017
Fixed Carbon	0.5106
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6798
Hydrogen (H)	0.0445
Sulphur (S)	0.0057
Nitrogen (N)	0.0145
Oxygen (O)	0.1678
Ash	0.0877
Total	1.0000

Gross Calorific Value

Btu/lb:	11640
Btu/short ton:	23.28×10^6
Btu/long ton:	26.07×10^6
MJ/kg:	27.07

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 85.91	lb	
10^6 Btu	= 0.04296	short tons	
10^6 Btu	= 0.03835	long tons	

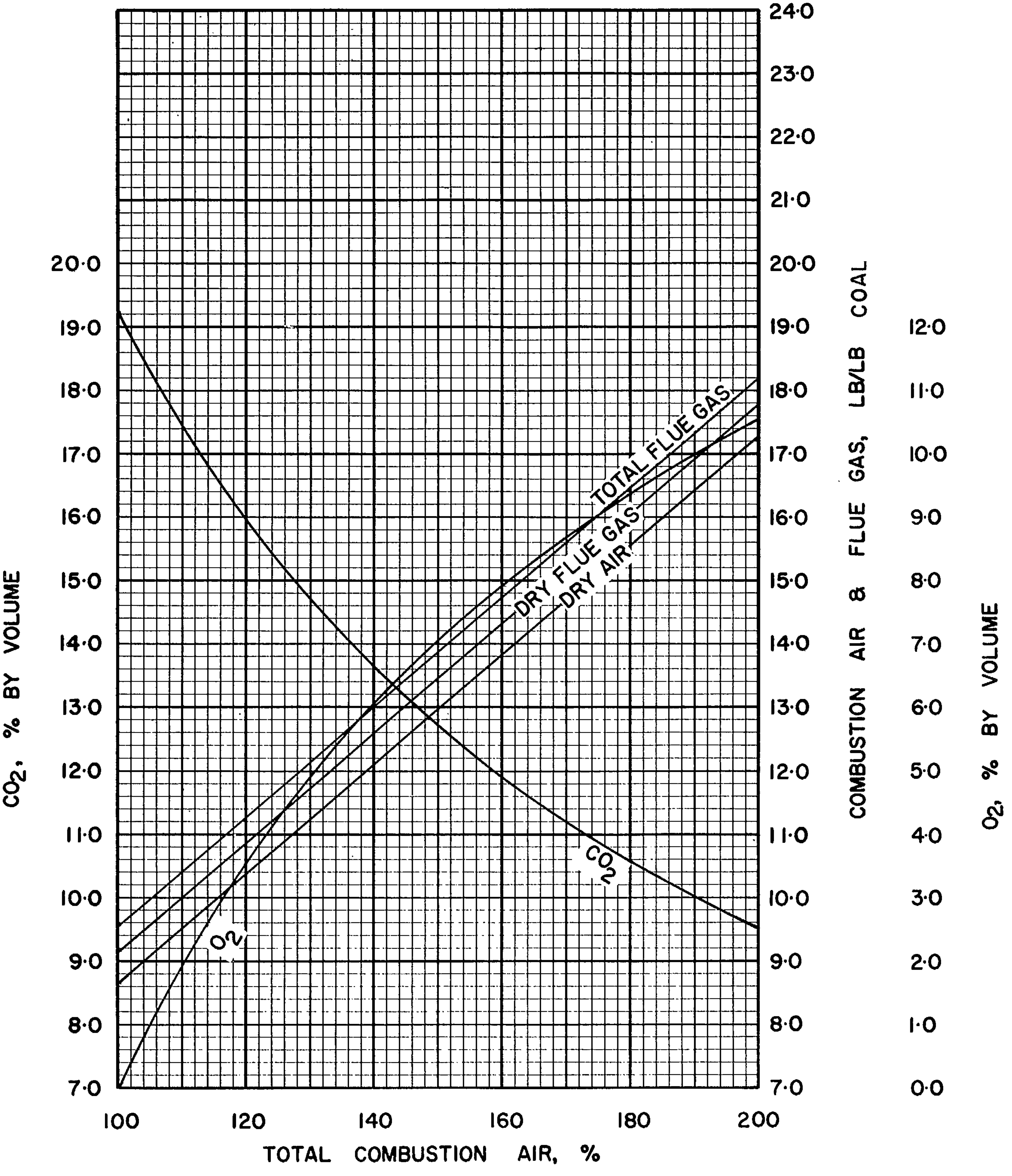


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC · 8 · 3

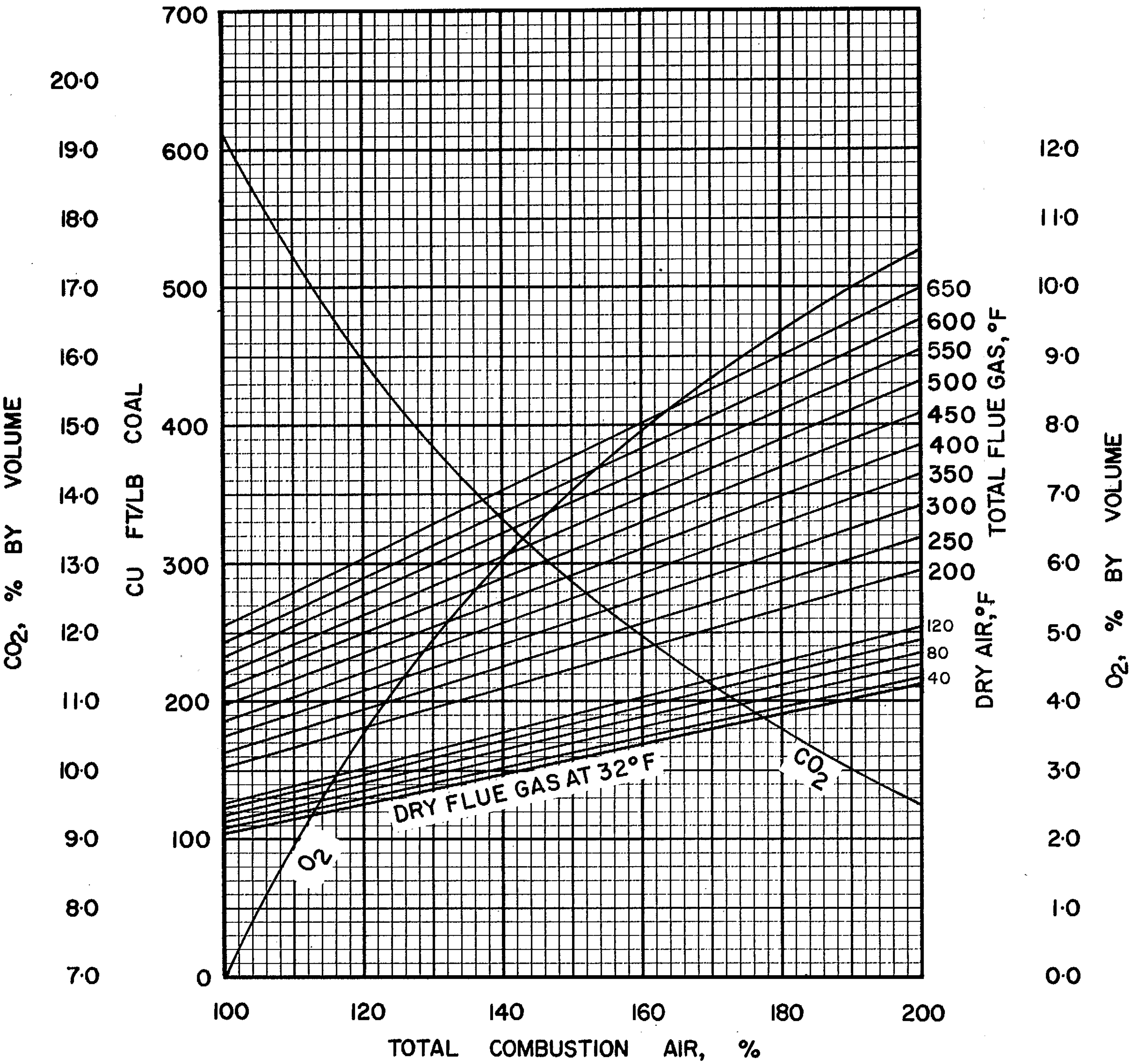


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 8 · 3

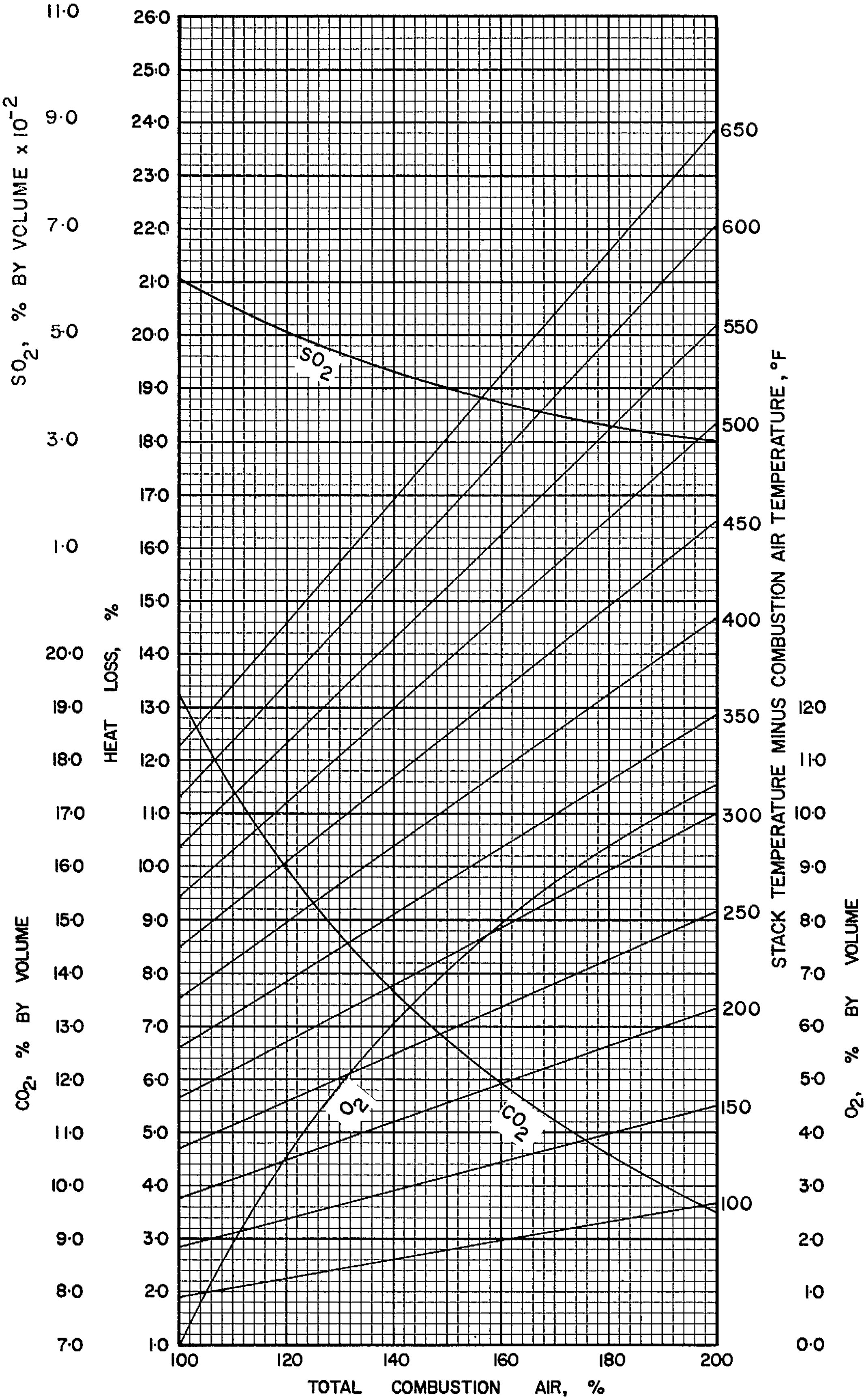


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS ABC·8·3

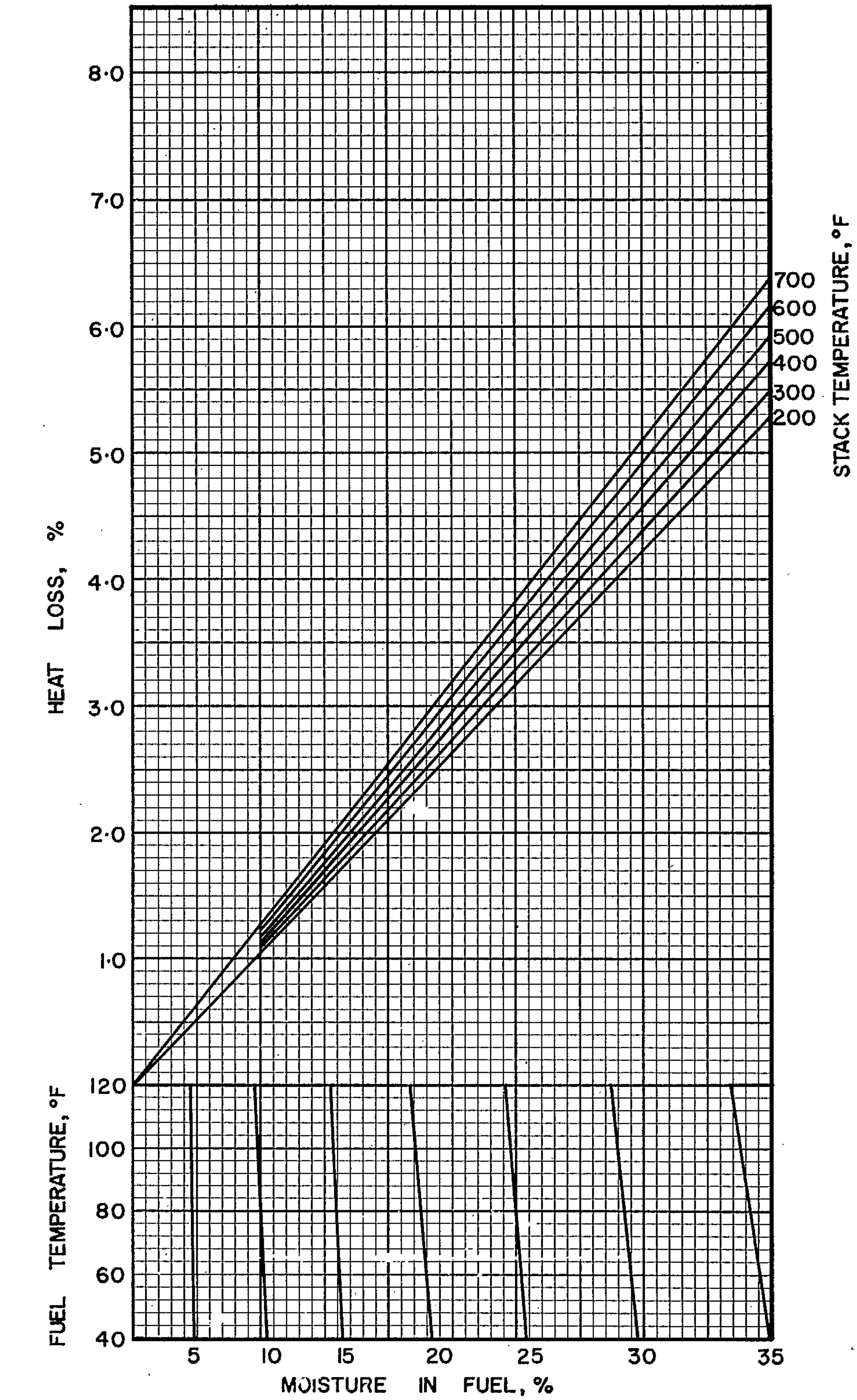


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC · 8 · 3

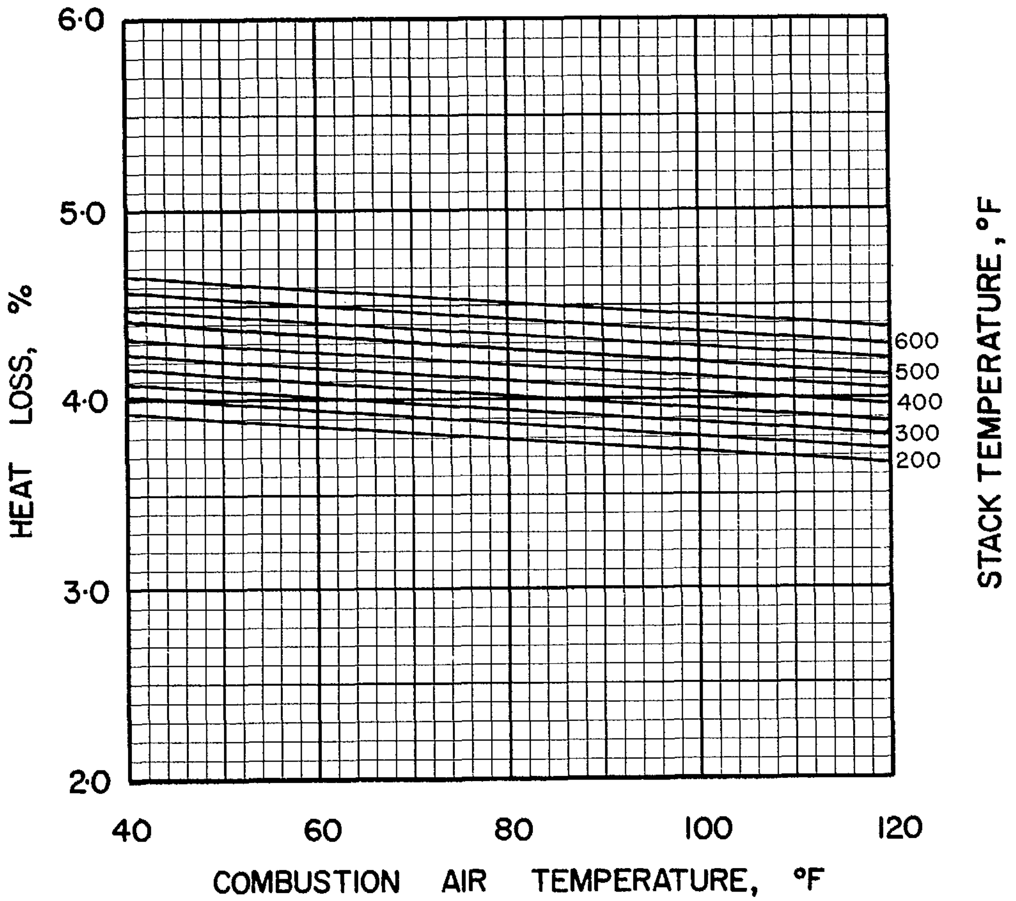


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·8·3

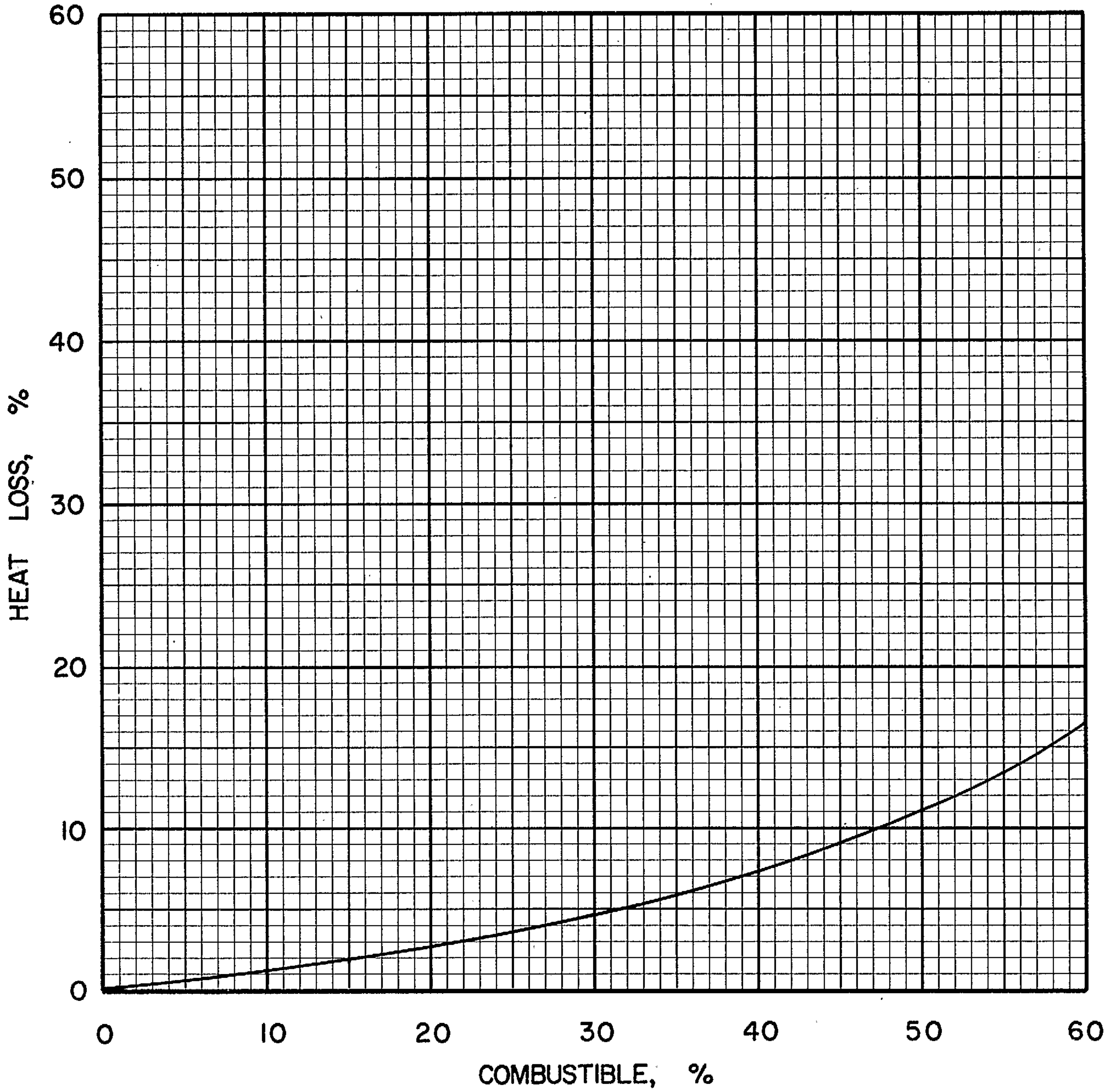


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·8·3

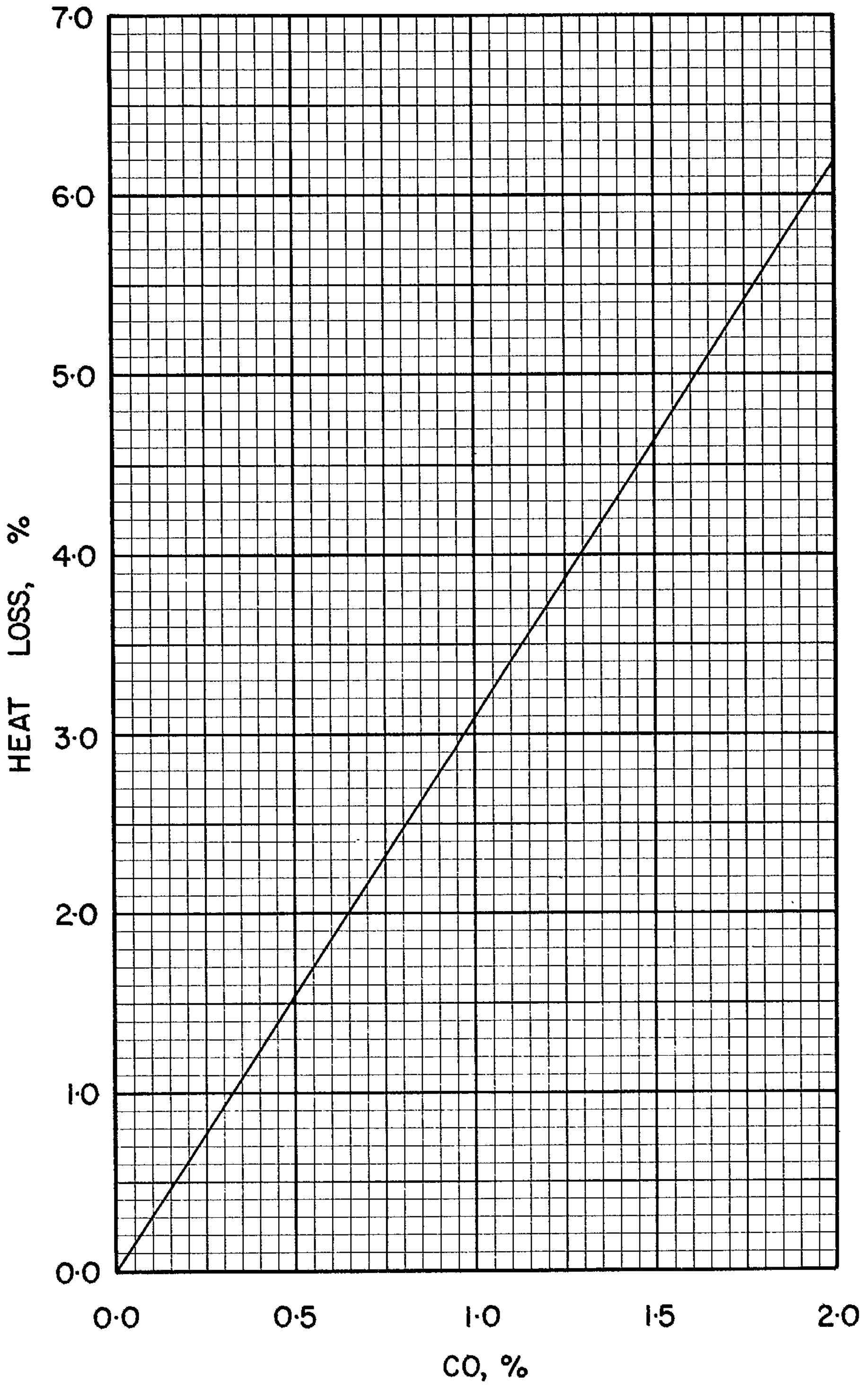


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 8 · 3

COAL ABC 9-1, FORESTBURG COLLIERIES, CASTOR, 1 in. x 3/8 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.0818
Volatile Matter	0.3876
Fixed Carbon	0.5306
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6844
Hydrogen (H)	0.0447
Sulphur (S)	0.0107
Nitrogen (N)	0.0138
Oxygen (O)	0.1646
Ash	0.0818
Total	1.0000

Gross Calorific Value

Btu/lb:	11653
Btu/short ton:	23.31×10^6
Btu/long ton:	26.10×10^6
MJ/kg:	27.10

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	85.81	lb	
10^6 Btu	=	0.04291	short tons	
10^6 Btu	=	0.03831	long tons	

