

Production and Distribution of SF₆ by End-Use Application

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Abstract

Sulfur hexafluoride (SF₆) is a long-lived, highly potent greenhouse gas that is included under the 1997 Kyoto Protocol, which *if ratified* would limit emissions of the major greenhouse gases. While SF₆ is not produced in large quantity, the production volume of this compound had not been quantified previously in a systematic manner. In 1996, the first-ever compilation of worldwide sales data was conducted by an independent contractor through a voluntary effort by the SF₆ producers. As a result of this global cooperative effort, sales and distribution data for SF₆ have now been compiled from the major manufacturers around the world for the period 1961-1999. The most recent update of the data survey was completed in October 2000. This report represents the most comprehensive summary of data available on SF₆ production and distribution by end use. The data are important for analyzing trends, sources, and applications of SF₆ as well as calculating emissions. A continued effort is underway to involve all SF₆ producers, including those in China and Russia and any other countries not currently part of the data report.

Introduction

Objectives

The primary purpose of the data collection exercise is to provide the scientific community with global data on use of sulfur hexafluoride (SF₆) since the beginning of reported production. The initial survey, conducted in 1996/97, compiled historical annual data on the use of SF₆ from 1961 through 1996. The data were reported by the major end-use application areas, which can then be correlated with atmospheric emissions. It is the aim of the current study to expand the coverage of the data survey to include all known SF₆ producers -- beyond the six companies who participated in the initial survey. The SF₆ data summary has been updated through 1999 with projections of SF₆ use through 2002, as envisioned by the chemical manufacturers. RAND served as an independent party to compile and report aggregated data on total sales of SF₆.

Significance

The SF₆ data collection effort provides valuable information for decision makers around the world as well as the broader scientific community. The results from the study are being used to analyze trends, sources, and applications as well as to calculate emissions and correlate production data with atmospheric measurements (Maiss and Brenninkmeijer, 1998, 2000; Olivier and Bakker, 2000). This update of the survey provides three more years of data, which can be applied to emissions estimates and correlated with atmospheric measurements. In the future, if additional producers participate, the expanded coverage will provide a more accurate account of the global production levels of SF₆.

Approach

The expanded SF₆ data collection exercise had two components: 1) investigating SF₆ producers worldwide, including enlisting the initial six companies and identifying other producers and seeking their commitment to participate in the survey; and 2) conducting the 1997-1999 survey update. The current study was concluded in October 2000. Seven companies from the United States, Europe, Japan, and South Africa participated in the data survey. Discussions with other producers in China and Russia are still underway in the hope that they will participate in future updates of the data survey.

The data survey was structured around the primary market sectors to provide information on emissions patterns. SF₆ is used in a variety of applications, including as an insulating material in electrical transmission and distribution equipment such as in gas-insulated substations, circuit breakers, and other switchgear. The magnesium industry uses SF₆ to prevent the rapid oxidation and burning that occurs when the molten metal directly contacts air. In addition, SF₆ is used for plasma etching in semiconductor manufacturing, as a reactive gas in aluminum recycling to reduce porosity, as thermal and sound insulation, and in atmospheric tracer studies and medical applications (U.S. EPA, 2000).

Summary of Results

Data on total annual sales have been provided by the reporting companies for the period 1961 - 1999, along with projections for the years 2000-2002. The aggregated data are summarized in Table 1; all data are reported in metric tons. The sales data are organized according to the primary end-use markets. Cumulative data for the period 1961-1999 show the following overall distribution of sales by market sector:

50%	Original Equipment Manufacturers
31%	Electric Utilities
6%	Magnesium Industry
3%	Usage for Adiabatic/Shock-Absorbing Properties (e.g., tires)
3%	Electronics Industry
7%	All Other Uses (accelerators, optical fiber production, glazing, biotechnology, lighting, medical, refining, pharmaceutical, laboratory/university research, soundproof windows)

Table 2 provides a summary of the annual change in sales by end-use application since the previous survey (1996-1999), as well as cumulative totals for 1996 and 1999 for comparison. The results show an overall decrease in total sales of about 2,500 metric tons since the last report was compiled.

