ADVANCES IN USA AIR POLLUTION RULES - ENHANCED LEAK DETECTION AND REPAIR

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Abstract

Enhanced Leak Detection and Repair Programs (Enhanced LDAR or ELP) began to appear in consent decrees in 2009. Refineries and chemical plants are subject to these programs when the USA's Environmental Protection Agency (EPA) finds standard LDAR programs deficient. Enhanced LDAR is designed to systematically improve the quality and effectiveness of LDAR.

This paper aims to educate the reader on the latest activities governing pollution control of USA plants. The regulations show the convergence of sealing technology and regulatory requirements. Enhanced LDAR requires performance based testing to qualify valves and valve stem seals so that the release of hazardous air pollutants and greenhouse gases (GHGs) will be minimized.

Background

The terms, “Enhanced Leak Detection and Repair Program,” and, “Enhanced LDAR,” became known in USA petroleum and chemical process plants in 2009. Unlike other mandates this did not appear as regulation but in consent decrees. Enhanced LDAR is used by the EPA, to correct LDAR programs found to be deficient. It demands actions that go beyond current regulations. Enhanced LDAR encompasses a number of elements such as quality control, training, monitoring, repairs, and most notably, equipment upgrades.

In 1998, the EPA came to the realization that LDAR programs were not having the desired effect. They were not promoting a proactive approach to seek and stop fugitive emissions from valves, pumps, connectors and other plant equipment. Investigations of emissions from refineries revealed that the actual leakage and emission rates were two or more times higher than what was being reported.[1] The findings prompted the EPA and US Department of Justice (DOJ) to focus on oil refiners and pursue consent decrees.

A brief history of noteworthy USA environmental regulations is given in Table 1 beginning with the first legislation in 1955.

Table 1
USA Regulations Milestones

1955 – Air Pollution Control Act – provided research and technical assistance related to air pollution control.
1962 – Rachel Carson, “Silent Spring” – a book credited with launching the USA environmental movement. It documented the effects of pesticides on the environment.
1963 – Clean Air Act – affected industrial plant sites.
1970 – President Nixon created the EPA.
1970 – Clean Air Act - added motor vehicle sources.
1972 – Clean Water Act
1990 – Clean Air Act amended – introduced the permit process and LDAR.
2009 – EPA declares GHGs a danger to public health because they promote global warming. In 2010 US legislators filed a resolution against the declaration.

The Air Pollution Control Act of 1955 was instituted to provide research and technical assistance related to air pollution control[2]. In 1962 Rachel Carson’s book, “Silent Spring” launched environmental activism with its exposé of the affects of pesticides on birds and the environment. The Clean Air Act (CAA) of 1963 affected all industrial plant sites, known as stationary sources. In 1970 President Nixon instituted the EPA and the CAA was expanded to include emissions motor vehicles. In 1990 the CAA was amended instituting LDAR programs and the permit process. By this time regulatory compliance was a part of the operations of any oil or chemical processing plant. In December of 2009 the EPA declared six GHGs to be a danger to human health because of their contribution to climate change: “GHGs are the primary driver of climate change, which can lead to hotter, longer heat waves that threaten the health of the sick, poor or elderly; increases in ground-level ozone pollution linked to asthma and other respiratory illnesses; as well as other threats to the health and welfare of Americans.”[3] This marked the first time that the EPA formally declared GHGs caused climate change and so posed a health danger to USA citizens. Since, EPA has the responsibility and authority to protect the public’s health it opened the door to develop and mandate regulation via legislation, directives and consent decree. While this declaration by the EPA has been challenged the fact remains that controlling and eliminating air pollution is a priority.

Aims of Enhanced LDAR

The spirit of LDAR is to actively look for and eliminate leaks. In a regulated environment the tendency is to only do what is required. This paper will summarize the elements of a typical, Enhanced LDAR Program with special emphasis on the element of Equipment Upgrades. This element requires the use of valves with performance warranted valve stem sealing technologies, valve replacement and preventive maintenance programs. Furthermore, sealing and valve technologies' performance must be verified by documented tests.

