

# GAS SENSORS AND GAS METERING: APPLICATIONS AND MARKETS



IAS012C  
August 2014

Andrew McWilliams  
*Project Analyst*

ISBN: 1-56965-909-5



**BCC Research**  
49 Walnut Park, Building 2  
Wellesley, MA 02481 USA  
866-285-7215 (toll-free within the USA),  
or (+1) 781-489-7301  
[www.bccresearch.com](http://www.bccresearch.com)  
[information@bccresearch.com](mailto:information@bccresearch.com)

**TABLE OF CONTENTS**

<b>TOPIC</b>	<b>PAGE NO.</b>
CHAPTER 1 INTRODUCTION	2
STUDY GOALS AND OBJECTIVES	2
REASONS FOR DOING THE STUDY AND INTENDED AUDIENCE	2
SCOPE OF REPORT	3
METHODOLOGY	3
INFORMATION SOURCES	4
ANALYSTS' CREDENTIALS	4
RELATED BCC RESEARCH REPORTS	4
BCC RESEARCH WEBSITE	5
DISCLAIMER	5
CHAPTER 2 SUMMARY	7
<i>SUMMARY TABLE GLOBAL MARKET FOR GAS FLOW METERS, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY PRODUCT TYPE, THROUGH 2019 (\$ MILLIONS)</i>	7
<i>SUMMARY FIGURE TRENDS IN GLOBAL MARKET FOR GAS FLOW METERS, SENSORS/MONITORS, AND SECONDARY FLOW, 2013-2019 (\$ MILLIONS)</i>	7
CHAPTER 3 OVERVIEW	10
HISTORY OF GAS FLOW METERING AND GAS SENSING/MONITORING	10
GAS FLOW METERS	10
GAS ANALYZERS	12
SECONDARY INSTRUMENTATION	12
TECHNOLOGIES	12
APPLICATIONS	13
<i>TABLE 1 OVERVIEW OF MAJOR APPLICATIONS FOR GAS FLOW METERING, GAS SENSORS/MONITORS, AND SECONDARY GAS FLOW INSTRUMENTATION BY MARKET SEGMENT</i>	13
MARKET SUMMARY	17
PRODUCT CATEGORY	17
<i>TABLE 2 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY PRODUCT CATEGORY, THROUGH 2019 (%)</i>	17
<i>FIGURE 1 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET PRODUCT SEGMENTS, 2013-2019 (%)</i>	17
APPLICATION SEGMENTS	18
<i>TABLE 3 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY TYPE OF APPLICATION, THROUGH 2019 (\$ MILLIONS)</i>	18
<i>FIGURE 2 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET APPLICATION SEGMENTS, 2013-2019 (%)</i>	18
GEOGRAPHICAL SEGMENTS	19
<i>TABLE 4 MARKET FOR GAS FLOW METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY REGION, THROUGH 2019 (\$ MILLIONS)</i>	19
<i>FIGURE 3 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET GEOGRAPHICAL SEGMENTS, 2013-2019 (%)</i>	19
CHAPTER 4 GAS SENSING AND MONITORING TECHNOLOGIES	22
DETECTION AND MEASUREMENT TECHNOLOGIES	22
EXTRACTIVE MANUAL TECHNIQUES	22