Table 1. Total Annual Sales of SF₆ (1961-1999)

SF ₆ Sales by End-Use Applications							
YEAR	Utilities	Original Equip. Manufacturers	Magnesium Industry	Electronics Industry	Adiabatic Properties Usage	All Other Uses (listed below)	TOTAL
<i>(units in metric tons)</i>							
1961	0	91	0	0	0	0	91
1962	14	145	0	0	0	0	159
1963	14	181	0	0	0	9	204
1964	18	204	14	0	0	14	250
1965	32	231	23	0	0	18	304
1966**	61	233	27	2	5	23	374
1967**	63	239	32	5	9	27	392
1968**	63	256	36	5	14	32	428
1969**	84	269	41	7	14	36	496
1970**	140	277	44	9	14	44	606

YEAR	Utilities	Original Equip. Manufacturers	Magnesium Industry	Electronics Industry	Adiabatic Properties Usage	All Other Uses (listed below)	TOTAL
1971**	468	289	71	10	14	72	1,018
1972**	465	313	63	11	14	64	1,017
1973**	600	455	83	11	14	84	1,385
1974**	582	484	46	12	14	72	1,378
1975	737	759	120	13	14	111	1,754
1976	986	1,010	195	13	14	126	2,344
1977	999	1,224	214	13	14	151	2,615
1978	1,022	1,470	256	13	20	134	2,915
1979	1,272	1,957	312	15	32	188	3,776
1980	1,262	2,141	321	16	35	216	3,991
1981	1,465	1,987	320	17	54	210	4,053
1982	1,459	2,187	360	18	59	246	4,329
1983	1,392	1,995	374	17	80	233	4,091
1984	1,655	2,552	397	16	108	232	4,960
1985	1,730	2,444	437	20	111	254	4,996
1986	1,960	2,423	431	38	110	300	5,262
1987	1,855	2,570	415	73	146	265	5,324
1988	1,863	2,440	398	100	162	307	5,270
1989	1,978	2,607	363	117	270	323	5,658
1990	2,094	2,951	385	140	220	435	6,225
1991	2,178	3,258	357	151	260	682	6,886
1992	2,022	3,463	266	201	290	645	6,887
1993	2,286	3,084	274	229	290	658	6,821
1994	2,107	3,590	354	262	325	587	7,225
1995	1,776	4,009	399	300	356	617	7,457
1996	1,795	4,139	544	307	344	442	7,571
1997	1,642	3,726	178	361	393	366	6,665
1998	1,351	3,530	148	373	175	351	5,929
1999	1,040	2,837	165	474	134	417	5,067
Subtotal	42,530 (31%)	68,020 (50%)	8,463 (6%)	3,369 (3%)	4,128 (3%)	8,991 (7%)	136,172
Company Estimates							
2000 (E)	991	2,957	151	517	117	470	5,203
2001 (E)	924	2,984	122	574	105	682	5,392
2002 (E)	898	3,024	71	595	15	491	5,096

NOTES:

1. "All Other Uses" includes accelerators, optical fiber production, glazing, biotechnology, lighting, medical, refining, pharmaceutical, laboratory/university research, and soundproof windows.
2. For the years 1966-1974 (**), some companies could not provide a breakdown by end use. TOTAL SALES includes an additional 672 metric tons sold in these years not accounted for in the end-use breakdown. The sum of sales by end use does not equal total sales.
3. Manufacturers provided projections for sales in 2000-2002. These estimates are marked with (E).
4. For the years 1961-1996, utilities and accelerators were reported together in the same category. Beginning with 1997, accelerators were included in the category of "All Other Uses" and "Utilities" became a stand-alone category. No adjustments were made to prior data.
5. In the 2000 report, one company made a correction to the category distribution of their previously reported data. Sales shown previously as "Utilities" were moved to "Original Equipment Manufacturers."
6. Data from Nuclear Energy Corp. of South Africa are included in the report beginning in 1997.

