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Status of Air Pollution Regulations Affecting Gas Turbines in 80 Nations

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This paper summarizes regulations from 80 countries covering air pollution emissions from gas turbines. The paper includes emission and ground level concentration standards for particulates, sulfur dioxide, oxides of nitrogen, visible emissions, and carbon monoxide.

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R. J. KETTERER N. R. DIBELIUS

The emissions of air pollutants from stationary gas turbines result from the combustion process. It is, therefore, necessary for the combustion research, development, and design engineers to know what the legal air pollution regulations are in order to assure that the gas turbine will be in compliance with the law existing in the country where it will be installed. This paper is intended to be a general review of the air pollution regulations of 80 countries (107 Jurisdications). It is over-simplified in some cases, and will undoubtedly be outdated rather quickly; therefore, the original up-to-date regulations must be consulted for a specific installation at any given location. At the present time, there is considerable activity in many countries of the world regarding air pollution control. The general objective of air pollution regulations is to prevent the air quality from degrading to the point which would adversely affect the health or well-being of the population. The development of good regulations involves balancing the benefit of industrialization against the bad effects of the pollution that industrialization produces. Air pollution regulations fall into two categories: emission standards and ambient air quality standards.

Emission standards put limits on the concentration of specific air pollutants which may be discharged into the atmosphere. The air pollutants emitted by stationary gas turbines include oxides of sulfur, oxides of nitrogen, particulates (including smoke), carbon monoxide, and unburned hydrocarbons. The oxides of sulfur result from the oxidation of the sulfur in the fuel and are proportional to the sulfur content of the fuel burned. The oxides of nitrogen result from the oxidation of the nitrogen from the air at high temperatures and from the oxidation of the nitrogen in the fuel. Smoke, carbon monoxide, and unburned hydrocarbons result from incomplete combustion of fuel. Particulates other than soot and carbon result from the ash in the fuel and the oxidation of ash-producing substances. Shown in Table 2 are the limits of specific air pollutants which may be discharged into the atmosphere from stationary gas turbine sources. We have used extensive footnotes in order to keep the table itself readable; these should be consulted as appropriate. The same comment applies to Table 3. Care must be exercised in applying the limits from Table 2 to any specific case, because the interpretation as to whether gas turbines are covered is often not clear. Only in the case of Sweden is there specific reference to gas turbines, and there it is only in the measurement of soot emissions. The confusion results because there are open- and closed-cycle turbines further divided into simple-cycle, regenerative cycle, and combined gas turbine/steam turbine cycle plants. The open-cycle gas turbines are a type of internal combustion engine, whereas the closed cycles are not. The combined cycle plants use heat-recovery steam generators to produce the steam for the steam turbine portion of the cycle by indirect heat transfer to the working fluid and, in addition, may use auxiliary firing. The definitions used in the regulations were not designed to distinguish between the internal combustion diesel or Otto cycles and the gas turbine Brayton cycle, or between the gas turbine Brayton cycle and the straight steam turbine cycle or the steam boiler system which produces heating steam. If a gas turbine is to be installed at a specific site, it is important to determine whether the control agency intends to apply the emission regulations to gas turbines, even though a strict interpretation of the wording of the regulations might not include gas turbines. A description of the sources for the corresponding countries is shown in Table 5.

Ambient air quality standards are the maximum allowable concentration of specified pollutants at ground level. The ambient air quality standards for 25 countries (31 Jurisdictions) are listed in Table 3. Included in this table are control regulations which take the form of point-of-impingement standards. [These are indicated by the footnote (T) in the table.] Under

Table 1 Countries Investigated

COUNTRY	EMISSION STANDARDS IN TABLE #:	AMBIENT CONCENTRATION STANDARDS IN TABLE #:	STANDARDS FOR SULFUR CONTENT OF FUEL IN TABLE #:	NO_x STANDARD
AFGHANISTAN				NONE
ARGENTINA		III		
" - BUENOS AIRES		III		
AUSTRALIA	II			
" - NEW SOUTH WALES	II			
" - QUEENSLAND	II			
" - SOUTH AUSTRALIA	II			
" - VICTORIA	II			
" - WESTERN AUSTRALIA	II			
AUSTRIA			IV	
" - INNSBRUCK			IV	
BANGLADESH				NONE
BELGIUM		III	IV	
BOLIVIA				NONE
BRAZIL				NONE
" - GUANABARA				NONE
" - SAO PAULO				NONE
" - SANTO ANDRE	II			
" - SAO BERNARDO DE CAMPO	II			
BULGARIA		III		
BURMA				NONE
CANADA		III		
" - ALBERTA	II	III		
" - BRITISH COLUMBIA				NONE
" - MANITOBA	II	III		
" - NEW BRUNSWICK	II			
" - NEWFOUNDLAND	II	III		
" - ONTARIO	II	III		
" - PRINCE EDWARD ISLAND				NONE
" - QUEBEC				NONE
" - " - MONTREAL	II			
" - SASKATCHEWAN		III		
CHILE				NONE
COLOMBIA				NONE
COMORO ISLANDS				NONE
COSTA RICA				NONE
CZECHOSLOVAKIA	II	III		
DAHOMEY				NONE
DEMOCRATIC REPUBLIC OF GERMANY (EAST GERMANY)	II	III		
DENMARK			IV	
ECUADOR				NONE
EL SALVADOR				NONE
ETHIOPIA				NONE
FEDERAL REPUBLIC OF GERMANY (WEST GERMANY)	II	III	IV	
" - NORDRHEIN - WESTPHALIA	II		IV	

Table 1 (cont'd)