<b>TOPIC</b>	<b>PAGE NO.</b>
Nitrogen Oxides	22
CO	23
Oxygen	23
Sulfur Dioxide	23
VOCs	23
INSTRUMENTED TECHNIQUES	23
CEMS	24
<i>FIGURE 4 TYPICAL SAMPLING SYSTEMS FOR AN ONSTREAM ANALYZER</i>	24
Sample Transport and Conditioning	25
Sample Gas Analysis	26
Wet-Basis Gas Analysis	26
Dry-Basis Gas Analysis	26
Data Acquisition System	26
Cross-Duct (or Cross-Stack) Monitoring Technology	27
System Integration	27
CEMS Applications	28
<i>TABLE 5 CEMENT INDUSTRY APPLICATIONS OF CEMS</i>	28
<i>TABLE 6 COAL FIRED POWER PLANT APPLICATIONS OF CEMS</i>	28
<i>TABLE 7 IRON AND STEEL INDUSTRY APPLICATIONS OF CEMS</i>	29
STACK GAS/SOURCE SAMPLING	29
Stack/Source Sampling Procedure	29
Selection of Sampling Position in the Stack/Source	30
<i>TABLE 8 MINIMUM NUMBER OF TRAVERSE POINTS ACROSS THE STACK</i>	30
Measurement of Gas Flow Rate (Pollutant Emission Rate)	30
Measurement of Stack Gas Velocity	30
Determination of Temperature of Gas	31
<i>TABLE 9 PROBES USED FOR DIFFERENT TEMPERATURE RANGES</i>	31
Determination of Pressure	31
Bourdon	31
Bellows	31
Diaphragm	32
Capacitive or Inductance	32
Resistive, Strain Gauge	32
Piezoelectric	32
Types of Temperature Transmitters	32
<i>FIXED VS. PORTABLE GAS SENSORS AND MONITORS</i>	33
The Basic Fixed System	33
Key Considerations	33
Intrinsically Safe	34
Explosion Proof	34
Fixed Systems Best Practice	34
Basic Portable Gas Detectors	34
Key Considerations	35
Portables Best Practice	36
Advanced Sensors for Multi-Sensor Instruments	36
Other Types of Direct Reading Sensors	36
MICRO- AND NANOSENSORS	37

<b>TOPIC</b>	<b>PAGE NO.</b>
MICROELECTROMECHANICAL SENSORS	37
MEMS Gas Sensing Technologies	37
Electrochemical Sensors	37
Mass Sensors	37
Applications	38
<i>TABLE 10 POTENTIAL APPLICATIONS OF MEMS CHEMICAL AND GAS SENSORS</i>	38
Automotive	38
Life Sciences	39
Environmental Protection	39
Military/Public Safety	39
Industrial Leak Detection and Process Control	39
NANOSENSORS	39
Nano-Gas Sensing Technologies	39
Nanotubes	40
Carbon Nanotubes	40
Other Types of Nanotubes	40
Nanoribbons	41
Nanowires	41
Nano-Cantilevers	42
Nanoparticles	43
Nanoceramics	43
Graphene	44
CHAPTER 5 GAS FLOW METERING: TECHNOLOGIES AND MARKETS	47
TECHNOLOGIES	47
<i>TABLE 11 FLOW METER TECHNOLOGIES</i>	47
DP FLOW METERS	47
Orifice Plate	47
Flow Nozzles	48
Venturi Tube	48
<i>FIGURE 5 VENTURI FLOW METER</i>	48
Elbow Meter	49
<i>FIGURE 6 ELBOW FLOW METER</i>	49
PD FLOW METERS	49
Diaphragm Meters	49
Rotary Meters	50
TURBINE FLOW METERS	50
THERMAL MASS FLOW METERS	51
Direct-Heat Flow Meters	52
Externally Heated Flow Meters	52
Heated-Tube Design	52
Bypass-Type Design	53
Air Velocity Probes	53
VARIABLE AREA FLOW METERS	54
Slotted Tube Flow Meters	55
Vane and Piston Flow Meters	55
MFC	55

