INDUSTRIAL GASEOUS LEAK DETECTION MANUAL

ORVIS M. KNARR

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No person succeeds in life without the immeasurable love, wisdom, dedication and companionship of another. My life, family and career exceeded all expectations because of the unbounded support of my beloved wife Bonnie who departed this world on November 17, 1996. Her constant love and faith were my inspiration for 35 years. I dedicate this work to the memory of her courageous battle against the horrible disease of scleroderma.

Preface

One universal technology—high-sensitivity leak detection using trace gas—plays a major role in today's manufacturing processes. An expanding sphere of technology depends on the integrity of enclosures of all shapes and sizes to provide quality products and services.

Excessive gas molecules, or too few, or too many wrong ones can interfere with every aspect of our lives. Higher-than-normal pressure in a TV tube will scatter the stream of electrons into a useless spray, and oxygen leaking into a lightbulb soon degrades the filament, resulting in premature failure. Air conditioners and refrigerators do not cool if refrigerant leaks out, and the effects of leaking containers range from irritating to catastrophic. The list can go on and on, but unwanted molecules plague most major industries in one way or another.

Although gaseous leak detection technology has matured over the past quarter century into a useful quality assurance tool in nearly every industry, the core of leak detection knowledge is limited. Knowledge and experience remain confined mostly to leak detector manufacturers and major users for no apparent reason. Gaseous leak detection is challenged by extensive growth potential in the coming century with a major disadvantage: lack of a cohesive agenda to expand basic knowledge, training, and experience in the field.

High-vacuum manufacturers publish promotional literature and operating manuals and offer training courses on a regular basis. Appropriate technical societies offer handbooks and conduct training, but the overall effort by the leak detection industry lacks a cohesive program. This results in far too many manufacturing engineers and technicians working with antiquated ideas and erroneous knowledge gleaned from "experts," or none at all.

This text addresses that lack by explaining the science, equipment, and procedures in relatively simple terms and relating them to everyday examples. Not all those in leak detection need become an instant expert, but they should begin to acquire a solid and rounded knowledge of this fascinating field. The horizon is endless with new challenges daily, and a view of where we have been should put it into perspective.

Industrial Gaseous Leak Detection Manual begins with a historic look at leakage through the ages and a simplistic explanation of its technology. Chapter 2 explains gas behavior in our natural world as well as within manufactured parts and systems. It introduces the terms and expressions of gas flow and lays the groundwork for working in the leak detection world. Chapter 3 outlines the breadth of products and systems that depend on leak detection while Chap. 4 attempts to narrow the communications gap by relating the science of leak detection to real-world products.

Chapter 5 describes equipment and techniques used in typical medium-sensitivity applications while Chap. 6 describes the helium mass spectrometer leak detector and its components and procedures for high-sensitivity leakage testing. It describes residual gas analysis and its possibilities for future leak detection. The advantages and limitations of optional accessories and equipment are described in Chap. 7 to enable readers to make intelligent selections when they buy.

The importance of tuning and calibrating the leak detector and the part or system under test is discussed in detail in Chap 8. Too few operators understand the significance of time constants and response in large-system leak testing. Chapters 9 and 10 describe the applications and techniques used to test parts and systems from thimble size to electric power generating plants.

Chapter 11 is the first known approach to identify the issues facing leak detector manufacturers, users, and automatic assembly line manufacturers as they integrate helium mass spectrometers into high-speed production test facilities. It deals with the design, materials, and fabrication of test fixtures and the importance of the control interface. Chapter 12 discusses the significant issues of standards, sensitivity, training, and certification in the industry.

The text emphasizes the importance of the human element in all forms of leak test technology, and it targets those who do the work: manufacturing engineers, technicians, and operators. It addresses major points of knowledge to help those who specify, buy, use, and manage the leak test facilities throughout industry. The text avoids complex formulas and explanations, if possible, in describing gas behavior, pressure, and density below atmospheric pressure.