Fugitive emissions are a concern not only of the EPA, but of plant environmental managers, LDAR leaders, reliability and maintenance departments, and the communities in which the emissions are being released. Beyond saving financial penalties for non-compliance there are real savings to be realized by keeping fugitive emissions where they belong. Cutting emissions improves production yields which, in turn, improve profitability.

Methods and Results

Emissions

In the refining, chemical and petrochemical industries, pollutants released during the normal course of operations are often referred to as, "process emissions." The term, "emissions," for the purposes of this paper will refer to what the EPA calls, "fugitive emissions." These are regulated hazardous air pollutants (HAPs) and volatile organic compounds (VOCs) that have escaped from a process system's components that are assumed to be sealed. LDAR departments serving as fugitive emission vigilantes conduct costly and time-consuming programs involving individual monitoring of tens of thousands of plant components, e.g. valves, flanged-joints, pumps, compressors, pressure relief devices and end connections. LDAR departments devote much time and effort to gathering information, maintaining databases, and generating the requisite reports, but the ultimate objective of LDAR is to find and stop the leaks.

Consent Decree Process

A consent decree is a negotiated settlement between the EPA-DOJ and the plant site. In return for a settling the charges of not complying with environmental regulations a plant site agrees to pay fines, take actions to correct non-compliance (called injunctive relief) and perform special projects. The injunctive relief includes such things as installation of new equipment like scrubbers and carrying out Enhanced LDAR Programs. Special projects can range from funding and carrying out trials of new technologies to building community health care clinics. Table 2 shows plants sites that now must perform ELP.

Table 2
Consent Decrees Requiring Enhanced LDAR Programs[6]

Company Name and Consent Decree Date	Injunctive Relief	Civil Penalties	Required Supplemental Environmental Projects
Dow Chemical July 29, 2011	1) Enhanced LDAR 2) Equipment compliance demonstrations	US$2.5M	None.
Western Refining June 30, 2011	1) Enhanced LDAR 2) Upgrades and audits of fluidized catalytic cracking units (FCCU), benzene program and flares. 3) Estimate cost of US$60M	US$1.45M	None.
Hovensa, LLC	1) Enhanced LDAR	US$5.375M	US$4.875M fund for

January 26, 2011	2) Upgrades and audits of FCCU, benzene program and flares.		projects benefiting the Virgin Islands.
Murphy Oil September 28, 2010	1) Enhanced LDAR 2) Upgrades and audits of FCCU, benzene program and flares.	US$1.25M	1) Fence-line/remote ambient air-monitor system and web publication of data. 2) US$1.5M for oil-water separator and coker upgrades.
Shell Chemical LP/Shell Chemical Yabucoa, Inc. March 31, 2010	1) Enhanced LDAR 2) Facility shutdown and equipment upgrades.	US$3.5M	US$193K to support local educational environmental activities and emergency organisations.
[7]Vertellus Agriculture and Nutrition Specialties, LLC August 25, 2009	1) Enhanced LDAR 2) Installation of new incinerator.	US$425K	US$705K to upgrade pumps with technology that will eliminate fugitive emissions.
Ineos ABS USA Corporation/Lanxess Corporation July 31, 2009	1) Enhanced LDAR 2) Monitoring and upgrade of flare, spill reporting and acrylonitrile processes	US$3.1M	None