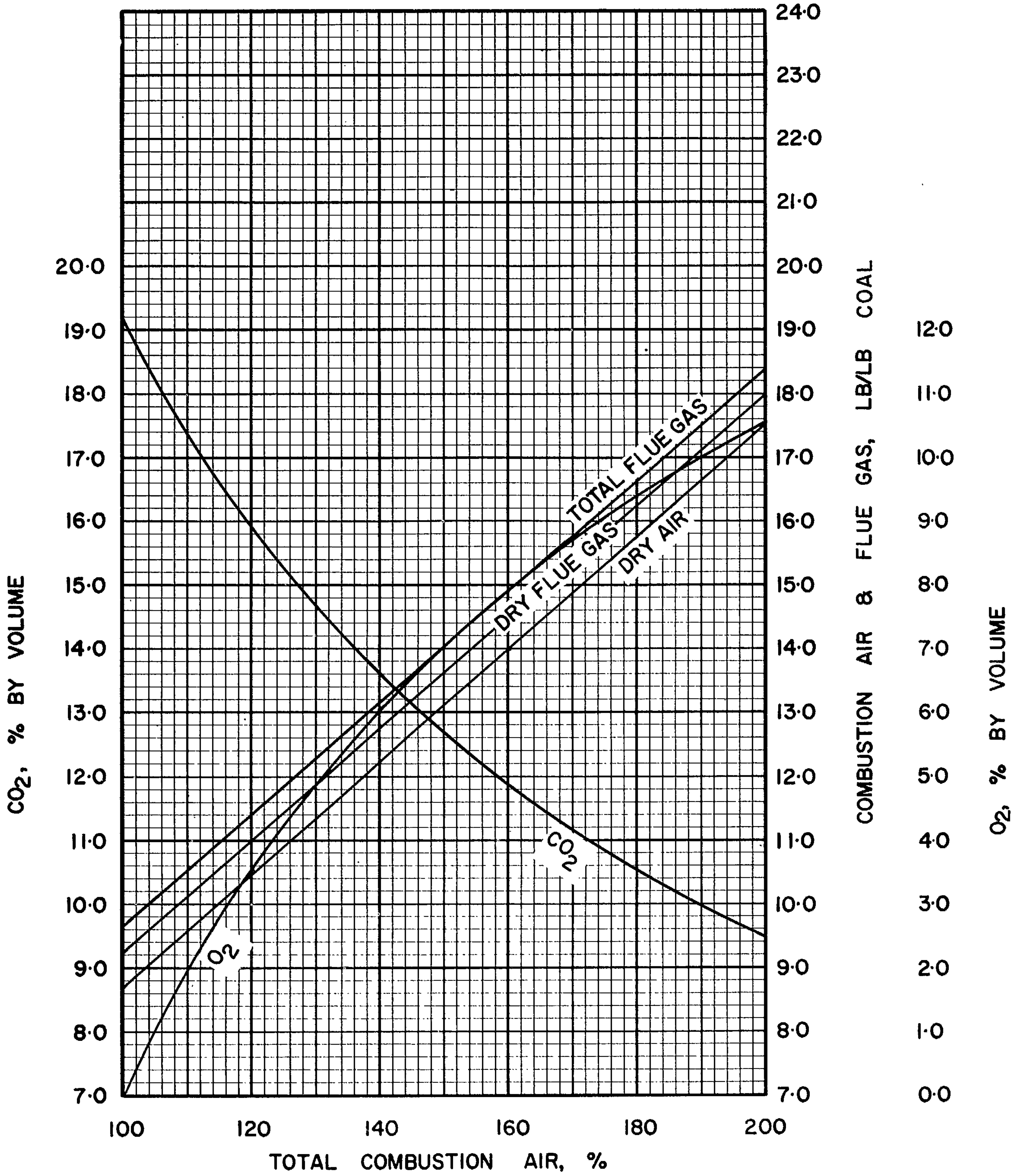


FIGURE I· COMBUSTION DATA, WEIGHT BASIS

ABC·9·1

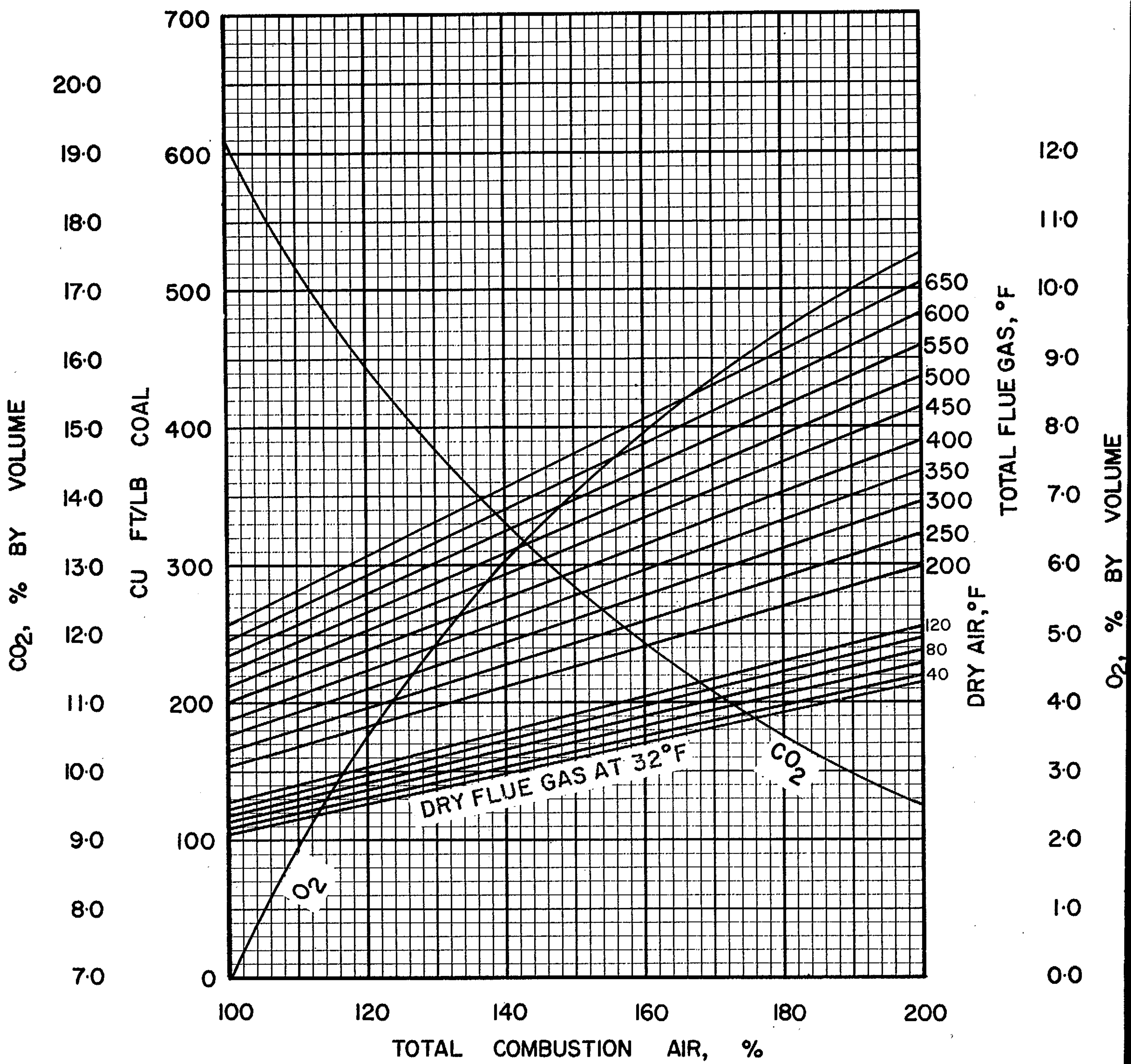


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·9·1

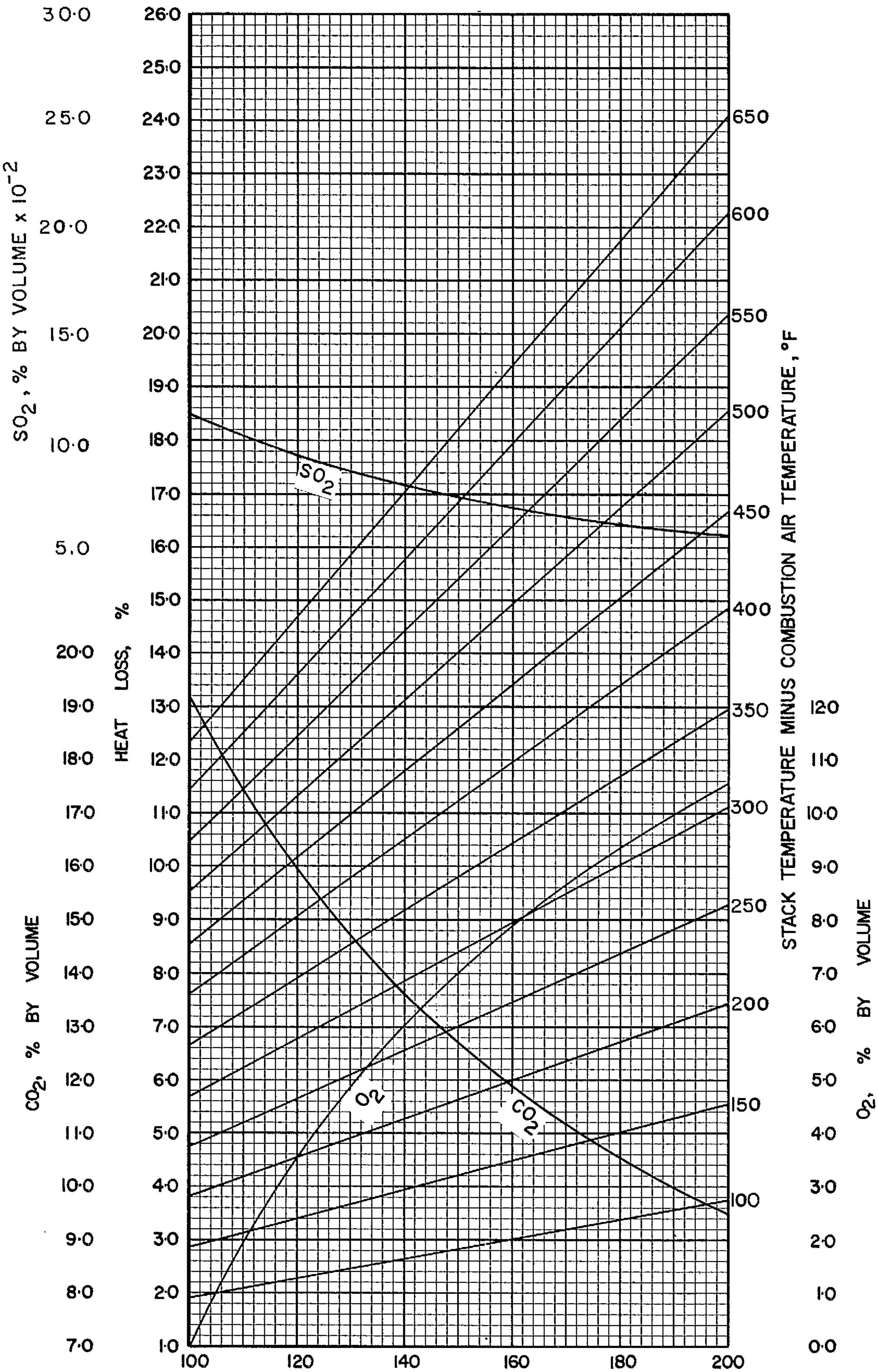


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·9·1

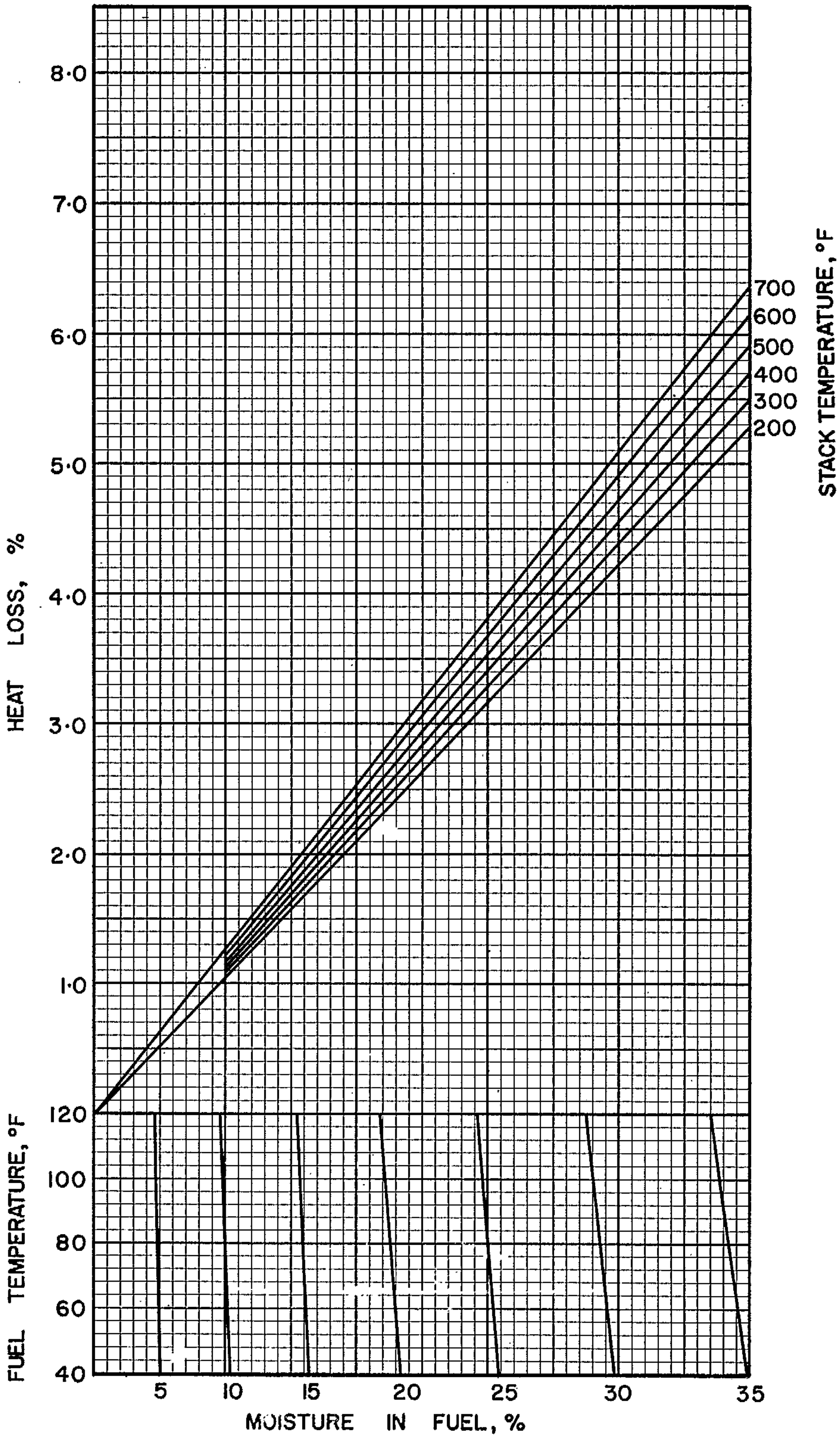


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·9·1

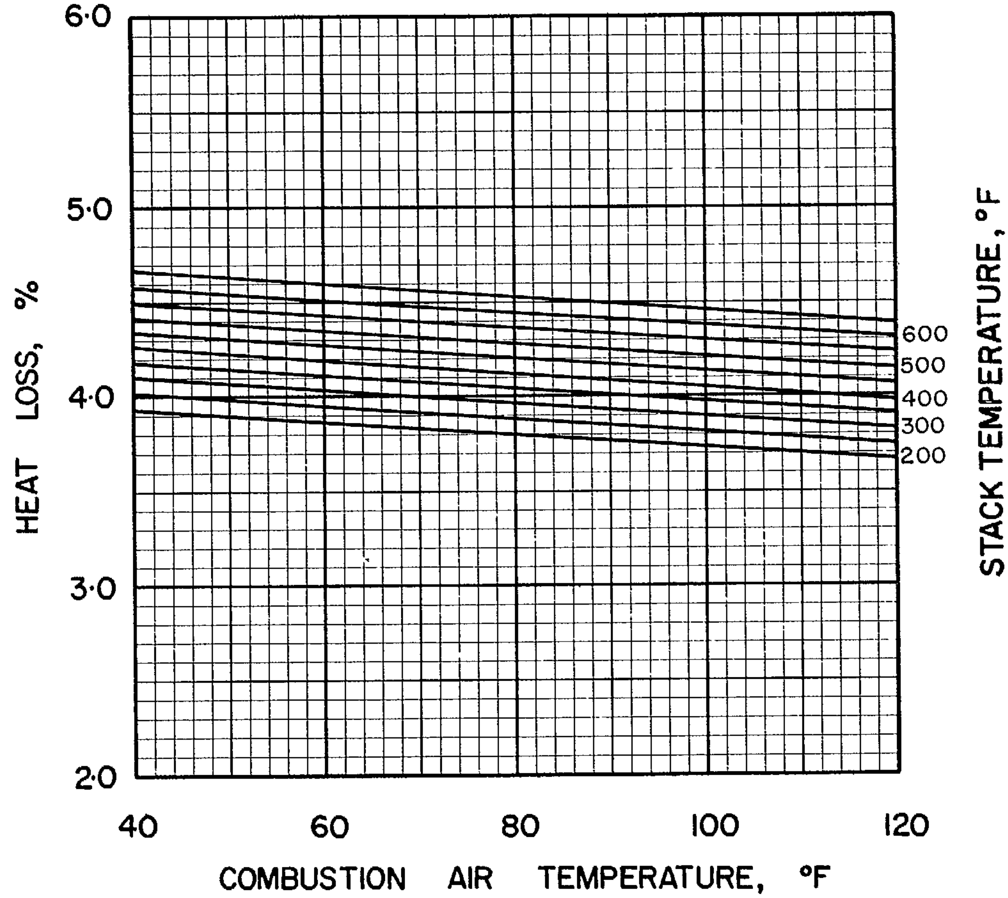


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC · 9 · 1

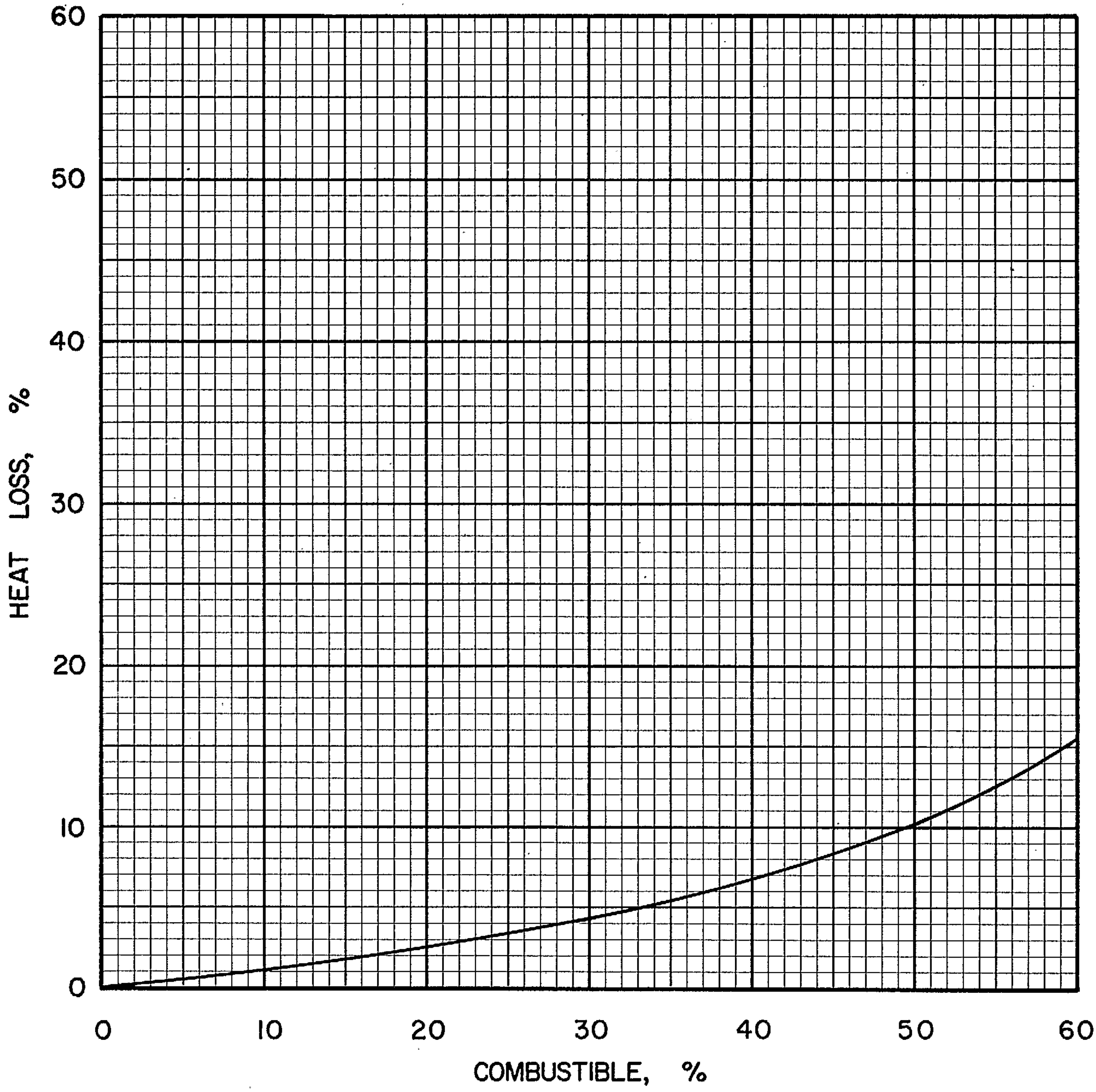


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC · 9 · 1

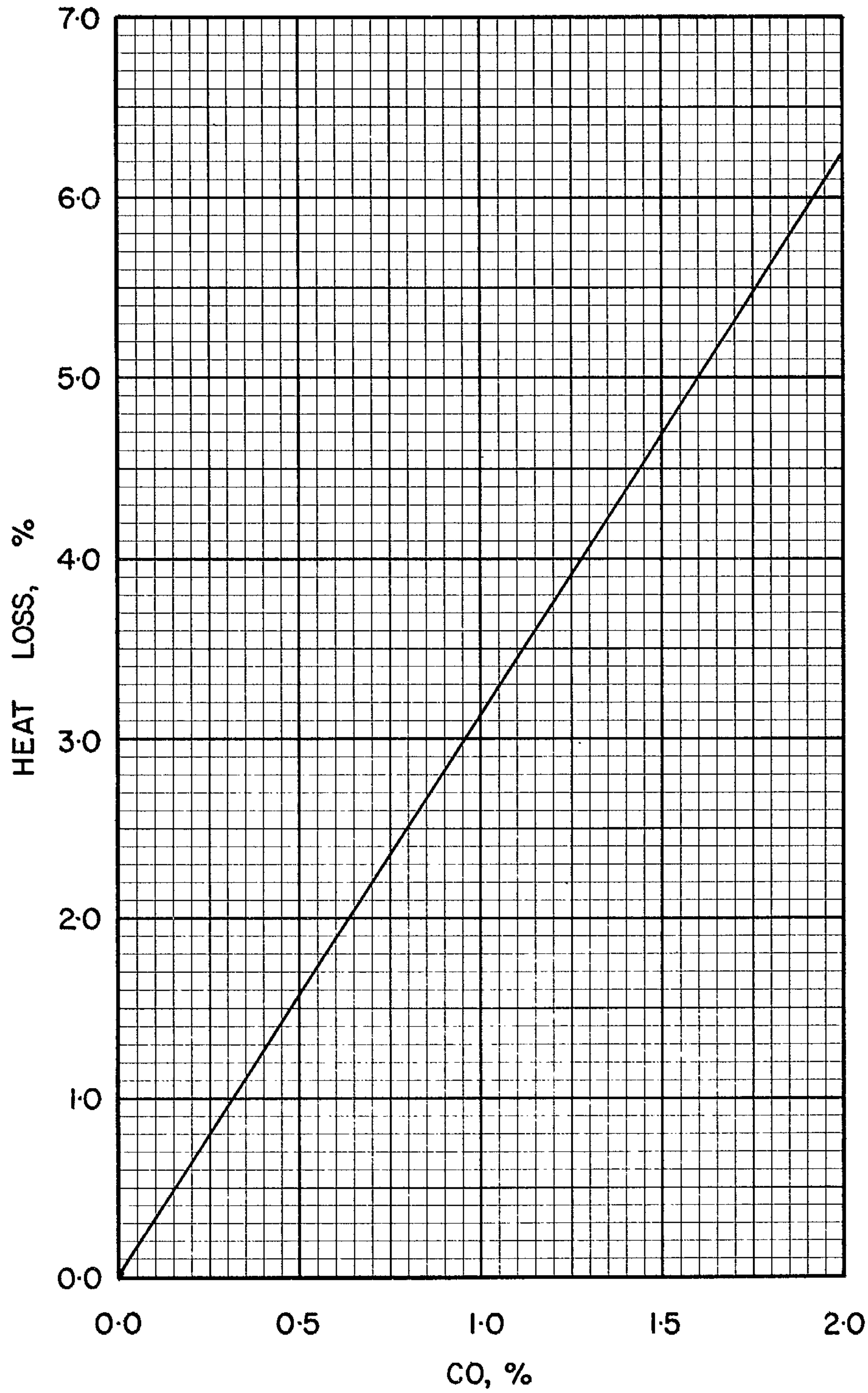


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·9·1

COAL ABC 9-2, FORESTBURG COLLIERIES, CASTOR, – 3/8 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.0955
Volatile Matter	0.3830
Fixed Carbon	0.5215
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6773
Hydrogen (H)	0.0445
Sulphur (S)	0.0065
Nitrogen (N)	0.0138
Oxygen (O)	0.1624
Ash	0.0955
Total	1.0000

Gross Calorific Value

Btu/lb:	11590
Btu/short ton:	23.18×10^6
Btu/long ton:	25.96×10^6
MJ/kg:	26.95

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 86.28 lb
10^6 Btu = 0.04314 short tons
10^6 Btu = 0.03852 long tons