Reporting Companies

1. Air Products and Chemicals, Inc. (USA)
 - Air Products Canada Ltd. (Canada)
 - Air Products PLC (U.K.)
2. Asahi Glass Chemicals, Ltd. (Japan)
 - AGA Chemicals, Inc. (USA)
3. Ausimont S.p.A. (Italy)
4. Honeywell International, Inc. (formerly AlliedSignal) (USA)
 - Honeywell Canada, Inc. (Canada)
5. Kanto Denka Kogyo Co., Ltd. (Japan)
6. Nuclear Energy Corporation of South Africa (formerly Atomic Energy Corp.) (South Africa)
7. Solvay Fluor und Derivate GmbH (Germany)

Table 2. Annual Change by Category for 1996-1999

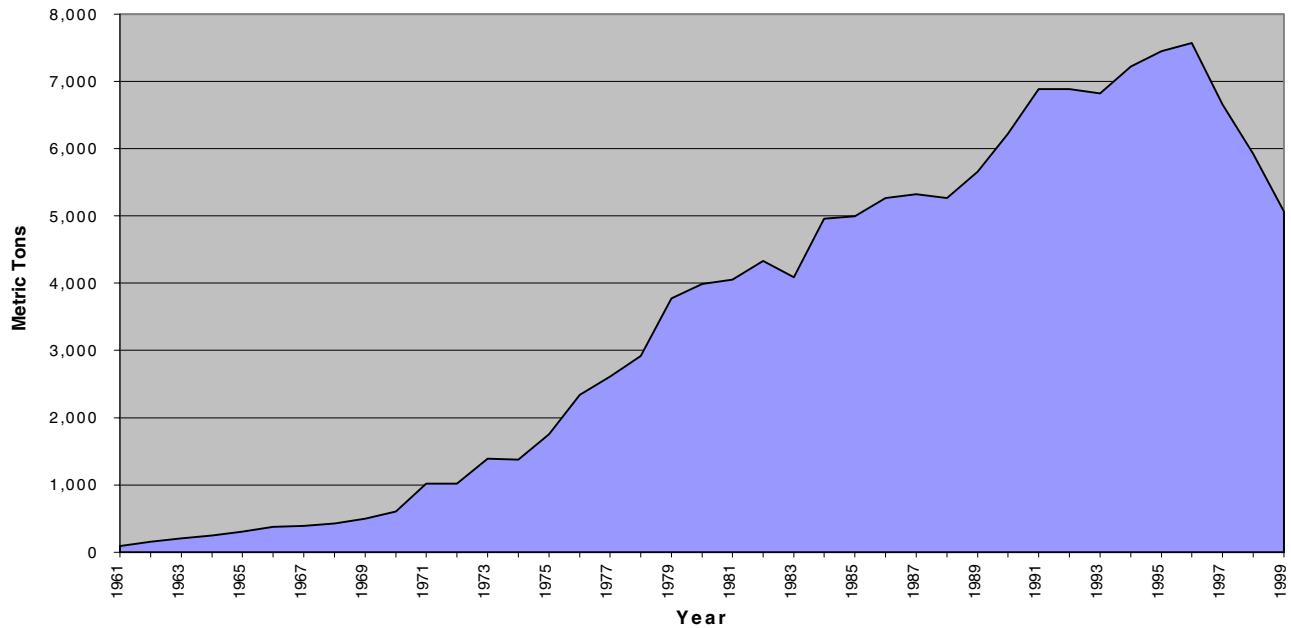
Annual Change	Utilities	Original Equip. Manufacturers	Magnesium Industry	Electronics Industry	For Adiabatic Properties	All Other Uses (listed above)	TOTAL SALES
1996-1997	(153) -9%	(414) -10%	(366) -67%	54 18%	49 14%	(76) -17%	(906) -12%
1997-1998	(290) -18%	(195) -5%	(30) -17%	12 3%	(218) -55%	(15) -4%	(736) -11%
1998-1999	(312) -23%	(693) -20%	17 12%	101 27%	(41) -23%	67 19%	(862) -15%
Overall Difference: 1996-1999 (Total annual sales)							(2,504) -33%

Cumulative Totals (metric tons)

1996	38,497	57,927	7,972	2,161	3,426	7,857	118,512
Total							
1999	42,530	68,020	8,463	3,369	4,128	8,991	136,172
Total							
Difference (1996-99)	4,033 10%	10,093 17%	491 6%	1,208 56%	702 20%	1,134 14%	17,660 15%

As illustrated in Figure 1, total sales of SF₆ peaked at 7,571 metric tons in 1996, which was the last year of the previous survey. Some experts speculated that production of SF₆ would continue to increase. However, total sales have been in decline since 1996 -- by 12% in 1997, 11% in 1998 and 15% in 1999. Annual sales in 1999 totaled 5,067 metric tons, which is about the same level of sales as reported in 1985 -- almost 15 years ago.

