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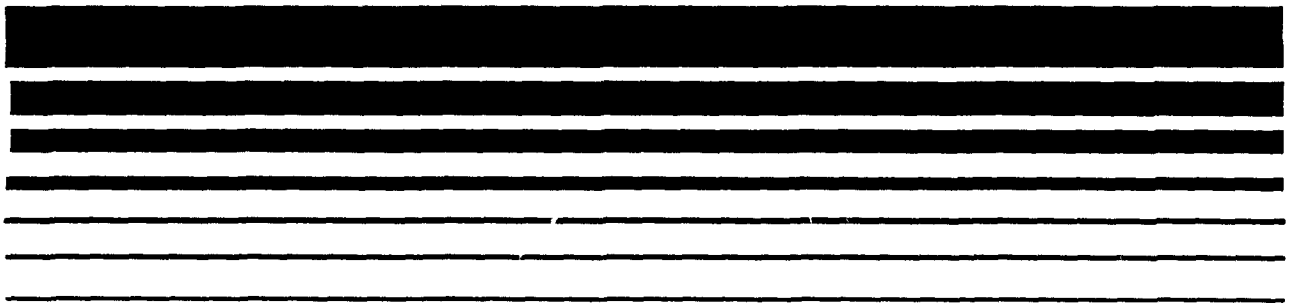
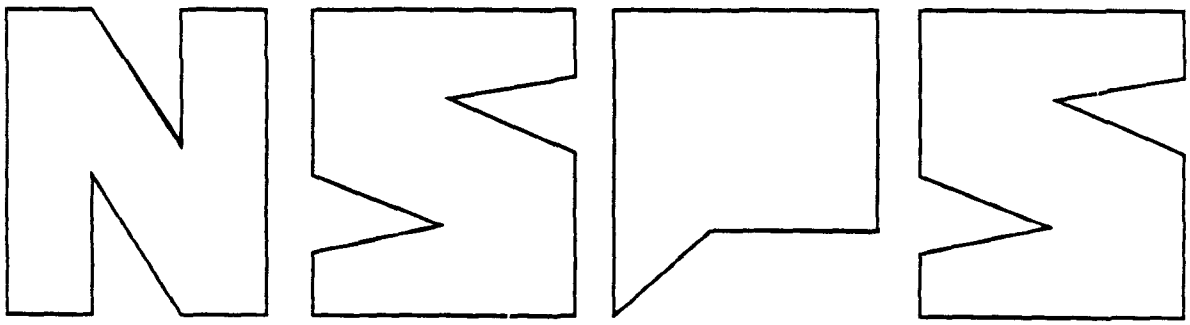
Projected Impacts of Alternative Particulate Matter New Source Performance Standards for Industrial-Commercial-Institutional Nonfossil Fuel-Fired Steam Generating Units





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PROJECTED IMPACTS OF ALTERNATIVE PARTICULATE MATTER NEW SOURCE PERFORMANCE STANDARDS FOR INDUSTRIAL-COMMERCIAL-INSTITUTIONAL NONFOSSIL FUEL-FIRED STEAM GENERATING UNITS

Emission Standards Division

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, N.C. 27711

May 1989

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1.0 INTRODUCTION

This report presents projected environmental, cost, and energy impacts of alternative new source performance standards (NSPS) for small nonfossil fuel-fired steam generating units (i.e., boilers). Small boilers are defined as industrial-commercial-institutional units having a heat input capacity of 29 MW (100 million Btu/hour) or less.

The two categories of nonfossil fuels burned in small boilers are wood and solid waste. Solid waste that meets the definition of municipal solid waste (MSW) will be addressed under a separate NSPS. Wood is the most commonly used nonfossil fuel among small boilers, as discussed in the memorandum "Population Projection for Small Mixed Fuel-Fired Steam Generating Units."[1] Since wood will be the only nonfossil fuel covered by standards developed for this source category, the impacts of alternative standards are evaluated for small wood-fired boilers. In addition, since wood contains negligible amounts of sulfur, alternative sulfur dioxide (SO_2) emission standards will not be developed for wood combustion. Therefore, this report focuses on alternative particulate matter (PM) emission standards.

