Fugitive Emissions from Valves and Pipe Fittings (aka Fugitive Emissions and Me)

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This presentation will cover:

• A summary of the history of fugitive emissions and leak detection and repair (LDAR)

• A concise review of LDAR regulatory approaches in the US and abroad

• How LDAR control has progressed over the last four decades and what the future may bring

• On the eve of my retirement, a little retrospective on my career in fugitive emissions

You should leave this session with an understanding of various regulatory approaches and why they were configured as they were.
The Ages of LDAR

- Prehistoric
- Research Years
- Regulatory Years
- Turnkey Compliance Years
- Enforcement Alert Years
- Consent Decree Years
- The Epiphany
- The Future
<table>
<thead>
<tr>
<th>LDAR</th>
<th>BUZZ</th>
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<tbody>
<tr>
<td>Prehistoric</td>
<td>Fifth grader</td>
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<tr>
<td>Research Years</td>
<td>Texaco to Radian</td>
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<tr>
<td>Regulatory Years</td>
<td>Trendy 30s</td>
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<tr>
<td>Turnkey Compliance Years</td>
<td>Funky 40s</td>
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<td>Enforcement Alert Years</td>
<td>Turning 50</td>
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<td>Consent Decree Years</td>
<td>URS to Sage</td>
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<tr>
<td>The Epiphany</td>
<td>Still waiting</td>
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<tr>
<td>The Future</td>
<td>Retirement</td>
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Before Rachel Carson’s *Silent Spring* …
Before there was an EPA …

The Health, Education, and Welfare Department in 1958 sent Dr. Bernie Steigerwald to perform a site survey of Los Angeles area refineries, concluding:

- Some components leak
- There are many components with the potential to leak
- Cumulatively equipment leaks could present a pollution problem
EPA invested in research to determine environmental problems, and specific to fugitive emissions:

- One large project went to Radian Corporation to measure atmospheric emissions from petroleum refineries
  - *Instrument monitoring for presence of leaks*
  - *Correlation equations and emission factors*
  - *Bagging procedure later formalized by EPA*

- Another large project went to Rockwell Corporation teaming with Texas A&M University to measure emissions from oil & gas production
  - *Leak detection by Soap scoring*
It was known/suspected that most components did not leak significantly.

Method of measuring fugitive mass emission rate is called “bagging”.

Bagging was too expensive to be used in a shotgun approach with the potential to mostly measure insignificant leaks.

We needed a tool to identify leaks and roughly categorize them by size – to screen out the non-leakers from more interesting subjects.
Research – Vacuum Bagging Train

[Diagram showing vacuum bagging train components: Bag Around Valve, Syringe, Sample Bag, Pump, DGM, KO, T.]
Checking all potentially leaking areas with a portable hydrocarbon detector was selected.

- Bacharach TLV Sniffer
- Century OVA-108

This screening method was eventually formalized as EPA Method 21.

Method 21 now calls for recording only the maximum reading, but in screening we also:

- Recorded readings at 90°, 180°, and 270° from the maximum, and
- Calculated averages of the 4 readings
Research developed correlation equations and emission factors used as basis for regulations

EPA conducted more limited research into SOCMI chemicals and natural gas plant emissions in the early 1980s

CMA (now ACC) funded research on emissions from ethylene oxide, butadiene, and phosgene in the late 1980s

API and WSPA co-funded additional refinery research in the early 1990s

EPA has added the new data to the old rather than replacing the old data
<table>
<thead>
<tr>
<th>Operation</th>
<th>Valve Leak Percent, 10,000 ppm</th>
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<tbody>
<tr>
<td>Onshore Production</td>
<td>6.4%</td>
</tr>
<tr>
<td>Offshore Production</td>
<td>2.8%</td>
</tr>
<tr>
<td>Gas Plant</td>
<td>27.5%</td>
</tr>
</tbody>
</table>

### Early US Chemical Leak Percents

<table>
<thead>
<tr>
<th>Group</th>
<th>Percent Leaking ≥10,000 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G/V</td>
</tr>
<tr>
<td>Overall</td>
<td>11.4%</td>
</tr>
<tr>
<td>Ethylene</td>
<td>14.8%</td>
</tr>
<tr>
<td>High Level</td>
<td>5.6%</td>
</tr>
<tr>
<td>Low Level</td>
<td>0.3%</td>
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</tbody>
</table>
Gas and light liquid service components are more likely to leak than heavy liquids.

The maximum screening value shows the best correlation coefficient to mass emissions.

Individual component emissions are small, but in aggregate they can be large.

Most components do not leak or leak at a very low level.