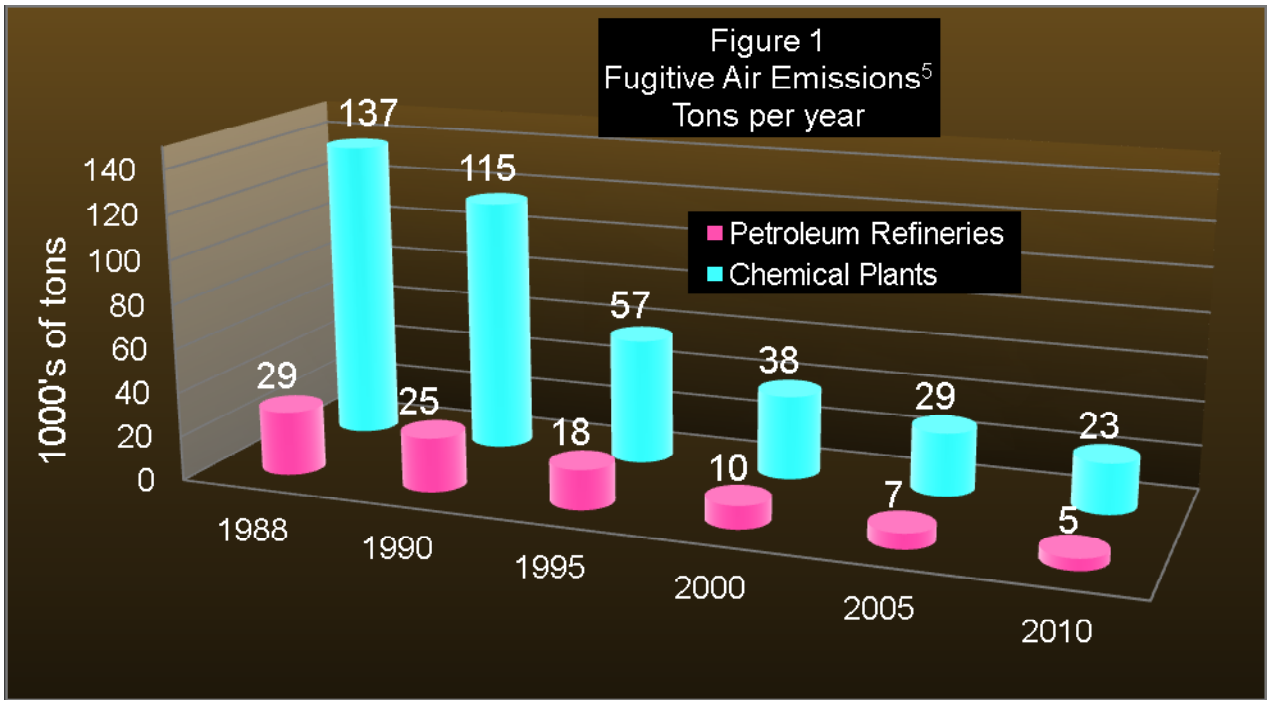
Enhanced Leak Detection and Repair Programs (ELP) appear in consent decrees and are designed to systematically improve the quality and effectiveness of industrial sites' LDAR programs, ELP is considered a standard fix for LDAR enforcement cases. Significantly, LDAR is a USA National Enforcement Initiatives: "For FY2011-13, EPA will use a national enforcement initiative approach to focus on excess emissions caused by facilities' failure to comply with EPA's leak detection and repair requirements and restrictions on flaring, and to address excess emissions during start-up, shutdown and malfunction events."[4] When an LDAR program is found wanting Enhanced LDAR is deemed the appropriate injunctive relief.

Two points of view emerge during the consent decree negotiation process. One, the plant can feel that the negotiation is legalized extortion since the process allows regulation to be created without the diligence of the legislative process. Two, the EPA and DOJ feel that despite ample regulatory guidance on performing a LDAR program if it is not being followed then Enhanced LDAR is justified. The consent decrees of 1998 to 2008 required that formal LDAR programs with dedicated management be instituted and plant managers be held responsible for information in the program's reports; this is now part of normal regulations. Table 3 shows the regulations citing LDAR programs. Emission results bear out the success of regulations. Figure 1 shows the decline in fugitive emissions beginning with 1988.