This analysis estimates the potential environmental, cost, and energy impacts associated with alternative PM emission regulations. These impacts are measured in terms of the projected changes that would occur under alternative PM emission standards versus existing regulations. The analysis of environmental impacts focuses on changes in levels of air emissions as well as changes in the amount of solid and liquid wastes generated. Cost impacts are evaluated in terms of incremental changes in the total annualized costs for boiler and pollution control equipment capital, operating, and fuel costs. Energy impacts are evaluated in terms of potential increases in energy consumption as a result of added PM control equipment.

This analysis examines projected impacts in the fifth year following proposal of standards. It was assumed that the recommended standards would be proposed in 1989 and that the impact analysis should, therefore, focus on projected results for new small nonfossil fuel-fired boilers installed in the 5-year period between 1989 and 1993. The emissions and energy demand projections presented in this report represent annual estimates for calendar year 1993.

This report addresses only nonfossil fuel consumption in new small boilers. It does not analyze fossil fuel-fired steam generating units (i.e., coal, oil, and natural gas). The potential national impacts for fossil fuel-fired small boilers are presented in a separate report.

A summary of the national impacts analysis is presented in Section 2.0. Projections of the number of new wood-fired small boilers are presented in Section 3.0. The results of the national impacts analysis are presented in Section 4.0.

2.0 SUMMARY

To analyze the potential national impacts of PM control, the number of small wood-fired boilers projected for both industrial and commercial-institutional uses was estimated for the 5-year period from 1989 to 1993. Based on recent sales data and the assumption of level sales over this period, a total of 105 new wood-fired boilers was projected. A discussion of the bases for the costs used in this analysis is found in Reference 2.

Four boiler sizes were examined representing small commercial-institutional units, large commercial-institutional units, small industrial units, and large industrial units. However, only high capacity factor (0.55) units were examined because, according to a National Council for Air and Stream Improvement report, most of the wood-fired boilers in these size ranges operate at this, or higher, levels.[3]

National Impacts

The national impacts of the PM control alternatives were estimated by aggregating the model boiler impacts over the projected national 5-year population of 105 new wood-fired boilers.

As shown in Table 2-1, the primary national environmental impact would be the reduction in PM emissions from new, modified, and reconstructed small wood-fired boilers resulting from the promulgation of NSPS. Under the regulatory baseline, total national PM emissions from small wood-fired boilers are estimated at 2,700 Mg/yr (2,970 tons/yr) for 1993. Under standards based on Regulatory Alternative Level I, total national PM emissions in 1993 are estimated at 1,650 Mg/yr (1,810 tons/yr), a 39 percent reduction from baseline PM emission levels. Under Regulatory Alternative

TABLE 2-1. NATIONAL IMPACTS OF REGULATORY ALTERNATIVES FOR PM CONTROLS ON SMALL WOOD-FIRED BOILERS IN 1993

Regulatory alternative	Annual PM emissions		Total annualized costs[a,b]	Annualized cost of control[c]	Cost effectiveness				Solid waste production rate		Incremental solid waste production rate[f]	
					Average[d]		Incremental[e]					
	Mg/yr	(tons/yr)	($1,000/yr)	($1,000/yr)	$/Mg	($/ton)	$/Mg	($/ton)	Mg/yr	(tons/yr)	Mg/yr	(tons/yr)
Baseline	2,700	(2,970)	103,750	-	-	-	-	-	36,600	(40,350)	-	-
Level I	1,650	(1,810)	105,140	1,390	1,383	(1,257)	1,383	(1,257)	37,600	(41,400)	1,000	(1,100)
Level II	1,020	(1,130)	109,900	6,150	3,671	(3,337)	7,103	(6,457)	38,300	(42,200)	1,700	(1,900)
Level III	680	(750)	113,150	9,400	4,653	(4,230)	9,423	(8,566)	38,600	(42,600)	2,000	(2,300)

[a]Based on model boilers with a capacity utilization factor of 0.55 and zero wood price.

[b]Includes the costs for boilers.

[c]Difference in the total annualized costs associated with the regulatory baseline and alternative control levels.

[d]Compared to Regulatory Baseline.