<b>TOPIC</b>	<b>PAGE NO.</b>
ANNUBAR	56
CORIOLIS FLOW METERS	57
Tube Designs	57
ULTRASONIC FLOW METERS	58
VORTEX FLOW METER	59
OTHER TECHNOLOGIES	60
Optical Flow Meters	60
Sonar-Based Flow Meters	60
SELECTING A FLOW METER	61
Performance Comparisons	61
<i>TABLE 12 COMPARISON OF SELECTED GAS FLOW METER OPTIONS AND COSTS</i>	61
Flow Meter Advantages and Disadvantages	62
<i>TABLE 13 FLOW METER ADVANTAGES AND DISADVANTAGES</i>	62
The Importance of Accuracy	63
<i>TABLE 14 IMPORTANCE OF DEGREE OF ACCURACY IN GAS FLOW METERING (%)</i>	63
What is Reliability?	64
<i>TABLE 15 IMPORTANCE OF RELIABILITY IN SPECIFYING/PURCHASING GAS FLOW METERS (%)</i>	64
Other Gas Flow Meter Selection Criteria	64
Installed Base	65
SUPPLIERS	65
<i>TABLE 16 GAS FLOW METER VENDOR LEADERS AND PRODUCTS OFFERING</i>	66
MARKETS	66
APPLICATION SEGMENTS	66
<i>TABLE 17 GLOBAL MARKET FOR GAS FLOW METERS BY APPLICATION, THROUGH 2019 (\$ MILLIONS)</i>	67
<i>FIGURE 7 GLOBAL DEMAND FOR GAS FLOW METERING BY MARKET SECTOR APPLICATION, 2013-2019 (%)</i>	67
<i>TABLE 18 GAS FLOW METERING BY METER TYPE/APPLICATION CHART</i>	68
Custody (Ownership) Transfer	68
<i>TABLE 19 GLOBAL DEMAND FOR CUSTODY TRANSFER GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	69
Stack Gas Monitoring	69
<i>TABLE 20 GLOBAL DEMAND FOR STACK GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	70
Flare Gas Flow Metering and Monitoring	70
<i>TABLE 21 GLOBAL DEMAND FOR FLARE GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	71
Utility Applications	71
<i>TABLE 22 GLOBAL DEMAND FOR UTILITY GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	71
CNG	72
<i>TABLE 23 GLOBAL DEMAND FOR CNG FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	72
Low Flow Gas Flow metering	73
<i>TABLE 24 GLOBAL DEMAND FOR LOW GAS FLOW RATE METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)</i>	73
TECHNOLOGY SEGMENTS	74

<b>TOPIC</b>	<b>PAGE NO.</b>
<i>TABLE 25 GLOBAL DEMAND FOR GAS FLOW METERS BY TYPE OF TECHNOLOGY, THROUGH 2019 (\$ MILLIONS)</i>	74
<i>FIGURE 8 GLOBAL DEMAND FOR GAS FLOW METERING BY TECHNOLOGY SEGMENT, 2013-2019 (%)</i>	74
DP	75
<i>TABLE 26 GLOBAL DEMAND FOR DP GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	75
PD	75
<i>TABLE 27 GLOBAL DEMAND FOR PD GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	76
Turbine	76
<i>TABLE 28 GLOBAL DEMAND FOR TURBINE GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	77
Thermal Mass	77
<i>TABLE 29 GLOBAL DEMAND FOR THERMAL MASS GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	77
MFCs	78
<i>TABLE 30 GLOBAL DEMAND FOR MFCs GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	78
Annubar	78
<i>TABLE 31 GLOBAL DEMAND FOR ANNUBAR GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	78
Ultrasonic	79
<i>TABLE 32 GLOBAL DEMAND FOR ULTRASONIC GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	79
Coriolis	79
<i>TABLE 33 GLOBAL DEMAND FOR CORIOLIS GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	80
Doppler Vortex	80
<i>TABLE 34 GLOBAL DEMAND FOR DOPPLER VORTEX GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	80
CHAPTER 6 GAS SENSOR/MONITORING TECHNOLOGIES	82
TECHNOLOGIES	82
IR SENSING/MONITORING TECHNOLOGY	82
FTIR	82
NDIR Technology	83
SOLID-STATE SENSING/MONITORING TECHNOLOGY	83
CATALYTIC BEAD SENSING/MONITORING TECHNOLOGY	84
GAS CHROMATOGRAPHY	84
Flame Ionization Detection Technology	84
TC Analyzers	85
Electron Capture Detector	85
PIDs	86
Flame Photometric Detector	86
UV Sensing/Monitoring Technology	87
Chemiluminescent Analyzers	87
ELECTROCHEMICAL SENSING/MONITORING TECHNOLOGY	87
PARAMAGNETIC ANALYZERS	87
OTHER TECHNOLOGIES	88