COUNTRY	EMISSION STANDARDS IN TABLE #:	AMBIENT CONCENTRATION STANDARDS IN TABLE #:	STANDARDS FOR SULFUR CONTENT OF FUEL IN TABLE #:	NO STANDARD
FIJI ISLANDS				NONE
FINLAND		III		
FRANCE	II	III	IV	
" - PARIS			IV	
GAMBIA				NONE
GREAT BRITAIN	II		IV	
GREECE			IV	
HONDURAS				NONE
HONG KONG	II			
INDIA				NONE
INDONESIA				NONE
IRAN				NONE
IRAQ				NONE
IRELAND	II			
ISRAEL		III		
ITALY	II	III	IV	
IVORY COAST				NONE
JAPAN	II	III	IV	
KENYA				NONE
LAOS				NONE
LEBANON				NONE
LIBERIA				NONE
LIBYA				NONE
MADAGASCAR				NONE
MALAYSIA				NONE
MALAWI				NONE
MALTA				NONE
MAURITIUS				NONE
MEXICO	II			
NETHERLANDS		III		
NEPAL				NONE
NEW GUINEA				NONE
NEW ZEALAND	II			
NIGERIA				NONE
NORWAY			IV	

Table 1 (cont'd)

COUNTRY	EMISSION STANDARDS IN TABLE #:	AMBIENT CONCENTRATION STANDARDS IN TABLE #:	STANDARDS FOR SULFUR CONTENT OF FUEL IN TABLE #:	NO STANDARD
PAKISTAN				NONE
PANAMA				NONE
PERU				NONE
PHILIPPINES	II	III		
POLAND		III		
REPUBLIC OF KOREA (SOUTH KOREA)				NONE
ROMANIA		III		
SINGAPORE	II			
SOUTH AFRICA				NONE
SPAIN		III		
" - MADRID	II		IV	
SWEDEN	II	III	IV	
SWITZERLAND	II	III	IV	
TANZANIA				NONE
THAILAND				NONE
TOGO				NONE
TURKEY		III		
UGANDA				NONE
UNITED STATES	II	III		
UNION OF SOVIET SOCIALIST REPUBLICS		III		
VENEZUELA		III		
YUGOSLAVIA	II	III	IV	
" - SARAJEVO	II			
" - SERBIA	II	III		
" - ZAGREB	II			
ZAIR				NONE
ZAMBIA				NONE

these, the source must be controlled so that the value given is not exceeded at ground level at any point not on the emitter's own property.

We have tried to maintain the units preferred in the original documents, except that we have used mg/cu m instead of μg/cu m in the few cases where the latter occur (e.g., United States standards). In the cases where ambient concentrations are expressed in parts per million, the following multiplication factors can be used at standard conditions to convert to mg/cu m.

Conversion Factors

Gas	ppm	mg/cu m
CO	1	1.150
SO_2	1	2.620
NO_2	1	1.880

Table 2

COUNTRY	VISIBLE EMISSION[Q]	SOOT	PARTICULATE MATTER	SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO
CANADA (MANITOBA)	RINGELMANN 2		0.57 G/M^3[K]	SULFUR COMPOUNDS AS SO_2[C] 0.2 VOL. %		
CANADA (MONTREAL)	RINGELMANN 1		PRORATED BETWEEN: 0.60 LB/MBTU/HR AT 10 MBTU/HR AND 0.1 LB/MBTU AT 200 MBTU/HR			
CANADA (NEW BRUNSWICK)	RINGELMANN 2					
CANADA (NEW FOUNDLAND)	RINGELMANN 2					
CANADA (ONTARIO)	RINGELMANN 2					
CZECHOSLOVAKIA			5.0 KG/HR[B] ALSO, FOR TOTAL PARTICULATE FOR 30 M. STACK: 31 KG/HR[J]	FOR 30 M STACK: 22.5 KG/HR[J]		60 KG/HR[B]
DAHOMEY						
DEMOCRATIC REPUBLIC OF GERMANY (E. GERMANY)				COMPLEX FORMULA BASED ON EFFECTIVE STACK HEIGHT AND BACKGROUND LEVELS		
FEDERAL REPUBLIC OF GERMANY (WEST GERMANY)			150 MG/M^3			VAPORIZING OIL BURNER: 0.1 VOL %[D]

Table 2 (cont'd)

COUNTRY	VISIBLE EMISSIONS	SOOT	PARTICULATE MATTER	SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO
FRANCE			SMOKELESS ZONE 1:(N) 0.43 G/M^3(I) (0.60 G/10^6 CAL) SMOKELESS ZONE 2: 0.86 G/M^3(I) (1.20 G/10^6 CAL)	SPECIAL ZONES 1 & 2: 2.0 G/10^4 CAL		0.05 VOL. % (ELECTRICAL GENERATORS)
GREAT BRITAIN	RINGELMANN 2		LIQUID-FIRED:(L) LOG EMISS = 0.7263 (LOG MBTU/HR) - 0.2485		1.0 GRAINS/FT^3(S)	1.0 GRAINS/FT^3(E)
HONG KONG	RINGELMANN 2					
IRELAND	RINGELMANN 2					
ITALY	RINGELMANN 3		(I)	0.20 VOL %		
JAPAN			OIL & GAS BURNING, SPECIAL DISTRICTS < 40,000 M^3/HR. EXHAUST: 0.2 G/M^3 > 40,000 M^3/HR. EXHAUST: 0.05 G/M^3 OIL & GAS BURNING OTHER DISTRICTS < 40,000 M^3/HR. EXHAUST: 0.30 G/M^3 40,000-200,000 EXHAUST: 0.20 G/M^3 > 200,000-200,000 EXHAUST: 0.10 G/M^3	COMPLEX FORMULA BASED ON EFFECTIVE STACK HEIGHT AND LOCALITY	NEW GAS-FIRED BOILER: 130 PPM(G) EXISTING GAS-FIRED BOILER: 170PPM(G) NEW OIL-FIRED BOILER: 180 PPM(H) EXISTING OIL-FIRED BOILER: 230 PPM(H) NEW TAR-FIRED BOILER: 180 PPM(H) EXISTING TAR-FIRED BOILER: 280 PPM(H)	
MEXICO	RINGELMANN 2		< 63 MK CAL./HR.: 80 G/M K-CAL. < 63 MK CAL./HR.: 45 G/M K-CAL.			