The bulk of the emissions come from a small percentage of high leakers.
EPA Reference Method 21 was formalized from the portable analyzer screening method

- Analyzer specifications were drafted around a model of the OVA-108 (primarily) and the TLV Sniffer (establishing outer boundaries)
- Analyzer evaluation procedures were added
- Calibration procedures were added
- Monitoring procedures were formalized

Method 21 also included a Type II “no detectable emission” determination using soap bubble testing
EPA regulations generally are based on one of the three types of standards:

- Emissions limits (preferred)
  - Can be mass based (lb/hr) or concentration based (ppm)
  - Must be capable of being met by all regulated facilities
  - Must be measurable by EPA to determine compliance
  - Lack of data on specific seals used did not allow identification of superior performing technologies
  - EPA decided that they could not determine reasonable and verifiable emission limits for equipment leaks
EPA regulations generally are based on one of the three types of standards:

- **Work practice specification**
  - What to do
  - When to do it
  - How to do it

- **Equipment Modifications/Standards**
  - Changes to components or component configurations
After regulations had been place for years, LDAR compliance became routine.

Specialized LDAR contractors developed offering:

- Lower labor costs and benefits
- Expertise in LDAR
- “Turnkey” compliance, saying:
  - Your core competency is making chemicals or petroleum products
  - Ours is LDAR compliance
  - Leave your compliance in our hands
  - And many sites did

Contracts went to lowest bidder, putting pressure on technicians to increase productivity.
### Scotland Refinery – Early 1990s

<table>
<thead>
<tr>
<th>Service</th>
<th>Valve Leak Percent 10,000 ppm</th>
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</thead>
<tbody>
<tr>
<td>Gas/Vapor</td>
<td>6.9%</td>
</tr>
<tr>
<td>Light Liquid</td>
<td>5.5%</td>
</tr>
<tr>
<td>Heavy Liquid</td>
<td>0.1%</td>
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Petroleum Industry Fugitive Emissions Pre Consent Decree

http://www.epa.gov/enviro/facts/tri/search.html
Chemical Industry Fugitive Emissions
Pre & Post Consent Decree

http://www.epa.gov/enviro/facts/tri/search.html
New Basis for Non-Compliance

- Most fugitive equipment leak provisions are work practices (LDAR provisions such as frequency of monitoring, inspection method, leak definition, etc.)

- Violation of a work practice required seeing a failure or finding records that documented failure to follow the work practice

- Court case upheld EPA position that finding significantly higher leak percent was sufficient evidence of non-compliance with the work practice requirements

- EPA issued Enforcement Alert for LDAR in 1999
Consent Decree Years

Negotiated settlement of alleged violations.
Covers many environmental areas, including LDAR.

- Requires an audit every 1 to 2 years
- Lowers leak definitions as low as 250/1000 ppm
- Adds a minimization attempt at 100/200 ppm
- Requires extraordinary repair attempts
- Adds a calibration drift assessment
- Requires electronic data logging and management
- Requires QA/QC of monitoring data
- Some add requirements for low emission technology (Low E)
EPA started negotiating CDs for refineries that included enhanced LDAR programs (ELPs) starting around 2000.

- Currently have 32 CD settlements covering 109 refineries, well over 90% of the industry by capacity
- Several second round CDs have been issued

EPA started negotiating CDs for chemicals around 2009 and natural gas plants with some oil and gas production sites around 2013.
Improvements to LDAR

- Early years monitoring was a two-man team – one to operate the analyzer and one to record data on a clipboard.
- LeakTracker developed a cable connection between analyzers and a proprietary datalogger.
- Now Bluetooth™ wirelessly transmits readings from analyzer to most dataloggers.
- Newer analyzers can read higher concentrations (50,000 ppm).
- Some analyzers have LDAR-specific features, such as monitoring for a quick drop in flow rate indicating probe plugging or water pick up.
Facilities under CDs have achieved some significant improvements:

1. Valve average leak rates have been reduced:
   - 10.5% leaked at 10,000 ppm in mid-1970s
   - 5% leaked at 10,000 ppm in late 1990s
   - 1.4% leaked at 10,000 ppm in early 2000s
   - 1.1% leaked at 500 ppm over 2013 & 2014

2. Delay of Repair (DOR) components pre-CD often numbered in the hundreds to thousands and now under CDs from dozens to low hundreds.

3. Audit comparative monitoring shows significant improvement in agreement, indicating facility monitoring is more in line with Method 21 expectations.
Fig. 2 Capacity-Adjusted TRI Emissions for Valves and Pumps, lbs/1,000 BPY
Yet EPA continues to find problems with LDAR:

- CD follow-up audits have still shown some discrepancies in leak detection effectiveness
- EPA has made LDAR a national enforcement priority for more than a decade, and it will remain so until at least 2016
- Federal and state LDAR enforcement task force is communicating more issues among groups
- EPA has started to doubt whether facilities will ever be able to consistently conduct Method 21 in the manner that EPA intends
The Epiphany

- Just as EPA was doubting that Method 21 could ever be implemented as intended.
- Hovensa Refinery on St. Croix offered to allow their informal packing upgrade program to be formalized in their CD.
- Several packing manufacturers began to guarantee low emission performance.
- API 622 packing test protocol was published.
- Chevron began making presentations on their decade-long voluntary valve low emission packing program.

\[\text{Epiphany}\]
Epiphany - Challenges

Early companies negotiating CDs where EPA was trying to include low emissions (Low E) technology fought the provision:

- EPA was infringing on the core process technology when they try to specify which components to use.
- Processes are licensed and only a limited list of valves and packings are allowed.
- The Low E technology does not exist for all types of valves.
- The costs of employing Low E valves would be tremendous.
- The Low E alternatives might not be safe, reliable, or available in a timely manner, etc.
Commercial unavailability clause addressed many of the challenges to Low E.