<b>TOPIC</b>	<b>PAGE NO.</b>
Mass Spectrometry	88
Hot-Wire Anemometers	89
Air Duct Traversing	89
MEMS Sensors	90
Nano-Gas Sensors	90
<i>TABLE 35 NANO-GAS SENSOR TECHNOLOGIES</i>	91
Nanotubes	91
Nanoribbons	91
Nanowires	92
Nano-Cantilevers	92
Nanoceramics	93
Graphene Sensors	93
SUPPLIERS	93
<i>TABLE 36 GAS FLOW SENSORS/MONITORS SUPPLIER LEADERS AND PRODUCTS OFFERING</i>	94
MARKETS	94
APPLICATION SEGMENTS	95
<i>TABLE 37 GLOBAL DEMAND FOR GAS SENSING/MONITORING BY APPLICATION, THROUGH 2019 (\$ MILLIONS)</i>	95
<i>FIGURE 9 GLOBAL DEMAND FOR GAS SENSING/MONITORING BY MARKET SECTOR APPLICATION, 2013-2019 (%)</i>	95
Custody Transfer	96
<i>TABLE 38 GLOBAL DEMAND FOR CUSTODY TRANSFER SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	96
Stack Gas Monitoring	97
<i>TABLE 39 GLOBAL DEMAND FOR STACK GAS SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	97
Flare Gas Monitoring	98
<i>TABLE 40 GLOBAL DEMAND FOR FLARE GAS SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	98
Utility Applications	98
<i>TABLE 41 GLOBAL DEMAND FOR UTILITY SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	99
CNG	99
<i>TABLE 42 GLOBAL DEMAND FOR CNG SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	100
Low Flow Rate Gas	100
<i>TABLE 43 GLOBAL DEMAND FOR LOW GAS FLOW RATE SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	100
TECHNOLOGY SEGMENTS	101
<i>TABLE 44 GLOBAL DEMAND FOR GAS SENSOR/MONITORING BY TYPE OF PF TECHNOLOGY, THROUGH 2019 (\$ MILLIONS)</i>	101
<i>FIGURE 10 GLOBAL DEMAND FOR GAS SENSOR/MONITORING BY TECHNOLOGY SEGMENT, 2013-2019 (%)</i>	101
IR Gas Sensors/Monitors	102
<i>TABLE 45 GLOBAL DEMAND FOR IR SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	103
Solid-State Gas Sensors	103
<i>TABLE 46 GLOBAL DEMAND FOR SOLID-STATE SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	103

TOPIC	PAGE NO.
Catalytic Gas Sensors	104
<i>TABLE 47 GLOBAL DEMAND FOR CATALYTIC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	104
Gas Chromatography Sensors	104
<i>TABLE 48 GLOBAL DEMAND FOR GC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	104
Electrochemical Gas Sensors	105
<i>TABLE 49 GLOBAL DEMAND FOR ELECTROCHEMICAL SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	105
Paramagnetic Gas Sensors	105
<i>TABLE 50 GLOBAL DEMAND FOR PARAMAGNETIC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	106
Chemiluminescence Gas Sensors	106
<i>TABLE 51 GLOBAL DEMAND FOR CHEMILUMINESCENCE SENSORS/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	106
UV Gas Sensors	107
<i>TABLE 52 GLOBAL DEMAND FOR ULTRA-VIOLET SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	107
CHAPTER 7 SECONDARY GAS FLOW METERING TECHNOLOGIES	109
TECHNOLOGIES	109
TEMPERATURE MEASUREMENT	109
<i>TABLE 53 OVERVIEW OF TEMPERATURE SENSORS</i>	109
DENSITY MEASUREMENT	110
PRESSURE MEASUREMENT	111
<i>TABLE 54 OVERVIEW OF PRESSURE SENSORS</i>	111
SUPPLIERS	112
<i>TABLE 55 SECONDARY GAS FLOW INSTRUMENTATION SUPPLIER/VENDOR MARKETS</i>	112
APPLICATION SEGMENTS	113
<i>TABLE 56 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY APPLICATION, THROUGH 2019 (\$ MILLIONS)</i>	113
<i>FIGURE 11 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY MARKET SECTOR APPLICATION, 2013-2019 (%)</i>	113
Custody (Ownership) Transfer of Natural Gas	114
<i>TABLE 57 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN CUSTODY TRANSFER OF NATURAL GAS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	115
Stack Gas Monitoring	115
<i>TABLE 58 GLOBAL DEMAND FOR SECONDARY AS FLOW INSTRUMENTATION FOR STACK GAS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	115
Flare Gas Monitoring	115
<i>TABLE 59 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN FLARE METERING BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	116
Utility Applications	116
<i>TABLE 60 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN UTILITY APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	117
CNG	117
<i>TABLE 61 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN CNG APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	118