Table 2 (cont'd)

COUNTRY	VISIBLE EMISSIONS	SOOT	PARTICULATE MATTER	SO_2	NO_x (AS NO_2 UNLESS NOTED)
NEW ZEALAND	CLEAN AIR ZONES: RINGELMANN 1 OTHER AREAS: RINGELMANN 2		0.25 G/M^3 (A)		
PHILIPPINES	RINGELMANN 3		0.40 GRAINS/FT^3		
SINGAPORE	RINGELMANN 2		0.40 G/M^3		ANY PROCESS OTHER THAN ACID MFG: (S) 2.0 G/M^3
SPAIN (MADRID)	RINGELMANN 2				
SWEDEN		GAS TURBINES: AV. < 500 HR/YR BACHARACH 5 AV. > 500 HR/YR., BACHARACH 3, OIL BURNERS, BACHARACH 3	OIL STEAM-ELECTRIC PLANTS > 300 MW: 1 KG/TON FUEL OIL BURNING INSTALLATION (EXISTING): < 50 MW: TOTAL PTCLS: 2.0 KG/TON FUEL COMBUSTIBLE: PTCLS: 1.5 KG/TON FUEL > 50 MW: TOTAL PTCLS: 1.0 KG/TON FUEL COMBUSTIBLE: PTCLS: 1.5 KG/TON OIL-BURNING INSTALLATIONS (NEW): TOTAL PTCLS: 1.5 KG/TON FUEL COMBUSTIBLE: 1.0 KG/TON FUEL	OIL STEAM-ELECTRIC PLANTS > 300 MW: 20.0 KG/TON FUEL	
SWITZERLAND			> 1000 KG/HR FUEL: (O) PROGRAMMED SOOT BLOW: 150 MG/M^3 HAND-DRIVEN SOOT BLOW: 200 MG/M^3		

Table 2 (cont'd)

COUNTRY	VISIBLE EMISSIONS	SOOT	PARTICULATE MATTER	SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO
UNITED STATES	IN PROCESS			IN PROCESS	IN PROCESS	IN PROCESS
YUGOSLAVIA	RINGELMANN 3					
YUGOSLAVIA (SARAJEVO)		OIL < 10,000 K. CAL./HR: BACHARACH 4 OIL 10,000 - 650,000 K. CAL./HR.: BACHARACH 3 LIGHT OIL, > 650,000 K. CAL./HR.: BACHARACH 2 MEDIUM OIL > 650,000 K. CAL./HR.: BACHARACH 3 HEAVY OIL, > 650,000 K. CAL./HR.: BACHARACH 4	NEW PLANTS: 150 MG/M^3(K) EXISTING PLANTS 300 MG/M^3			
YUGOSLAVIA (SERBIA)	RINGELMANN 3					
YUGOSLAVIA (ZAGREB)		OIL BURNING: BACHARACH 3				

The ground level concentration of pollutants originating from gas turbine emission can be calculated by any one of a number of atmospheric diffusion models. These models include a calculation of plume rise and atmospheric dispersion of the plume. A detailed discussion of diffusion modeling is beyond the scope of this paper; however, the following is a brief description of the subject.

The exhaust gas data required to make the calculations are the velocity, temperature, and mass flow along with the height and diameter of the exhaust stack. Also required is the rate of emissions of sulfur dioxide, oxides of nitrogen, carbon monoxide, unburned hydrocarbons, and particulates.

Calculations of one to three hour ground level concentrations of pollutants can be made as a function of wind speed and atmospheric stability and presented versus the probability of occurrence of given atmospheric conditions. Calculations of the annual arithmetic mean ground level concentration of pollutants can be made using an appropriate computer program into which is fed the exhaust parameters and the distribution of wind direction, speed, and stability class.

The calculated ground level concentration of pollutants can be superimposed upon existing ground level concentrations for proposed gas turbine sites. The result can then be compared to ambient air quality regulations to determine if the site is suitable for a gas turbine after considering the air quality requirements. Each site is different and must be analyzed independently. The reader who is interested in the details of calculating the ground level concentration of pollutants is referred to in References (1), (2), and (4).[1]

Besides the emission and ambient air level controls, there are regulations covering the sulfur content of fuels for stationary sources. These regulations are shown in Table 4; as with other tables, we have not attempted to show state and local regulations in the United States. We have discussed these in Reference (3). Numerous local jurisdictions in the United States do have regulations covering the sulfur content of fuels. Forty-five countries appear to have no air pollution regulations, and these are listed in Table 1 with no reference to the other Tables.

We wish to acknowledge the help of Professor A. C. Stern and Mr. Werner Martin, of the Department of Environmental Sciences and Engineer-

[1] Underlined numbers in parentheses designate References at end of paper.

Table 3 Ambient Concentration Standards (Including Point of Impingement Limits)