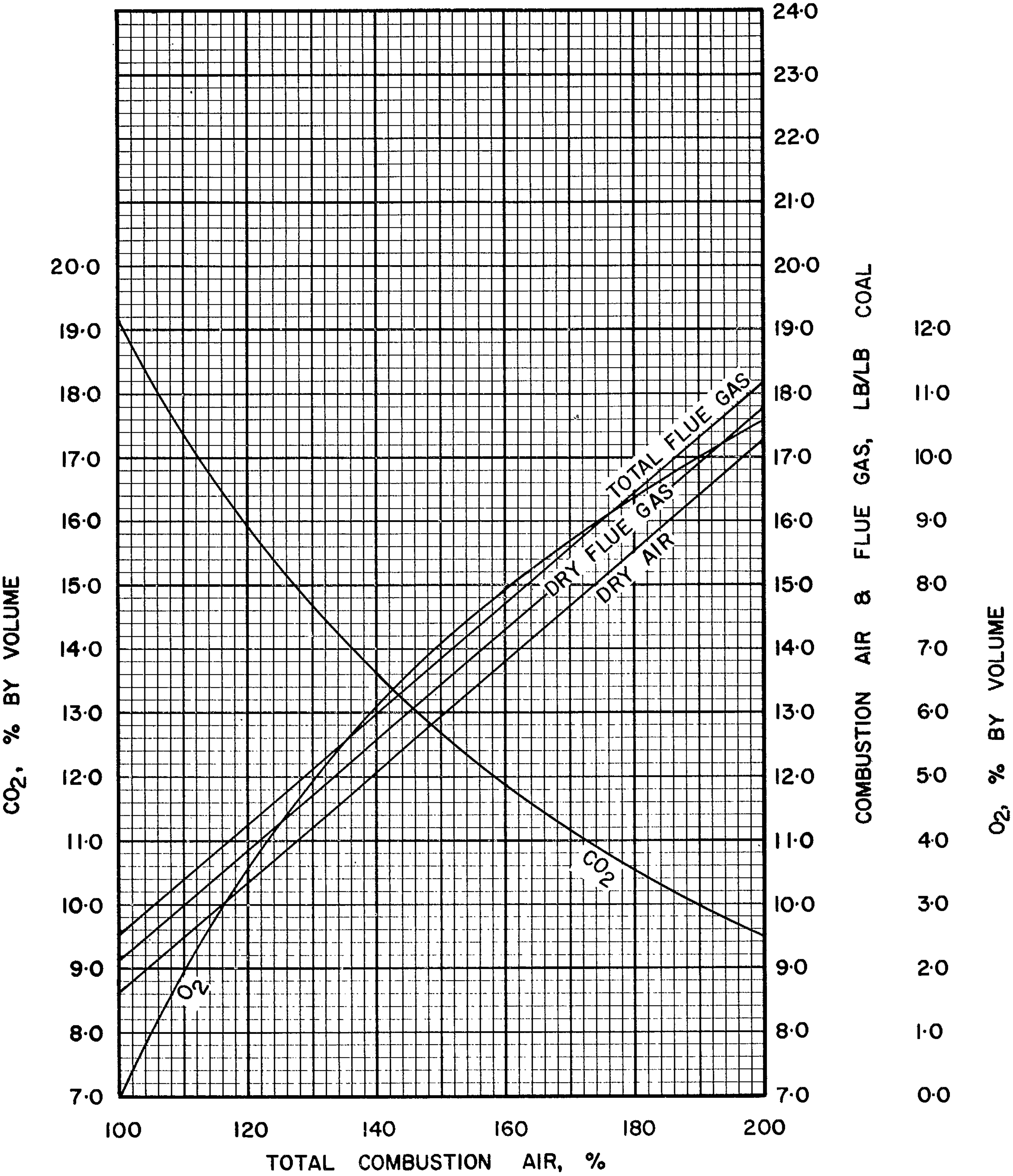


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC·9·2

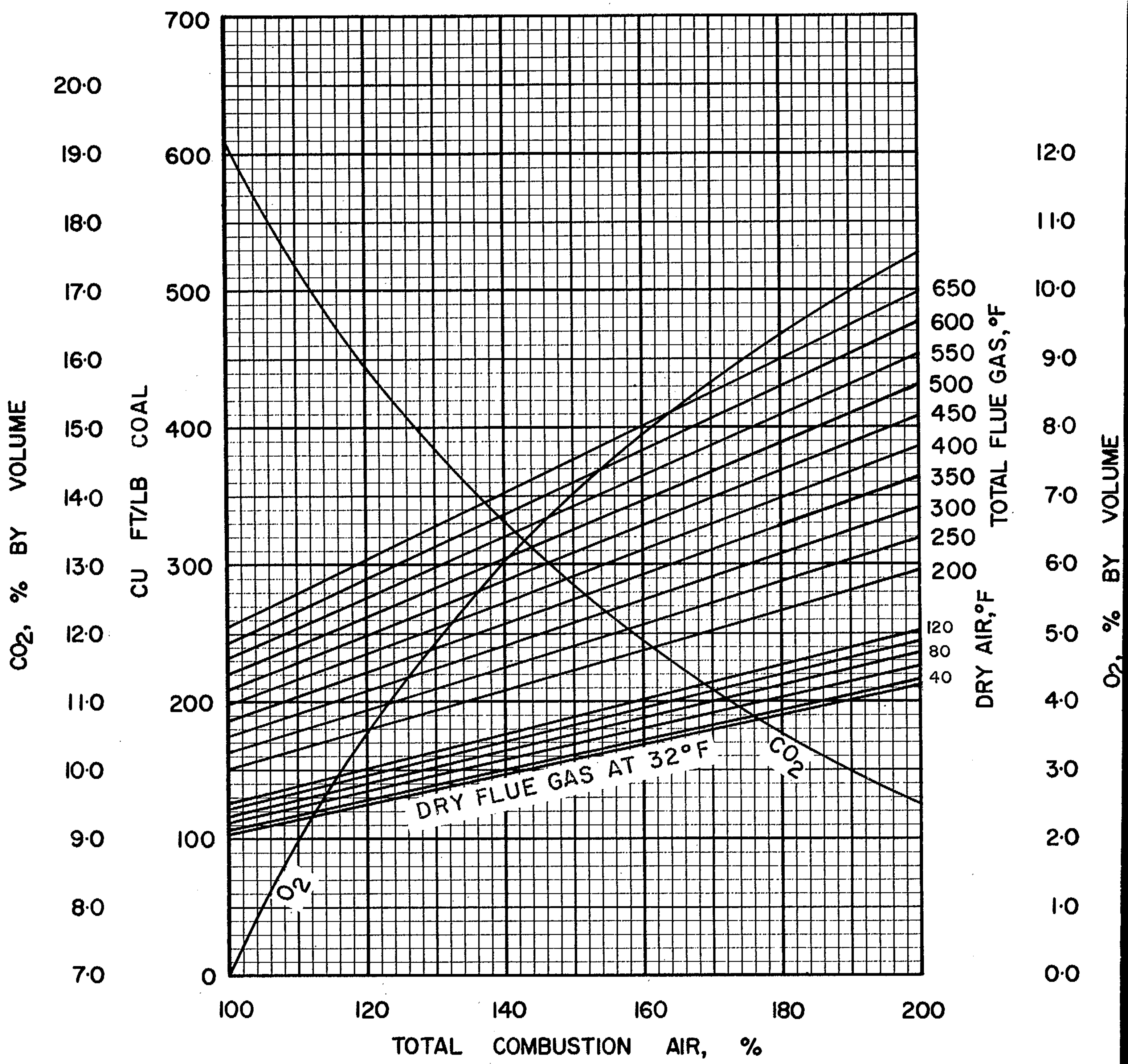


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 9 · 2

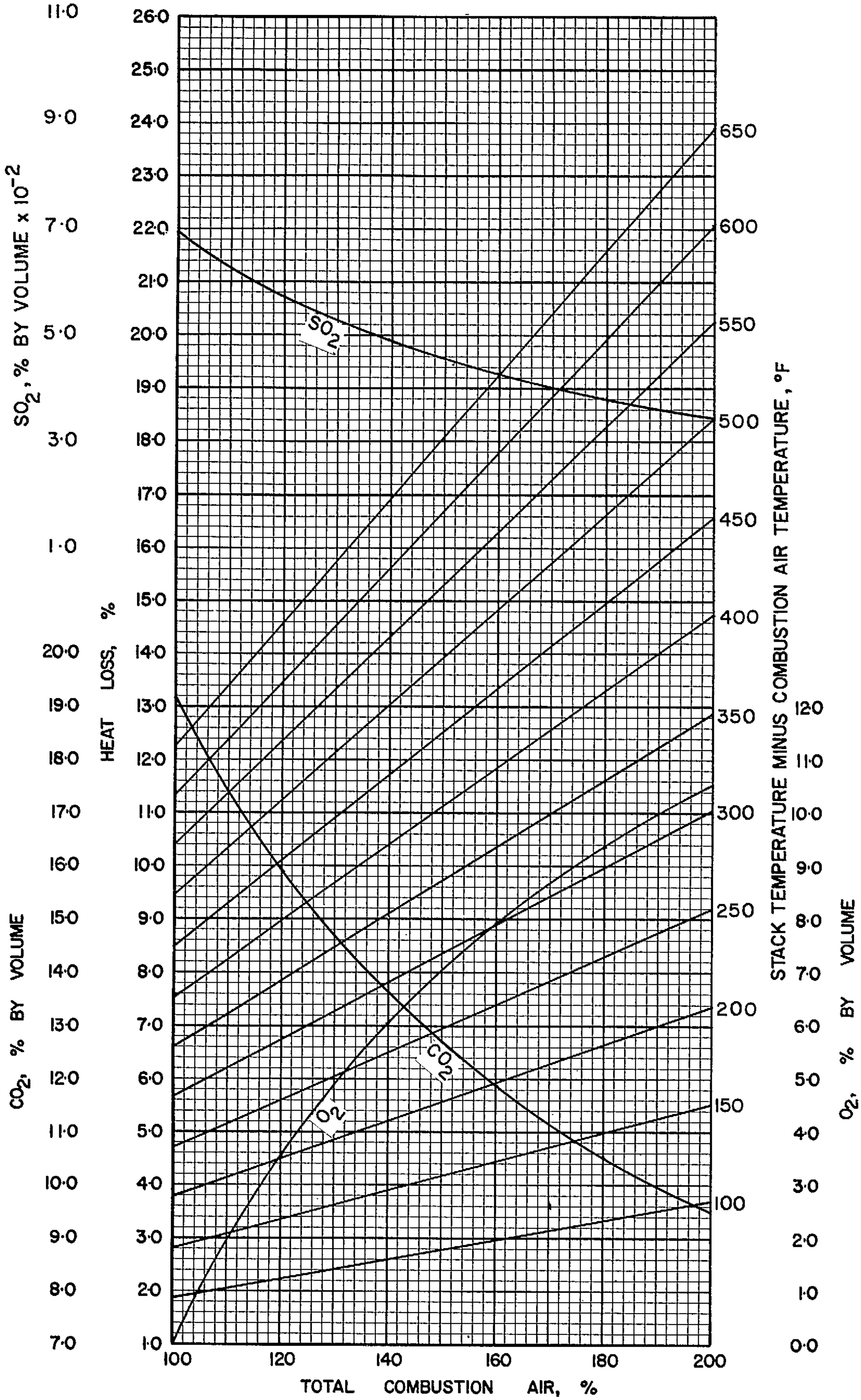


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC· 9 ·2

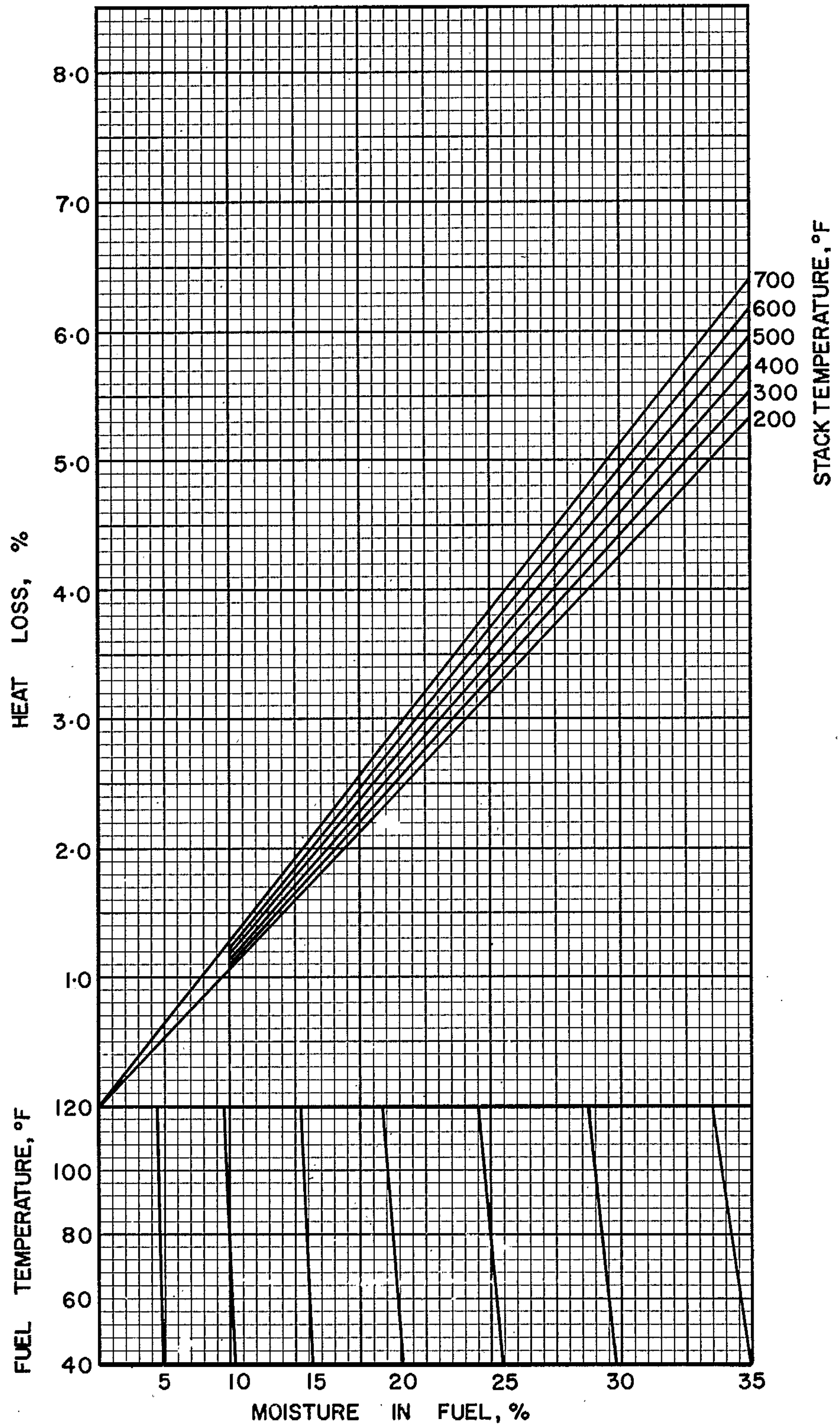


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·9·2

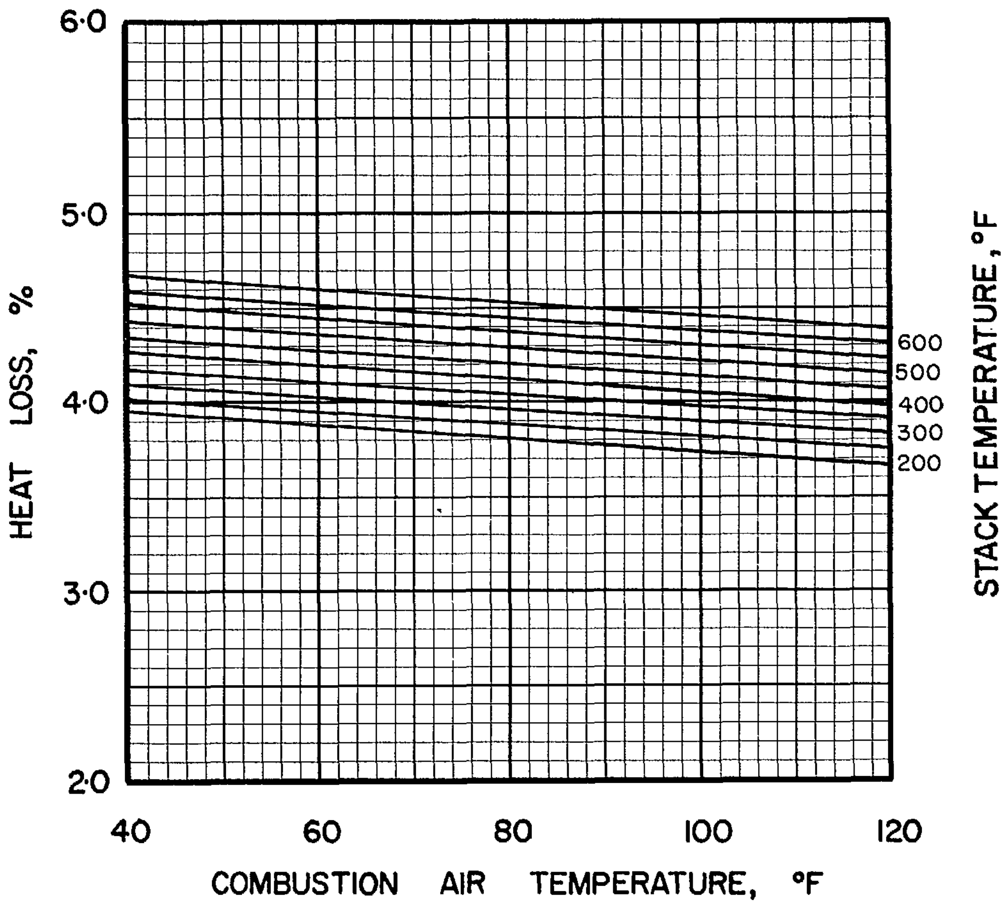


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·9·2

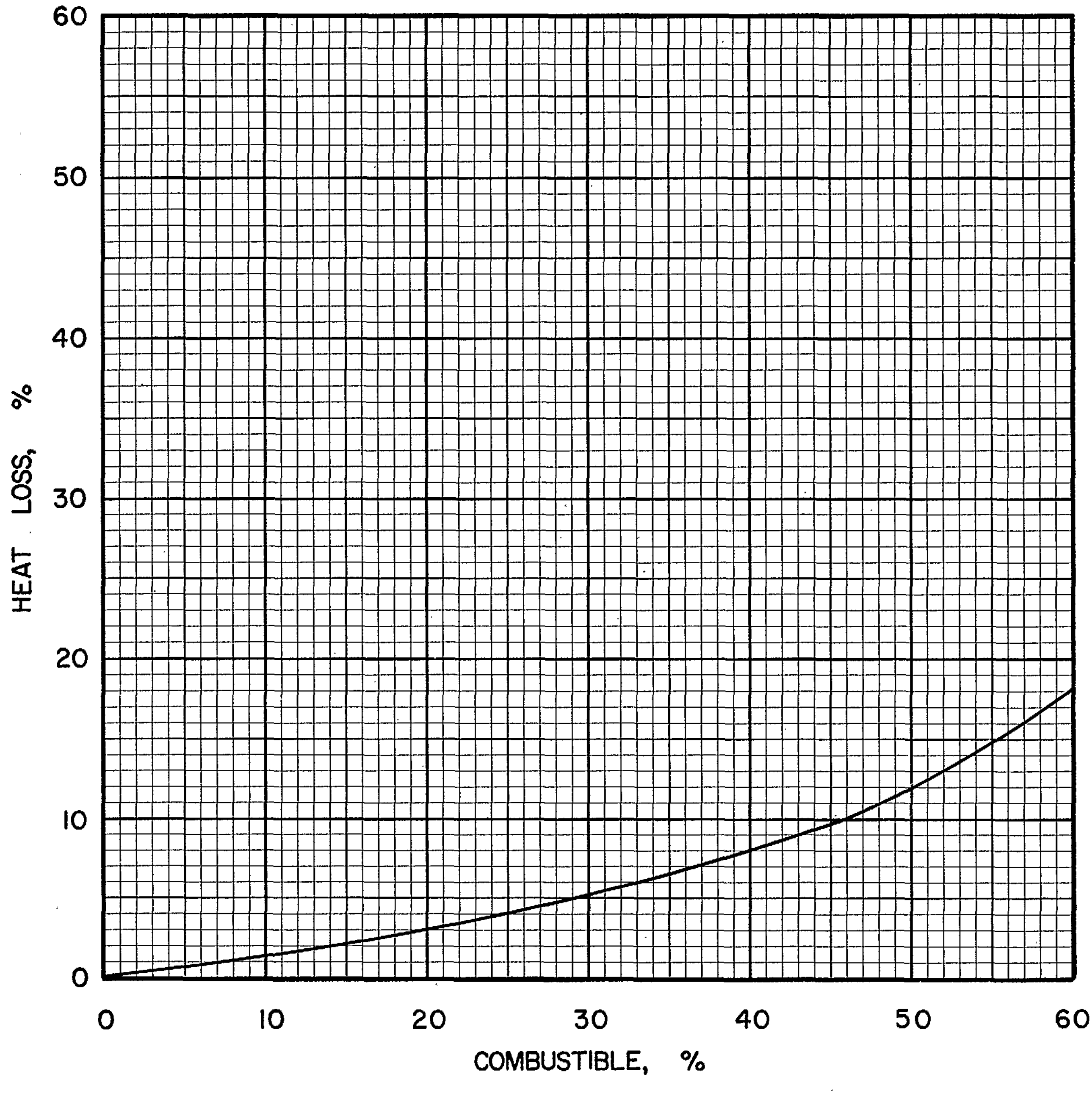


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·9·2

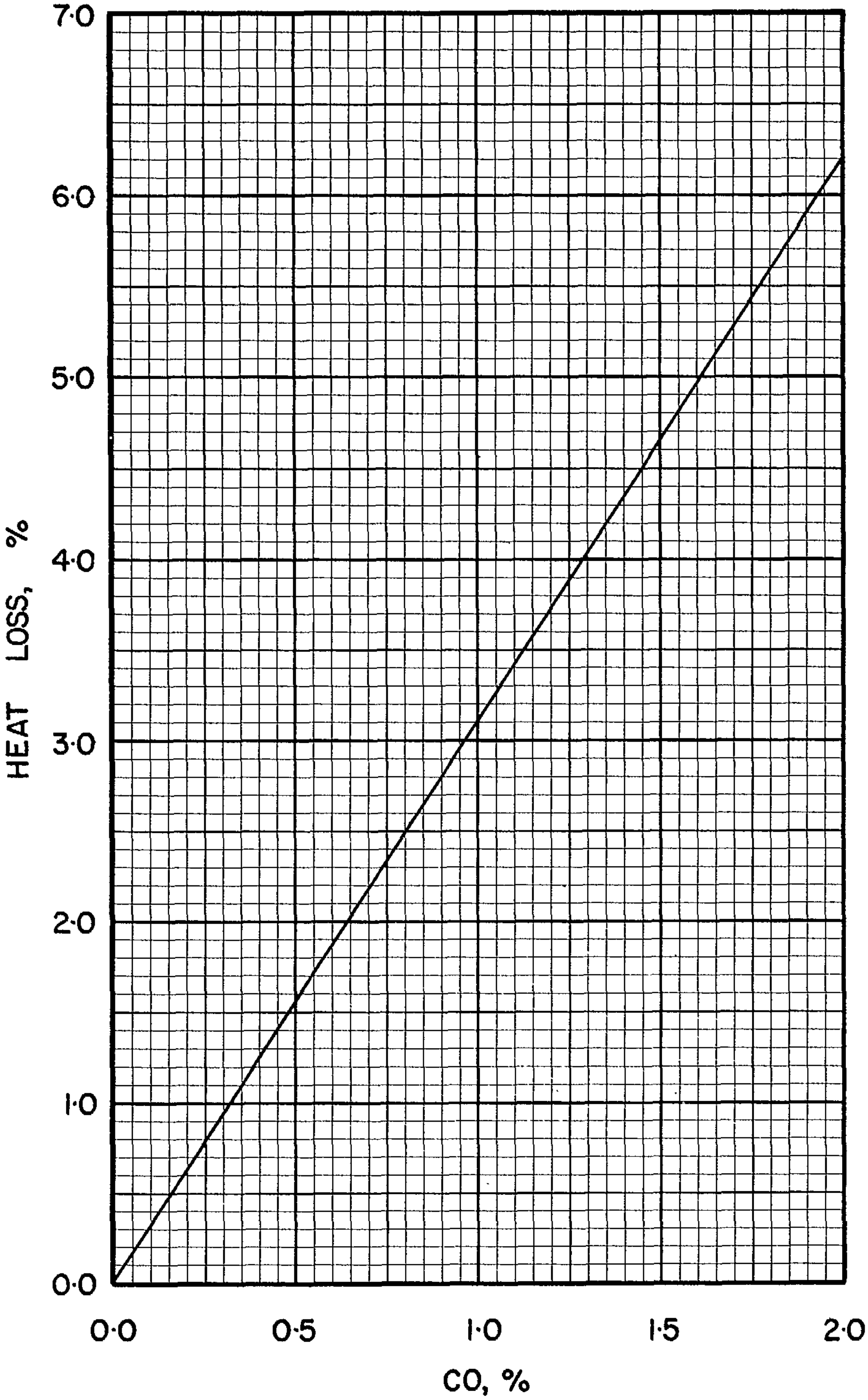


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·9·2

COAL ABC 10-1, GREAT WEST COAL CO., SHEERNESS, 1 1/4 in. x 1/2 in.

Typical Moisture Range: 25–35%

Proximate Analysis (lb/lb dry coal)

Ash	0.0931
Volatile Matter	0.3975
Fixed Carbon	0.5094
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6552
Hydrogen (H)	0.0434
Sulphur (S)	0.0061
Nitrogen (N)	0.0134
Oxygen (O)	0.1888
Ash	0.0931
Total	1.0000

Gross Calorific Value

Btu/lb:	10950
Btu/short ton:	21.90×10^6
Btu/long ton:	24.53×10^6
MJ/kg:	25.46

Conversion Factors

1 short ton	=	0.8929	long tons	= 2000 lb
10^6 Btu	=	91.32	lb	
10^6 Btu	=	0.04566	short tons	
10^6 Btu	=	0.04077	long tons	