<b>TOPIC</b>	<b>PAGE NO.</b>
Low Gas Flow Rate Applications	118
<i>TABLE 62 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN LOW GAS FLOW RATE APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	118
TECHNOLOGY SEGMENTS	118
<i>TABLE 63 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)</i>	119
<i>FIGURE 12 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY TECHNOLOGY SEGMENT, 2013-2019 (%)</i>	119
Temperature Sensors	120
<i>TABLE 64 GLOBAL DEMAND FOR TEMPERATURE SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	120
Pressure Sensors	120
<i>TABLE 65 GLOBAL DEMAND FOR PRESSURE SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	120
Density Measurement	121
<i>TABLE 66 GLOBAL DEMAND FOR DENSITY SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)</i>	121
CHAPTER 8 MAJOR GEOGRAPHICAL MARKETS	123
<i>TABLE 67 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY REGION, THROUGH 2019 (\$ MILLIONS)</i>	123
CHAPTER 9 APPENDIX A: PURCHASING CRITERIA	125
FLOW METERS	125
<i>TABLE 68 IMPORTANT FACTORS IN SPECIFICATION/PURCHASING OF FLOW METERS (SCALE IS 1 TO 5)</i>	125
GAS SENSORS/MONITORS	126
<i>TABLE 69 IMPORTANT FACTORS IN SPECIFICATION/PURCHASING OF GAS SENSORS/MONITORS (SCALE IS 1 TO 5)</i>	126
CHAPTER 10 APPENDIX B: COMPANY PROFILES	128
THE ABB GROUP (ABB ANALYTICAL)	128
ACCULEX	128
ALICAT SCIENTIFIC INC.	128
ALTECH ENVIRONMENT USA	129
AMALGAMATED INSTRUMENTS CO. PTY, LTD.	129
AMETEK INC.	129
ASIA PACIFIC MICROSYSTEMS INC. (APM)	130
AUTOMATIC FLARE SYSTEMS, LTD.	131
BACHARACH INC.	131
BASELINE-MOCON INC. (BASELINE)	131
BROOKS INSTRUMENT	132
CASELLA USA	132
CIDRA	132
CIMTECHNIQUES INC.	133
CITY TECHNOLOGY, LTD.	133
COUNTRONICS	134
DAVIDSON INSTRUMENTS	134