COUNTRY	PARTICULATES		SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO	COMMENT
	SUSPENDED	DUSTFALL				
ARGENTINA	0.15 MG/M^3(30 DAY)$^{(D)}$		0.07 MG/M^3(30 DAY)			
ARGENTINA (BUENOS AIRES)		1.0 MG/CM^2/MO		0.45 PPM (1 HR)$^{(C)}$	50 PPM(1 HR)$^{(B)}$ 10 PPM (8 HR)$^{(C)}$	
BELGIUM			0.15 MG/M^3(24 HR)$^{(M)}$			
BULGARIA	0.5 MG/M^3(20 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$		.50 MG/M^3(20 MIN)$^{(B)}$ .05 MG/M^3(24 HR)$^{(C)}$	MAX. 0.085 MG/M^3(20 MIN)$^{(B)}$ 0.085 MG/M^3(24 HR)$^{(C)}$	3.0 MG/M^3(20 MIN)$^{(B)}$ (MAX.) 1.0 MG/M^3(24 HR)$^{(C)}$	
CANADA	0.12 MG/M^3(24 HR)$^{(B, H)}$ 0.07 MG/M^3(1 YR)$^{(C, H)}$		0.9 MG/M^3(1 HR)$^{(B, H)}$ 0.3 MG/M^3(24 HR)$^{(C, H)}$		35 MG/M^3(1 HR)$^{(B, H)}$ 15 MG/M^3(8 HR)$^{(C, H)}$	
CANADA (ALBERTA	0.10 MG/M^3(24 HR)$^{(B)}$ 0.06 MG/M^3(1 YR)$^{(C)}$	RESIDENTIAL: 53 MG/100 CM^2/MO COMMERCIAL: 158 MG/100 CM^2/MO	0.525 MG/M^3(30 MIN)$^{(B)}$ 0.45 MG/M^3(1 HR)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$ 0.03 MG/M^3(1 YR)$^{(C)}$	0.4 MG/M^3(1 HR)$^{(B)}$ 0.2 MG/M^3(24 HR)$^{(C)}$ 0.06 MG/M^3(1 YR)$^{(C)}$	15 MG/M^3(1 HR)$^{(B)}$ 6 MG/M^3(8 HR)$^{(C)}$	
CANADA (MANITOBA)	0.12 MG/M^3(24 HR)$^{(B)(N)}$ 0.07 MG/M^3(1 YR)$^{(C)}$ 0.100 MG/M^3(24 HR)$^{(E, N)}$ 0.060 MG/M^3(1 YR)$^{(E, N)}$	AIR BASIN AVG., 1 Mo.:$^{(N)}$ 0.8 MG/CM^2/DAY SINGLE POINT AVG., 1 MO.$^{(N)}$ 1.5 MG/CM^2/DAY^T 15 TONS/MI.^{2}/MO(1 MO.)$^{(N)}$	0.9 MG/M^3(1 HR)$^{(B)(N)}$ 0.3 MG/M^3(24 HR)$^{(C)(N)}$ 0.06 MG/M^3(1 YR)$^{(C)(N)}$ 0.30 PPM (30 MIN)$^{(T)(N)}$	0.38 MG/M^3(1 HR)$^{(B)(N)}$ 0.13 MG/M^3(24 HR)$^{(C)(N)}$ 0.1 MG/M^3(1 YR)$^{(C)(N)}$	15 MG/M^3(1 HR)$^{(B)(N)}$ 6 MG/M^3(8 HR)$^{(C)(N)}$ 5.0 PPM(30 MIN)$^{(T)(N)}$	SULFATION (SO_3): 1.0 MG/100 CM^2/DAY (30 DAYS) (N)
CANADA (NEWFOUNDLAND)	0.12 MG/M^3(24 HR)$^{(B)}$ 0.07 MG/M^3(1 YR)$^{(C)}$ 0.100 MG/M^3(30 MIN)$^{(T, H)}$	7.0 GM/M^{2}MO(1 MO AVG.) 4.6 GM/M^2/YR(1 MO AVG.) 5.25 GM/M^2(30 DAY)$^{(H, T)}$	0.73 MG/M^3(1 HR)$^{(B)}$ 0.29 MG/M^3(24 HR)$^{(C)}$ 0.06 MG/M^3(1 YR)$^{(C)}$ 0.880 MG/M^3(30 MIN)$^{(T, H)}$	0.4 MG/M^3(1 HR)$^{(B)}$ 0.2 MG/M^3(24 HR)$^{(C)}$ 0.51 MG/M^3(30 MIN)$^{(T, H)}$	15 MG/M^3(1 HR)$^{(B)}$ 6 MG/M^3(8 HR)$^{(C)}$ 8 PPM (24 HR)$^{(C)}$ 6.25 PPM (30 MIN)$^{(H, T)}$	
CANADA (ONTARIO)	0.09 MG/M^3(24 HR)$^{(B, E)}$ 0.06 MG/M^3(1 YR)$^{(C, E)}$ 0.100 MG/M^3(30 MIN)$^{(T)}$	15 TONS/MI^2/MO(30 DAY)^T	0.73 MG/M^3(1 HR)$^{(B,E)}$ 0.29 MG/M^3(24 HR)$^{(C,E)}$ 0.06 MG/M^3(1 YR)$^{(C,E)}$ 0.30 PPM (30 MIN)$^{(T)}$	0.4 MG/M^3(1 HR)$^{(B, E, T, S)}$ 0.2 MG/M^3(24 HR)$^{(C, E, T, S)}$ 0.25 PPM(30 MIN)$^{(T)}$	40 PPM(1 HR)$^{(B, E)}$ 8 PPM (24 HR)$^{(C, E)}$ 15 PPM(8 HR)$^{(C, E)}$ 5 PPM (30 MIN)$^{(T)}$	SULFATION (SO_3): 0.4MG/100CM^2/DAY (30 DAY)
CANADA (SASKATCHEWAN)	0.15 MG/M^3(24 HR)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(T)}$	2.0 MG/CM^{2}MO.(30 DAYS)$^{(T)}$	1.0 MG/M^3(1 HR)$^{(B)}$ 0.2 MG/M^3(24 HR)$^{(C)}$ 1.0 MG/M^3(1 HR)$^{(T)}$ 0.2 MG/M^3(24 HR)$^{(T)}$ 4.0 MG/M^3(30 DAY)$^{(T, U)}$	0.04 MG/M^3(1 HR)$^{(B, S, T)}$ 0.02 MG/M^3(24 HR)$^{(C, S, T)}$		SULFATION (SO_3): 0.8MG/100CM^2/DAY (30 DAYS)
CZECHOSLOVAKIA	0.5 MG/M^3(30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$		0.5 MG/M^3(30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$	0.3 MG/M^3(30 MIN)$^{(B)}$ 0.1 MG/M^3(24 HR)$^{(C)}$	6.0 MG/M^3(30 MIN)$^{(B)}$ 1.0 MG/M^3(24 HR)$^{(C)}$	

Table 3 (cont'd)