Table 3
Federal Regulations Requiring LDAR Programs with Method 21 Leak Monitoring
40CFR: Protection of the Environment

Part	Description
60	Standards of Performance for New Stationary Sources (NSPS)
61	National Emissions Standards for Hazardous Air Pollutants (NESHAP)

63	NESHAP for Source Categories - Maximum Achievable Control Technology (MACT)
65	Consolidated Federal Air Rule
264	Standards For Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities
265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities



Enhanced LDAR
Enhanced LDAR Program documents begin by defining terms such as an open-ended line, certified low-leaking valves and packings, and equipment and process scope. Typical ELP contains 14 parts; these can vary by site and consent decree. See Table 4.

Table 4
Elements of Enhanced Leak Detection and Repair Program

• A: Applicability-General • B: Monitoring Frequency • C: Monitoring Methods and Equipment • D: Leak Detection and Repair Action Levels • E: Leak Repairs • F: Delay of Repair • G: Equipment Upgrades, Replacement and Improvement	• H: Management of Change • I: Training • J: Quality Assurance and Control • K: LDAR Audits and Corrective Actions • L: Certification of Compliance • M: Recordkeeping • N: Reporting

Part A sets forth the general requirements of the program. These are in addition to and not in lieu of existing local, state and federal regulations. In the event of conflicts, the more stringent requirements prevail. A plan applying to the entire site is required, and must include a component tracking program, personnel roles and responsibilities, justification of the number of employees needed to execute the plan and implementation.

Part B addresses monitoring frequency. Depending on the type of component, the frequency is set for monthly, quarterly or annual intervals. Existing regulations that require more frequent monitoring take precedence. Pumps and agitators must be monitored monthly, valves and closure devices for open-ended lines quarterly, and connectors/flanges annually. Failure to meet the higher performance standards for new equipment and repacked valves will result in even more frequent monitoring associated record keeping and reporting. Equipment replaced or valves repacked per Part G must be monitored monthly for 12 months after which monitoring frequency can be increased to yearly.

After two years of emission compliance, a site may be eligible for extended monitoring intervals. For example valves and closure devices may be monitored annually, and connectors every two years. However if any component leaks during this two-year period, it will be subject to monthly monitoring until it complies, and then monthly for 12 months thereafter.

Part C covers emission monitoring. It requires using Method 21[8] with a vapor analyzer and data logger (Figure 2). If the analyzer is found to undergo calibration drift, components measured by the instrument need to be re-monitored.

Part D addresses LDAR action levels. These are the leak levels at which repair is required (Table 5).

Table 5
Part D - LDAR Action Levels

Component	Leak Definition Action Level (ppm)
Valve	250
Connector	250
Pump	500
Agitator	2,000
OEL – open ended line at closure device)	250

Figure 2 – Method 21 uses an organic vapor analyzer (OVA) or toxic vapor analyzer (TVA). The component is approached and, “sniffed,” to record the leak concentration. Here the gasket seal of valve flange is monitored. Photo courtesy of Team Industrial Services

Any time a leak is detected by human audio, visual or olfactory sensing (called an “AVO”), it must be repaired according to the standard schedule at the time it is discovered.

Part E deals with leak repairs. The first attempt must be made within 5 days and the final attempt within 15 days of detection. Follow-up monitoring is done within one business day of any repairs or maintenance. The objective is to achieve the best repair with the lowest possible rate of emission. If a component such as a valve cannot be repaired to comply or removed from service would it be drilled and tapped, unless it’s precluded by safety, mechanical, quality or environmental factors. At this point or after two unsuccessful drill and tap attempts, the component may be put on the delay-of-repair (DOR) list, where it must be assessed and justified for inclusion per Part F of the ELP. **Part F** is dedicated to DOR. Drilling and tapping of valves is considered a last resort.

Part G - Equipment upgrades

Part G is the most progressive and demanding part of ELP. It pushes LDAR to a more proactive preventive level, raising the bar above the normal monitoring, corrective action and reporting and exemplifying the spirit of Enhanced LDAR. It defines and prescribes specific action to control valve stem seals.

Equipment replacement/improvement was first included in two consent decrees in 2009. Designed to improve the emissions performance of valves and connectors, it requires a list of all valves in the covered process units to be compiled. Any new valve must be certified as low-leak and fitted with certified low-leak packing.