[e]Compared to a less stringent alternative.

[f]Solid waste production associated with PM control.

Level II, total national PM emissions in 1993 are estimated at 1,020 Mg/yr (1,130 tons/yr), a 62 percent reduction from baseline PM emission levels. Under Regulatory Alternative Level III, total national PM emissions in 1993 are estimated at 680 Mg/yr (750 tons/yr), a 75 percent decrease from baseline PM emission levels.

The control of PM emissions from small wood-fired boilers would also increase the amount of solid waste produced as a by-product of pollution control, a secondary environmental impact. The amount of solid waste generated under the baseline by pollution control devices and small wood-fired boilers is 36,600 Mg/yr (40,350 tons/yr). The incremental amount of solid waste generated as a result of additional PM control would range from 3 percent of baseline rates for Regulatory Alternative Level I to 6 percent of baseline rates for Regulatory Alternative Level III. Such wastes are nonhazardous; environmentally acceptable methods for their disposal are readily available.

As with national environmental impacts, projected national cost impacts vary according to the stringency of the various regulatory alternatives. Under the baseline, total national before-tax annualized costs for small wood-fired boilers and PM controls in 1993 are estimated to be $103,750,000. Under standards based on Regulatory Alternative Level I, total national annualized PM control costs are estimated to be $105,140,000/yr, which represents a 1 percent increase over baseline costs. Under standards based on Regulatory Alternative Level II, total national annualized PM control costs are estimated to be $109,900,000/yr, which represents a 6 percent increase over baseline costs. Under standards based on Regulatory Alternative Level III, total national annualized PM control costs are estimated to be $113,150,000/yr, which represents an 9 percent increase over baseline costs.

The projected national incremental cost effectiveness of the various regulatory alternatives varies as a function of cost and emission reductions. The estimated national incremental cost effectiveness of standards based on Regulatory Alternative Level I over the regulatory baseline is $1,383/Mg ($1,257/ton) of PM removed. The estimated national incremental cost effectiveness of standards based on Regulatory Alternative Level II over Regulatory Alternative Level I is $7,103/Mg ($6,457/ton) of PM removed. The estimated national incremental cost effectiveness of standards based on

Regulatory Alternative Level III over Regulatory Alternative Level II is $9,423/Mg ($8,566/ton) of PM removed.

Energy consumed to operate the PM control equipment is estimated to increase only slightly under the various regulatory alternatives compared to the baseline.

3.0 PROJECTIONS OF NEW WOOD-FIRED SMALL BOILERS

Projections of the number of new boilers expected to be built over the 5-year period from 1989 to 1993 were made using annual sales data available for the years 1985 and 1986 from the American Boiler Manufacturers Association (ABMA). Based on historical sales trends, it was assumed that boiler sales would remain level over the 5-year period. The number of new boilers expected to be built over this 5-year period was estimated for four boiler size ranges: 0.8 to 2.9 MW (3 to 10 million Btu/hour); 2.9 to 8.7 MW (10 to 30 million Btu/hour); 8.7 to 15 MW (30 to 50 million Btu/hour); and 15 to 29 MW (50 to 100 million Btu/hour). These size ranges were selected based on boiler type and the sector (i.e., industrial, commercial, or institutional) in which the unit is found.

In the 0.8 to 2.9 MW (3 to 10 million Btu/hour) size range, only commercial-institutional (including watertube, firetube, and firebox) units are found. Commercial-institutional units dominate the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range, although a few industrial units are also found. In the upper size ranges [8.7 to 15 MW (30 to 50 million Btu/hour) and 15 to 29 MW (50 to 100 million Btu/hour)], industrial (watertube) units predominate.

As presented in Table 3-1, new wood-fired small boilers were projected for each of the four size ranges using an average of the 1985 and 1986 sales data. Using the 1986 sales data for illustration, the following discussion describes the method used to disaggregate the number of wood-fired boilers in each of the four size ranges.