COUNTRY	PARTICULATES		SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO	COMMENT
	SUSPENDED	DUSTFALL				
DEMOCRATIC REPUBLIC OF GERMANY (EAST GERMANY)	0.5 MG/M^3(10-30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$		0.5 MG/M^3(10-30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$	0.1 MG/M^3(10-30 MIN)$^{(B)}$ 0.004 MG/M^3(24 HR)$^{(C)}$	3.0 MG/M^3(10-30 MIN)$^{(B)}$ 1.0 MG/M^3(24 HR)$^{(C)}$	
FEDERAL REPUBLIC OF GERMANY (WEST GERMANY)	0.48 MG/M^3(30 MIN)$^{(I)}$	GENERAL 0.42 GM/M^2/DAY$^{(V)}$ 0.65 GM/M^2/DAY$^{(W)}$ INDUSTRIAL 0.85 GM/M^2/DAY$^{(V)}$ 1.3 GM/M^2/DAY$^{(W)}$	0.75 MG/M^3(30 MIN)$^{(B)}$ 0.4 MG/M^3(30 MIN)$^{(C)}$	0.2 MG/M^3(30 MIN ONCE IN 8 HRS) (NO_2) 0.1 MG/M^3(30 MIN) (NO_2)$^{(C)}$	40 MG/M^3(B, H) 10 MG/M^3(C, H)	
FINLAND	0.5 MG/M^3(30 MIN)$^{(B, F)}$ 0.15 MG/M^3(24 HR)$^{(C, F)}$	10 MG/M^2/MO$^{(L)}$	0.72 MG/M^3(30 MIN)$^{(B, F)}$ 0.25 MG/M^3(24 HR)$^{(C, F)}$ 0.18 MG/M^3(1 YR)$^{(C, F)}$	0.56 MG/M^3(30 MIN)$^{(B, H, S)}$ 0.20 MG/M^3(24 HR)$^{(C, H, S)}$	40 MG/M^3(1 HR)$^{(B, F)}$ 10 MG/M^3(8 HR)$^{(C, F)}$	
FRANCE	0.35 MG/M^3(24 HR)$^{(B)}$ 0.06 MG/M^3(1 YR)$^{(C)}$		1.0 MG/M^3(24 HR) 0.75 MG/M^3(24 HR)(PARIS)			
PHILLIPPINES	INDUSTRIAL: 0.900 MG/M^3(1 HR)$^{(T)}$ 0.300 MG/M^3(24 HR)$^{(T)}$ RESIDENTIAL: 0.600 MG/M^3(1 HR)$^{(T)}$ 0.200 MG/M^3(24 HR)$^{(T)}$		2.0 PPM (1 HR)$^{(T)}$ 0.30 PPM (24 HR)$^{(T)}$	2.0 PPM (1 HR)$^{(T)}$ 0.30 PPM (24 HR)$^{(T)}$	100 PPM (1 HR)$^{(T)}$ 30 PPM (24 HR)$^{(T)}$	
POLAND	PROTECTED AREAS: 0.6 MG/M^3(20 MIN)$^{(B)}$ 0.2 MG/M^3(24 HR)$^{(C)}$ SPECIAL AREAS: 0.2 MG/M^3(20 MIN)$^{(B)}$ 0.075 MG/M^3(24 HR)$^{(C)}$	PROTECTED AREAS: 250 TONS/KM^2/YR SPECIAL AREAS: 40 TONS/KM^2/YR 6.5 TONS/KM^2/YR	PROTECTED AREAS: 0.9 MG/M^3(20 MIN)$^{(B)}$ 0.35 MG/M^3(24 HR)$^{(C)}$ SPECIAL AREAS: 0.25 MG/M^3(20 MIN)$^{(B)}$ 0.075 MG/M^3(24 HR)$^{(C)}$	PROTECTED AREAS: 0.6 MG/M^3(20 MIN)$^{(B)}$ 0.2 MG/M^3 (24 HR)$^{(C)}$ SPECIAL AREAS: 0.15 MG/M^3(20 MIN)$^{(B)}$ 0.05 MG/M^3(24 HR)$^{(C)}$	3.0 MG/M^3(20 MIN)$^{(B)}$ 0.5 MG/M^3(24 HR)$^{(C)}$	
ROMANIA	0.5 MG/M^3(30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$	200 TONS/KM^2/YR	0.75 MG/M^3(20 MIN)$^{(B)}$ 0.25 MG/M^3(24 HR)$^{(C)}$	0.3 MG/M^3(30 MIN)$^{(B, S)}$ 0.1 MG/M^3(24 HR)$^{(C, S)}$	6.0 MG/M^3(30 MIN)$^{(B)}$ 2.0 MG/M^3(24 HR)$^{(C)}$	
SPAIN	0.6 MG/M^3(30 MIN)$^{(B, H)}$ 0.202 MG/M^3(30 DAYS)$^{(B, H)}$ 0.3 MG/M^3(24 HR)$^{(C, H)}$ 0.13 MG/M^3(1 YR)$^{(C, H)}$	200 MG/M^2/DAY	0.8 MG/M^3(30 MIN)$^{(H, B)}$ 0.4 MG/M^3(30 DAY)$^{(H, C)}$ 0.256 MG/M^3(30 DAY)$^{(H, C)}$ 0.15 MG/M^3(1 YR)$^{(H, C)}$	0.4 MG/M^3(30 MIN)$^{(B, H)}$ 0.2 MG/M^3(24 HR)$^{(C, H)}$	45.0 MG/M^2(30 MIN)$^{(B, H)}$ 15.0 MG/M^2(8 HR)$^{(C, H)}$	
SWEDEN	0.1 MG/M^3(1 HR)$^{(I)}$		0.625 MG/M^3(30 MIN)$^{(B, N)}$ 0.25 MG/M^3(24 HR)$^{(C, N)}$ 0.125 MG/M^3(30 DAY)$^{(C, N)}$			
SWITZERLAND			0.75 MG/M^3(30 MIN)$^{(B, O)}$ 0.5 MG/M^3(24 HR)$^{(C, O)}$ 1.25 MG/M^3(30 MIN)$^{(B, P)}$ 0.75 MG/M^3(24 HR)$^{(C, P)}$			