Part G - Valves

Low-leak valve and packing certification requires a written guarantee by the manufacturer that the valve will maintain a rate of leakage not to exceed 100 ppm for five years, or documentation that the valve has been tested and the performance demonstrated (Figures 3 and 4). Most plants require both. Documentation of guarantees from each vendor is required and must be retained on-site as proof of compliance. EPA does not prescribe one performance test over another. The guidance is to use, “good engineering judgment,” to assess a manufacturer’s warranty claims and test data.

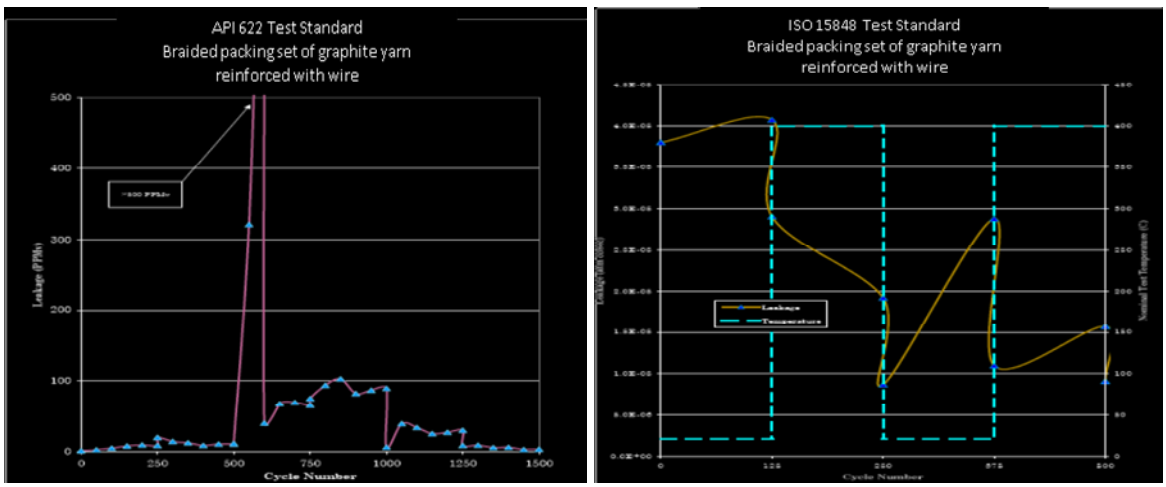
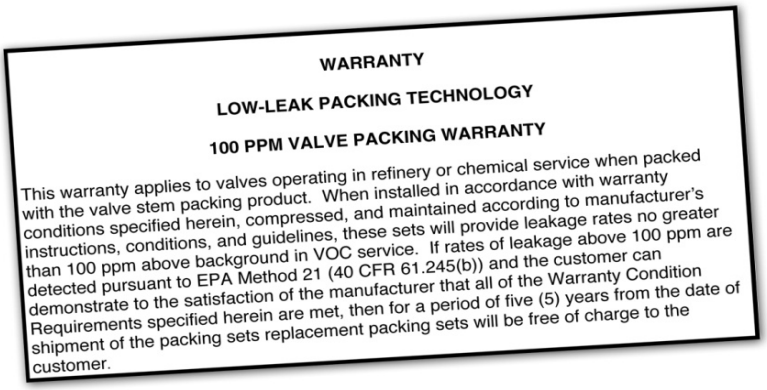


Figure 3 – Typical test result documentation.

Valves with stem seals leaking at or above 250 ppm must be replaced with a certified low-leak valve or repacked with certified low-leak packing within 30 days. If the corrective action requires a unit shutdown, it may be deferred to the first scheduled maintenance shutdown.