Based on the ABMA 1986 sales data for commercial-institutional units, 6,054 boilers were sold in 1986. However, this number includes boilers firing all types of fuels. The total number of wood-fired units sold for all size ranges, including boilers larger than 29 MW (100 million Btu/hour), was

TABLE 3-1. PROJECTIONS OF NEW WOOD-FIRED SMALL BOILERS
BASED ON ABMA SALES DATA (1985 AND 1986)

Boiler size range MW (million Btu/hour)	1985		1986		Average		5-Year Projection	
	Number of boilers	Average size MW (million Btu/hour)	Number of boilers	Average size MW (million Btu/hour)	Number of boilers	Average size MW (million Btu/hour)	Number of boilers	Average size MW (million Btu/hour)
0.8-2.9 (3-10)	8[a]	1.5 (5)	11[a]	1.5 (5)	10	1.5 (5)	50	1.5 (5)
2.9-8.7 (10-30)	4[b]	5.0 (17)	5[c]	5.3 (18)	5	5.3 (18)	25	5.3 (18)
8.7-15 (30-50)	5[d]	10.5 (36)	2[d]	13.2 (45)	4	11.4 (39)	20	11.4 (39)
15-29 (50-100)	2[d]	22 (75)	1[d]	22 (75)	2	22 (75)	10	22 (75)
TOTAL	19		19		21		105	

[a] All commercial-institutional boilers.
[b] 3 commercial-institutional and 1 industrial boilers.
[c] 4 commercial-institutional and 1 industrial boilers.
[d] All industrial boilers.

35. To estimate how many of these 35 wood-fired boilers were in the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range, it was assumed that the wood-fired boilers were distributed among the various size ranges in the same percentages as the total number of boilers sold. For example, 671 boilers in the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range were sold. This number is about 10 percent of the 6,054 total boilers (all sizes) sold. Thus, the percentage of wood-fired boilers between 2.9 and 8.7 MW (10 and 30 million Btu/hour) was estimated to be about 10 percent, or four new boilers projected per year. Applying this same methodology to the 8.7 to 15 MW (30 to 50 million Btu/hour) size range, the projected number of new boilers is less than one per year.

The average boiler size of the four wood-fired boilers in the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range was estimated by assuming that the average boiler size for wood-fired boilers would be the same as that for boilers of all fuel types. Based on this assumption, the average size of a wood-fired boiler within the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range is about 4.2 MW (15 million Btu/hour).

The same methodology was used to estimate the number of wood-fired boilers in the 0.8 to 2.9 MW (3 to 10 million Btu/hour) size range. As a result, it was calculated that 11 wood-fired boilers were sold in the 0.8 to 2.9 MW (3 to 10 million Btu/hour) size range. The average boiler size was estimated to be 1.5 MW (5 million Btu/hour).

In the ABMA 1986 sales data for large industrial boilers, boiler sales were presented by fuel and size range. In the 2.9 to 8.7 MW (10 to 30 million Btu/hour) size range, 1 wood-fired unit was sold with a heat input capacity of 8.7 MW (30 million Btu/hour); in the 8.7 to 15 MW (30 to 50 million Btu/hour size) range, 2 wood-fired units were sold with an average heat input capacity size of 13 MW (45 million Btu/hour); in the 15 to 29 MW (50 to 100 million Btu/hour) size range, 1 wood-fired unit was sold with a heat input capacity of 22 MW (75 million Btu/hour).

The average number of industrial and commercial-institutional boilers for 1985 and 1986 estimated in each size range is shown in Table 3-1. Sales of both new industrial and commercial-institutional wood-fired small boilers are projected to remain at these average levels during the 5-year period from 1989 to 1993. Therefore, 50 (10 x 5 years) small commercial-institutional

boilers with a total heat input capacity of 860 MW (250 million Btu/hour) are projected for the 0.8 to 2.9 MW (3 to 10 million Btu/hour) size range; 25 (5 x 5 years) industrial and commercial-institutional boilers with a total heat input capacity of 1550 MW (450 million Btu/hour) are projected for the 10 to 30 million Btu/hour size range; 20 (4 x 5 years) industrial boilers with a total heat input capacity of 2690 MW (780 million Btu/hour) are projected for the 30 to 50 million Btu/hour size range; and 10 (2 x 5 years) industrial boilers with a total heat input capacity of 2590 MW (750 million Btu/hour) are projected for the 15 to 29 MW (50 to 100 million Btu/hour) size range.