Table 3 (cont'd)

COUNTRY	PARTICULATES		SO_2	NO_x (AS NO_2 UNLESS NOTED)	CO	COMMENT
	SUSPENDED	DUSTFALL				
TURKEY	0.15 MG/M^3(24 HR)$^{(J, K)}$		0.15 MG/M^3(24 HR)$^{(J, K)}$ 0.30 MG/M^3(24 HR)$^{(J, Q)}$			
UNITED STATES	.075 MG/M^3(1 YR)$^{(B)}$ (GEO. MEAN) **.260 MG/M^3(24 HR)$^{(B, A)}$** .060 MG/M^3(1 YR)$^{(C)}$ (GEO. MEAN) **.150 MG/M^3(24 HR)$^{(C, A)}$**		0.08 MG/M^3(1 YR)$^{(B)}$ 0.365 MG/M^3(24 HR)$^{(A, B)}$ 1.3 MG/M^3(3 HR)$^{(A, C)}$	0.1 MG/M^3(1 YR)$^{(B, C)}$	10 MG/M^3(8 HR)$^{(B, C)}$ 40 MG/M^3(1 HR)$^{(B, C)}$	HYDROCARBONS (NOT CH_4): 0.16 MG/M^3 6-9 AM$^{(A, B, C)}$
U.S.S.R.	0.5 MG/M^3(30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$	SOOT: 0.15 MG/M^3(30 MIN)$^{(B)}$ 0.05 MG/M^3(24 HR)$^{(C)}$	0.5 MG/M^3(30 MIN)$^{(R)}$ 0.5 MG/M^3(24 HR)$^{(R)}$	0.085 MG/M^3(30 MIN)$^{(B, S)}$ 0.085 MG/M^3(24 HR)$^{(C, S)}$	3.0 MG/M^3(30 MIN)$^{(B)}$ 1.0 MG/M^3(24 HR)$^{(C)}$	
VENEZUELA						
YUGOSLAVIA			0.5 MG/M^3(30 MIN)$^{(B)}$ 0.15 MG/M^3(24 HR)$^{(C)}$	0.085 MG/M^3(20 MIN)$^{(B, S)}$ 0.085 MG/M^3(24 HR)$^{(C, S)}$	3.0 MG/M^3(30 MIN)$^{(B)}$ 1.0 MG/M^3(24 HR)$^{(C)}$ 3.0 MG/M^3(30 MIN)$^{(T)}$ 1.0 MG/M^3(24 HR)$^{(T)}$	
YUGOSLAVIA (SERBIA)			0.50 MG/M^3(30 MIN)$^{(T)}$ 0.15 MG/M^3(24 HRS)$^{(T)}$	0.085 MG/M^3(30 MIN)$^{(T, S)}$ 0.085 MG/M^3(24 HR)$^{(T, S)}$		
ZAIR						
ZAMBIA						

Table 4 Sulfur Limits in Fuel Oil (as used for Power Generation)

COUNTRY	TYPE OF FUEL	% SULFUR
AUSTRIA	LIGHT OIL	1.5
	MEDIUM OIL	2.5
	HEAVY OIL	3.5
AUSTRIA - INNSBRUCK	ALL OIL	1.0
BELGIUM	LIGHT FUEL OIL	1.5
	MEDIUM OIL	2.7
	HEAVY OIL	3.8
	EXTRA HEAVY OIL	4.5
DENMARK COPENHAGEN AND FREDERICKSBERG	HEAVY FUEL OIL	2.5
	ALL OTHER TYPES	1.0
FEDERAL REPUBLIC OF GERMANY (W. GERMANY)	EXTRA LIGHT FUEL OIL	0.8
	HEAVY FUEL OIL	2.8
FEDERAL REPUBLIC OF GERMANY (NORDRHEIN-WEST-FALEN)	USES > 800,000 K CAL/HR	1.8
FRANCE	LIGHT FUEL OIL	2.0
	MEDIUM FUEL OIL	2.0
	HEAVY FUEL OIL	4.0
FRANCE (PARIS)	ZONE 1	0.5
	ZONE 2 IF > 350 TH/HR.(1)	0.5
GREAT BRITAIN	- SEE "UNITED KINGDOM"	
GREECE	LIGHT FUEL OIL	3.5
	HEAVY FUEL OIL	4.0
	DIESEL FUEL	0.5
ITALY	EXTRA LIGHT OIL	2.5
	LIGHT FUEL OIL	3.0
	MEDIUM OIL	4.0
	HEAVY OIL	4.0
ITALY ZONE A	KEROSINE	1.1
	LIGHT FUEL OIL	3.0
(ZONE A - CITIES 70,000 - 300,000 IN CENTRAL OR NORTHERN ITALY, 300,000 - 1,000,000 IN SOUTHERN AND INSULAR ITALY, AND OTHER AREAS OF IMPORTANCE OR ADVERSE CONDITIONS)		
ITALY ZONE B	KEROSINE	1.1
	FUEL OIL FOR > 500,000 K CAL/HR	3.0
	FUEL OIL, VISC. $5^{o}E/50^{o}C$	4.0
(ZONE B = AREAS OVER 300,000 IN CENTRAL AND NORTHERN ITALY, OVER 1,000,000 IN SOUTHERN AND INSULAR ITALY, OR AREAS OF ADVERSE CONDITIONS)		
JAPAN	FUEL OIL	0.5 - 1.5 DEPENDING ON AREA AND SPECIAL DESIGNATION
NORWAY (DRANENEN)	FUEL OIL - SUMMER	2.5
	FUEL OIL - WINTER	1.2
SPAIN (MADRID)	FUEL OIL - INDUSTRIAL	3.0
SWEDEN	FUEL OIL	2.5

Table 4 (cont'd)

COUNTRY	TYPE OF FUEL	% SULFUR
SWEDEN (STOCKHOLM, MALMÖ, SÖTEBURG)		1.0
SWITZERLAND	EXTRA LIGHT FUEL OIL	0.5
	LIGHT FUEL OIL	2.0
	MEDIUM FUEL OIL	2.0
	HEAVY FUEL OIL	3.5
UNITED KINGDOM	LIGHT FUEL OIL	3.5
	MEDIUM FUEL OIL	4.0
	HEAVY FUEL OIL	4.5
	EXTRA HEAVY	5.0
YUGOSLAVIA (ZONE 1)	FUEL OIL	1.7
(ZONE 2)	FUEL OIL	2.5

(1) TH/HR. + THERMIES/HOUR = 1 X 10^6 CAL/HR.