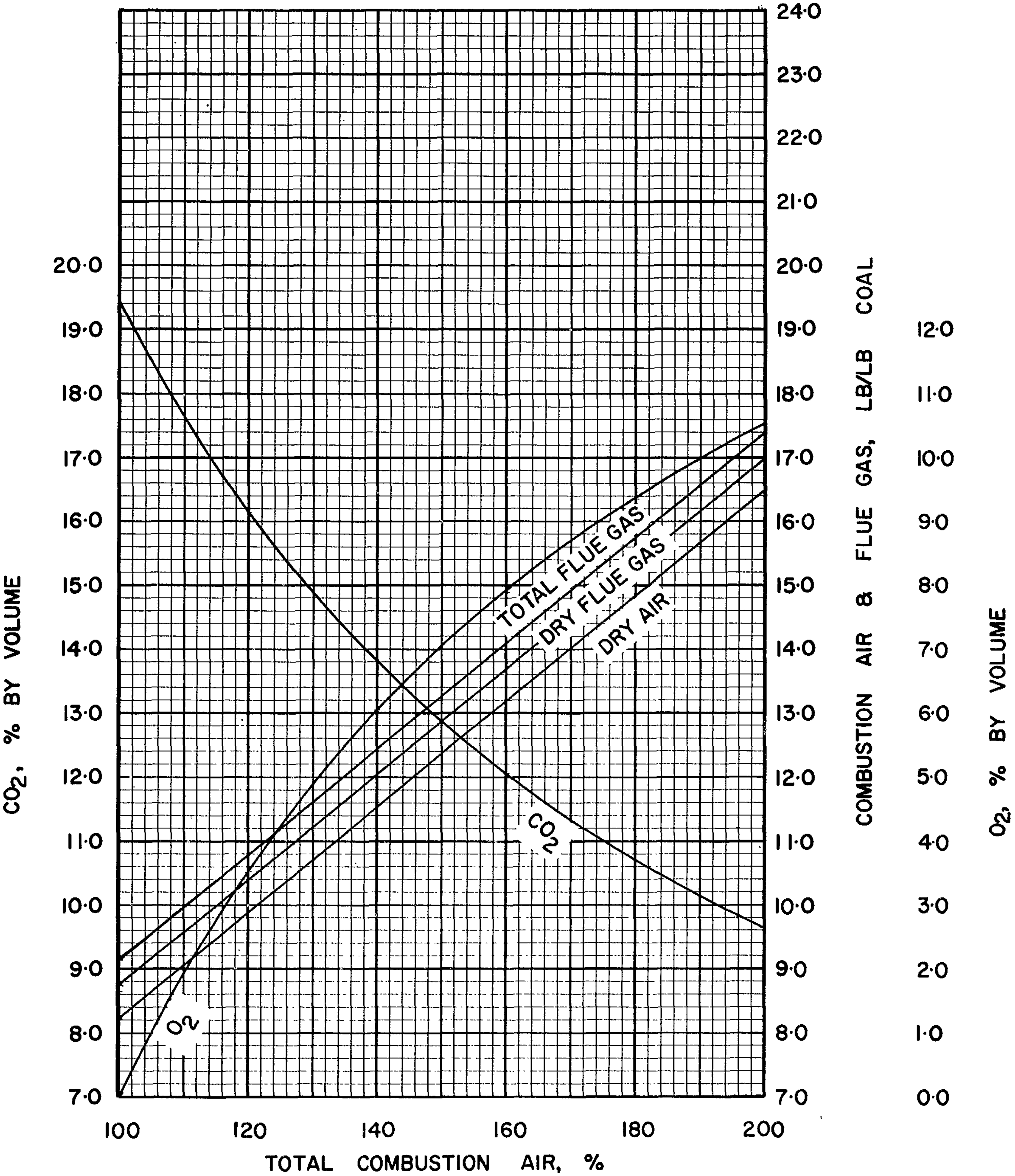


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC·10·1

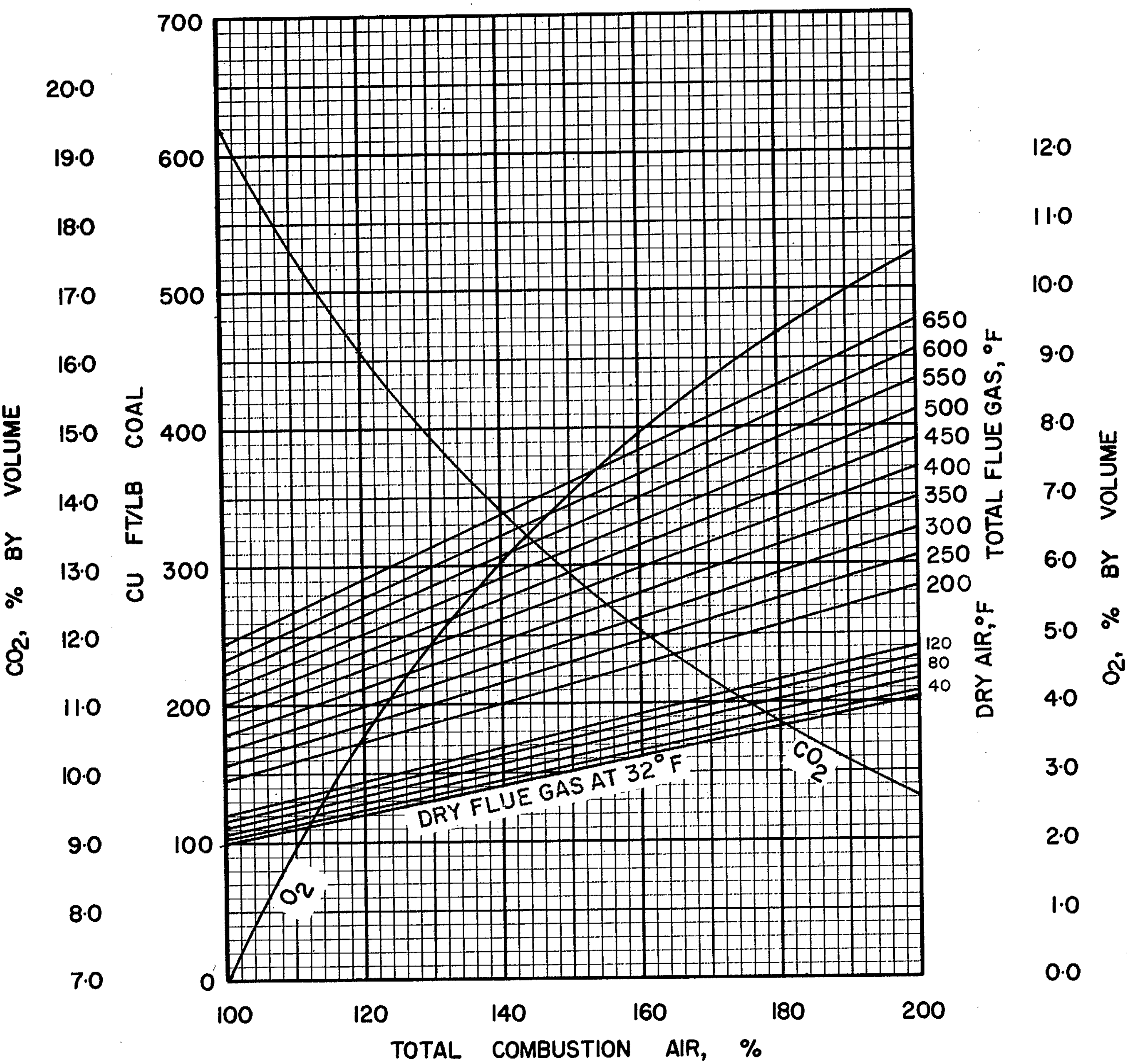


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 10 · 1

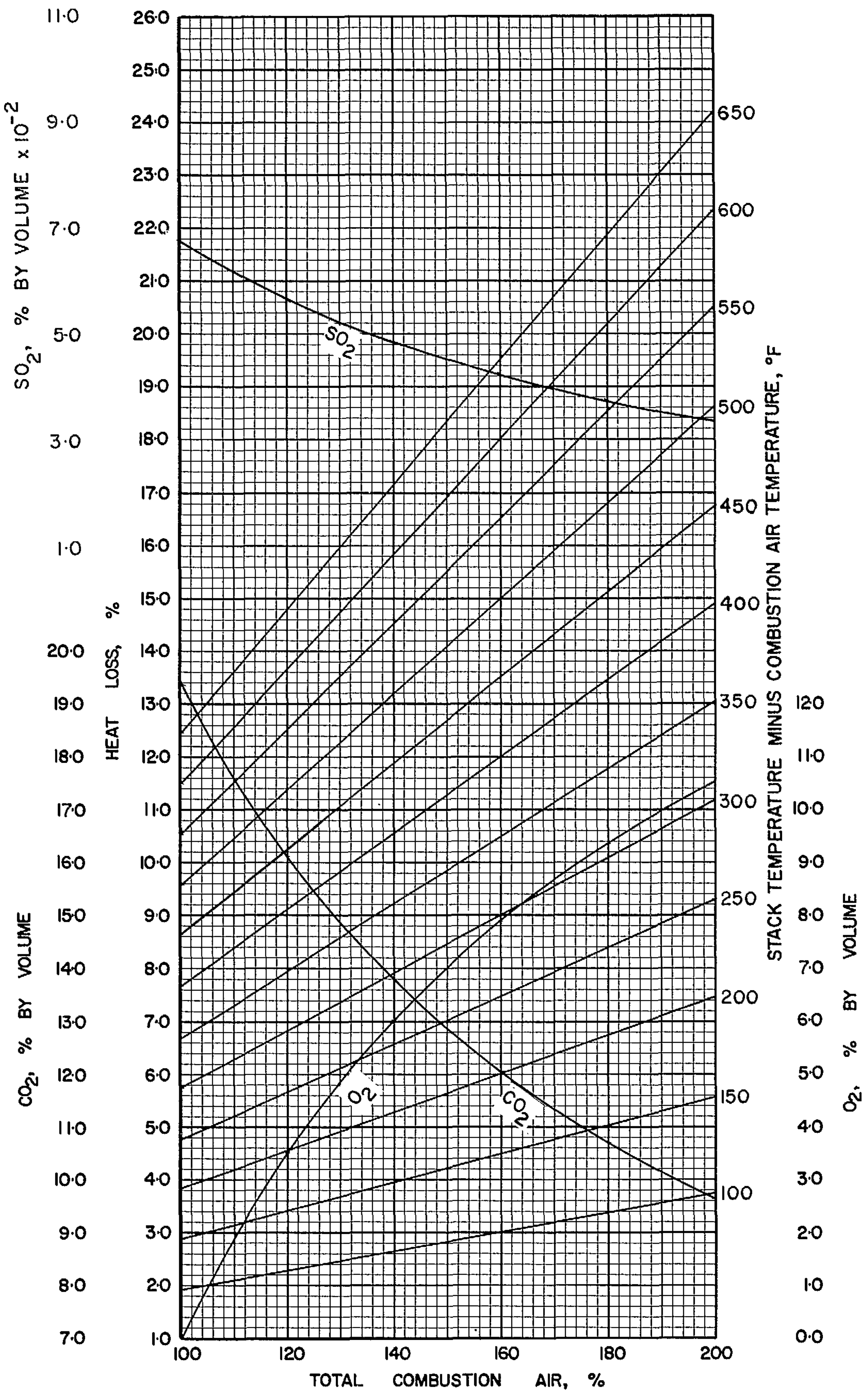


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·10·1

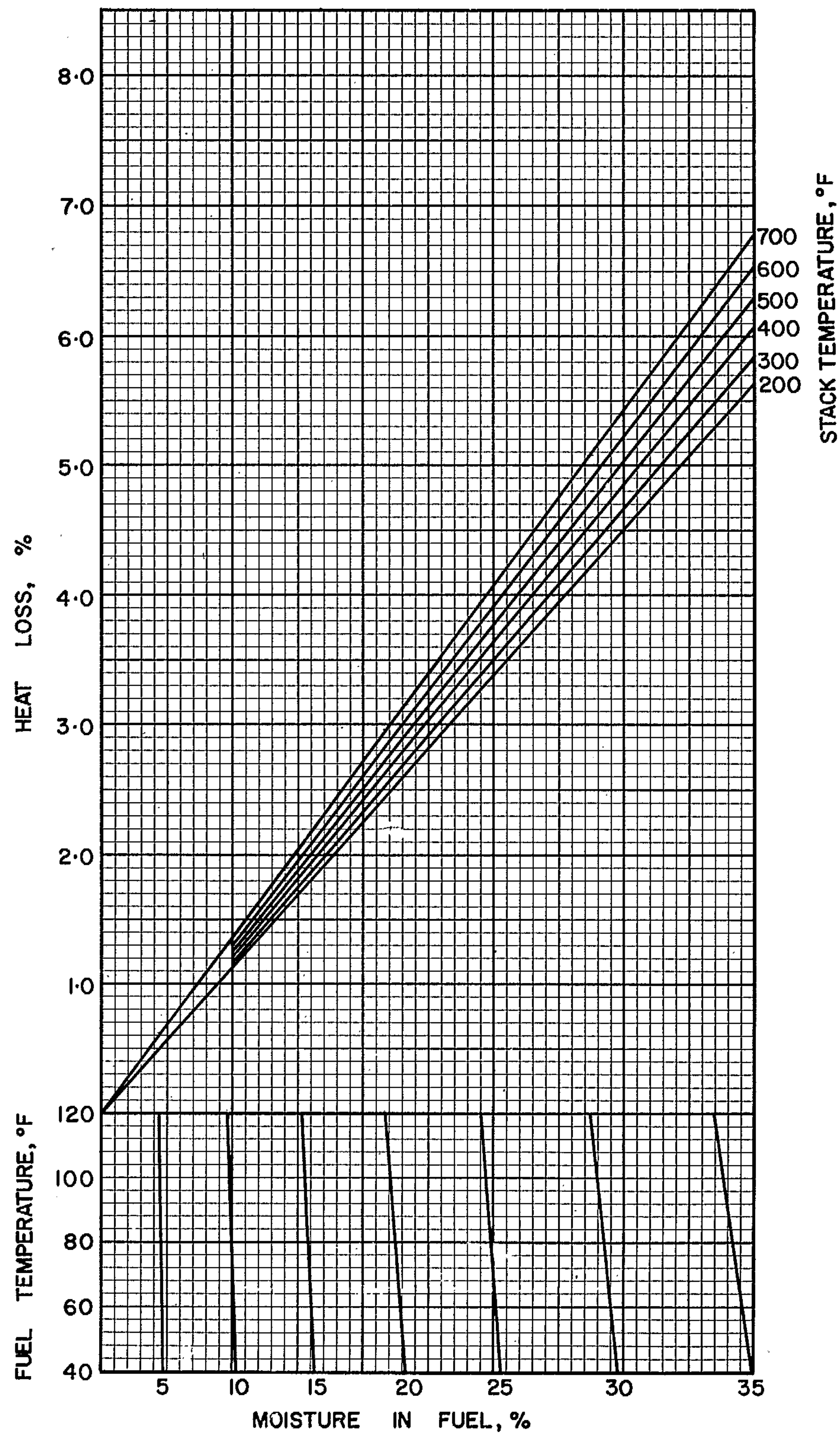


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC·10·1

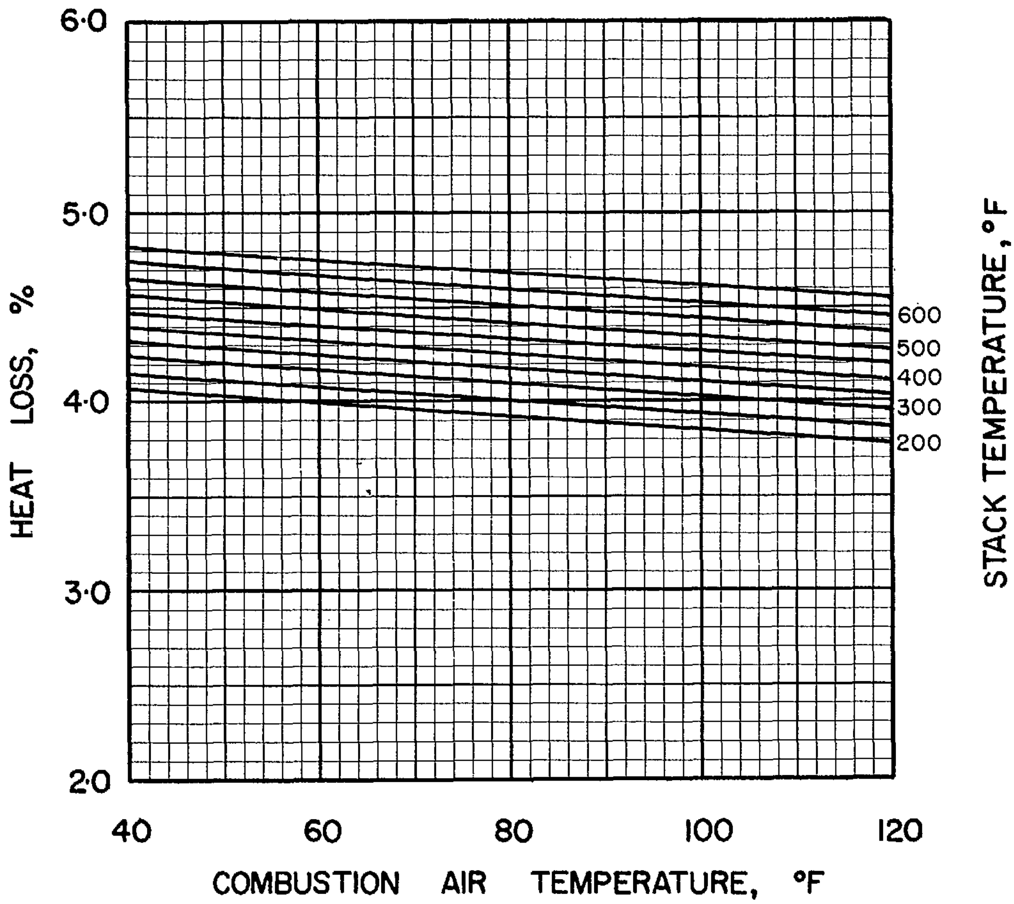


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·10·1

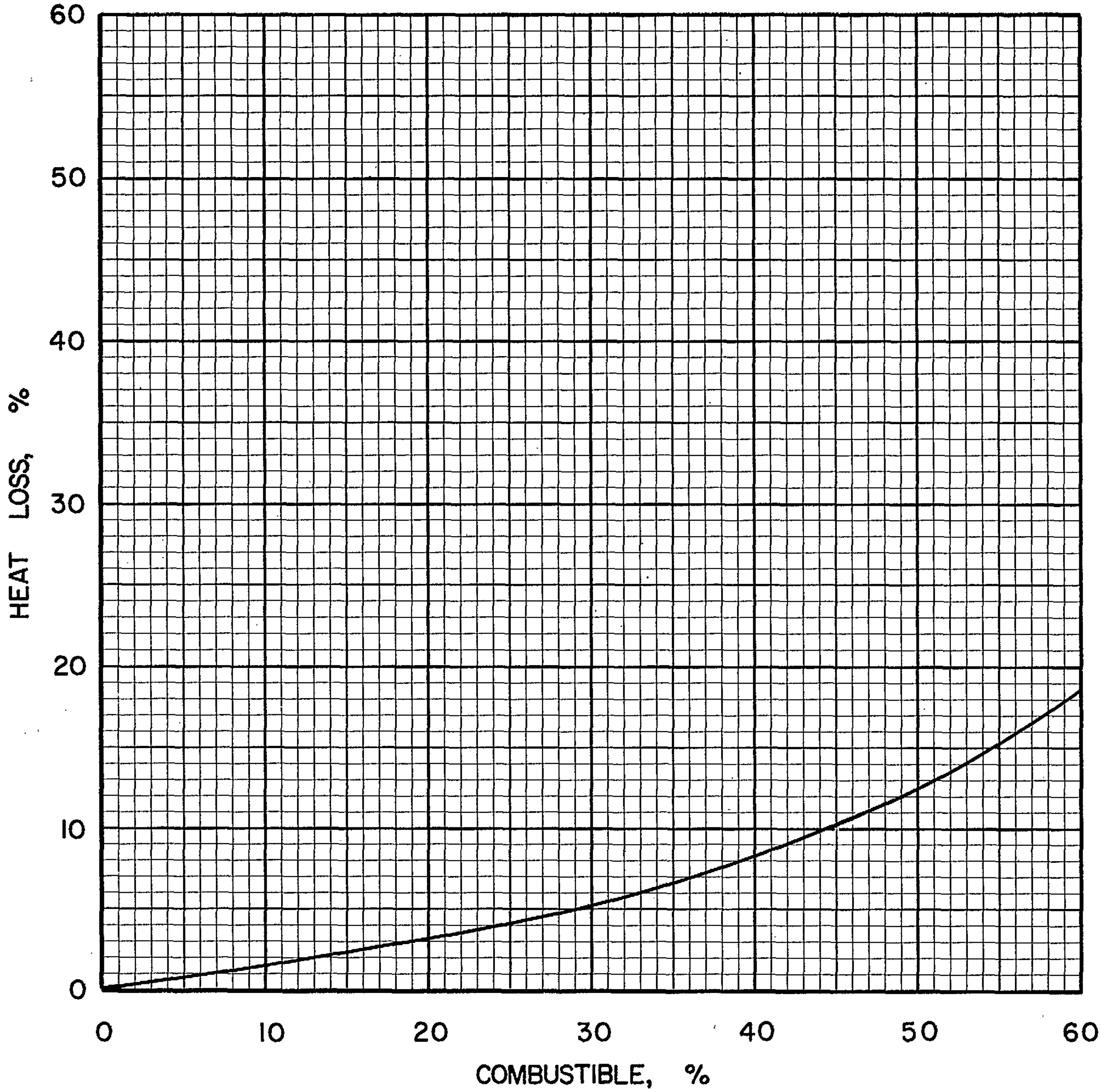


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·10·1

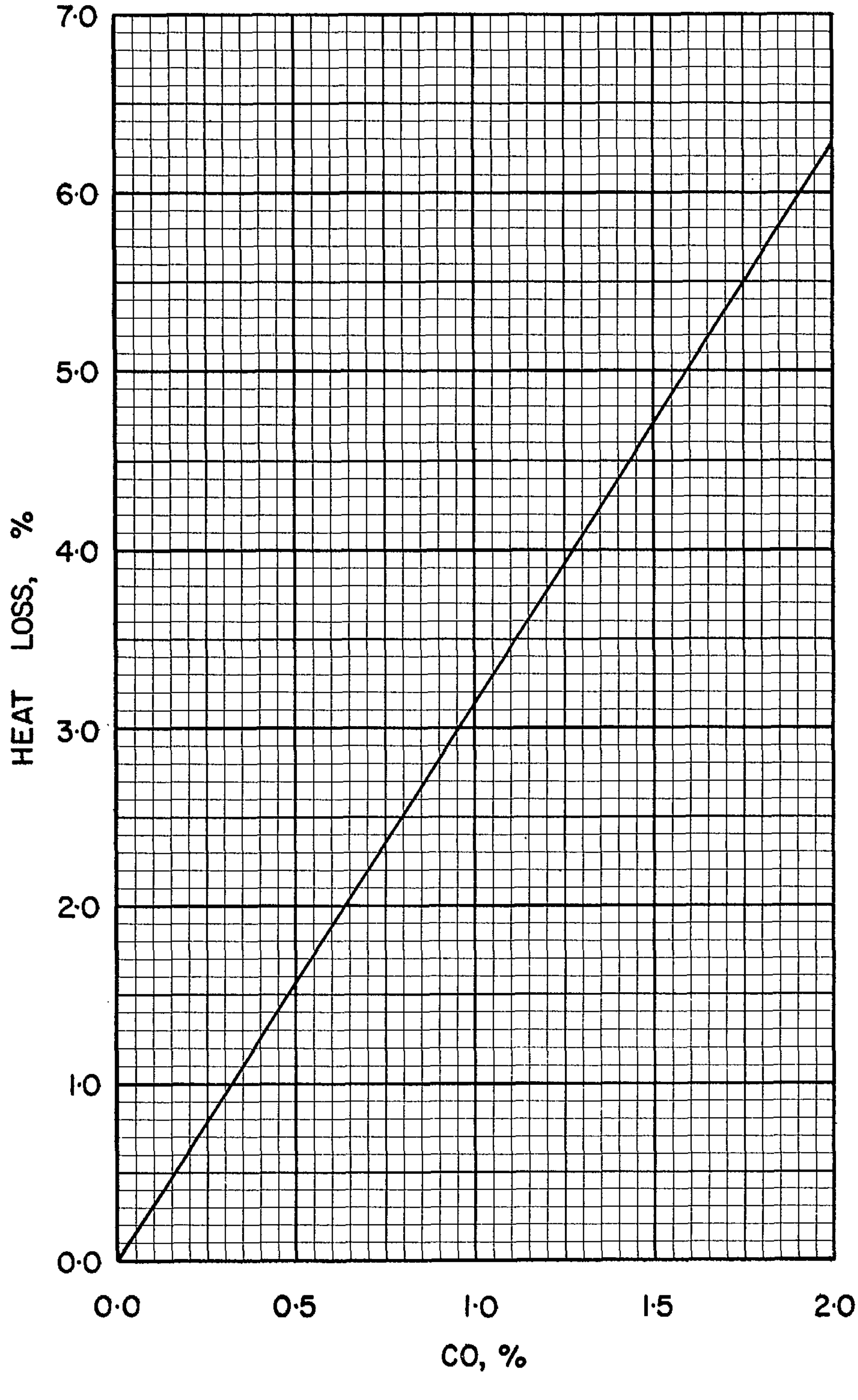


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·10·1

COAL ABC 10-2, GREAT WEST COAL CO., SHEERNESS, – 1/2 in.

Typical Moisture Range: 25–35%

Proximate Analysis (lb/lb dry coal)

Ash	0.1052
Volatile Matter	0.3941
Fixed Carbon	0.5007
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6497
Hydrogen (H)	0.0416
Sulphur (S)	0.0075
Nitrogen (N)	0.0135
Oxygen (O)	0.1825
Ash	0.1052
Total	1.0000

Gross Calorific Value

Btu/lb:	10890
Btu/short ton:	21.78×10^6
Btu/long ton:	24.39×10^6
MJ/kg:	25.32

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 91.83	lb	
10^6 Btu	= 0.04591	short tons	
10^6 Btu	= 0.04099	long tons	