Although the International Standards Organization suggests use of the pascal as a standard pressure unit, this text uses the more common units of torr, millitorr, and std cm^3/s. It also refers to the older pressure units of mmHg and micron [micrometer (μm)] because many users are comfortable with them. Also, current operating and service instructions include a variety of dated expressions that promise to be around for some time.

Those proficient in leak detection may work comfortably on the leading edge of the technology, but others do not, so they struggle with improper procedures, inappropriate or poorly maintained equipment, and dated or incomplete knowledge. High vacuum purists may not appreciate some of the examples or analogies, but our purpose is to assist those who feel uncomfortable in the sciences pertaining to gaseous leak detection.

Leak detection is a very interesting and fascinating field because it covers so many industries and scientific disciplines. Although our goal is to improve the level of knowledge in this exciting area, the primary objective is to provide a sense of comfort along the way and perhaps challenge the reader to pursue the subject in greater depth.

Orvis M. Knarr

ABOUT THE AUTHOR

Orvis M. Knarr is President of ORBON Associates, a consulting firm that specializes in helium leak testing. He has over 25 years experience as an application engineer in helium mass spectrometer leak detection, with particular expertise in the integration of helium leak detectors into automatic assembly and test lines over a wide range of industrial applications. Mr. Knarr is a contributing author to the book *Helium Mass Spectrometer Leak Detection.*

Acknowledgments

Nearly 40 years ago, one of my tasks as a new hire was to deliver delinquent valve bellows to a cantankerous, irascible engineering manager of a company for whom my company manufactured parts. He accepted nothing less than perfection, and our quality was occasionally substandard. The demands of job and commuting invariably timed my arrival at his home near dinner, a valued family event. I came to dread the stern lecture about shoddy quality and poor workmanship of the delivered parts, for I was only a delivery boy.

My dread later turned to respect and love as I had the privilege of working and traveling with this marvelous and talented engineer. For nearly a quarter of a century, we traversed the length and breadth of the United States putting sophisticated leak detection equipment where it should not be, but his efforts made it work.

Walton E. Briggs (1913–1988) was an extremely intelligent and practical engineer who espoused quality long before it became vogue. He believed in quality of life and workmanship and constantly demanded the highest standards of performance from everyone including himself.

He was at times arrogant and witty, but always an innovative thinker whose ideas and vision helped advance helium leak detection into its significant role today. His practical brilliance paved some of the way, and his quiet humor warmed the years of our business and personal relationship.

Walt led the way for many of us, and he provided the inspiration to succeed in this fascinating field. My desire now is to help others perform their leak- testing task with ease, surety, and confidence; and, hopefully, they too can have some fun along the way.

This book would not have been written without the efforts of the fine and dedicated people with whom I worked, some for nearly 40 years:

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Chapter

1

Getting Comfortable with Gaseous Leak Detection

Evolution of Leak Detection

Leaks have been a problem since nomadic travelers lost wine from their goatskins and grain from their sacks. Seafarers pounded oakum into the seams of their ships to keep out seawater and mended torn sails to prevent wind leakage. Early automobile owners patched flat tires (tubes) and leaky radiators. They fixed what they saw and did not concern themselves with things they could not see.

Early people had no way to preserve their food and water, so they did not stray far from sources of those necessities. As they abandoned caves for better shelter and began to explore, humans learned to create a personal and immediate environment and take it with them as they moved. Thus, they began the endless quest to control leakage and its effects on their lives.

Massive oil spills and radiation, chemical, or toxic waste leaks generate headlines because they are apparent. The magnitude of spillage or leakage is immediately visible, causing economic and ecological losses as well as lives. At the extreme end of the scale are tiny leaks whose effects may not become known for years. They also pose a substantial threat.

A relatively new industry evolved during the past 30 years to locate and measure leakage too small to be detected by earlier methods. Its primary role is to identify and quantify the passage of gas into or out of a part or system.

Unfortunately, an aura of mystery and perplexity continues to surround gaseous leak detection because relatively few people understand gas behavior. This rather specialized knowledge is common within the leak detection and high-vacuum community, but those at all levels in other industries grapple with misinformation or nebulous data concerning gas physics. The movement of gas molecules within confined volumes operating below atmospheric pressure is puzzling and therefore threatening.