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2 Stern, A. C., ed., Air Pollution (3 vols.), Academic Press, 1968.

3 Dibelius, N. R., and Ketterer, R. J., "Status of State Air Emission Regulations Affecting Gas Turbines," ASME Paper No. 73-WA/GT-8, 1973.

4 Anon., "Air Quality Display Model," U. S. Department of Health, Education, and Welfare Publication, No. PB 189144 (1969).

5 "Collection, Tabulation, Codification and Analysis of the World's Air Quality Management Standards," E. P. A. Contract No. 68-02-0556.

NOTES FOR TABLE 2

(A) Guideline for new plants
(B) Emissions above this level must be reported; emission periods of less than one hour may be proportionally higher
(C) Guideline
(D) Verein Duetscher Ingenieure Standard
(E) As NO_2
(F) For new plants
(G) On 5 percent O_2 basis
(H) On 4 percent O_2 basis
(I) Has stack height requirement
(J) Varies in a non-simple manner with stack height
(K) At 12 percent CO_2
(L) "Where material being heated is in contact with combustion gases but does not contribute grit or dust to them"
(M) At 50 percent excess air
(N) Zones are based on historical ambient levels. Zone 1 is essentially paris
(O) Maximum 4-hour average during 24 hour
(P) Soot blowing excepted
(Q) For "visible emissions" there is generally an exception made for start-up which has not been noted. The level noted here is the level which is prohibited
(R) Includes vessels
(S) As SO_3 equivalent
(T) Not applicable to gas turbine cycle
(U) Equation is good approximation over 50 x 10^6 Btu/hr

(NOTE: MBTU means million British thermal units in this table.)

NOTES FOR TABLE 3

(A) May be exceeded once per year
(B) Primary standard in case of United States; "short term" for other countries
(C) Secondary standard in case of United States; "long term" for other countries
(D) City of Buenos Aires
(E) Criteria for desirable quality
(F) Not a legal standard nationally, but may be invoked locally
(G) Tentative standards
(H) Proposed standards
(I) Basis for stack height calculation

Table 5 Description of Sources of Emission Limitations (see Table 2)

AUSTRALIA

VISIBLE	ALL STATIONARY FUEL BURNING SOURCES.
SOLID PARTICLES	ANY OTHER TRADE, INDUSTRY, PROCESS, INDUSTRIAL PLANT, OR FUEL BURNING EQUIPMENT.
SOOT	ANY BOILER OR FURNACE BURNING LIQUID OR GASEOUS FUELS
SO_2	NOT COVERED
NO_x	1. GAS FIRED POWER STATIONS. 2. ANY TRADE, INDUSTRY, OR PROCESS EXCEPT NITRIC OR SULPHURIC ACID PLANTS, OR GAS FIRED POWER STATIONS.
CO	ANY TRADE, INDUSTRY, OR PROCESS.

AUSTRALIA - NEW SOUTH WALES

VISIBLE	ANY TRADE, INDUSTRY, PROCESS, FUEL BURNING EQUIPMENT AND INDUSTRIAL PLANT
PARTICULATE	ANY TRADE, INDUSTRY, PROCESS, INDUSTRIAL PLANT OR FUEL BURNING EQUIPMENT EXCEPT .....(MINOR ITEMS)
NO_x	ANY TRADE, INDUSTRY, OR PROCESS EMITTING ..... OXIDES OF NITROGEN (OTHER THAN ACID MANUFACTURING).

AUSTRALIA - QUEENSLAND

VISIBLE	AN INDUSTRIAL PLANT OR FUEL BURNING EQUIPMENT EXCEPT ..... KILNS, AND VEHICLES AND VESSELS.
OXIDES OF N	ANY TRADE, INDUSTRY, OR PROCESS.
PARTICULATES	ANY TRADE, INDUSTRY, OR PROCESS, FUEL BURNING EQUIPMENT OR INDUSTRIAL PLANT (OTHER THAN PLANT OR EQUIPMENT USED FOR THE HEATING OF METALS) IN THE OPERATION OF WHICH DUST OR OTHER SOLID PARTICLES ARE EMITTED.

AUSTRALIA - SOUTH AUSTRALIA

VISIBLE	ANY CHIMNEY EXCEPT VEHICLES ..... DOMESTIC PREMISES, OR MINOR PLANT.

AUSTRALIA - VICTORIA

VISIBLE	CHIMNEY
NO_x	INDUSTRIAL PLANT (INCLUDES POWER PLANTS).
DUST	INDUSTRIAL PLANT, INCLUDING FUEL BURNING EQUIPMENT.

AUSTRALIA - WESTERN AUSTRALIA

SO_2	ANY CHIMNEY EMITTING > 1 LB SO_2/HR. SHALL FOLLOW UNITED KINGDOM MEMORANDUM #25/63 (5/15/63) "MEMORANDUM ON CHIMNEY HEIGHTS".
VISIBLE	CHIMNEY - (SCHEDULED PREMISES)

BRAZIL - SANTO ANDRE, SAO BERNARDO, SAO COETANO DEL SUL

PARTICULATE	COMBUSTION EXHAUST.
SO_2	COMBUSTION EXHAUST.