<b>TOPIC</b>	<b>PAGE NO.</b>
DRAGER SAFETY AG	135
DRSCADA AUTOMATION	135
ELSTER-INSTROMET N.V.	135
EMERSON PROCESS MANAGEMENT	135
ENDRESS+HAUSER INC.	136
FIGARO ENGINEERING INC.	136
FLORITE INTERNATIONAL INC.	137
FREHNIG INSTRUMENTS & CONTROLS	137
GAS TECHNOLOGY INSTITUTE (GTI)	137
GE SENSING	137
GENERAL MONITORS	138
HEDLAND IN-LINE FLOWMETERS	138
HONEYWELL INC.	138
HORIBA, LTD.	139
IFM EFECTOR INC.	140
IMPCO TECHNOLOGIES INC.	140
INNOVA AIRTECH INSTRUMENTS A/S	141
INSTRUMART	141
INTERNATIONAL SENSOR TECHNOLOGY	141
INVENSYS	142
J-TEC ASSOCIATES INC.	142
KEP-KESSLER-ELLIS PRODUCTS	142
LAND INSTRUMENTS INTERNATIONAL	143
MCCROMETER INC.	143
MICRO SYSTEMS & CONTROLS	143
MSA INSTRUMENTS DIVISION	143
QUEST TECHNOLOGIES	144
R2 CONTROLS INC.	144
SAGE METERING INC.	144
SERVOMEX CO. INC.	144
SIEMENS ENERGY & AUTOMATION INC.	145
SITRON USA INC.	145
SOUTH WEST RESEARCH INSTITUTE (SWRI)	145
SPINK CONTROLS	146
SYNECTIC DESIGN, LTD.	146
TELEDYNE ANALYTICAL INSTRUMENTS	146
TOKY ELECTRICAL CO., LTD.	147
VARIAN INC.	147
YOKOGAWA CORP. OF AMERICA	148
CHAPTER 11 APPENDIX C PATENT ANALYSIS	150
<i>FIGURE 13 U.S. GAS SENSOR/MONITOR PATENTS ISSUED SINCE 1975, BY PRODUCT TYPE (% OF PATENTS IDENTIFIED)</i>	150
GAS FLOW METER PATENTS	150
<i>FIGURE 14 U.S. GAS SENSOR FLOW METER PATENTS ISSUED SINCE 1975 BY TECHNOLOGY TYPE (% OF PATENTS IDENTIFIED)</i>	151
GAS SENSOR AND MONITOR PATENTS	151

<b>TOPIC</b>	<b>PAGE NO.</b>
<i>FIGURE 15 U.S. GAS SENSOR AND MONITOR PATENTS ISSUED SINCE 1975 BY TECHNOLOGY TYPE (% OF PATENTS IDENTIFIED)</i>	151
SECONDARY INSTRUMENTATION PATENTS	152
<i>FIGURE 16 U.S. SECONDARY GAS INSTRUMENTATION PATENTS ISSUED SINCE 1975, BY PARAMETER MEASURED (% OF PATENTS IDENTIFIED)</i>	152

**LIST OF TABLES**

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
SUMMARY TABLE GLOBAL MARKET FOR GAS FLOW METERS, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY PRODUCT TYPE, THROUGH 2019 (\$ MILLIONS)	7
TABLE 1 OVERVIEW OF MAJOR APPLICATIONS FOR GAS FLOW METERING, GAS SENSORS/MONITORS, AND SECONDARY GAS FLOW INSTRUMENTATION BY MARKET SEGMENT	13
TABLE 2 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY PRODUCT CATEGORY, THROUGH 2019 (%)	17
TABLE 3 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY TYPE OF APPLICATION, THROUGH 2019 (\$ MILLIONS)	18
TABLE 4 MARKET FOR GAS FLOW METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY REGION, THROUGH 2019 (\$ MILLIONS)	19
TABLE 5 CEMENT INDUSTRY APPLICATIONS OF CEMS	28
TABLE 6 COAL FIRED POWER PLANT APPLICATIONS OF CEMS	28
TABLE 7 IRON AND STEEL INDUSTRY APPLICATIONS OF CEMS	29
TABLE 8 MINIMUM NUMBER OF TRAVERSE POINTS ACROSS THE STACK	30
TABLE 9 PROBES USED FOR DIFFERENT TEMPERATURE RANGES	31
TABLE 10 POTENTIAL APPLICATIONS OF MEMS CHEMICAL AND GAS SENSORS	38
TABLE 11 FLOW METER TECHNOLOGIES	47
TABLE 12 COMPARISON OF SELECTED GAS FLOW METER OPTIONS AND COSTS	61
TABLE 13 FLOW METER ADVANTAGES AND DISADVANTAGES	62
TABLE 14 IMPORTANCE OF DEGREE OF ACCURACY IN GAS FLOW METERING (%)	63
TABLE 15 IMPORTANCE OF RELIABILITY IN SPECIFYING/PURCHASING GAS FLOW METERS (%)	64
TABLE 16 GAS FLOW METER VENDOR LEADERS AND PRODUCTS OFFERING	66
TABLE 17 GLOBAL MARKET FOR GAS FLOW METERS BY APPLICATION, THROUGH 2019 (\$ MILLIONS)	67
TABLE 18 GAS FLOW METERING BY METER TYPE/APPLICATION CHART	68
TABLE 19 GLOBAL DEMAND FOR CUSTODY TRANSFER GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	69
TABLE 20 GLOBAL DEMAND FOR STACK GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	70
TABLE 21 GLOBAL DEMAND FOR FLARE GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	71
TABLE 22 GLOBAL DEMAND FOR UTILITY GAS FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	71
TABLE 23 GLOBAL DEMAND FOR CNG FLOW METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	72
TABLE 24 GLOBAL DEMAND FOR LOW GAS FLOW RATE METERING BY METER TYPE, THROUGH 2019 (\$ MILLIONS)	73
TABLE 25 GLOBAL DEMAND FOR GAS FLOW METERS BY TYPE OF TECHNOLOGY, THROUGH 2019 (\$ MILLIONS)	74
TABLE 26 GLOBAL DEMAND FOR DP GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	75
TABLE 27 GLOBAL DEMAND FOR PD GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	76
TABLE 28 GLOBAL DEMAND FOR TURBINE GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	77
TABLE 29 GLOBAL DEMAND FOR THERMAL MASS GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	77