Many manufacturing and process engineers and technicians are uncomfortable with the terminology and lack a perception of the magnitude of the proportions involved. Nontechnical managers and associates with similar limitations are ill equipped to make decisions when evaluating business opportunities concerning products or services that require enclosure integrity.

We need to focus our energies on promoting the specialized knowledge of gas behavior and to blend it into the other manufacturing disciplines that use leak detectors or may do so in the future. Understanding gas physics is the key to successful leak detection. The knowledge has been around for a long time.

The early days

Certain scientists and technicians since Galileo's time have spent a significant part of their working hours challenging nature's abhorrence of vacuum on earth, and the vacuum industry still expends considerable effort to locate and repair leaks in high-vacuum systems. Since gaseous leak detection originated in laboratories and research facilities using high-vacuum equipment, it seems logical to trace its path from that setting to today's locale.

The science of gaseous leak detection began its move from the laboratory to industrial plants in the early 1940s to meet World War II needs. Later, it expanded to microelectronics production and similar applications, the "clean room" industries. Finally, it intruded on the hostile environment of the traditional industrial world in the middle to late 1960s.

The equipment has made impressive progress as an integral part of assembly and test processes in many industries, but its operating principles and the effects of numerous variables are seldom understood even after a quarter century's operation on the plant floor.

The first helium mass spectrometer leak detectors installed in the automotive industry introduced an entirely new concept, one accompanied by a unique and at times debatable vocabulary. The helium leak detector contingent was the first to "pump down to higher levels," and the equipment used to do it was unlike anything seen before in an automobile plant. The idea of pumping anything "down" to reach "higher" levels confounded those accustomed to pumping things "up" to achieve higher pressures; unfortunately, the puzzle continues some 25 years later.

Automobile torque converters were manufactured by the tens of thousands per shift amid welding slag, grinding dust, machining oils, and cooling fluids. In those environments, pressure could be several hundred pounds per square inch, and a "good" vacuum was 28 inches of mercury (inHg). At the time, each industry understood its own atmospheric and environmental definitions, and communication lagged because each faction resisted acceptance of the other's position.

Many process vacuum systems now reach ultrahigh-vacuum (UHV) pressures of 10^{-9} and 10^{-10} torr, while a few achieve extreme high-vacuum (XHV) pressures of 10^{-12} and 10^{-13} torr. Pressure levels of 10^{-9} torr were extremely rare when high-vacuum manufacturers began fabricating and shipping helium leak detectors to automobile manufacturing plants. The level of vacuum required to operate a helium leak detector was several decades below 28 inHg.

Initial shipments of leak detectors were accompanied by instructions with lengthy lists of dos and don'ts that baffled the recipients. In those environments, to "clean" something on a production line was to wipe it with an oily rag, a procedure guaranteed to horrify high-vacuum engineers.

Transition from the laboratory to the production floor

More industries sought improved leak test methods as product considerations required vastly improved performance, reliability, and economy. Automotive, refrigeration, air conditioning, and similar manufacturing entities needed faster, more sensitive, and more economical test methods to meet broadening business objectives. Product quality, manufacturing, test, and warranty issues were important elements, but cost control emerged as a key objective in the early 1970s: Bottom-line issues compelled a review of traditional leak test methods and equipment.

Immersion bubble testing (air-under-water, or dunk tank, testing) had served traditional industries well, but that method was labor-intensive and subject to errors of human judgment. Low initial capital equipment costs and maintenance were reasonable for current test specifications, but increased production quantities and higher quality standards strained existing leak test science capability, and poor results showed up as negative numbers on the balance sheets.

Halogen sniffing, pressure decay, and other manual leak test methods that sensed or measured the movement or accumulation of gas molecules were also popular. They, too, faced human limitations: attention span, judgment, and physical endurance—how many people can sit or stand for 8 h while observing strict operating and visual procedures without making errors?

Halogen leak detectors fared poorly in numerous automation