WARRANTY

LOW-LEAK PACKING TECHNOLOGY

100 PPM VALVE PACKING WARRANTY

This warranty applies to valves operating in refinery or chemical service when packed with the valve stem packing product. When installed in accordance with warranty conditions specified herein, compressed, and maintained according to manufacturer's instructions, conditions, and guidelines, these sets will provide leakage rates no greater than 100 ppm above background in VOC service. If rates of leakage above 100 ppm are detected pursuant to EPA Method 21 (40 CFR 61.245(b)) and the customer can demonstrate to the satisfaction of the manufacturer that all of the Warranty Condition Requirements specified herein are met, then for a period of five (5) years from the date of shipment of the packing sets replacement packing sets will be free of charge to the customer.

Figure 4 – Typical warranty

Valves found to be leaking between 100 ppm and 250 ppm must be noted, listed and prioritized in order of magnitude of leakage and the number of times they were found to be leaking. From this list it can be determined how many valves must be replaced or repacked. This is done by taking 10 percent of the valves leaking between 100 ppm and 250 ppm, less the number of valves on delay-of-repair, those previously fitted with low-leak packing and those scheduled for replacement or repair in the next scheduled shutdown.

A more stringent alternative of Part G requires that 20 percent of valves leaking between 100 ppm and 250 ppm be replaced or repacked. To reduce the number leak points, valves emitting HAPs can be eliminated from service, but their removal must not add other potential points of leakage.

In the event a certified low-leak valve or packing is not commercially available, a report must be submitted, identifying each affected valve(s), vendors contacted, and written documentation from each such vendor that a certified remedy is not available.

Part G - Connectors
Flanged, threaded, compression, cam-lock and quick-connect-type connectors are also subject to repair, replacement and improvement but do not require written guarantees and test documentation. Any connector found to leaking at or above 250 ppm must be repaired with technology that in the plant's judgment will attain a level of leakage below 250 ppm. As with valves a successful repair must be made within 30 days of detection. Connectors are subject to the same post replacement/repair monitoring requirements as valves. Connectors eliminated or replaced by welded joints or pipe replacement are considered to be repaired or improved.

All equipment replacements, improvements and eliminations must be reported, identifying the equipment, the action taken for compliance, and scheduling of future replacements and upgrades.

Part H deals with change management. All equipment added to or removed from a plant must be recorded and evaluated with regard to applicable LDAR requirements, and the documents retained. In addition all personnel and contractors responsible for monitoring, equipment maintenance and repairs, and other LDAR-related activities must be trained.

Part I covers training. It must commence within six months of initiation of ELP, with refreshers conducted annually.

Requirements for quality assurance, corrective actions and certification of compliance are set forth in **Parts J, K and L**. LDAR technicians certify daily that monitoring data is accurate and has been properly collected. Records of the LDAR department must be internally audited on a quarterly basis by a non-technician, but LDAR-trained employee. In addition to self-auditing, yearly third part audits are required.

Part M requires retention of all original records, including copies of all LDAR audits and documentation of prescribed ELP compliance. Monitoring data, leak repair, training and audit records must be retained for five years and equipment calibration records for one. Electronic records of monitoring data must be retained for the duration of the consent decree.

Compliance status reports per **Part N** must be filed at the intervals specified by the consent decree. The reports must include personnel assigned to LDAR activities, percentage of their time devoted to these functions, all instances of non-compliances, problems encountered in the process of compliance, training requirements, QA/QC deviations and corrective actions, and summary of LDAR audit results. The reports must be certified to be true and signed by the plant manager and an environmental or engineering management official.

Valve Stem Sealing Solutions

The EPA encourages the use of leak-less technologies, however the most prevalent method of controlling valve stem emissions is compression packing. Studies have indicated that leaking valve stems are by far the single largest source of fugitive emissions in processing plants (Figure 5).