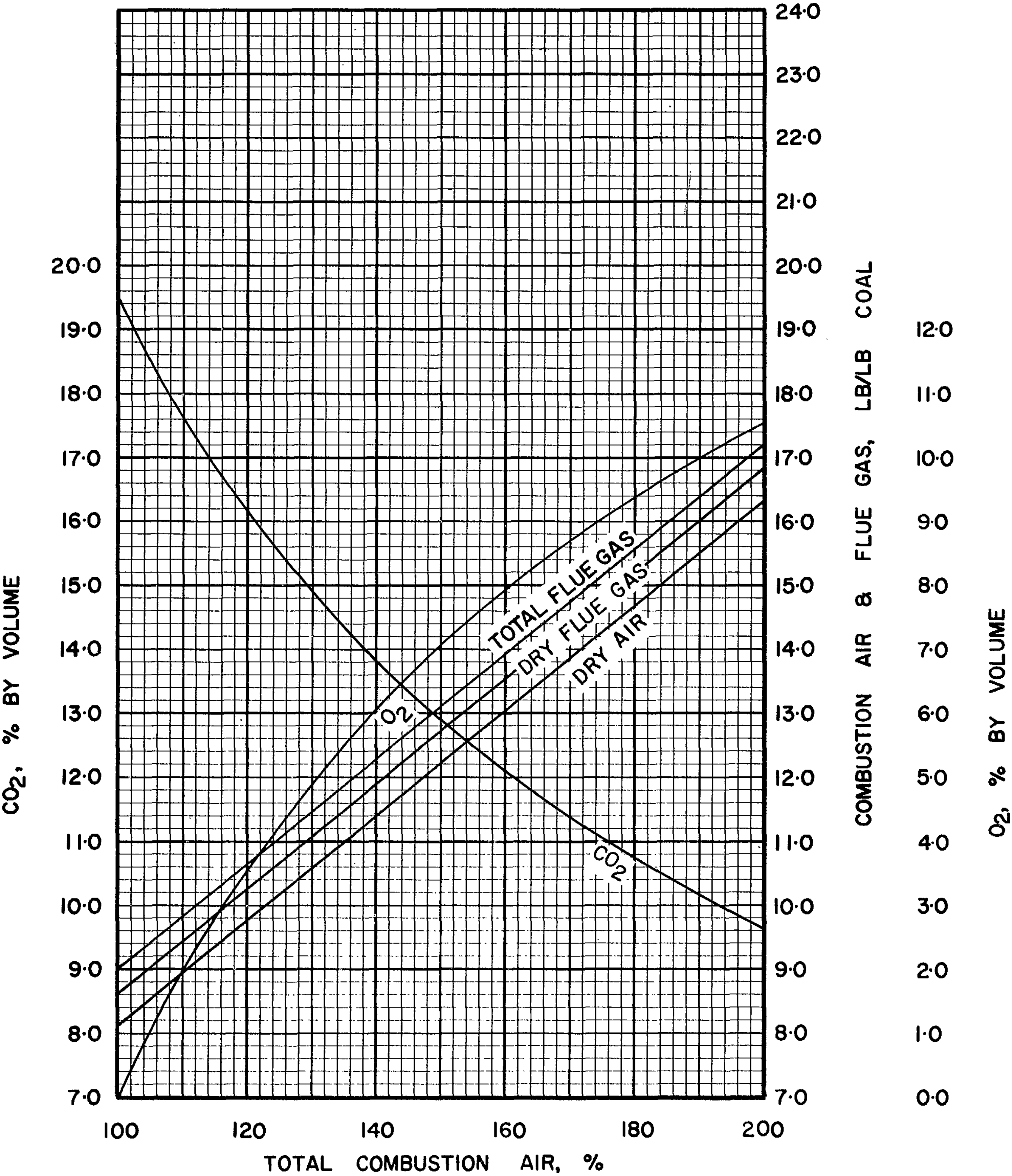


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC · 10 · 2

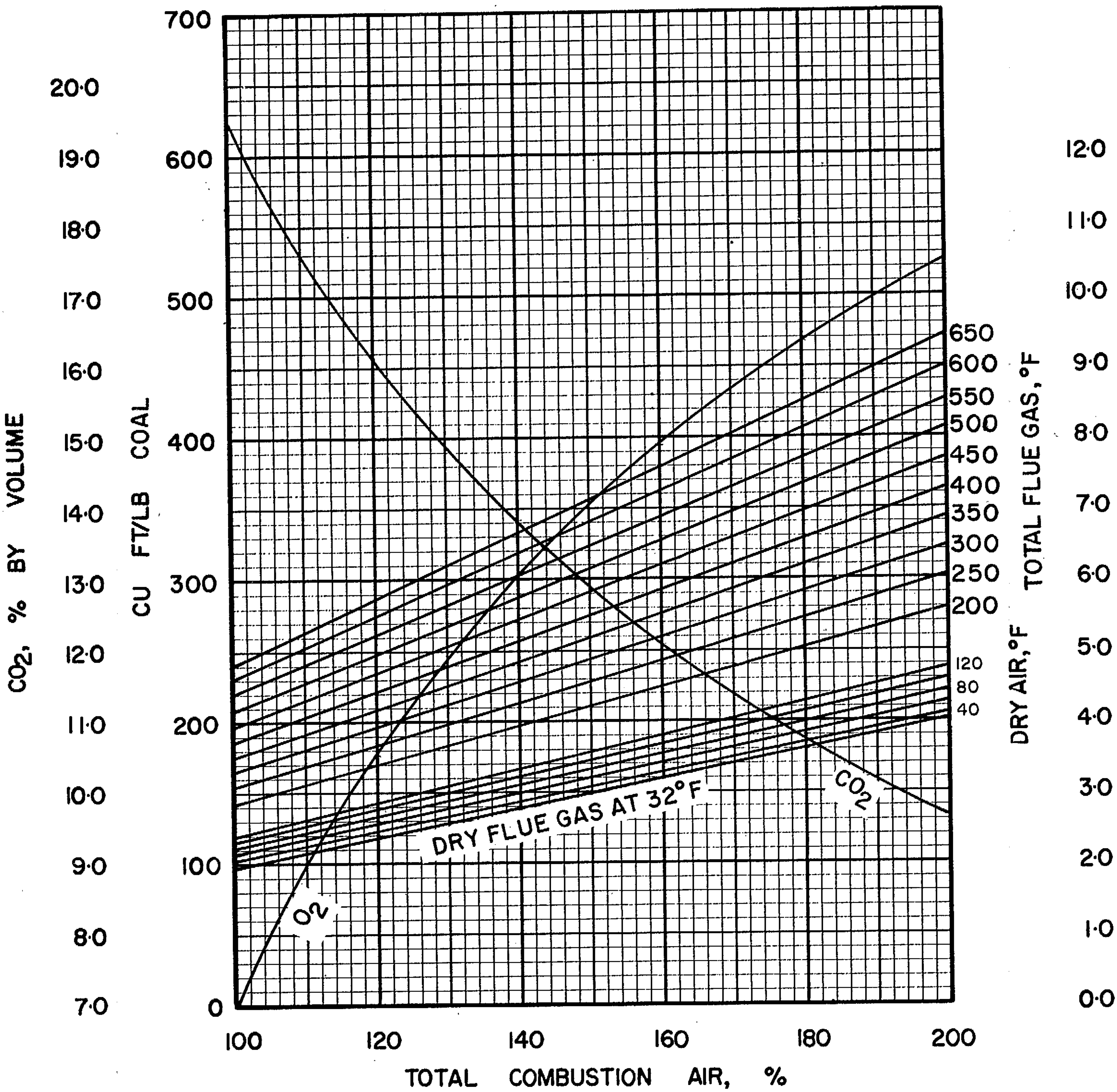


FIGURE 2· COMBUSTION DATA, VOLUME BASIS

ABC·10-2

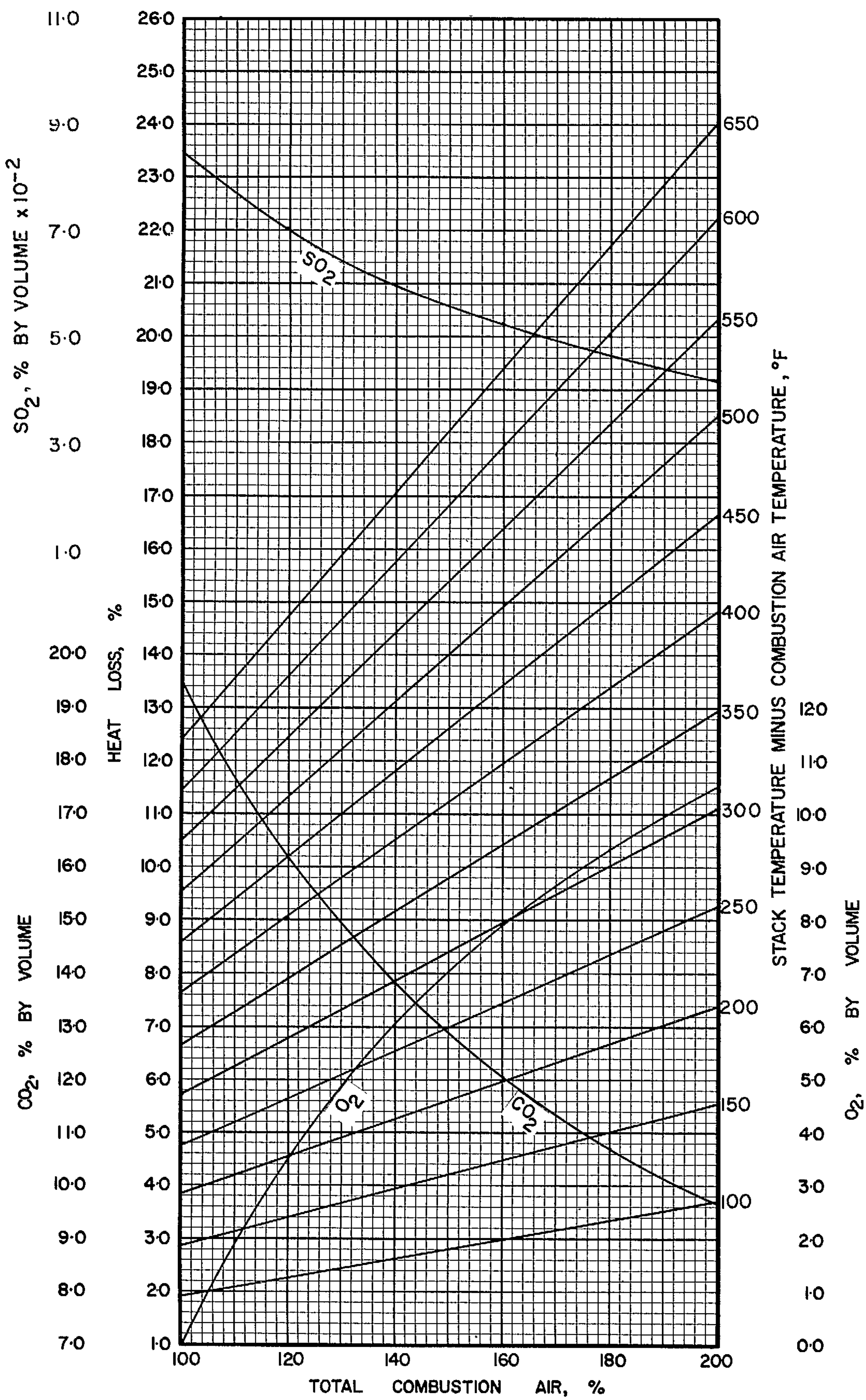


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·10·2

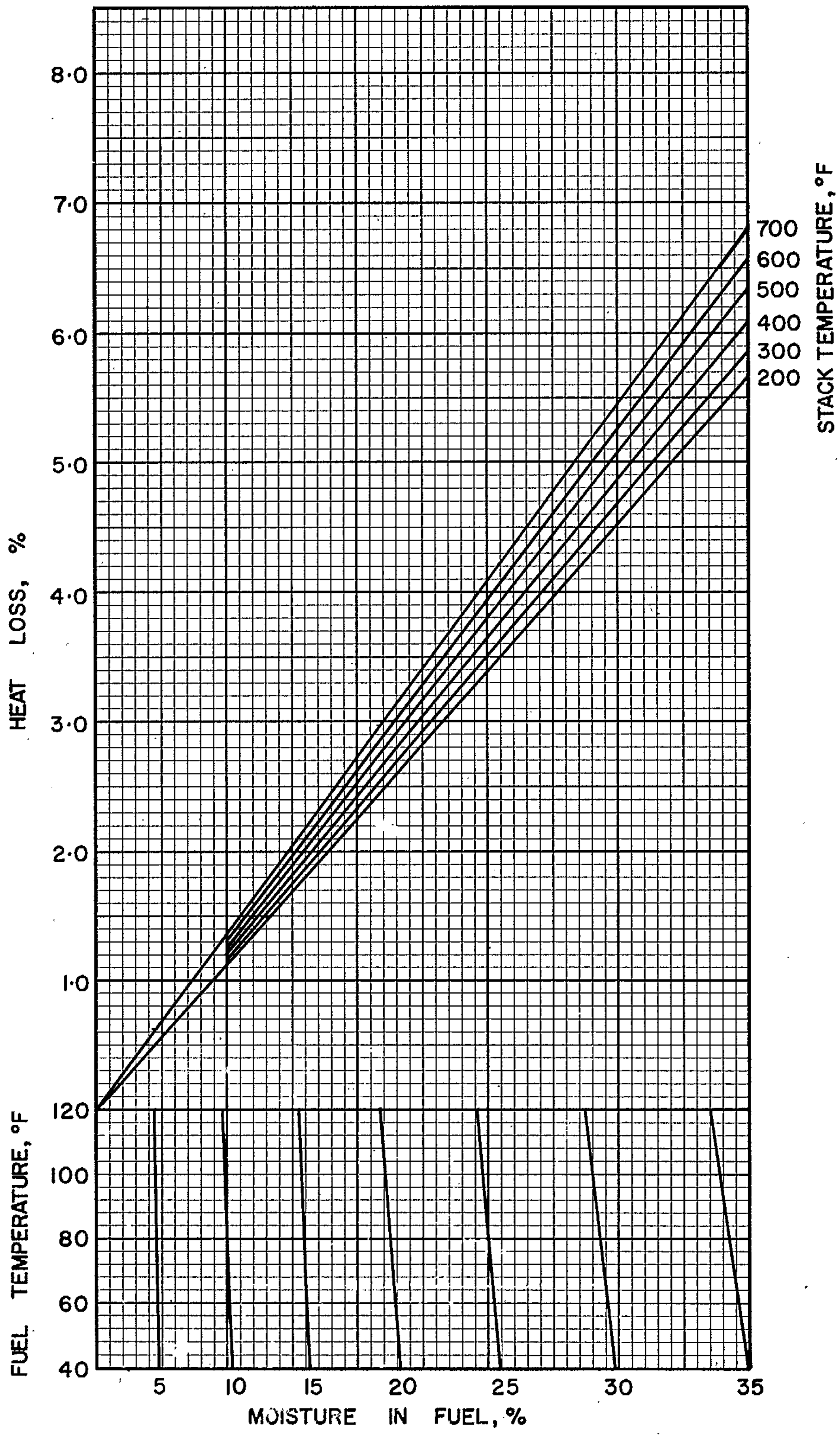


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·10·2

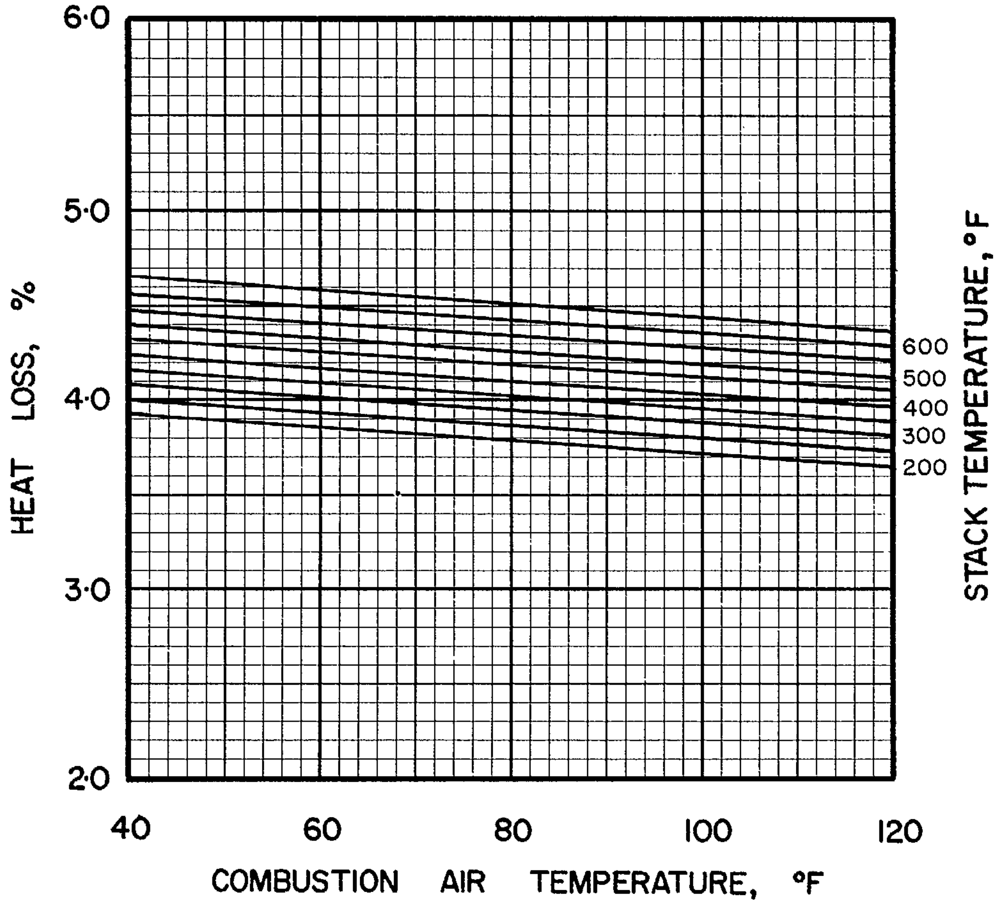


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·10·2

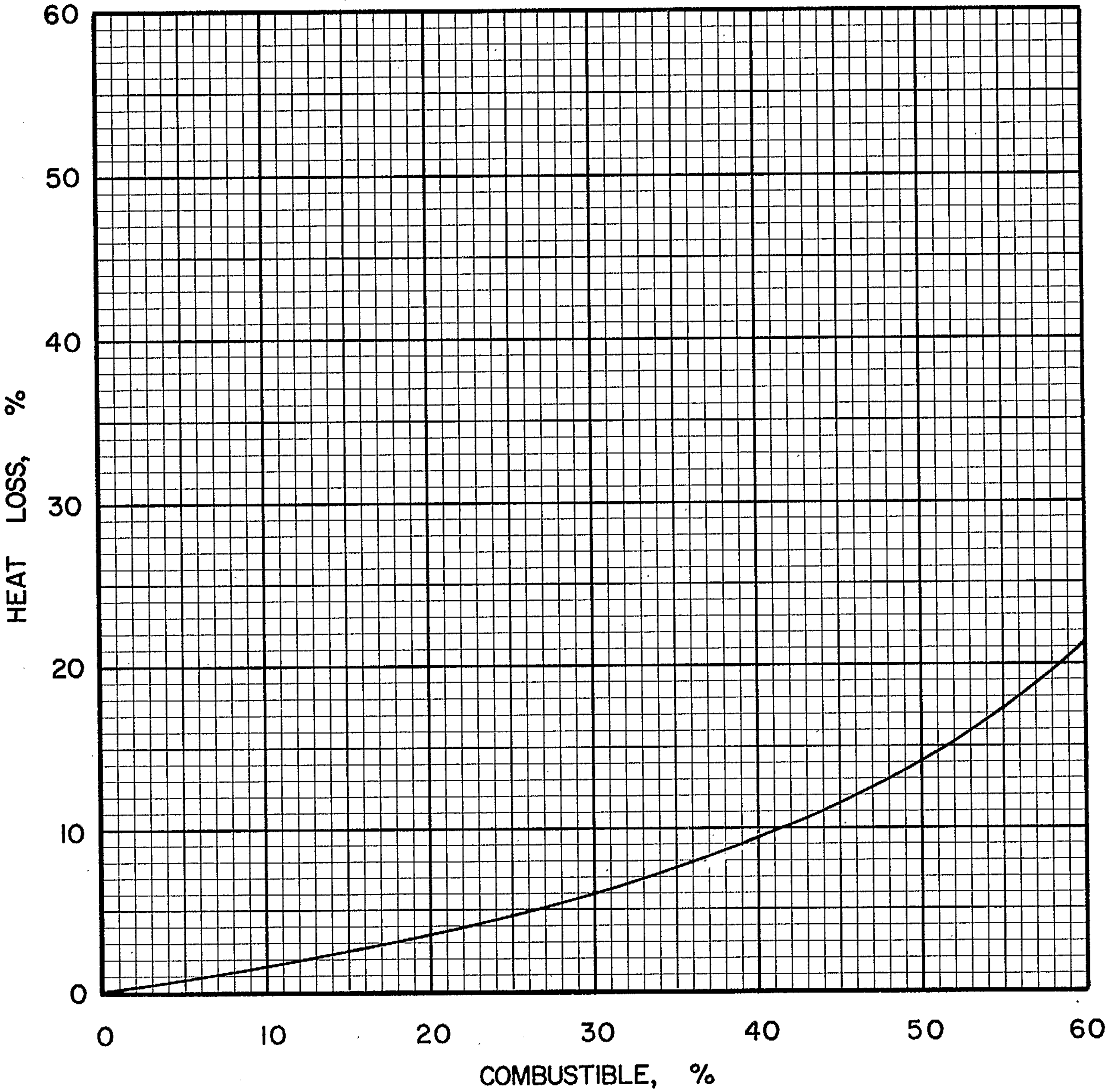


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·10·2

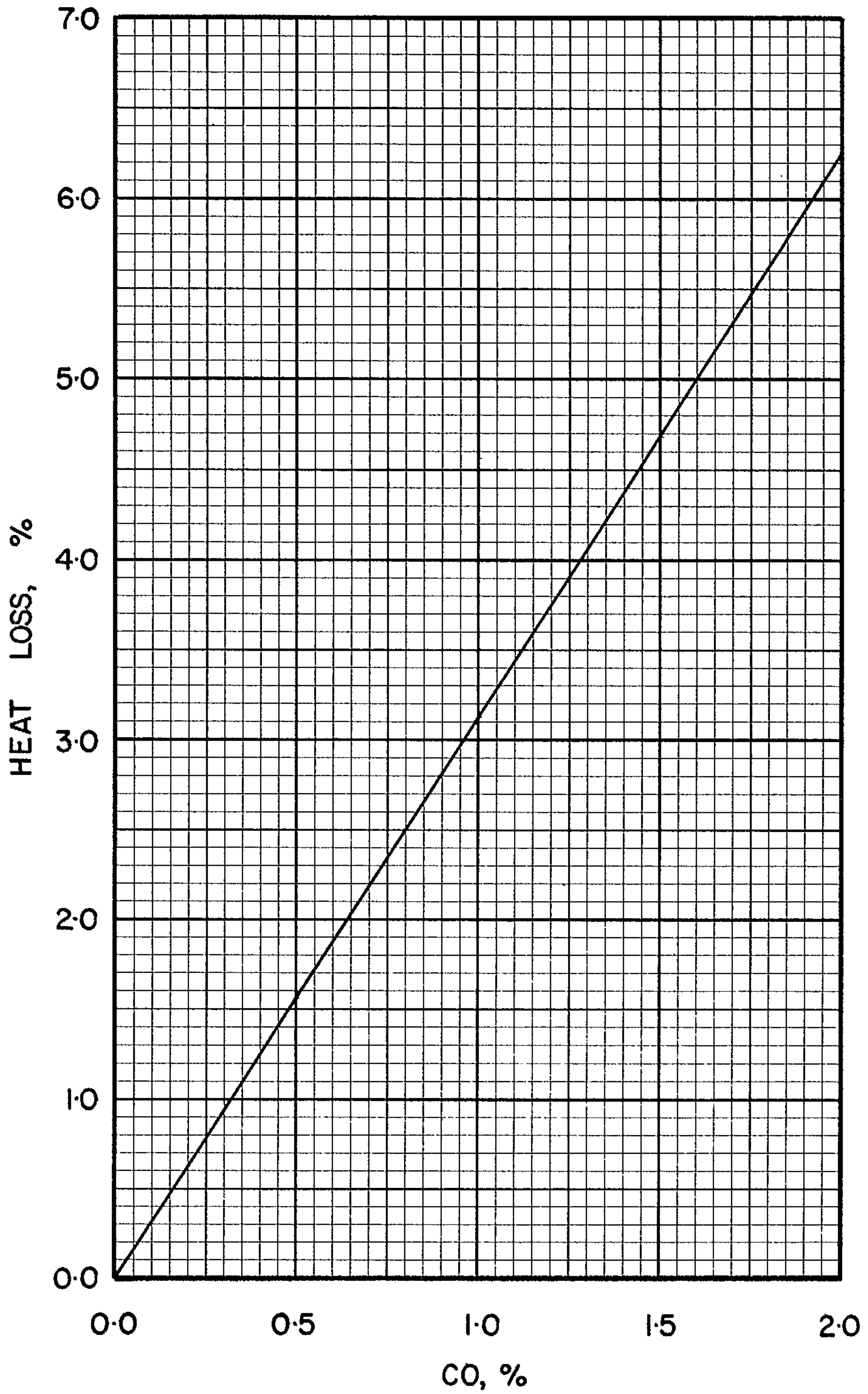


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·10·2

COAL ABC 11-1, SCISSONS' MINE, ARDLEY, No. 809, MINE RUN

Typical Moisture Range: 15–25%

Proximate Analysis (lb/lb dry coal)

Ash	0.0986
Volatile Matter	0.3570
Fixed Carbon	0.5444
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6798
Hydrogen (H)	0.0403
Sulphur (S)	0.0035
Nitrogen (N)	0.0101
Oxygen (O)	0.1677
Ash	0.0986
Total	1.0000

Gross Calorific Value

Btu/lb:	11363
Btu/short ton:	22.73×10^6
Btu/long ton:	25.45×10^6
MJ/kg:	26.42

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 88.00 lb
10^6 Btu = 0.04400 short tons
10^6 Btu = 0.03929 long tons