(J) For residential areas
(K) Recommended standard — not adopted
(L) Any combination of lead, chromium, or vanadium
(M) For protected areas
(N) Guideline
(O) March 1 to October 31
(P) November 1 to end of February
(Q) Industrial areas
(R) Combinations of SO_2 and NO_2, SO_2 and HF, SO_2 and phenol, SO_2 and sulfur acid (aerosol) are limited to SO_2 (actual)/SO_2 (allowable)+ X (actual)/X (allowable) = 1
(S) This is a nitrogen dioxide standard only
(T) This is a point-of-impingement emission limitation, effective beyond the property line of the source
(U) Lead peroxide candle
(V) Yearly average of 12 monthly averages
(W) Monthly average

Table 5 (cont'd)

CANADA - ALBERTA	
VISIBLE	ALL STATIONARY SOURCES EXCEPT ..... (MINOR ITEMS).
PARTICULATES	ALL STATIONARY SOURCES EXCEPT ..... (MINOR ITEMS).
CANADA - MANITOBA	
VISIBLE	NOT STATED.
PARTICULATES	ANY SOURCE.
SO_2	NOT STATED.
CANADA - NEW BRUNSWICK	
VISIBLE	NOT STATED.
CANADA - ONTARIO	
ALL POLLUTANTS	ANY STATIONARY SOURCE.
CANADA - QUEBEC - MONTREAL	
PARTICULATES	FUEL BURNING EQUIPMENT.
CZECHOSLOVAKIA	
PARTICULATES	FUEL BURNING SOURCES.
SO_2	FUEL BURNING SOURCES.
DEMOCRATIC REPUBLIC OF GERMANY (EAST GERMANY)	
SO_2	ALL EMITTERS.
FRANCE	
SO_2	COMBUSTION INSTALLATIONS.
PARTICULATES	SPACE HEATING.
ASH	INDUSTRIAL HEATING.
VISIBLE	SPACE HEATING.
GREAT BRITAIN	
PARTICULATES	(SCHEDULE 1) BOILER OR (SCHEDULE 2) A FURNACE WHICH IS AN INDIRECT HEATING APPLIANCE WHERE THE MATERIAL HEATED IS A GAS OR LIQUID.
NO_x	NITRATION AND OXIDATION PROCESSES. (PROBABLY REFERS TO CHEMICAL PROCESSES ONLY.)
HONG KONG	
VISIBLE	ANY FURNACE, OVEN, OR CHIMNEY WHICH IS NOT CAPABLE OF BEING OPERATED CONTINUOSLY WITHOUT EMITTING SMOKE WHICH.....WOULD BE DARKER THAN SHADE #1.
IRELAND	
VISIBLE	ANY PREMISES OTHER THAN A PRIVATE DWELLING.
ITALY	
PARTICULATES	THERMAL INSTALLATIONS.
SO_2	THERMAL INSTALLATIONS.
CO_2	THERMAL INSTALLATIONS.
JAPAN	
SOOT AND SMOKE EMISSION	BOILER OR ANY FACILITY DESIGNATED BY CABINET ORDER
SO_2	CLASSIFIED UNDER "SOOT AND SMOKE"
NO_x	BOILERS

Table 5 (cont'd)

MEXICO		
	VISIBLE	STATIONARY COMBUSTION EQUIPMENT, EXCEPT INCINERATORS.
	PARTICULATES	ANY INDUSTRIAL OPERATION, PROCESS, OR ACTIVITY IN WHICH FUELS DERIVED FROM PETROLEUM ARE USED FOR INDIRECT HEATING AND THE PRODUCTS OF COMBUSTION ARE NOT IN DIRECT CONTACT WITH THE MATERIALS OF THE PROCESS.
NEW ZEALAND		
	VISIBLE	REFERS TO "BRITISH STANDARDS" FOR MEASUREMENT METHODS.
	PARTICULATES	REFERS TO "BRITISH STANDARDS" FOR MEASUREMENT METHODS.
PHILLIPINES		
	VISIBLE	ANY FUEL BURNING EQUIPMENT.
	PARTICULATES	ANY SOURCE.
SINGAPORE		
	VISIBLE	CHIMNEY OF, OR USED IN CONNECTION WITH, ANY INDUSTRIAL OR TRADE PREMISES.
	PARTICULATES	ANY TRADE, INDUSTRY, PROCESS, FUEL BURNING EQUIPMENT OR INDUSTRIAL PLANT IN THE OPERATION OF WHICH DUST OR OTHER SOLID PARTICLES ARE EMITTED.
	NO_x	ANY TRADE, INDUSTRY, OR PROCESS (OTHER THAN NITRIC ACID MANUFACTURING, WHICH IS COVERED SEPARATELY).
SPAIN - MADRID		
	VISIBLE	HOME HEATING.
SWEDEN		
	VISIBLE	DIESEL ENGINES ARE LISTED SEPARATELY; THEY MUST NOT EMIT CLEARLY COLORED OR OPAQUE EXHAUST GASES. OTHER LISTINGS ARE FOR "BURNING INSTALLATIONS"
	PARTICULATES	THREE CLASSES: STEAM ELECTRIC POWER PLANTS GAS TURBINES BURNING INSTALLATIONS
	SO_2	STEAM ELECTRIC POWER PLANTS.
SWITZERLAND		
	PARTICULATES	OIL BURNING EQUIPMENT FOR PURPOSE OF .....ELECTRICITY PRODUCTION.
YUGOSLAVIA		
	VISIBLE	ANY CHIMNEY.
YUGOSLAVIA - SARAJEVO		
	PARTICULATES	HEATING INSTALLATIONS OVER 25,000 K CAL/HR.
	SOOT	HEATING INSTALLATIONS USING LIQUID FUELS.
YUGOSLAVIA - SERBIA		
	VISIBLE	1. DIESEL ENGINES WILL BE REGULATED SEPARATELY. 2. ANY CHIMNEY.
YUGOSLAVIA - ZAGREB		
	SOOT	HEATING INSTALLATIONS.

NOTES FOR TABLE V

QUOTATION MARKS HAVE BEEN OMITTED, BUT THESE ATTRIBUTIONS ARE AS NEARLY VERBATIM AS POSSIBLE.