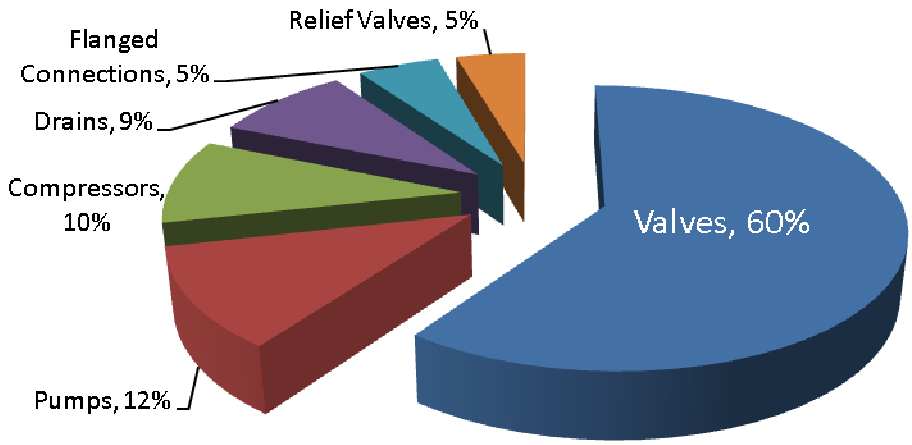


Fig. 5 – Valves account for 60% of fugitive emissions, making them the focus of enhanced and standard LDAR programs.

This can be controlled by following simple guidelines that take into account the valve service conditions, the seal supplier's recommendations, seal installation, and ongoing performance monitoring.

Sealing types

Different types of seals have different performance attributes such as how axial compression affects valve actuation force, radial expansion of the packing, friction and the ability to attain, maintain and adjust a seal for emission compliance. There are a number of viable choices for valve stem seals, notably die-formed flexible graphite, braided flexible graphite, engineered seal sets, bellows sealed valves, and live-loaded packing sets (Table 7).

Table 7 – Low emission packings and seals

Seal Type	Description	Attributes
Die-formed flexible graphite	• Graphite tape die-formed into flat rings with braided carbon or graphite end rings. • 95% carbon or above. • Rings come in various densities. Higher density for higher service pressures. • Good to 850ºF in air, 1200ºF in steam and pressures of 4000+ psig.	• Capable of 500 ppm leak performance. • This method has been in use for over 30 years. May not attain the low leak rates demanded by local regulations, consent decrees and plant owner specifications. • Rings are made for a specific valve stem and box size. • May require adjustments to get and maintain low emission result. • Multiple step installation.
Braided flexible graphite	• Wire reinforced flexible graphite yarn. • 95% + carbon purity usually with a manufacturer's proprietary yarn treatment. • Good to 850ºF in air, 1200ºF in steam and pressures of 4500 psig.	• Capable of <500 ppm and <100 ppm performance. • Came on the scene in the 1990's. • One size of braid can be used to pack many different sizes of valves. • May require adjustments at start-up to get low emission result. • Multiple step installation.
Engineered sets .	• Combination of die formed flexible graphite with various geometries and densities and braided carbon/graphite yarn packings. • Good to 850ºF in air, 1200ºF in steam and pressures of 10,000 psig.	• Capable of <500 ppm and <100 ppm performance. • Designs developed for low emissions regulations in the 1970's. • Sets are made to the specific valve stem and box size. • For engineered braids, one size can be used to pack many different sizes of valves. • Some types feature one step installation procedures. Favored by OEM valve manufacturers wanting low emission performance with assembly line speed of installation.
Bellows sealed valves	• Incorporated into the valve design. Packings are used as secondary seals. • Temperature and pressure depends on the bellow metallurgy, construction and design.	• Virtually zero emissions. • High cost - multiple times that of a standard packed valve. • If the seal fails there is no possibility of adjustment. The valve must be rebuilt or replaced.

	Made to match the valve pressure class and material rating.	
Live loading	• Disc spring (Belleville) washers are compressed on the gland follower under the gland stud nuts. • Temperature and pressure depends on the seal type used. Live loading does not enhance pressure and temperature ratings.	• Can be used with any packed valve. • Increases the energy in the gland stud bolts. As the packing consolidates the compressive load on the packing degrades to a lesser degree and can better maintain a seal. • Added expense. • Considered for valves with high number actuations, thermal cycles or difficult to monitor.