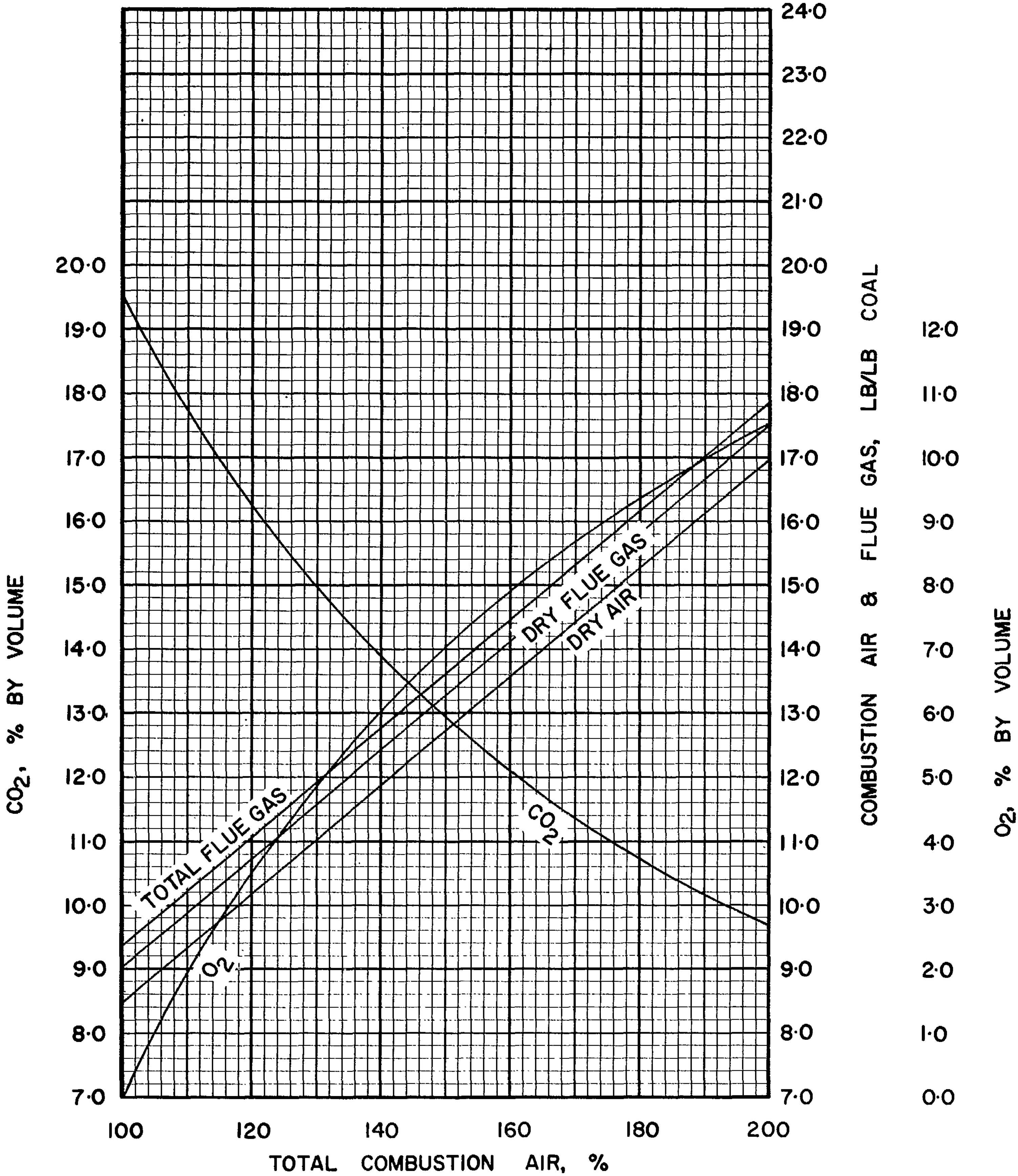


FIGURE I· COMBUSTION DATA, WEIGHT BASIS ABC·II·I

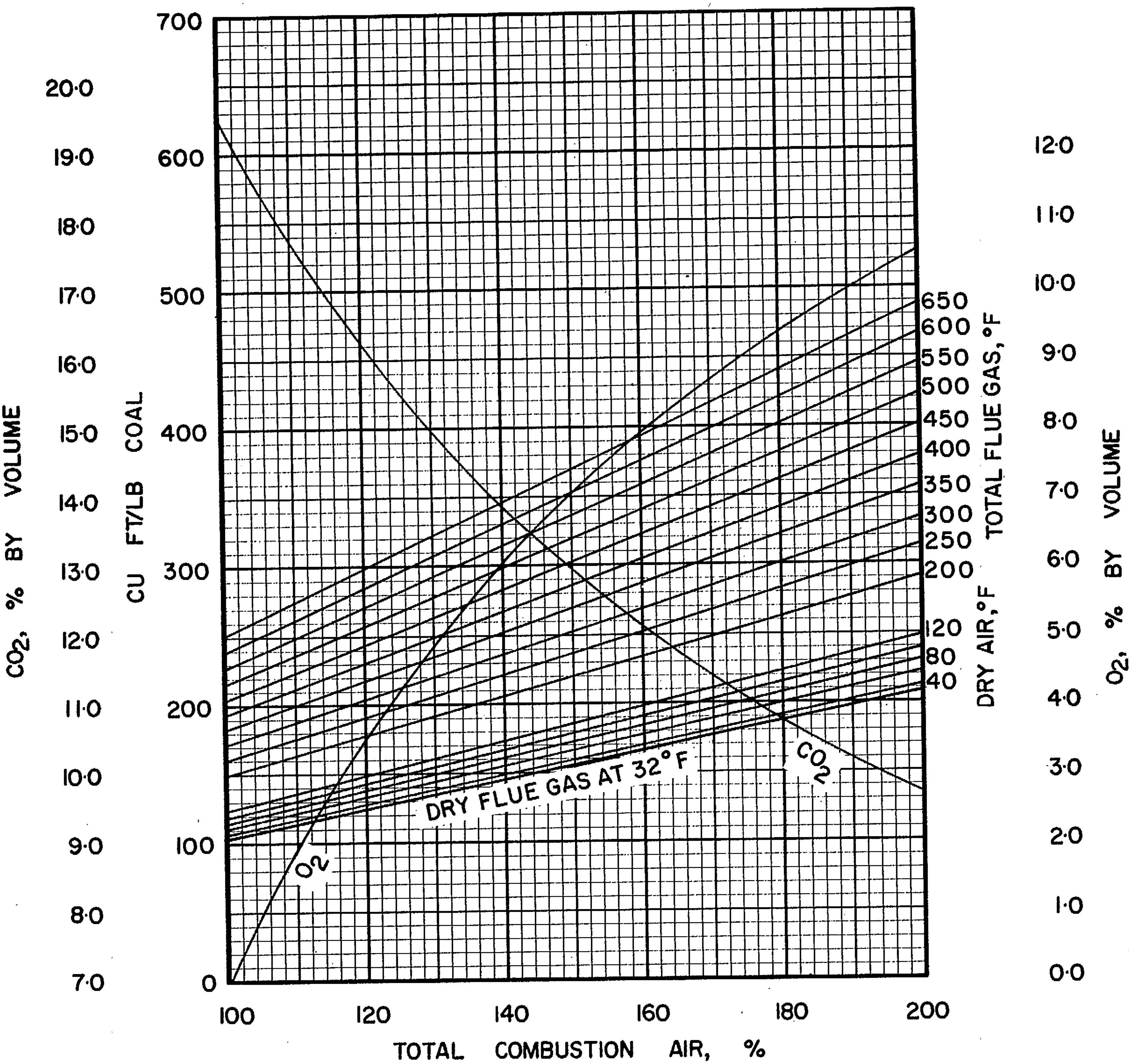


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC·11·1

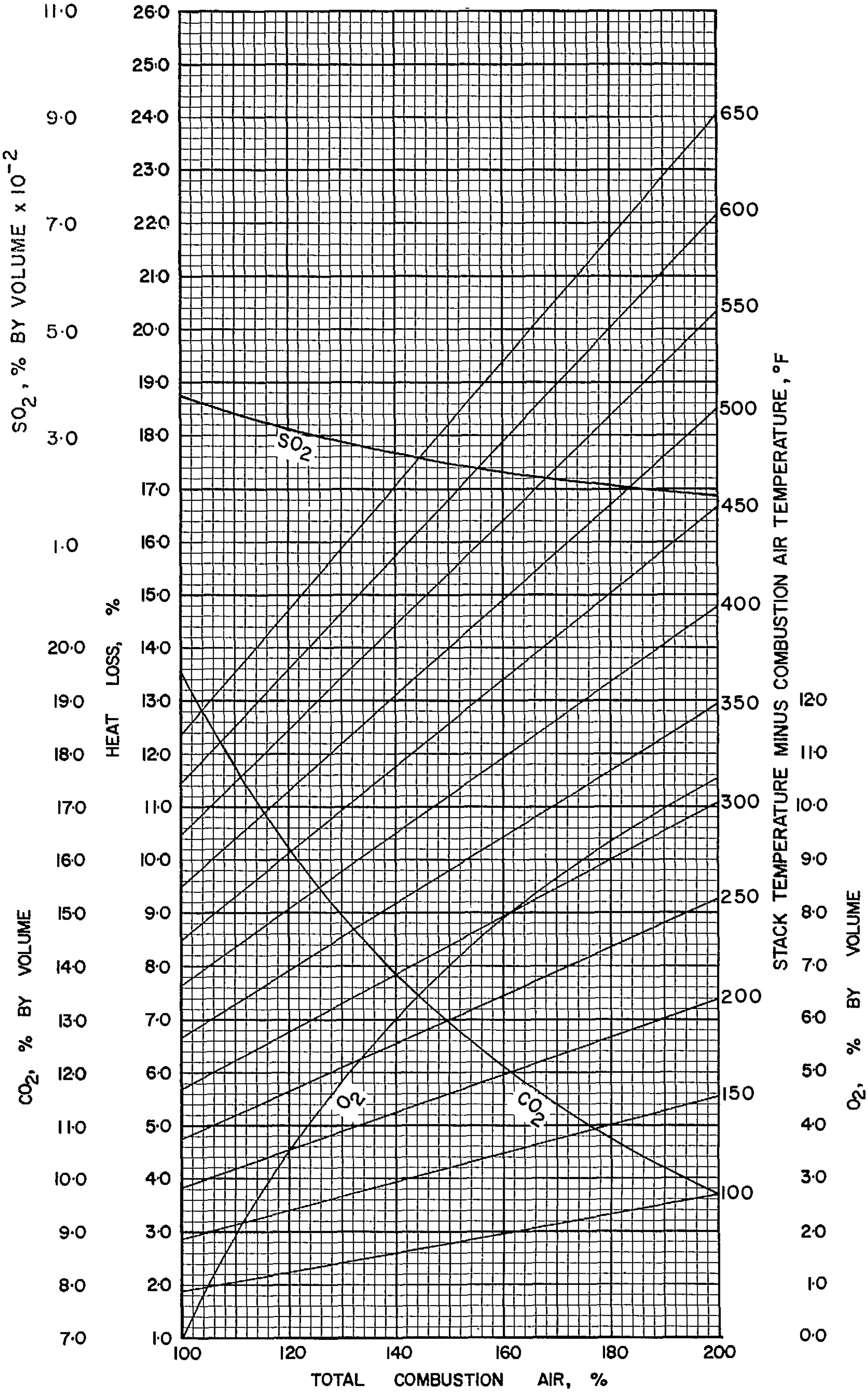


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·11·1

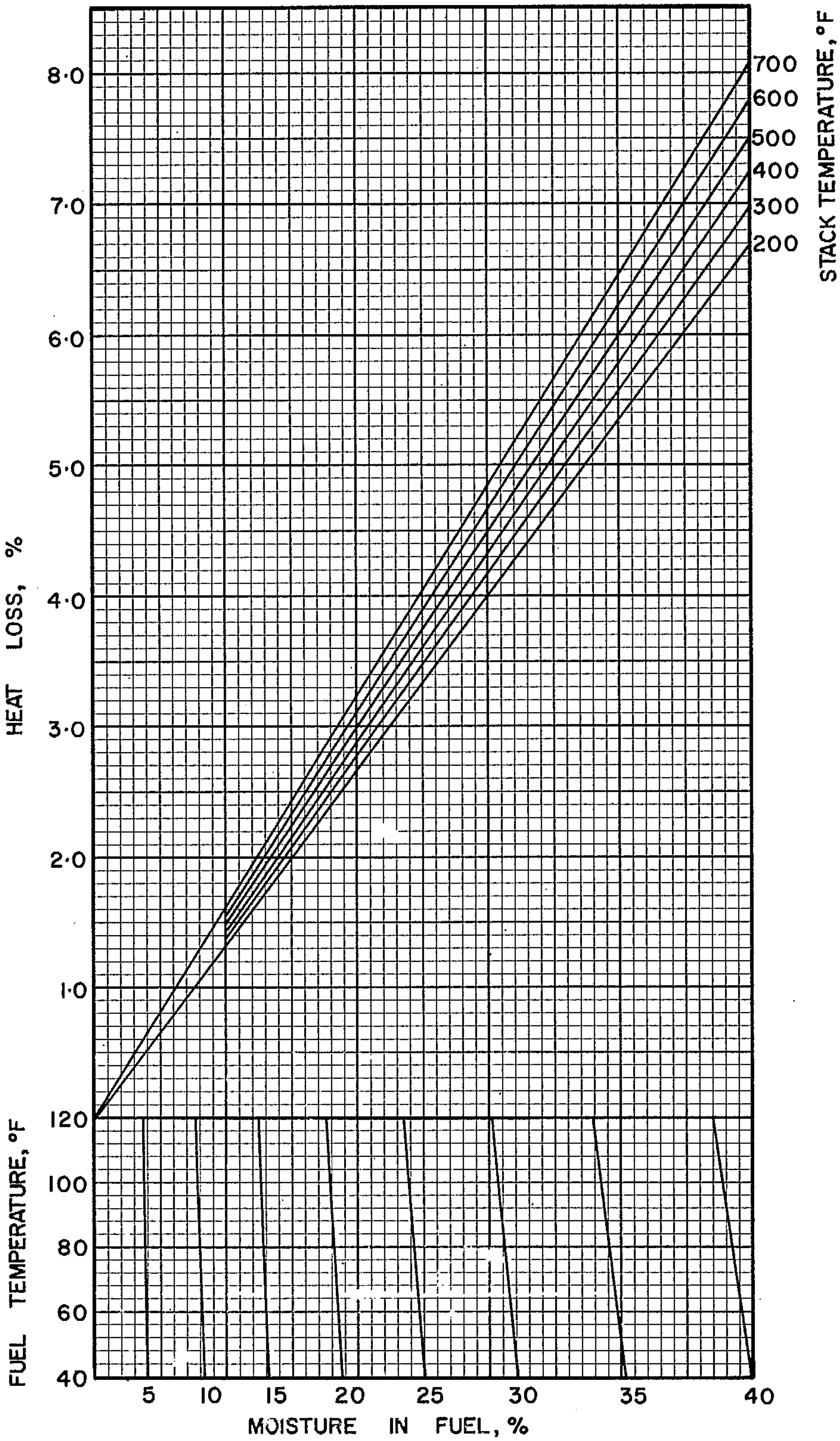


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·11·1

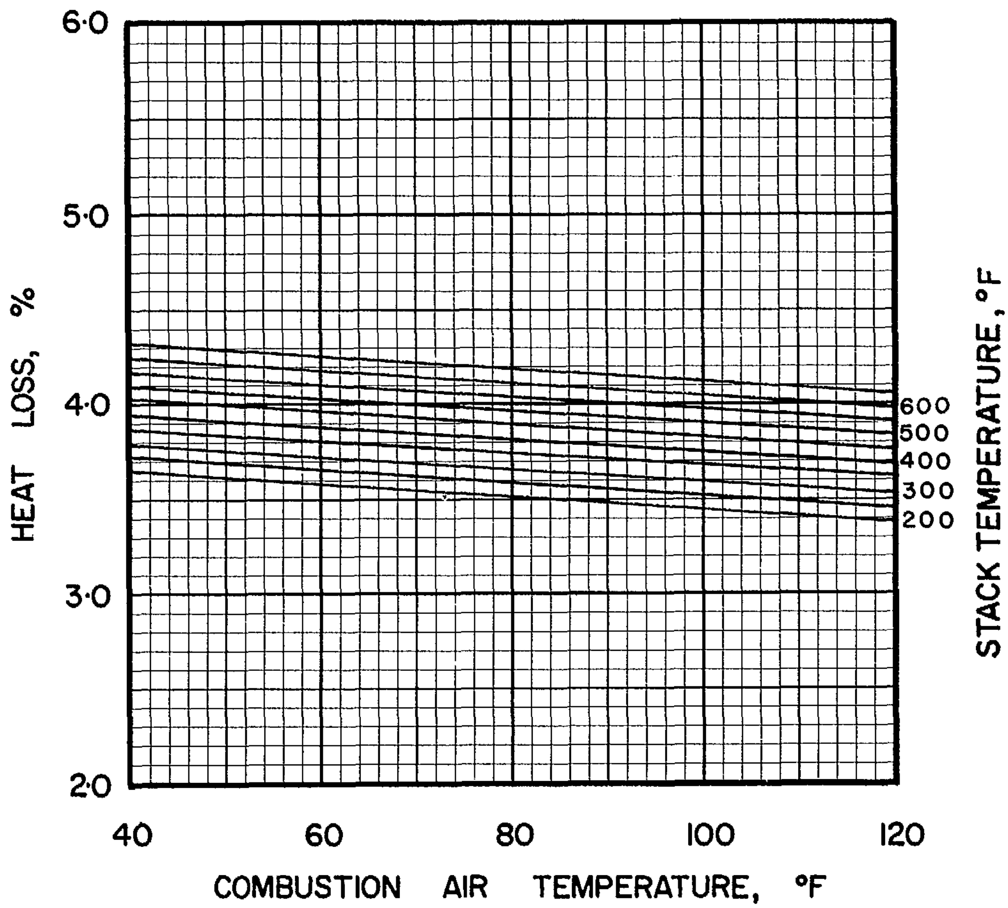


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC· 11 · 1

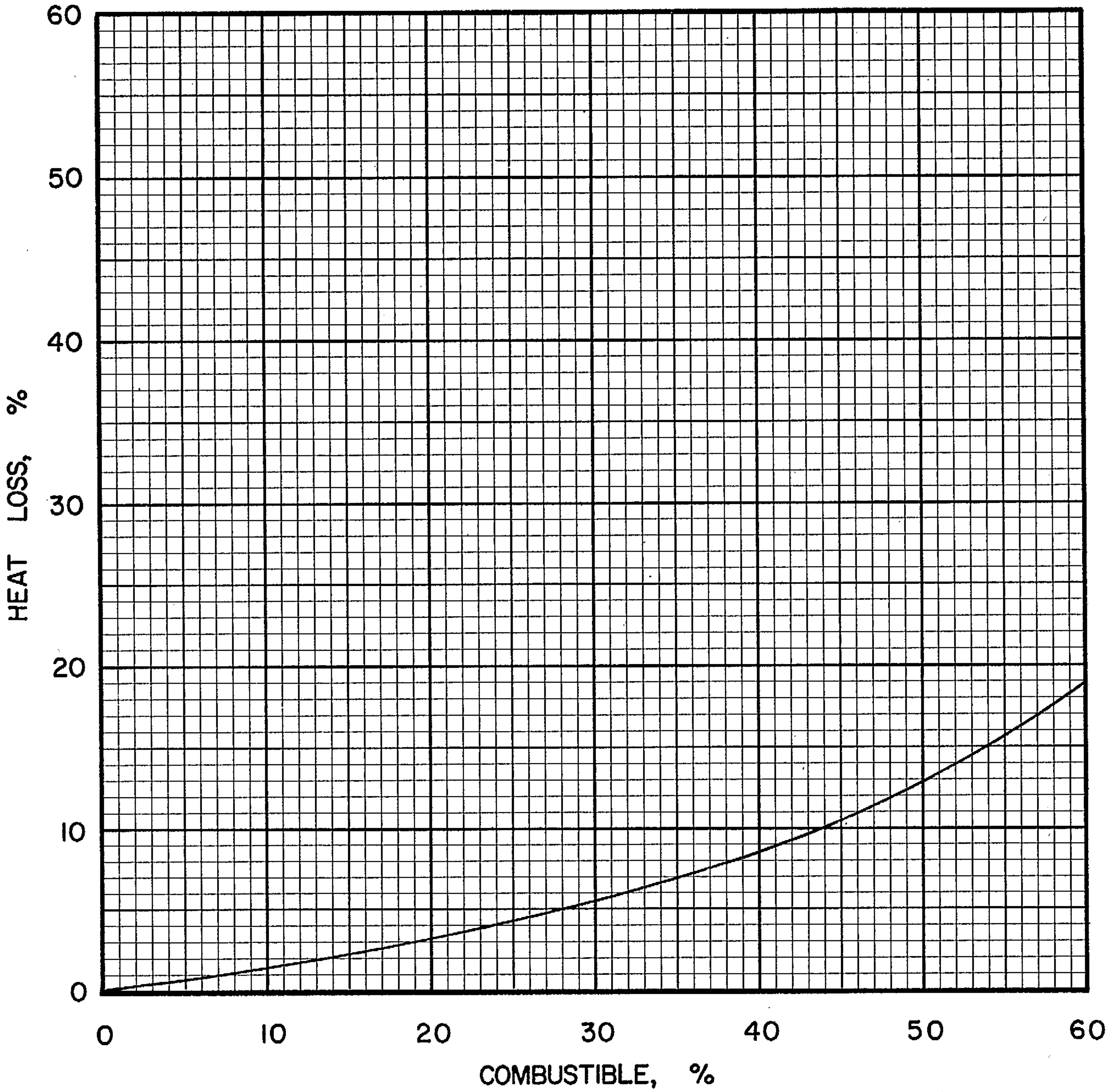


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·11·1

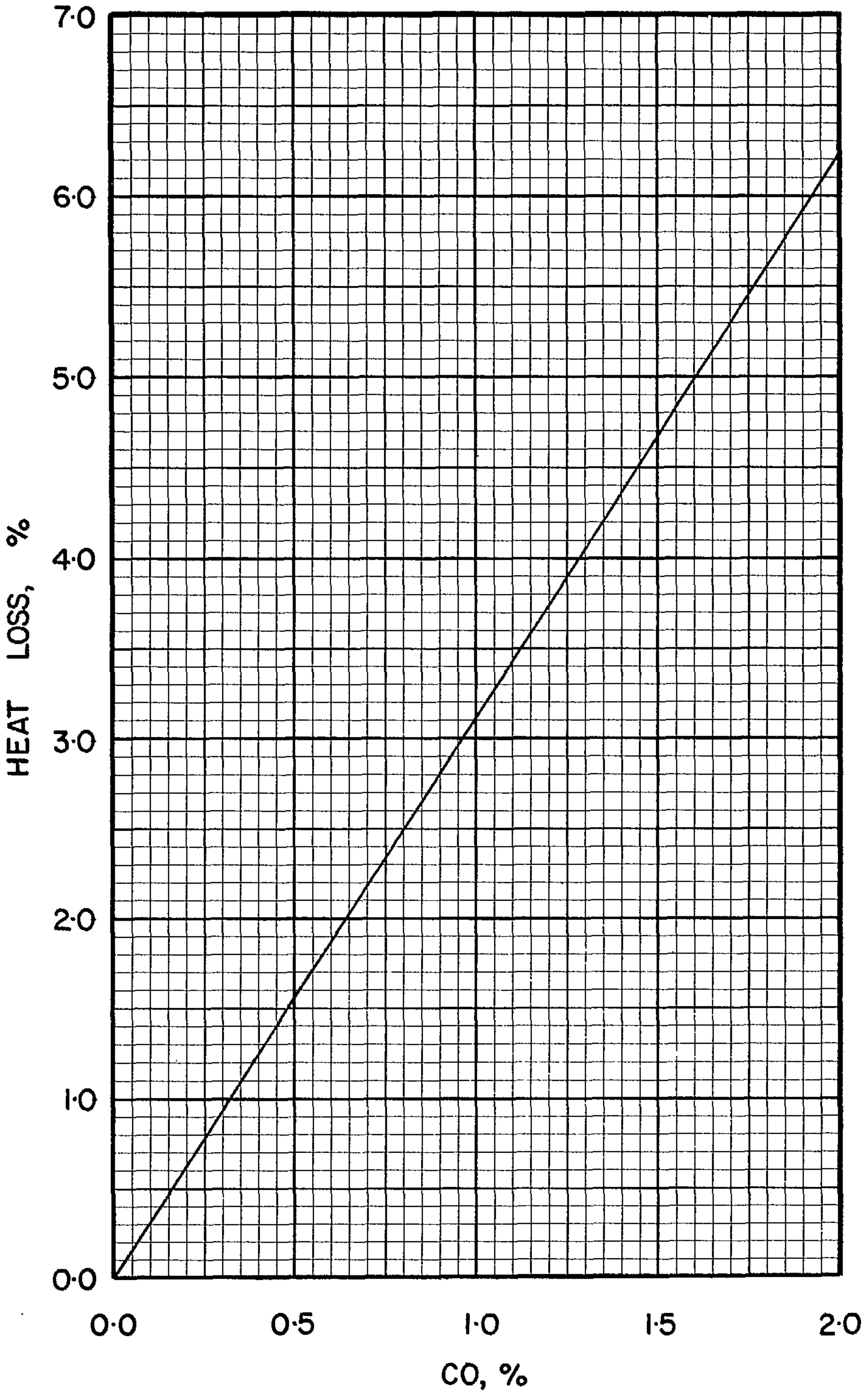


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC · 11 · 1

COAL ABC 12-1, STAR KEY MINES LTD., EDMONTON, 1 1/4 in. x 3/8 in.

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.1077
Volatile Matter	0.3901
Fixed Carbon	0.5022
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6552
Hydrogen (H)	0.0426
Sulphur (S)	0.0034
Nitrogen (N)	0.0115
Oxygen (O)	0.1796
Ash	0.1077
Total	1.0000

Gross Calorific Value

Btu/lb:	11050
Btu/short ton:	22.10×10^6
Btu/long ton:	24.75×10^6
MJ/kg:	25.70

Conversion Factors

1 short ton = 0.8929 long tons = 2000 lb
10^6 Btu = 90.50 lb
10^6 Btu = 0.04525 short tons
10^6 Btu = 0.04040 long tons

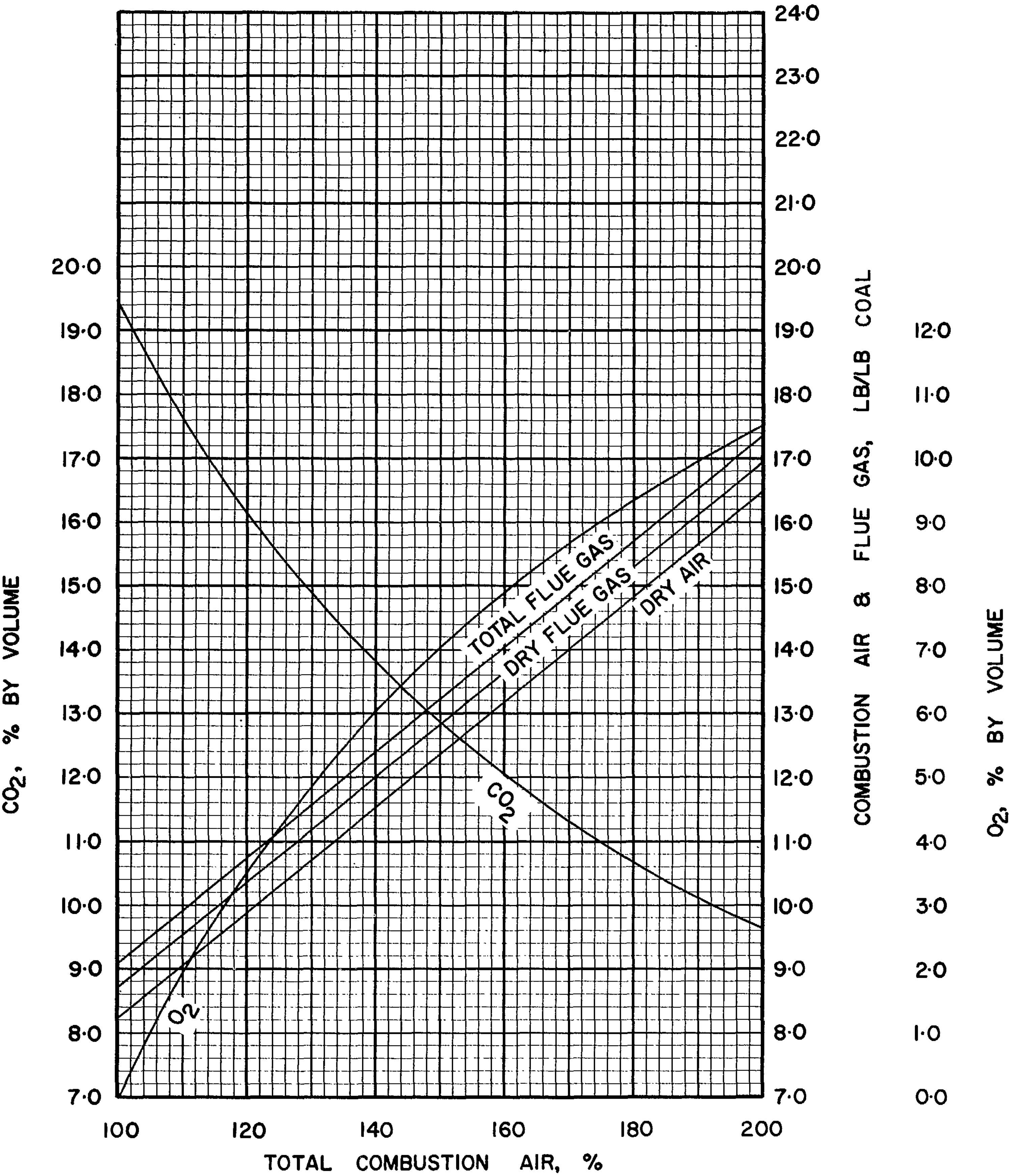


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC·12·1

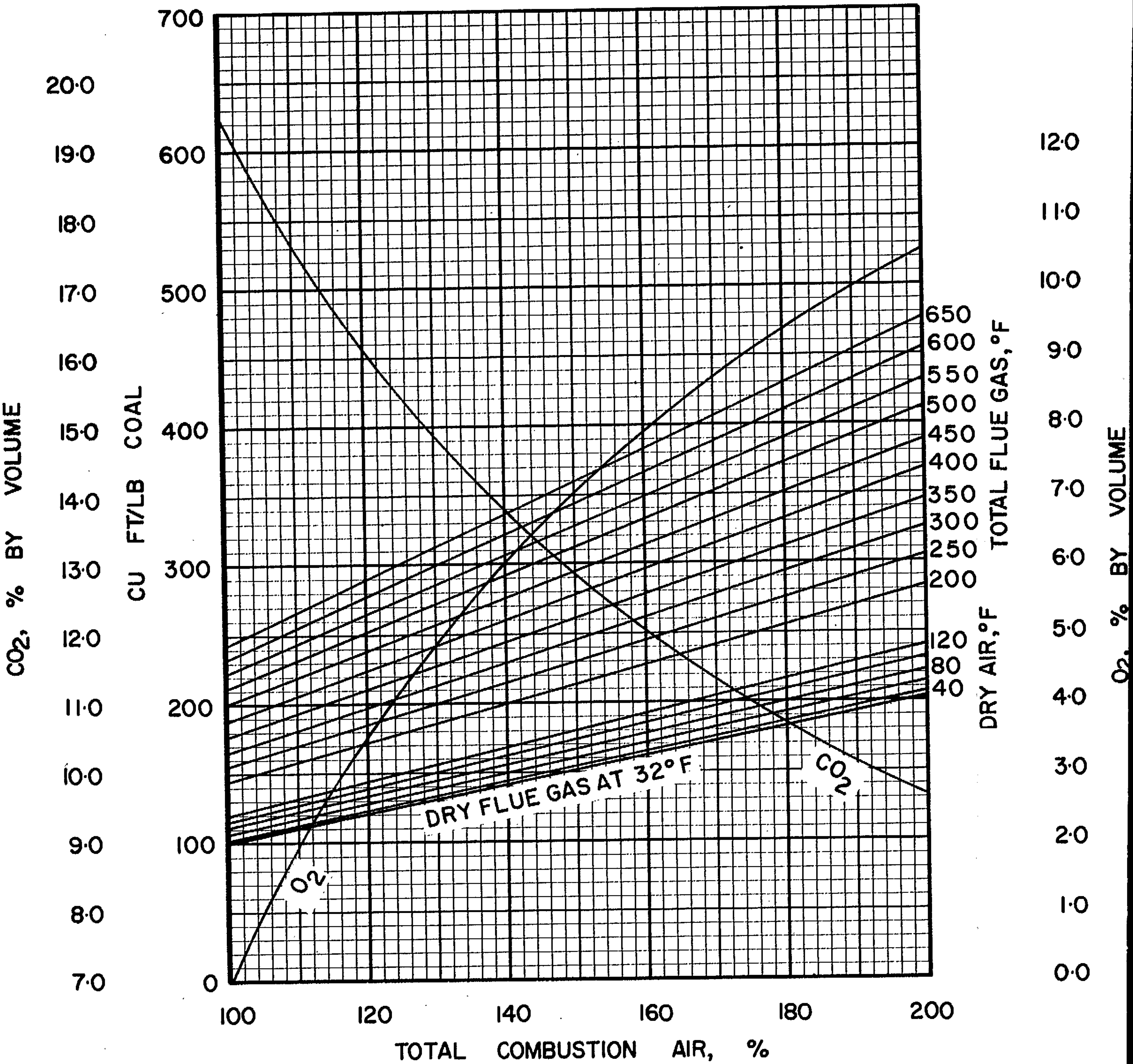


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC·12·1

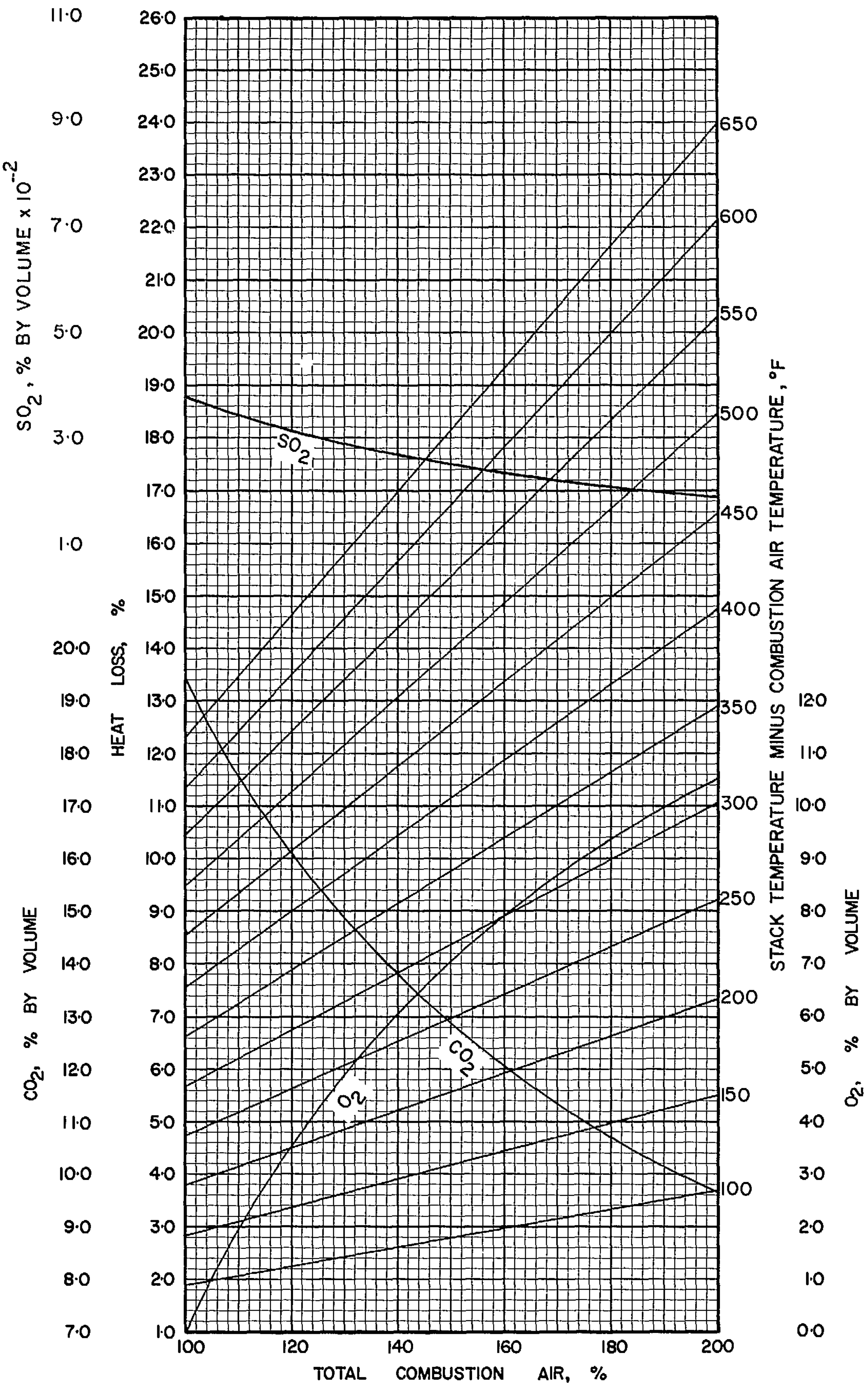


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·12·1

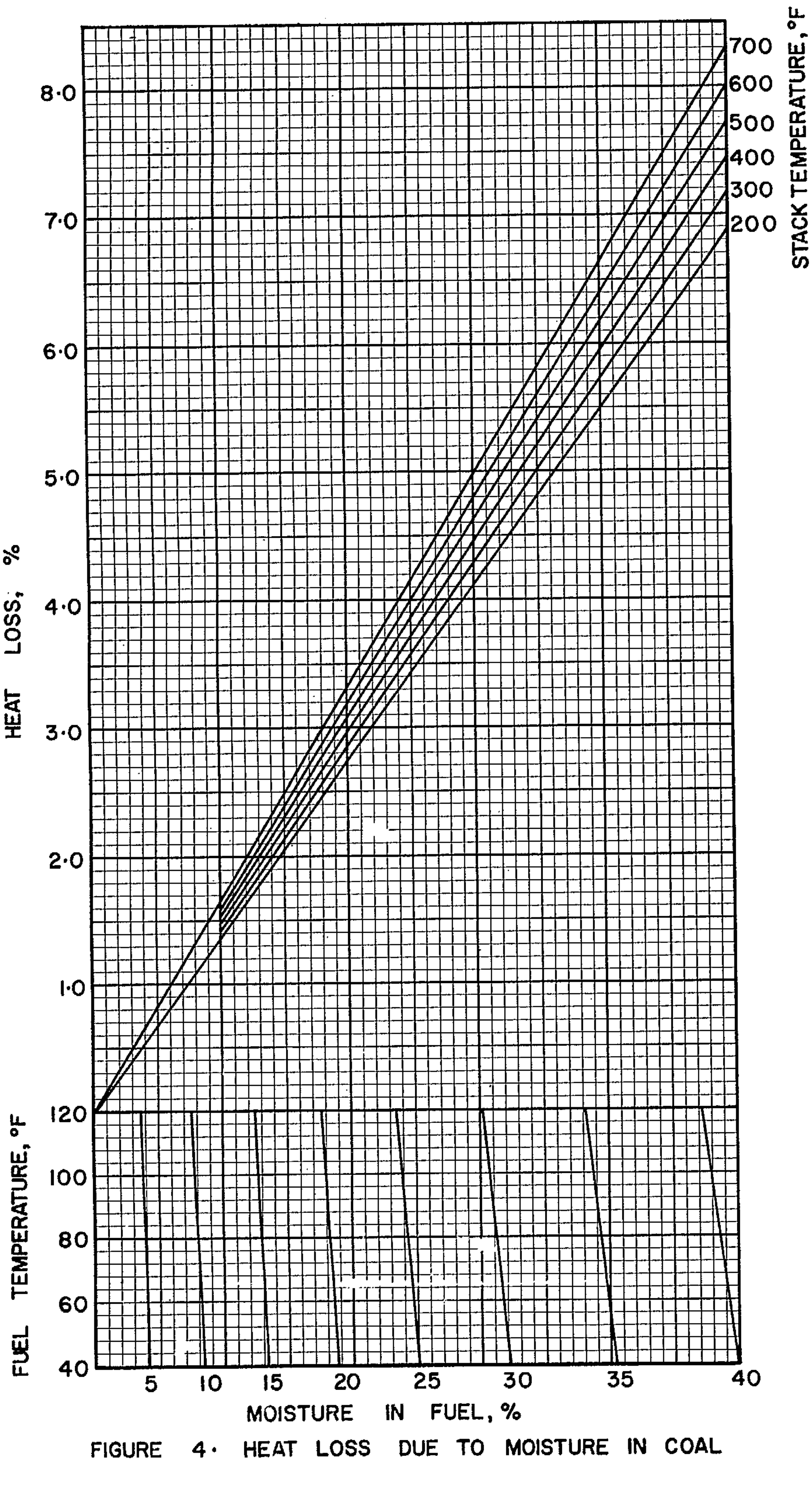


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·12·1

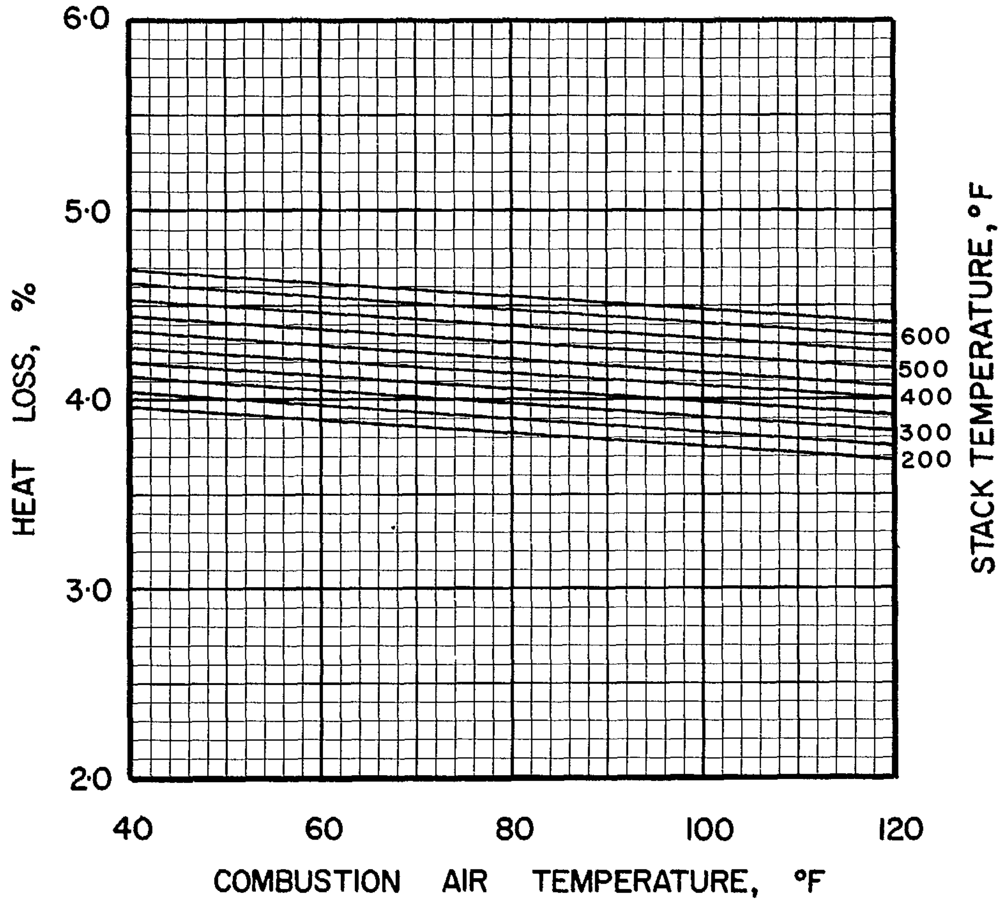


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·12·1

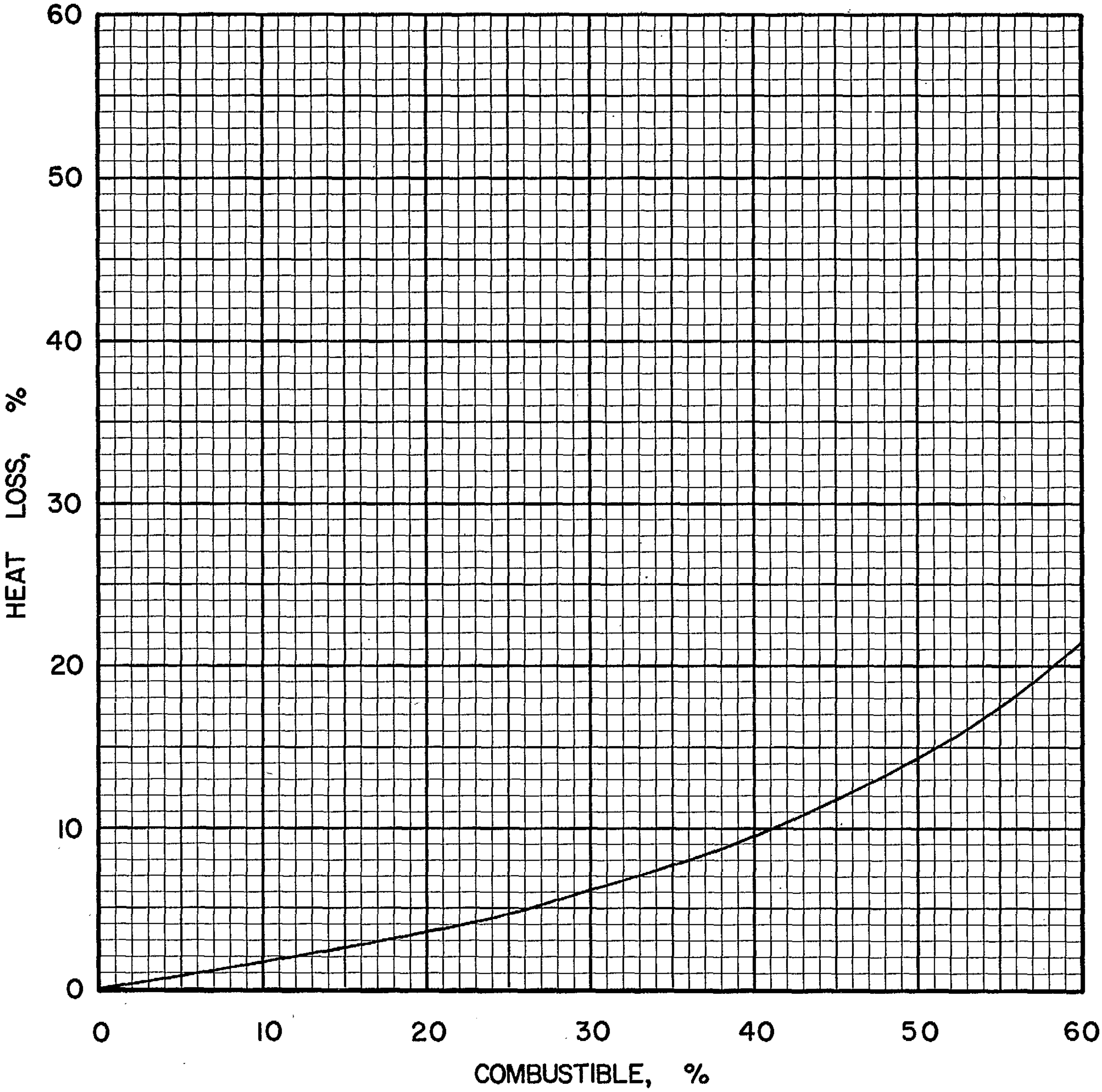


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC-12-1

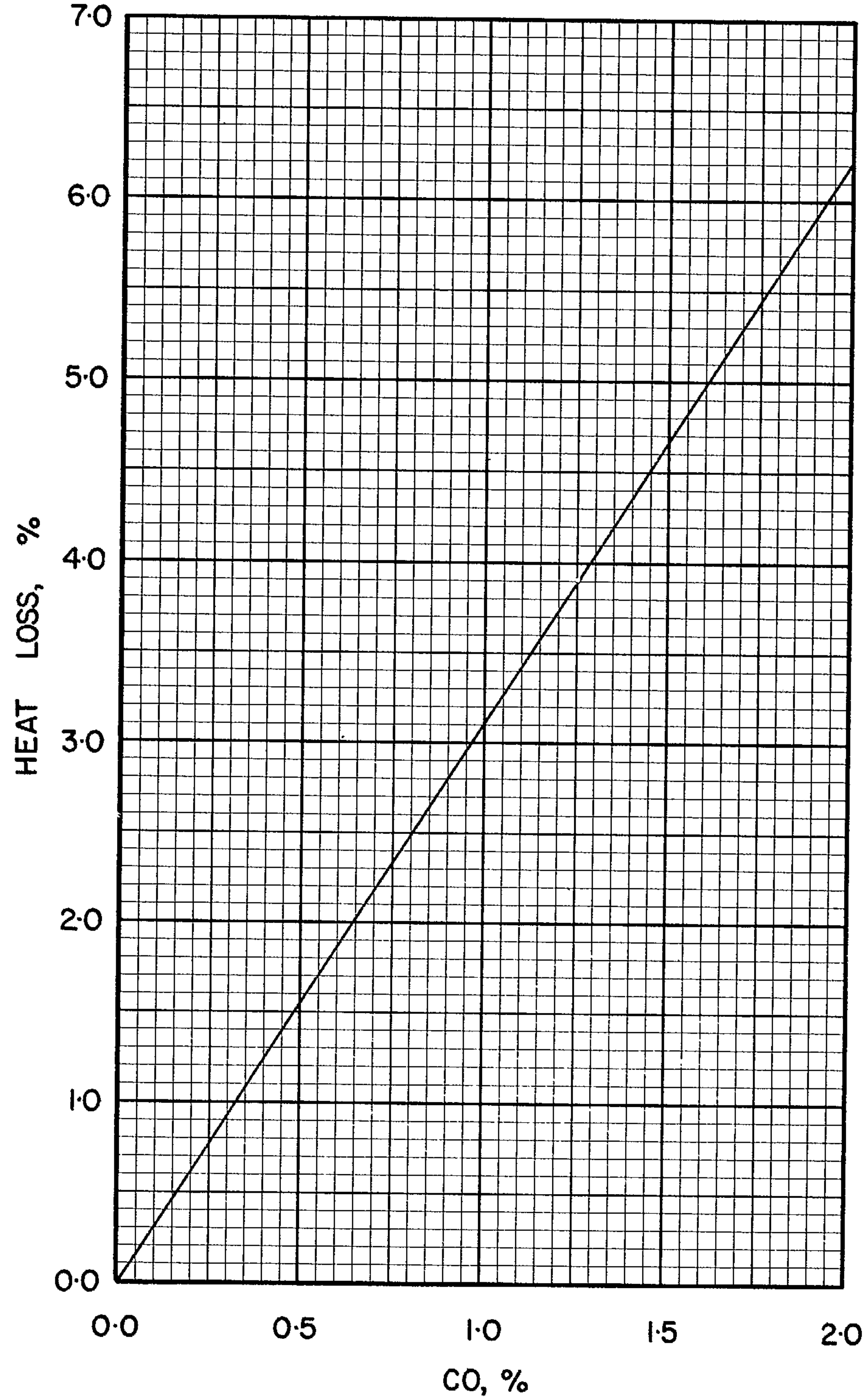


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·12·1

**COAL ABC 12-2, STAR KEY MINES LTD.,
EDMONTON, 3/8 in. x 0**

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.1612
Volatile Matter	0.3804
Fixed Carbon	0.4584
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6199
Hydrogen (H)	0.0395
Sulphur (S)	0.0041
Nitrogen (N)	0.0098
Oxygen (O)	0.1655
Ash	0.1612
Total	1.0000