4.0 NATIONAL IMPACTS

This section presents the results of the national impacts analysis of various regulatory alternatives limiting PM emissions from small wood-fired boilers. Because wood is the most commonly used nonfossil fuel among small boilers, it will be the only nonfossil fuel covered by standards developed for this source category. Hence, the national impact analysis is based on the impacts of regulatory alternatives for small wood-fired boilers. The projected population of 105 new wood-fired boilers, all operating at a 55 percent capacity factor, will be used to analyze each of the regulatory alternatives presented in Table 4-1.

4.1 ENVIRONMENTAL IMPACTS

The primary national environmental impact would be the reduction in PM emissions from new, modified, and reconstructed small wood-fired boilers resulting from the promulgation of NSPS. A range of PM emission reductions, reflecting the varying degree of stringency of the regulatory alternatives evaluated, is presented in Table 4-2.

Under the regulatory baseline, which is based on existing State and local regulations in the absence of an NSPS, total national PM emissions from small wood-fired boilers are estimated at 2,700 Mg/yr (2,970 tons/yr) for 1993. Regulatory Alternative Level I is an emission limit of 130 ng/J (0.30 lb/million Btu) based on the use of a double mechanical collection

TABLE 4-1. ALTERNATIVE PM CONTROL LEVELS FOR NONFOSSIL FUEL-FIRED BOILERS[4]

Alternative control level	Control technology basis	PM emission rate ng/J (lb/million Btu)	Cutoff MW (million Btu/hour)
Baseline	Single mechanical collector	a	
A	Double mechanical collector	130 (0.30)	8.7 (30)
B	Wet scrubber or electrostatic precipitator	40 (0.10)	8.7 (30)
C	Wet scrubber or electrostatic precipitator	40 (0.10)	2.9 (10)

[a]260 ng/J (0.60 lb/million Btu) for boilers larger than or equal to 8.7 MW (30 million Btu/hour) heat input; 190 ng/J (0.45 lb/million Btu) for boilers smaller than 8.7 MW (30 million Btu/hour) heat input.

TABLE 4-2. NATIONAL IMPACTS OF REGULATORY ALTERNATIVES FOR PM CONTROLS ON SMALL WOOD-FIRED BOILERS IN 1993

Regulatory alternative	Annual PM emissions Mg/yr	Annual PM emissions (tons/yr)	Total annualized costs[a,b] ($1,000/yr)	Annualized cost of control[c] ($1,000/yr)	Cost effectiveness: Average[d] $/Mg	Average[d] ($/ton)	Incremental[e] $/Mg	Incremental[e] ($/ton)	Solid waste production rate Mg/yr	Solid waste production rate (tons/yr)	Incremental solid waste production rate[f] Mg/yr	Incremental solid waste production rate[f] (tons/yr)
Baseline	2,700	(2,970)	103,750	-	-	-	-	-	36,600	(40,350)	-	-
Level I	1,650	(1,810)	105,140	1,390	1,383	(1,257)	1,383	(1,257)	37,600	(41,400)	1,000	(1,100)
Level II	1,020	(1,130)	109,900	6,150	3,671	(3,337)	7,103	(6,457)	38,300	(42,200)	1,700	(1,900)
Level III	680	(750)	113,150	9,400	4,653	(4,230)	9,423	(8,566)	38,600	(42,600)	2,000	(2,300)

[a]Based on model boilers with a capacity utilization factor of 0.55 and zero wood price.

[b]Includes the costs for boilers.

[c]Difference in the total annualized costs associated with the regulatory baseline and alternative control levels.

[d]Compared to Regulatory Baseline.

[e]Compared to a less stringent alternative.

[f]Solid waste production associated with PM control.