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
TABLE 30 GLOBAL DEMAND FOR MFCS GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	78
TABLE 31 GLOBAL DEMAND FOR ANNUBAR GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	78
TABLE 32 GLOBAL DEMAND FOR ULTRASONIC GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	79
TABLE 33 GLOBAL DEMAND FOR CORIOLIS GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	80
TABLE 34 GLOBAL DEMAND FOR DOPPLER VORTEX GAS FLOW METERING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	80
TABLE 35 NANO-GAS SENSOR TECHNOLOGIES	91
TABLE 36 GAS FLOW SENSORS/MONITORS SUPPLIER LEADERS AND PRODUCTS OFFERING	94
TABLE 37 GLOBAL DEMAND FOR GAS SENSING/MONITORING BY APPLICATION, THROUGH 2019 (\$ MILLIONS)	95
TABLE 38 GLOBAL DEMAND FOR CUSTODY TRANSFER SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	96
TABLE 39 GLOBAL DEMAND FOR STACK GAS SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	97
TABLE 40 GLOBAL DEMAND FOR FLARE GAS SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	98
TABLE 41 GLOBAL DEMAND FOR UTILITY SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	99
TABLE 42 GLOBAL DEMAND FOR CNG SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	100
TABLE 43 GLOBAL DEMAND FOR LOW GAS FLOW RATE SENSOR/MONITORING BY PRODUCT SEGMENT, THROUGH 2019 (\$ MILLIONS)	100
TABLE 44 GLOBAL DEMAND FOR GAS SENSOR/MONITORING BY TYPE OF PF TECHNOLOGY, THROUGH 2019 (\$ MILLIONS)	101
TABLE 45 GLOBAL DEMAND FOR IR SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	103
TABLE 46 GLOBAL DEMAND FOR SOLID-STATE SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	103
TABLE 47 GLOBAL DEMAND FOR CATALYTIC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	104
TABLE 48 GLOBAL DEMAND FOR GC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	104
TABLE 49 GLOBAL DEMAND FOR ELECTROCHEMICAL SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	105
TABLE 50 GLOBAL DEMAND FOR PARAMAGNETIC SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	106
TABLE 51 GLOBAL DEMAND FOR CHEMILUMESCENCE SENSORS/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	106
TABLE 52 GLOBAL DEMAND FOR ULTRA-VIOLET SENSOR/MONITORING BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	107
TABLE 53 OVERVIEW OF TEMPERATURE SENSORS	109
TABLE 54 OVERVIEW OF PRESSURE SENSORS	111
TABLE 55 SECONDARY GAS FLOW INSTRUMENTATION SUPPLIER/VENDOR	112
TABLE 56 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY APPLICATION, THROUGH 2019 (\$ MILLIONS)	113