Gross Calorific Value

Btu/lb:	10370
Btu/short ton:	20.74×10^6
Btu/long ton:	23.23×10^6
MJ/kg:	24.11

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 96.43	lb	
10^6 Btu	= 0.04822	short tons	
10^6 Btu	= 0.04305	long tons	

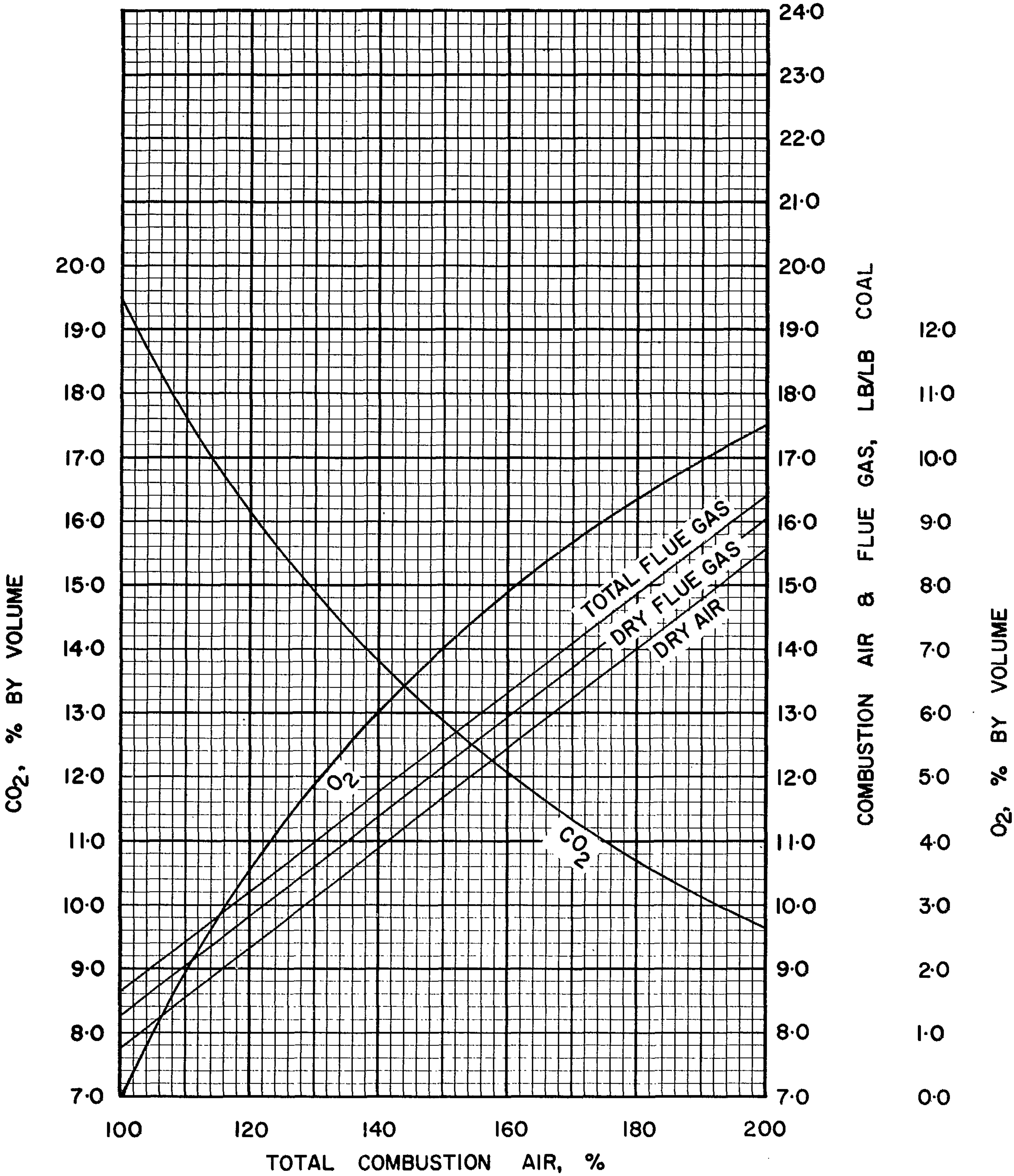


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS

ABC·12·2

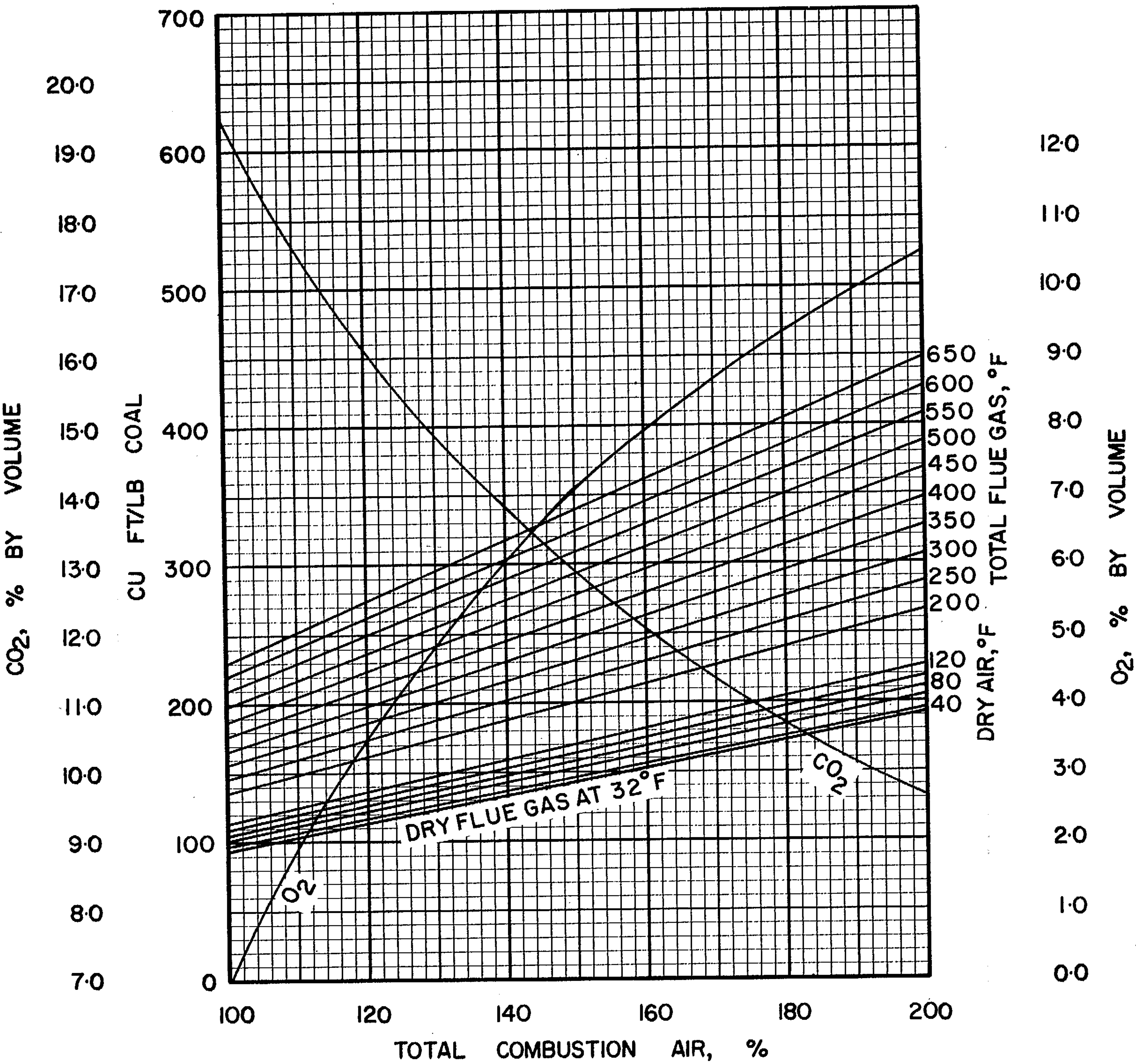


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC · 12 · 2

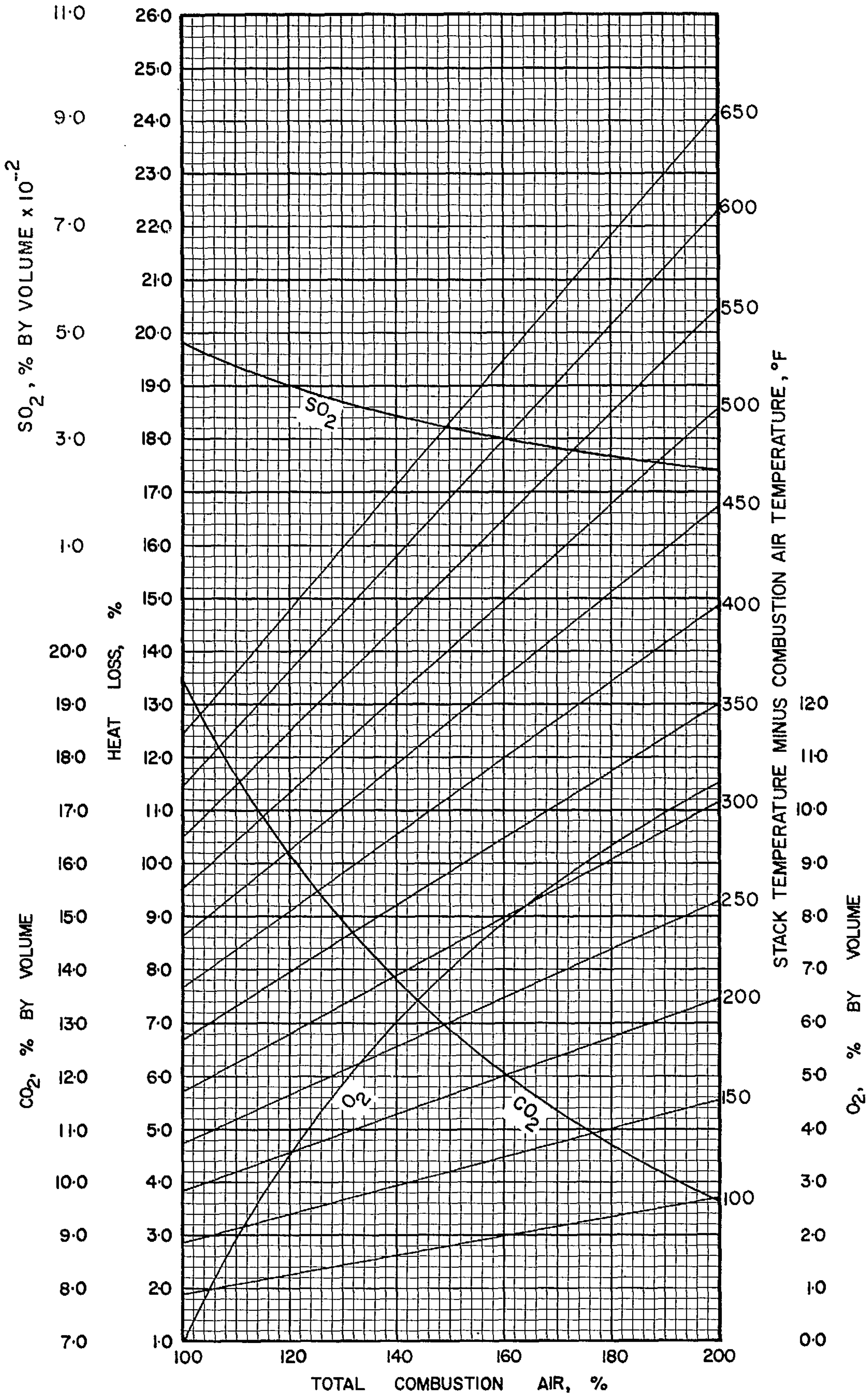


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·12·2

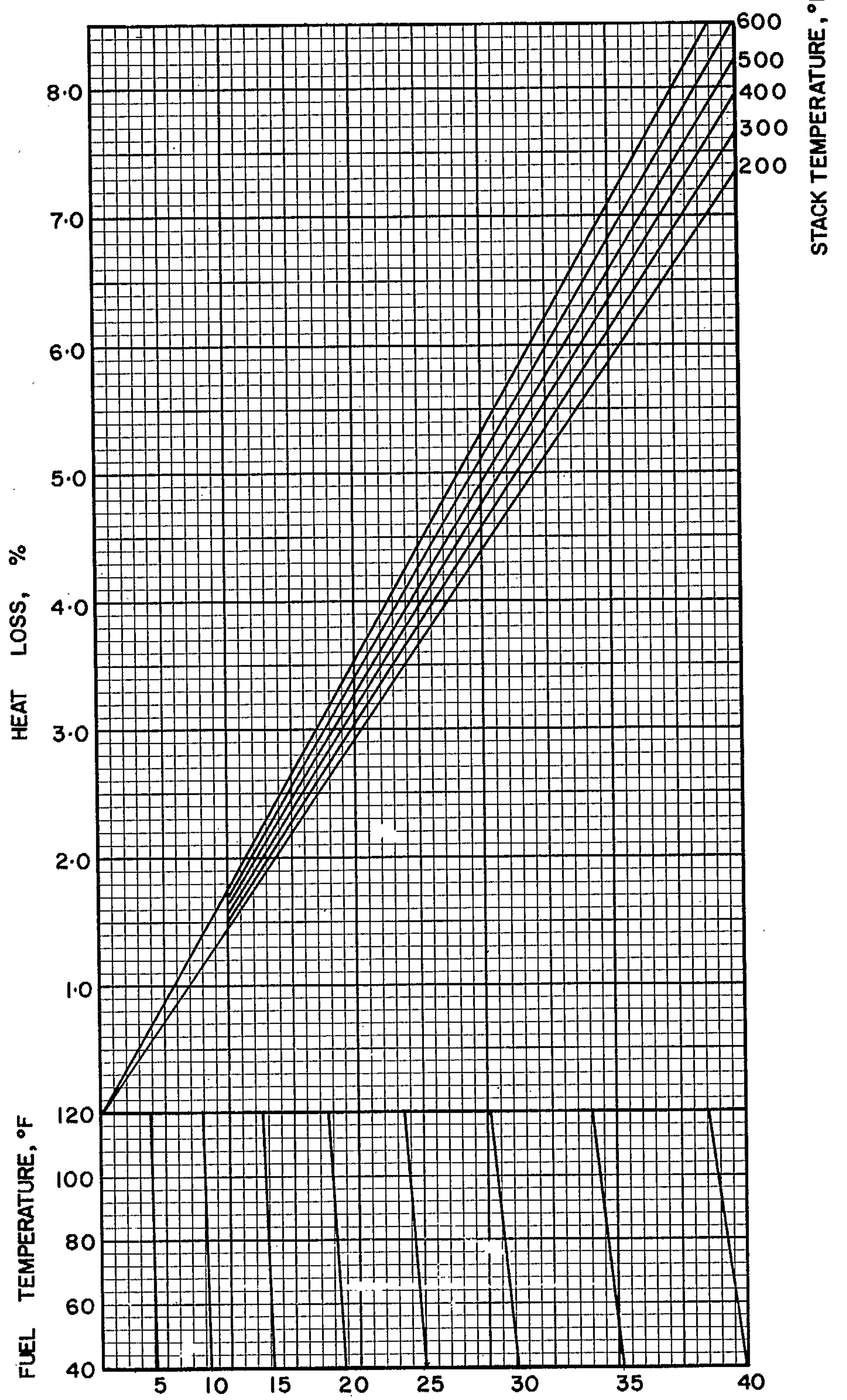


FIGURE 4· HEAT LOSS DUE TO MOISTURE IN COAL

ABC·12·2

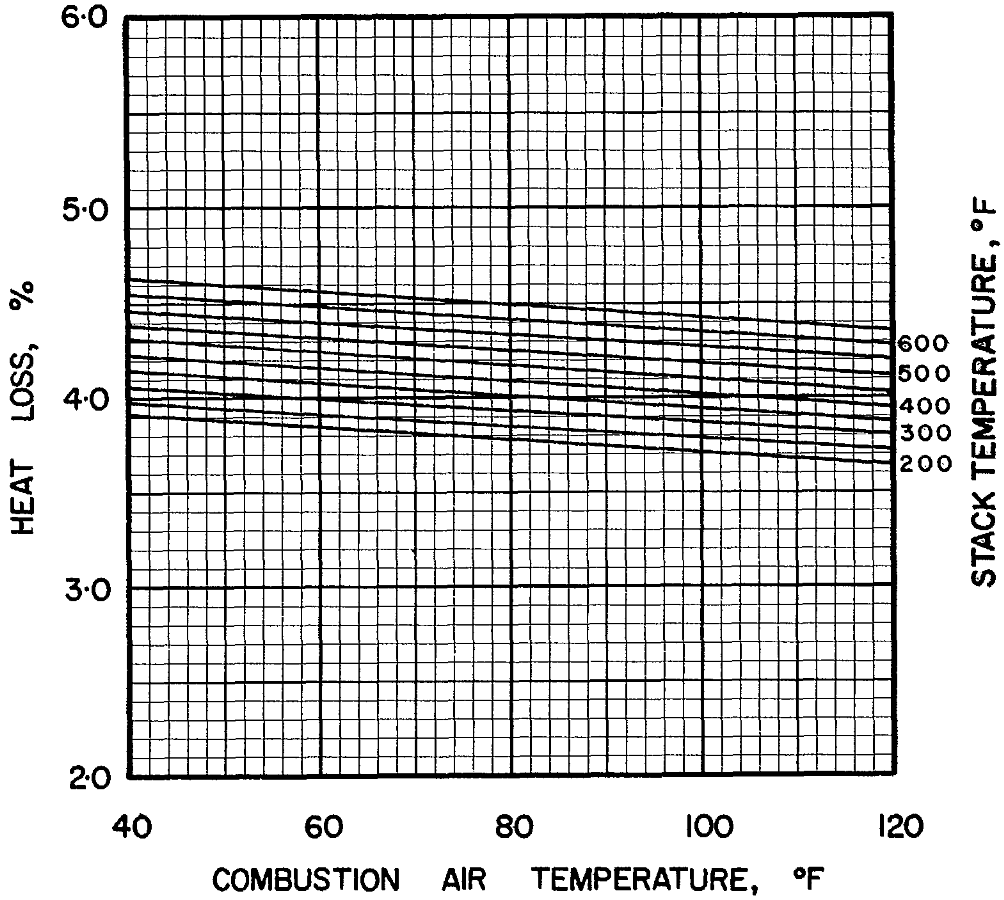


FIGURE 5 · HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·12·2

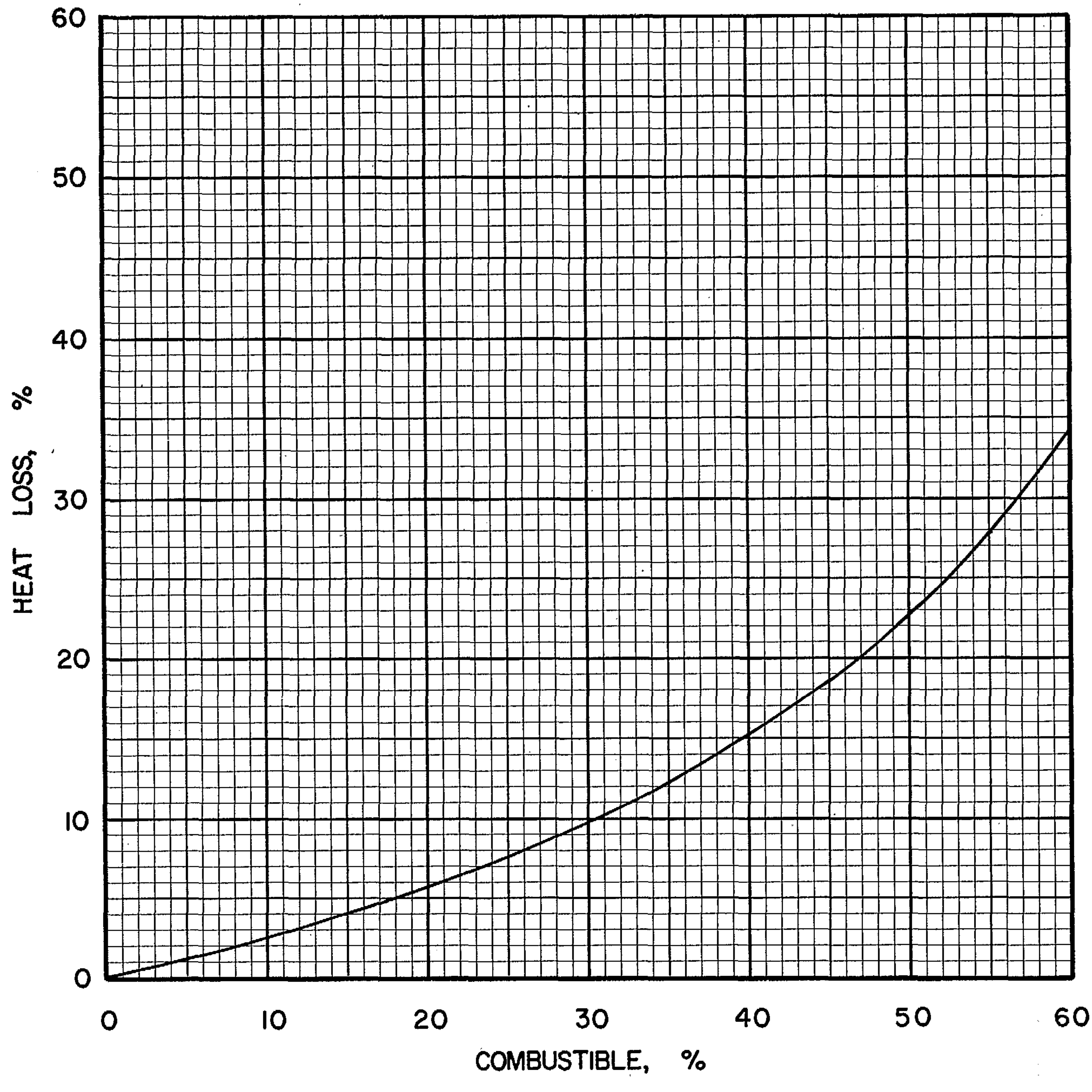


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC·12·2

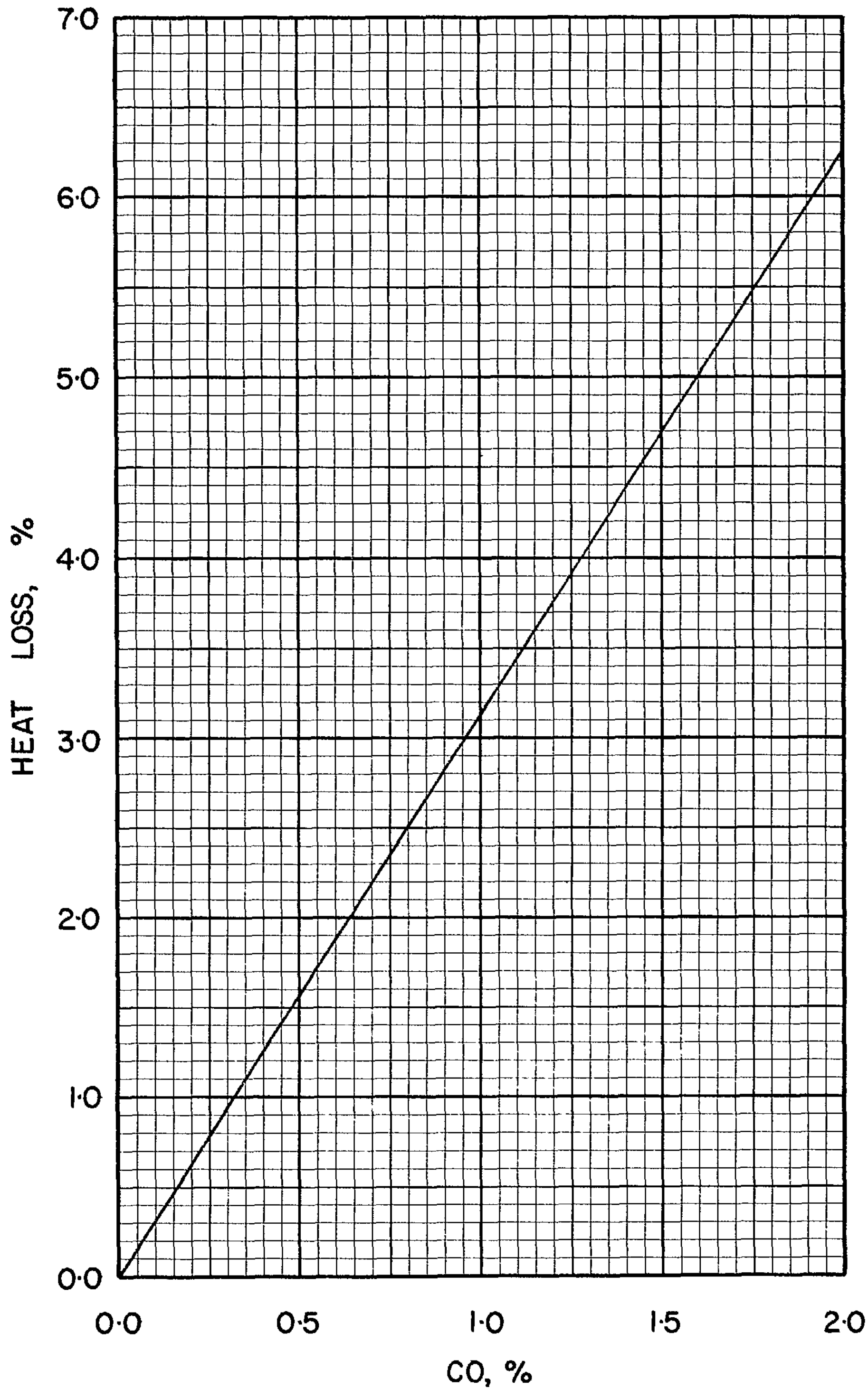


FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·12·2

COAL ABC 13-1, WHITEWOOD MINE, PEMBINA, 3/4 in. x 0

Typical Moisture Range: 20–30%

Proximate Analysis (lb/lb dry coal)

Ash	0.1253
Volatile Matter	0.3526
Fixed Carbon	0.5221
Total	1.0000

Ultimate Analysis (lb/lb dry coal)

Carbon (C)	0.6555
Hydrogen (H)	0.0385
Sulphur (S)	0.0025
Nitrogen (N)	0.0063
Oxygen (O)	0.1719
Ash	0.1253
Total	1.0000

Gross Calorific Value

Btu/lb:	10820
Btu/short ton:	21.64×10^6
Btu/long ton:	24.24×10^6
MJ/kg:	25.16

Conversion Factors

1 short ton	= 0.8929	long tons	= 2000 lb
10^6 Btu	= 92.42	lb	
10^6 Btu	= 0.04621	short tons	
10^6 Btu	= 0.04126	long tons	