**Figure 1. Total Annual Sales of SF₆
(1961-1999)**



Focusing on just the past 20 years, there has been mixed growth in the various market sectors, although original equipment manufacturers remains the largest market application (Figures 2 and 3). The electronics sector has increased steadily but represents a very small portion of the overall market. Most other sectors have declined in recent years.

Figure 2. Sales of SF₆ by End-Use Category (1980-1999)

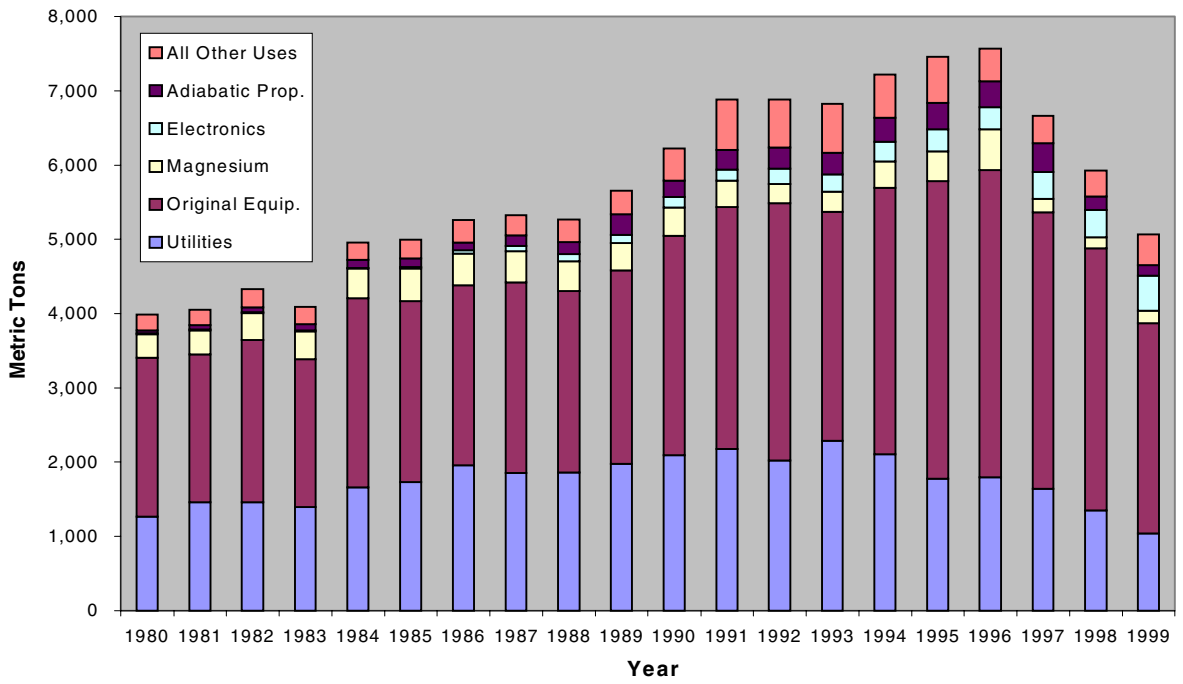
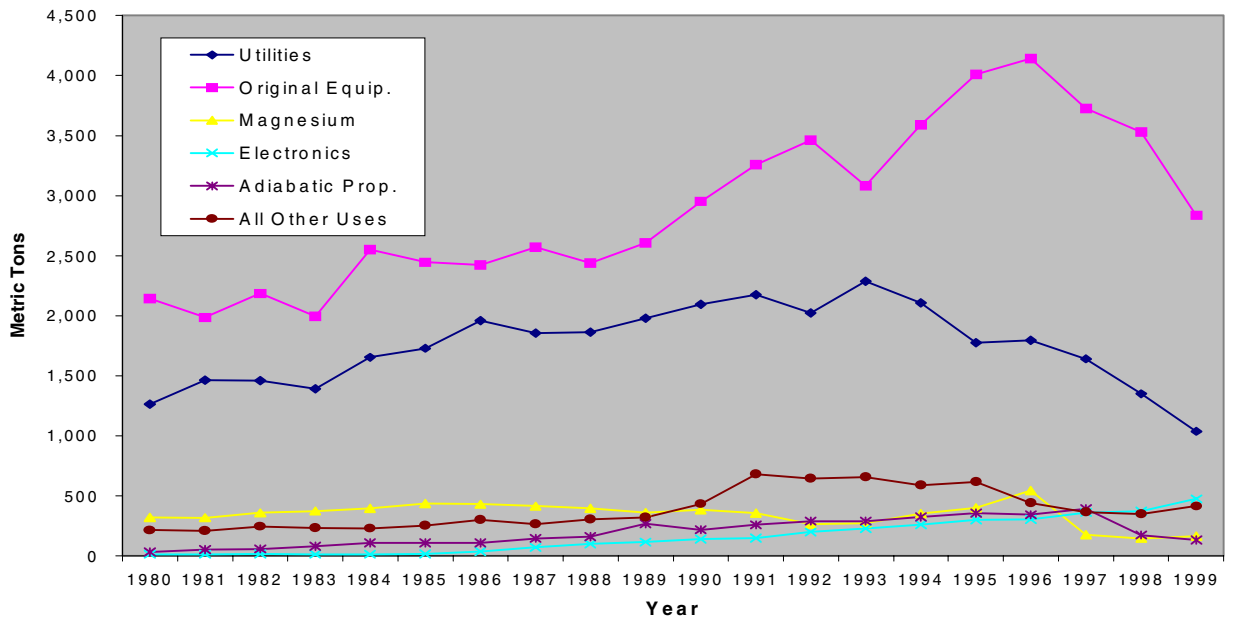