Availability of reasonable cost Low E packing sets for the majority of gate and globe valves helps reduce the cost issues.

EPA dug in on this new paradigm and found a way to include Low E on all recent CDs:

- Instead of “Find ‘Em and Fix ‘Em”
- It became “Prevent Leaks by Design”
CD audits provide data on both historical site leak percent for valves and for audit comparative monitoring.

- Comparative monitoring data for the units audited can be used to adjust facility-wide valve leak percent to a “verifiable” basis.

- The best facilities we audit have facility wide verifiable valve leaks at 500 ppm under 0.2%.

- The top quartile of facilities has have facility wide verifiable valve leaks at 500 ppm under 0.7%.

- And most facilities are just getting started with formal Low E valve purchase specifications!
Epiphany – Better Installation

Valves with better fit and finish and better packing sets are a big step forward, but for great results we also need:

- Thorough inspection of valves to be repacked is necessary.

- Setting packing compression by torque rather than feel.

- Hot torque to offset relaxation of compression soon after a new or repacked valve reaches normal service temperature (especially for hot service).

- Use of “Live Loading” technology for control valves and others that experience frequent use and temperature fluctuations.

- Use of stud tensioners to set compression rather than just bolt torque.
Several of the Consent Decrees for chemical facilities have a Low E requirement for connectors.

- Must replace if connectors leaks during 2 of any 3 consecutive monitoring events.
- Connectors replaced for any other reason must also be Low E.
Determination of Low E is less explicit than for valves, typically including:

- Replace with a weld
- Replace with a better gasket
- Replace with a new connector that engineering judgment indicates is less likely to leak
- Replace with a new version of same type
Many different process situations make this a complex field to generalize about, but…

- Welding is the ultimate Low E connector.
- Raised face flanges (and variations) can generally provide a better seal than flat face flanges.
- Hydraulic tensioners are better than clicker torque wrenches which are better than air impact wrenches which are better than hand tightening without torque.
Use new studs and proper lubrication.

Spiral wound gaskets can provide very good sealing but should include both inner and outer shield rings.

Minimize threaded connectors by back-welding or replacement with LokRing™ “cold weld” connectors.
Relatively small number of facilities are now required to upgrade 10% of valves and an undetermined percentage of connectors at each turnaround.

Many facilities are voluntarily requiring Low E for valves and some for connectors.

The penetration rate will be slow, given unit run lengths of 5 years or more, but results will improve faster because leakers are replaced first (not just a random 10%).

Requirement to meet API 622/624 standards in basic valve standards (API 600, 602, 603, etc.) may eventually bring all industry into Low E.
API 622 and 624 tests have been critical to the adoption of Low E technology, but we still need:

- Quarter turn valve tests (in progress)
- Tests for non-packing seals (diaphragm, O-ring, etc.)
- Tests for gaskets
- David Reeves “Show me the data”

With additional tests to guide purchases, more and better products will be developed to meet the new demand for low leak equipment.
Future – Impact on Monitoring

As leak percent's dip to 0.1% and below,

- Technician would only find 1 leak per thousand or more components monitored.
- EPA will be more willing to allow use of performance based monitoring, where the lower the leak % the less frequent monitoring is required (HON style) and perhaps extending to once every 4 or 5 years for extremely low leak levels.
- Optical imaging leak detection will continue to become more sensitive, and it will likely be approved as an alternative to Method 21 for use in LDAR.
- This combination should provide much lower emissions at lower cost of control.
At the rate technology is evolving, LDAR may no longer be needed 20 years from now!

• Sealing products with leak frequency so low that they (like welds) are considered virtually “leak free”

• Individual leak detection devices on each potential leak source with alarms to notify a leak has started

• Area monitors that can pick up tiny increases in background concentrations and scan to pinpoint the area of a leak

• Totally enclosed process facilities with emissions so low that personnel exposure limits inside would be no issue
Conclusions

The last 4 decades have seen incredible changes:

• Starting with research, then Method 21, then rules.
• Instruments evolving plus new data logging & tools.
• A time of reassessment in the 1990s.
• A complex mix of regulations.
• Regulation through enforcement allowing a wider range of provisions to be imposed in less time than conventional rule promulgation.
• Vast reductions in emissions of VOC and HAP have already been achieved.
• Sealing technology is likely to be the ultimate answer.
The last 4 decades have seen incredible changes:

- Move to a more effective approach of design to prevent leaks.
- Development of tests for packing and valves (and hopefully more to come) to allow an informed purchase.
- Retain a “safety net” of some level of monitoring to detect the few leaks that occur, with appropriate reduction in frequency and adoption of newer technology with lower costs.
- Near leak free operation could realistically become the norm.