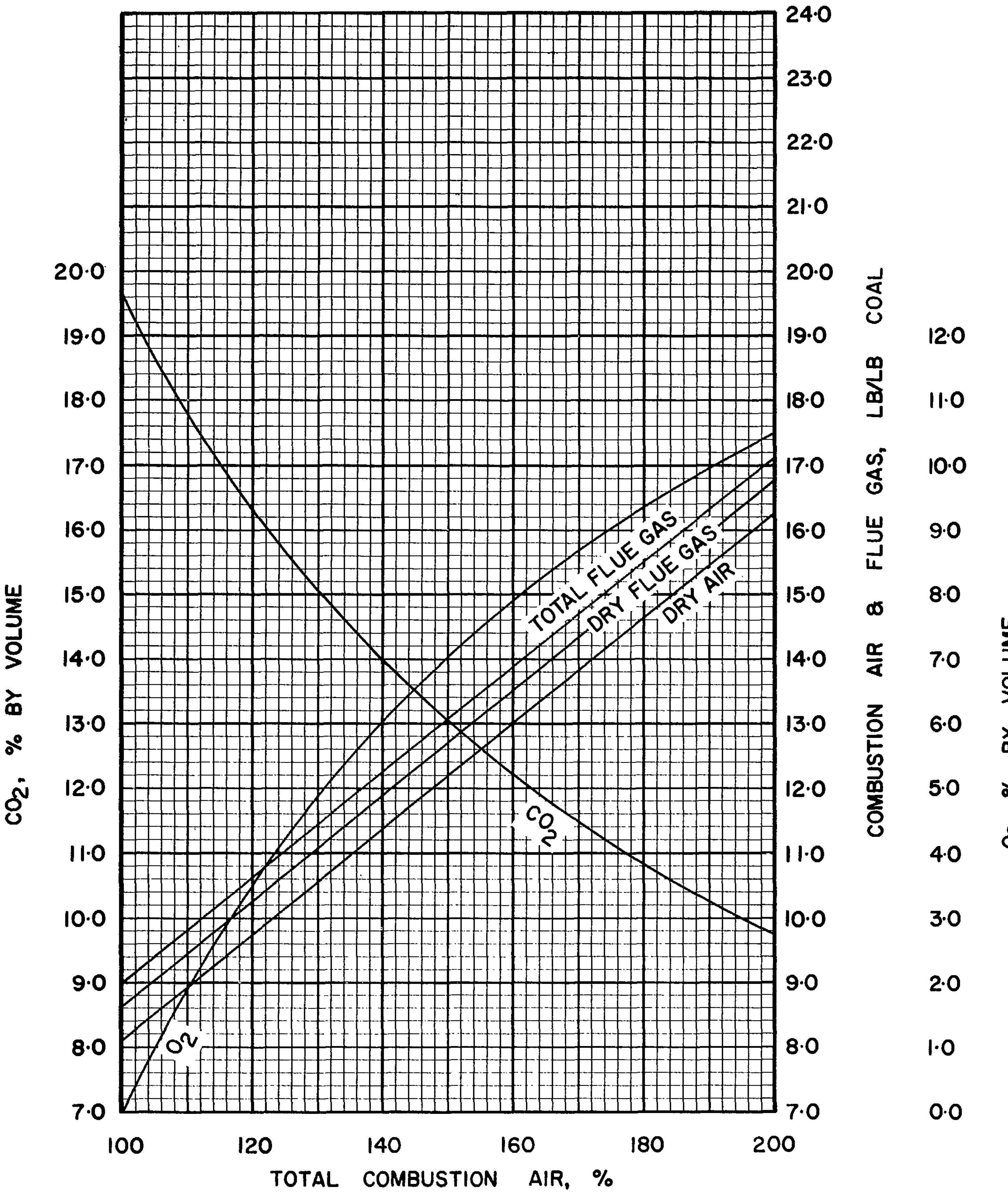


FIGURE 1· COMBUSTION DATA, WEIGHT BASIS ABC· 13·1

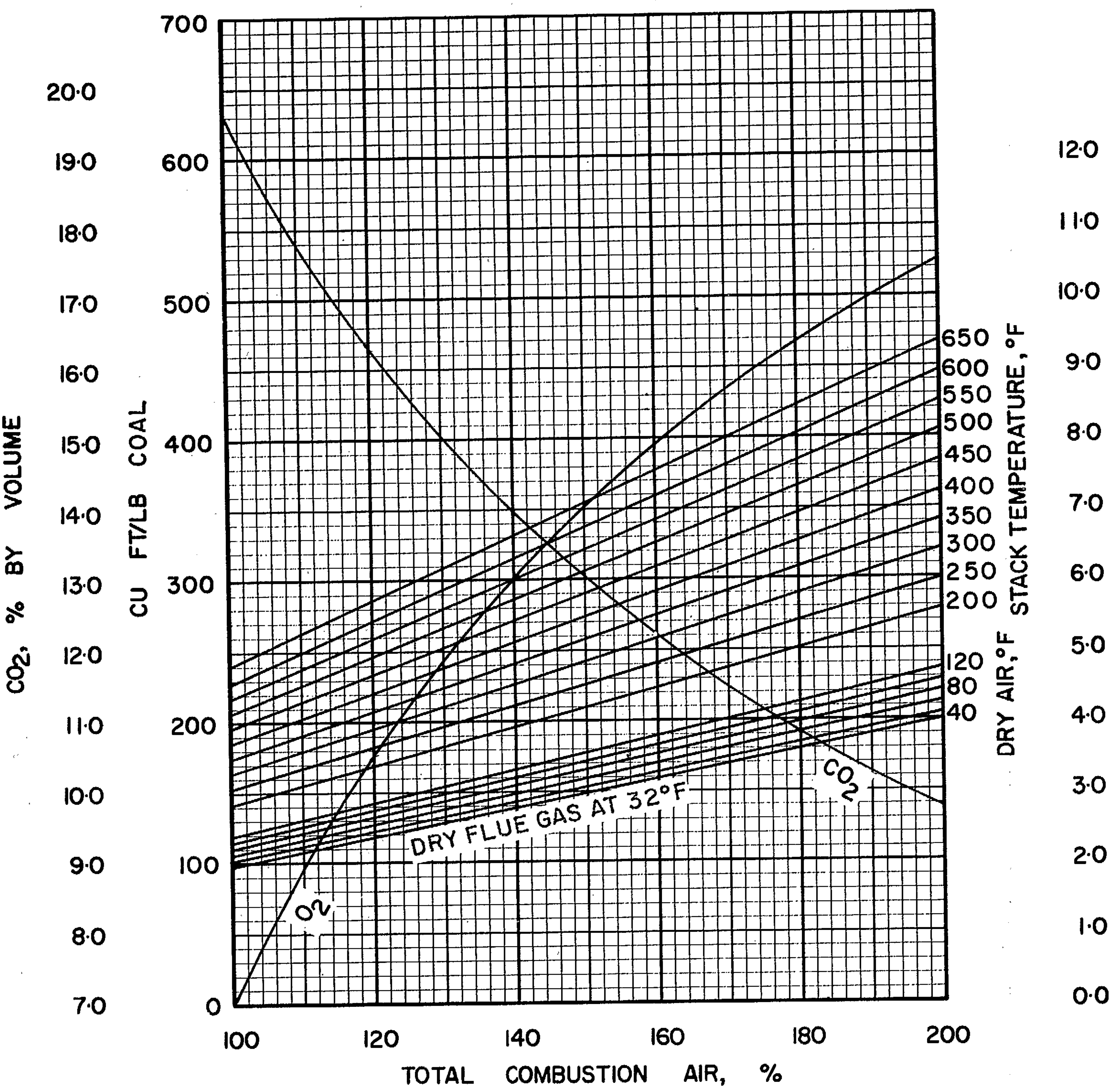


FIGURE 2 · COMBUSTION DATA, VOLUME BASIS

ABC· 13·1

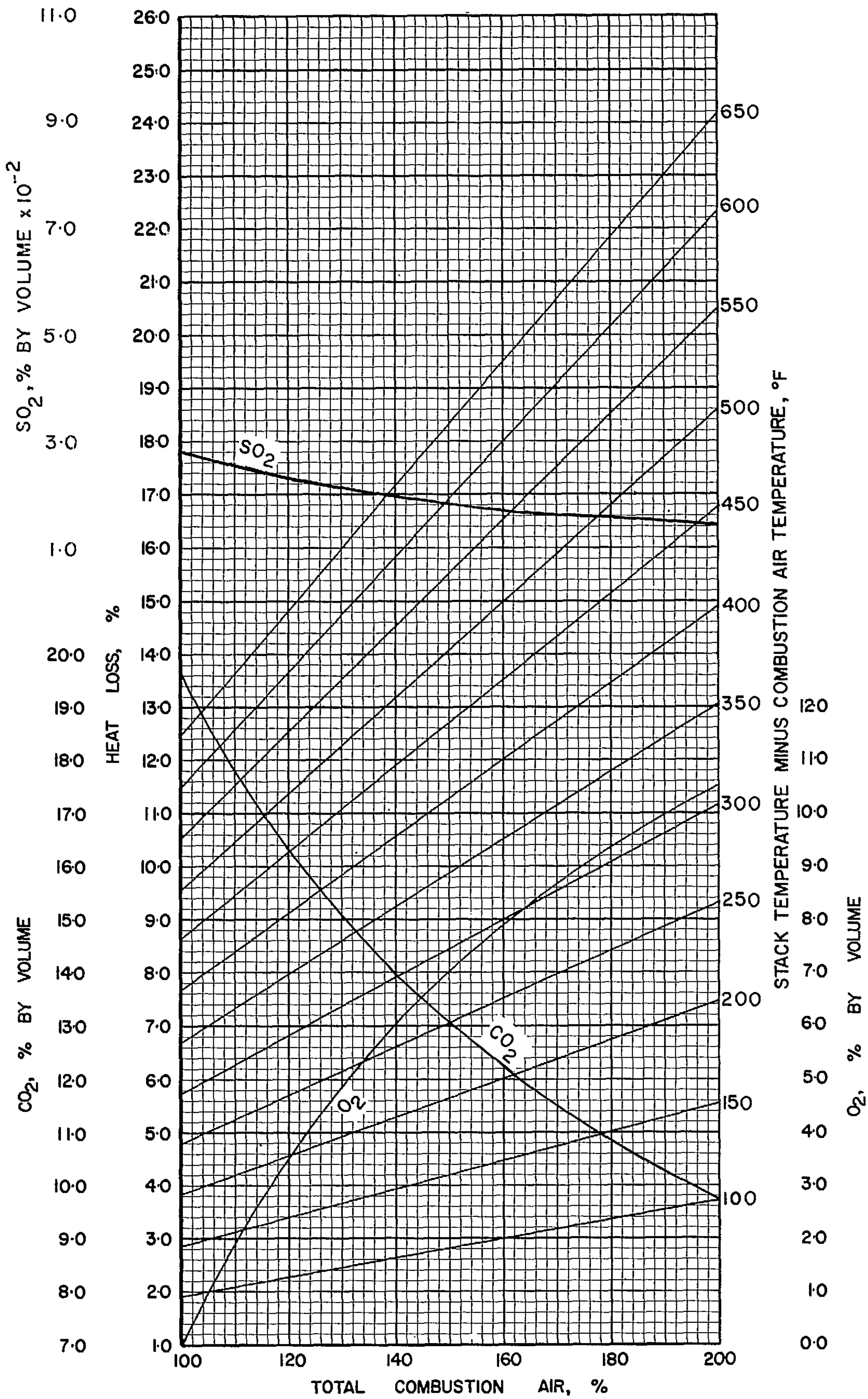


FIGURE 3· DRY FLUE GAS LOSS FOR A RANGE OF TEMPERATURE DIFFERENTIALS

ABC·13·1

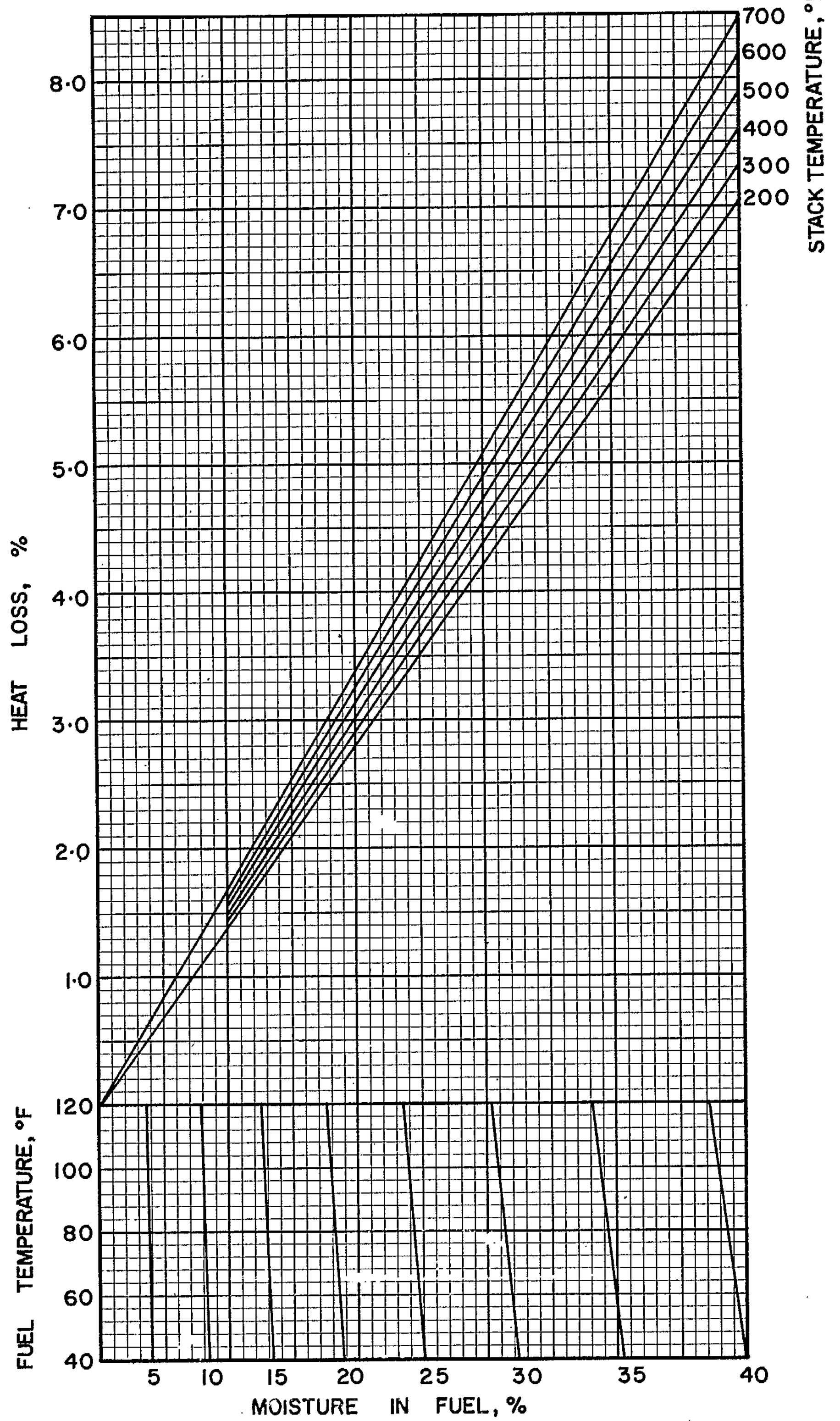


FIGURE 4 · HEAT LOSS DUE TO MOISTURE IN COAL

ABC· 13·1

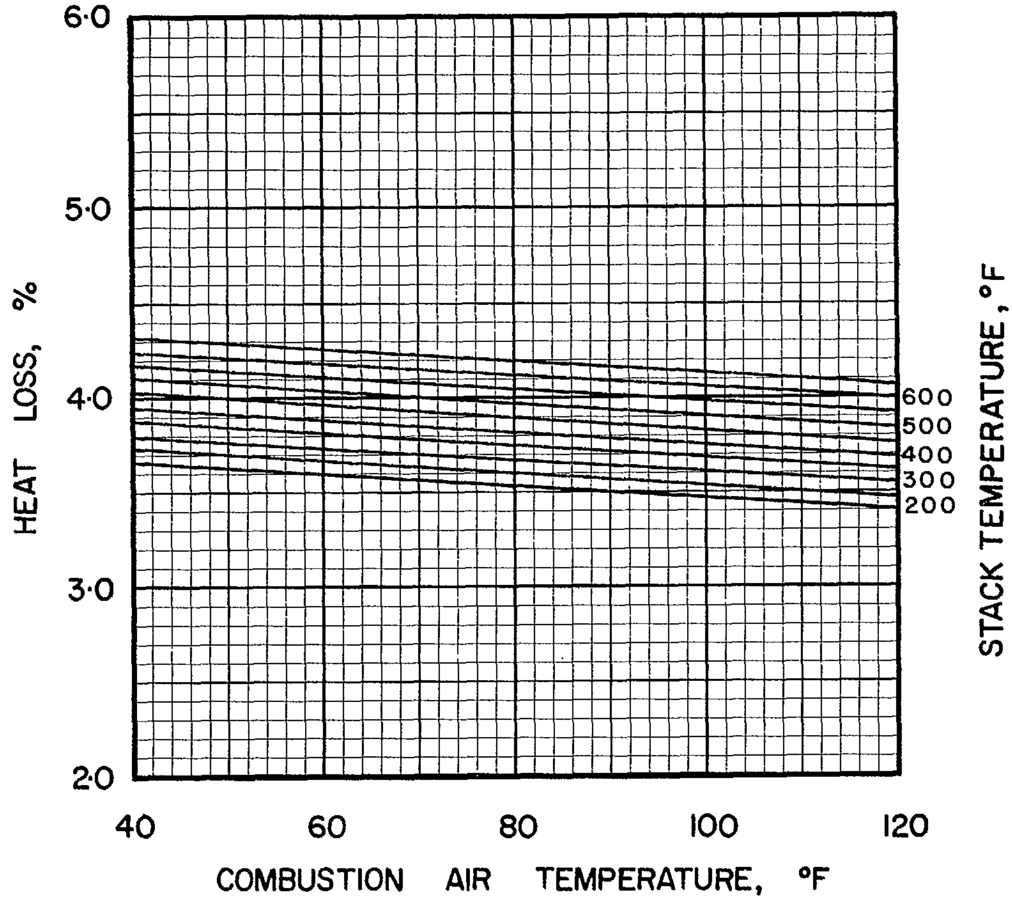


FIGURE 5· HYDROGEN LOSS FOR A RANGE OF STACK TEMPERATURES

ABC·13·1

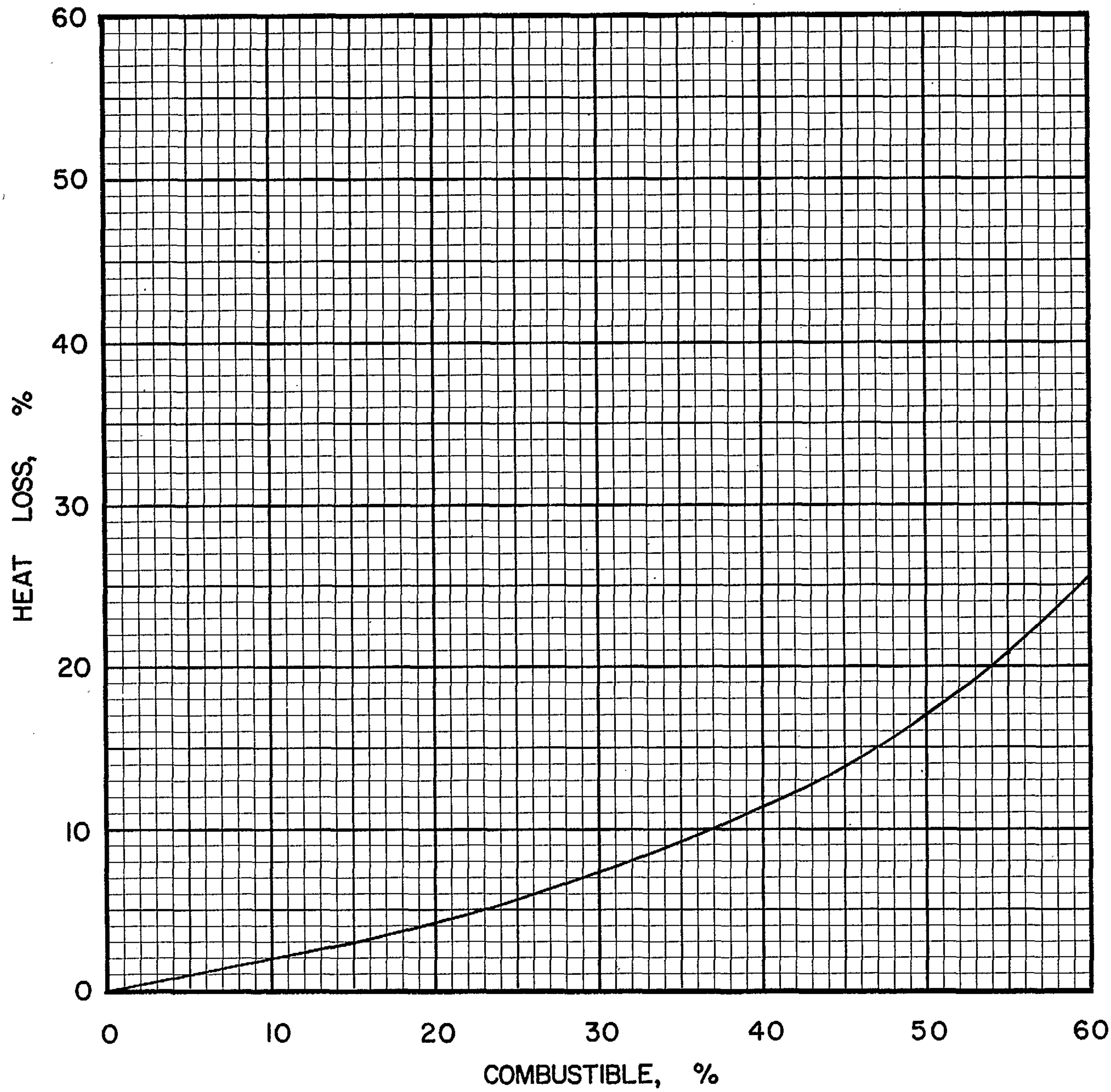


FIGURE 6 HEAT LOSS FOR A RANGE OF COMBUSTIBLE CONCENTRATIONS IN REFUSE

ABC-13-1

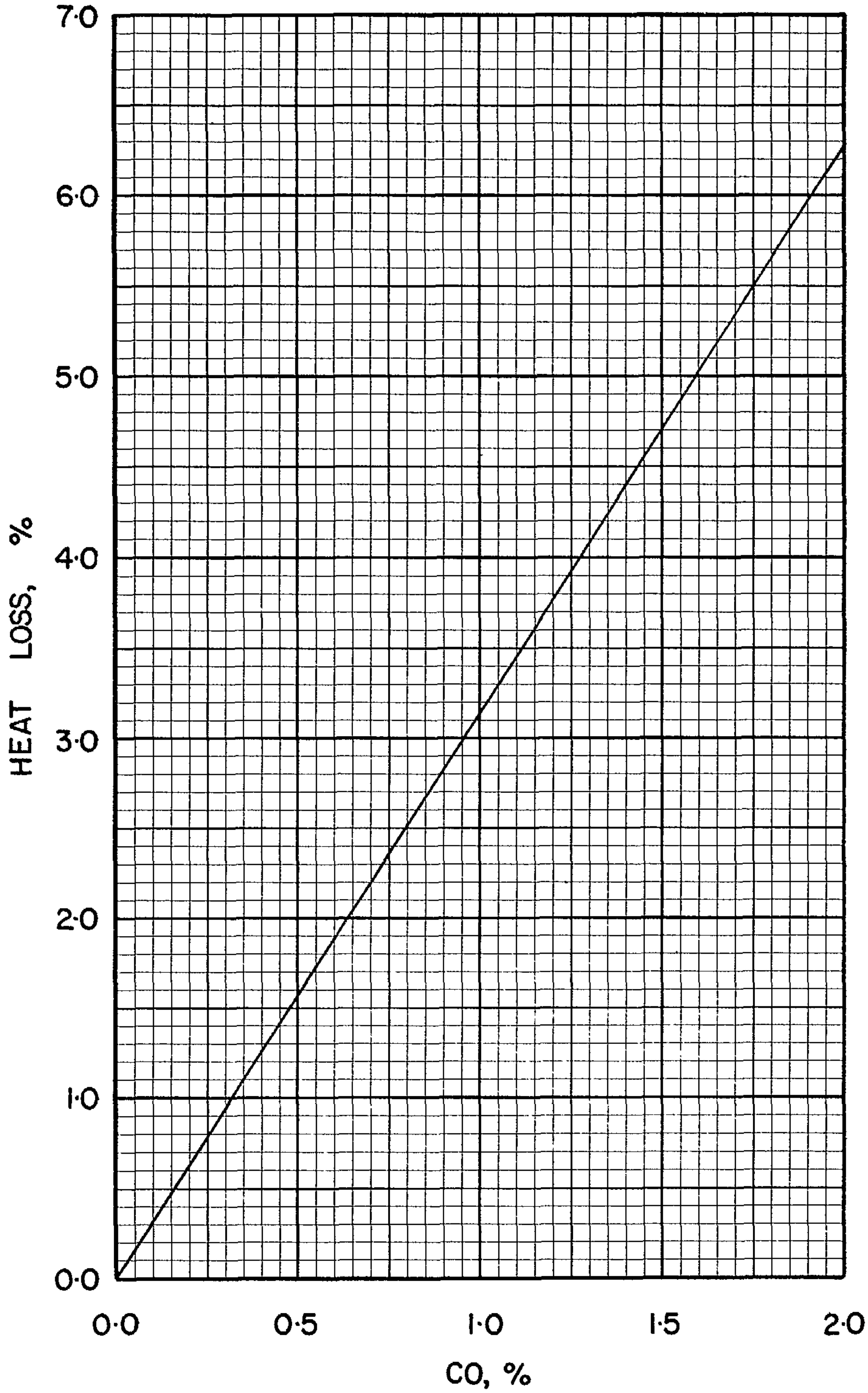


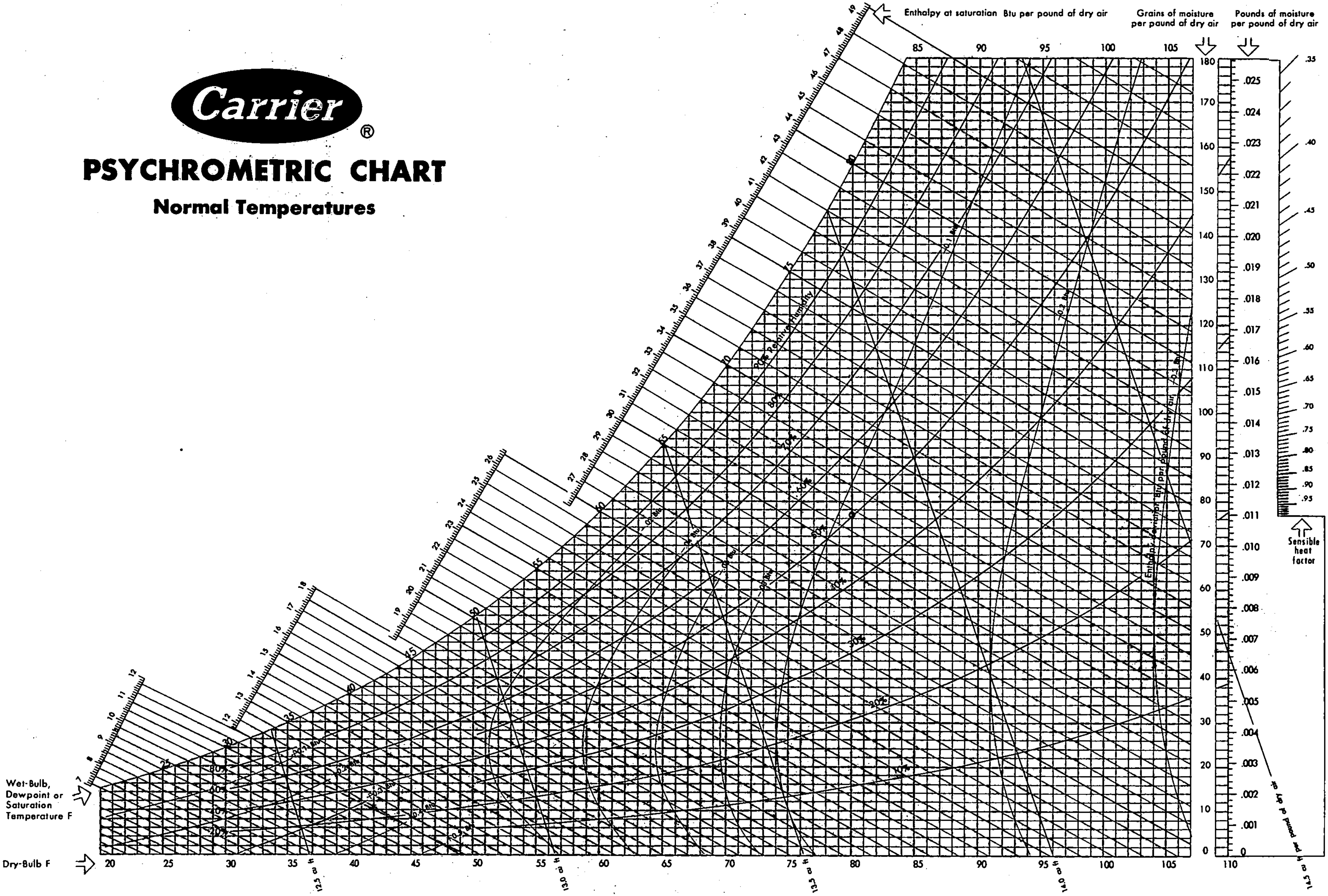
FIGURE 7 · HEAT LOSS FOR A RANGE OF CO CONCENTRATIONS, ASSUMING NEGLIGIBLE EXCESS AIR

ABC·13·1

Carrier®

PSYCHROMETRIC CHART

Normal Temperatures



Below 32 F, properties and enthalpy deviation lines are for ice.

Code (811154)

Canada. Mines branch.
Monograph 882: A combustion hand-boo
book for Canadian fuels. Vol. 3,
pt. 1: Coal. Part 1.

(Friedrich & Hayden)

~~1974. p.1-525.~~

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