<b>TABLE HEADING</b>	<b>PAGE NO.</b>
TABLE 57 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN CUSTODY TRANSFER OF NATURAL GAS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	115
TABLE 58 GLOBAL DEMAND FOR SECONDARY AS FLOW INSTRUMENTATION FOR STACK GAS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	115
TABLE 59 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN FLARE METERING BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	116
TABLE 60 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN UTILITY APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	117
TABLE 61 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN CNG APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	118
TABLE 62 GLOBAL DEMAND FOR SECONDARY GAS FLOW INSTRUMENTATION USED IN LOW GAS FLOW RATE APPLICATIONS BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	118
TABLE 63 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY TYPE OF INSTRUMENT, THROUGH 2019 (\$ MILLIONS)	119
TABLE 64 GLOBAL DEMAND FOR TEMPERATURE SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	120
TABLE 65 GLOBAL DEMAND FOR PRESSURE SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	120
TABLE 66 GLOBAL DEMAND FOR DENSITY SECONDARY INSTRUMENTATION BY APPLICATION SEGMENT, THROUGH 2019 (\$ MILLIONS)	121
TABLE 67 MARKET FOR GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION BY REGION, THROUGH 2019 (\$ MILLIONS)	123
TABLE 68 IMPORTANT FACTORS IN SPECIFICATION/PURCHASING OF FLOW METERS (SCALE IS 1 TO 5)	125
TABLE 69 IMPORTANT FACTORS IN SPECIFICATION/PURCHASING OF GAS SENSORS/MONITORS (SCALE IS 1 TO 5)	126

**LIST OF FIGURES**

<b>FIGURE TITLE</b>	<b>PAGE NO.</b>
SUMMARY FIGURE TRENDS IN GLOBAL MARKET FOR GAS FLOW METERS, SENSORS/MONITORS, AND SECONDARY FLOW, 2013-2019 (\$ MILLIONS)	7
FIGURE 1 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET PRODUCT SEGMENTS, 2013-2019 (%)	17
FIGURE 2 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET APPLICATION SEGMENTS, 2013-2019 (%)	18
FIGURE 3 GAS METERING, SENSORS/MONITORS, AND SECONDARY FLOW INSTRUMENTATION MARKET GEOGRAPHICAL SEGMENTS, 2013-2019 (%)	19
FIGURE 4 TYPICAL SAMPLING SYSTEMS FOR AN ONSTREAM ANALYZER	24
FIGURE 5 VENTURI FLOW METER	48
FIGURE 6 ELBOW FLOW METER	49
FIGURE 7 GLOBAL DEMAND FOR GAS FLOW METERING BY MARKET SECTOR APPLICATION, 2013-2019 (%)	67
FIGURE 8 GLOBAL DEMAND FOR GAS FLOW METERING BY TECHNOLOGY SEGMENT, 2013-2019 (%)	74
FIGURE 9 GLOBAL DEMAND FOR GAS SENSING/MONITORING BY MARKET SECTOR APPLICATION, 2013-2019 (%)	95
FIGURE 10 GLOBAL DEMAND FOR GAS SENSOR/MONITORING BY TECHNOLOGY SEGMENT, 2013-2019 (%)	101
FIGURE 11 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY MARKET SECTOR APPLICATION, 2013-2019 (%)	113
FIGURE 12 GLOBAL DEMAND FOR SECONDARY GAS FLOW METERING INSTRUMENTATION BY TECHNOLOGY SEGMENT, 2013-2019 (%)	119
FIGURE 13 U.S. GAS SENSOR/MONITOR PATENTS ISSUED SINCE 1975, BY PRODUCT TYPE (% OF PATENTS IDENTIFIED)	150
FIGURE 14 U.S. GAS SENSOR FLOW METER PATENTS ISSUED SINCE 1975 BY TECHNOLOGY TYPE (% OF PATENTS IDENTIFIED)	151
FIGURE 15 U.S. GAS SENSOR AND MONITOR PATENTS ISSUED SINCE 1975 BY TECHNOLOGY TYPE (% OF PATENTS IDENTIFIED)	151
FIGURE 16 U.S. SECONDARY GAS INSTRUMENTATION PATENTS ISSUED SINCE 1975, BY PARAMETER MEASURED (% OF PATENTS IDENTIFIED)	152