Guaranteed Performance and installation

Just as important as selecting the right seal for a particular valve application is making sure it is installed properly. Correct installation insures more even compression of the packing resulting in better emissions performance and longer service life. Begin by referring to the manufacturer's installation instructions; then remove all the old packing, inspect the stem and stuffing box for any visible defects, and replace or repair any worn or damaged components. Next, measure the stem and bore diameters and stuffing box depth to calculate the correct packing size and number of rings (Figure 6).

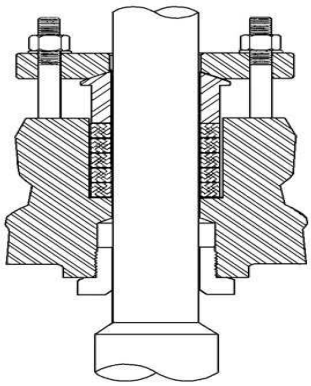


Figure 6 – Cross-section of a typical valve packing chamber with packing rings installed.

Figure 7 – Packing manufacturer's packing cutter.

If using braid, cut the rings to size using a mandrel the same size as the stem or a packing cutter (Figure 7). The rings are usually installed one at a time. Special care must be taken not to break die-formed flexible graphite rings when installing them over the stem and into the valve's packing box bore. Installation of engineered sets is governed by manufacturers' specific instructions.

After the packing has been installed, check for proper compression and actuate the valve per the manufacturer's instructions. Then make any necessary adjustments and monitor emission performance.

Most manufacturers offer performance guarantees and warranties specific to a particular type of packing. Promising a certain level of emission performance, these guarantees are subject to operating conditions and require installation to the manufacturer's specifications.

Most performance guarantees are dependent on the equipment's condition. If valves are worn and require rework, the packing performance guarantee may be rendered null and void. Most valve stem seals can wear over time, so service life limitations are typically specified in performance guarantees. It is advisable to get these programs in writing to assess their applicability to plant requirements.

Most performance guarantees are also contingent upon the credentials of the installers, which are usually trained and certified by the seal manufacturer. Manufacturer site supervision and accountability may also be available, but at a price.

Since the seal may be exposed to flammable media, it should be fire-safe as verified by API 607, API 589 or similar tests. It should also be capable of maintaining a seal that is thermally cycled and accommodates reasonable actuation force. This is especially important in control valves.

Summary/Conclusions

Enhanced LDAR pushes the limits to 100 ppm as the new standard for valve stem seals. LDAR remains a National Air Toxic Enforcement Initiative[4]. After focusing on refineries since 1998, EPA investigators and enforcers are concentrating on chemical process plants. Enhanced LDAR will be the norm wherever there are issues with LDAR programs.

Following this guidance on sealing selection, installation, engaging the expertise of sealing manufacturers and practicing the elements of proactive LDAR will prepare any chemical or oil processing plants for any type of inspection or audit. The rewards of good sealing selection and practices will manifest themselves in regulatory compliance, increased plant efficiency, improved profitability and a healthy work environment.

In summary Enhanced LDAR takes standard LDAR to a higher level of compliance, mandating the use of certified low-leak valves and packings, and aligning the regulations with the best available technologies and practices.

Footnotes

[1]EPA-305-D-07-001, "Leak Detection and Repair-A Best Practices Guide," (2007), App. E

[2]"Origins of Modern Air Pollution Regulations," EPA website, http://www.epa.gov/eogapti1/course422/apc1.html

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[4]National Enforcement Initiatives for Fiscal Years 2011-2013 - http://www.epa.gov/compliance/data/planning/initiatives/initiatives.html#airtoxic

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[7]EPS Newsroom webpage for Vertellus information - http://yosemite.epa.gov/opa/admpress.nsf/0/4090430D9914B1B18525761D0058A5C7

[8]"Method 21 - Determination of Volatile Organic Compound Leaks," http://www.epa.gov/ttn/emc/promgate/m-21.pdf

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Key words - LDAR, emissions, EPA, leak