Figure 3. Annual Sales of SF₆ by End-Use Application (1980-1999)



This study did not investigate the possible reasons for the observed trends. Other experts need to examine market factors and use patterns in the individual sectors. Some possibilities suggested for the recent decline in total sales include:

- Price increase in SF₆
- Emissions reduction efforts
- Better handling practices and procedures
- Leakage reduction in equipment and/or improved equipment design
- Increased recycling/reuse of SF₆

Since the initiation of the most recent SF₆ data survey update, several voluntary programs have been established to encourage emission reduction activities, such as the U.S. Environmental Protection Agency's partnerships with the electric utility industry and the magnesium industry. The results of such programs are beginning to emerge. The next update of the SF₆ data survey should reflect the preliminary efforts by various countries on improved handling and use of SF₆.

Conclusions

This historical compilation of annual SF₆ sales represents nearly 40 years of data and includes a distribution of sales by the major end-use applications. Such information allows correlations to be established between production, emissions and atmospheric measurements, which is an important effort of the research community. These data can also assist countries with estimating national emissions of SF₆ as required under the United Nations Framework Convention on Climate Change.

Several issues remain. The percentage of world production that is represented by this data report is not known. While there are other producers not currently included in the study, we speculate that this report represents a significant portion of worldwide capacity. So, how much of the decline in sales is due to a decreasing market size or because other production is not included in the survey results -- or a combination of both?

A continued effort is underway to expand participation to include all SF₆ producers. In addition, discussions are ongoing about the frequency of the reporting cycle. Many users of SF₆ have expressed concern about the 3-year time duration since the previous data report. The reporting cycle is likely to become either annual or biennial, assuming the sponsors are willing to support such an effort. In the future, there will also be additional collaboration with other data collection and emissions estimating programs.

Acknowledgments

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Note: RAND is a nonprofit institution that helps improve policy and decision making through research and analysis. This paper represents the views of the author. It does not necessarily reflect the opinions or policies of RAND or the project sponsors. The initial survey of SF₆ sales and distribution was conducted by Science & Policy Services, Inc. (Washington, DC); SPS was acquired by RAND in 1998. The subsequent SF₆ survey was conducted by the same investigator as for the first study to ensure continuity. Some publications have referenced the 1997 study by SPS.

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