(DMC) and a size cutoff of 8.7 MW (30 million Btu/hour). Total national PM emissions in 1993 under this alternative are estimated at 1,650 Mg/yr (1,810 tons/yr), a 39 percent reduction from baseline PM emission levels. Regulatory Alternative Level II is an emission limit of 43 ng/J (0.10 lb/million Btu) based on the use of an electrostatic precipitator (ESP) and a size cutoff of 8.7 MW (30 million Btu/hour). Total national PM emissions in 1993 under this alternative are estimated at 1,020 Mg/yr (1,130 tons/yr), a 62 percent reduction from baseline PM emission levels. Regulatory Alternative Level III is an emission limit of 43 ng/J (0.10 lb/million Btu) based on the use of an ESP and a size cutoff of 2.9 MW (10 million Btu/hour). Total national PM emissions in 1993 under this alternative are estimated at 680 Mg/yr (750 tons/yr), a 75 percent decrease from baseline PM emission levels.

The control of PM emissions from small wood-fired boilers would increase the amount of solid waste produced as a by-product of pollution control. The amount of solid waste generated under the baseline by pollution control devices and small wood-fired boilers is 36,600 Mg/yr (40,350 tons/yr). The amount of solid waste generated under standards based on Regulatory Alternative Level I is estimated to be approximately 37,600 Mg/yr (41,400 tons/yr) in 1993. This amount represents a 3 percent increase over baseline rates. The amount of solid waste generated under Regulatory Alternative Level II is estimated to be approximately 38,300 Mg/yr (42,200 tons/yr) in 1993, which represents a 5 percent increase over baseline rates. The amount of solid waste generated under Regulatory Alternative Level III is estimated to be approximately 38,600 Mg/yr (42,600 tons/yr) in 1993, which represents a 6 percent increase over baseline rates. Such wastes are nonhazardous; environmentally acceptable methods for their disposal are readily available.

4.2 COST IMPACTS

As with national environmental impacts, projected national cost impacts vary according to the stringency of the various regulatory alternatives. The costs used in this analysis are based on information in Reference 5. Under the baseline, total national annualized PM control costs for small wood-fired

boilers and PM controls in 1993 are estimated to be $103,750,000. Under Regulatory Alternative Level I, total national annualized PM control costs are estimated to be $105,140,000/yr, which represents a 1 percent increase over baseline costs. Under Regulatory Alternative Level II, total national annualized PM control costs are estimated to be $109,900,000/yr, which represents a 6 percent increase over baseline costs. Under Regulatory Alternative Level III, total national annualized PM control costs are estimated to be $113,150,000/yr, which represents an 9 percent increase over baseline costs.

The projected national incremental cost effectiveness of the various regulatory alternatives varies as a function of cost and emission reductions. The estimated national incremental cost effectiveness of standards based on Regulatory Alternative Level I over the regulatory baseline is $1,383/Mg ($1,257/ton) of PM removed. The estimated national incremental cost effectiveness of standards based on Regulatory Alternative Level II over Regulatory Alternative Level I is $7,103/Mg ($6,457/ton) of PM removed. The estimated national incremental cost effectiveness of standards based on Regulatory Alternative III over Regulatory Alternative Level II is $9,423/Mg ($8,566/ton) of PM removed.

4.3 ENERGY IMPACTS

Energy consumed to operate the PM control equipment is estimated to increase only slightly under the various regulatory alternatives compared to the baseline.

5.0 REFERENCES

1. Memorandum from Aul, Jr., E. F., Radian Corporation, to Maxwell, W. H. EPA/ISB. September 22, 1987. Population Projection for Small Mixed Fuel-Fired Steam Generating Units.

2. Model Boiler Cost Analysis for Controlling Particulate Matter (PM) Emissions from Small Steam Generating Units. U.S. Environmental Protection Agency, Research Triangle Park, N.C. EPA Publication No. EPA-450/3-89-15. May 1989.

3. Reference 1.

4. Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission Standards for Small Steam Generating Units. U.S. Environmental Protection Agency, Research Triangle Park, N.C. EPA Publication No. EPA-450/3-89-11. May 1989.

5. Reference 2.

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16. ABSTRACT

This report presents projected national environmental, cost, and energy impacts of alternative particulate matter (PM) air emission standards for new small industrial-commercial-institutional steam generating units (small boilers) firing wood. The analysis examines projected impacts in the fifth year following proposal of the standards. The report was prepared during development of proposed new source performance standards (NSPS) for small boilers.

17. KEY WORDS AND DOCUMENT ANALYSIS

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