Selection of Commercially Available Portable Local Exhaust Ventilation to be Evaluated for Effectiveness in Controlling Worker Exposures to Welding Fumes in Construction

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INTRODUCTION

Welding is common in construction and is performed by several trades, including boilermakers, pipefitters, ironworkers, sheet metal workers and others. Overexposures to welding fumes among these trades are of concern due to various toxic constituents found in welding fume, including manganese which is neurotoxic and hexavalent chromium which is carcinogenic. Despite documented overexposure to toxic metals from welding fume, there are a number of factors that restrict the availability and adoption of exposure controls on construction sites (Meeker et al. 2007; 2010). As part of its research project entitled, "Adoption of Innovations to Minimize (AIMS) Exposure to Dust and Fumes in Construction, the Center for Construction Research and Training (CPWR) is seeking to 1) identify technologically feasible and effective engineering controls to reduce worker exposures, 2) enhance adoption of exposure controls on construction jobs by contractors, and 3) provide training to workers to make sure adopted controls are used correctly to optimize their effectiveness.

A central part of AIMS is the formation and use of **Partnerships for Advancing Control Technologies (PACTs) in Construction.** The welding PACT is co-facilitated by Dr. Robert Herrick, Harvard University, and Ms. Pam Susi, CPWR. The welding PACT consists of representatives from a cross-section of interests including construction contractors, government, equipment manufacturers/suppliers, labor representatives and academic researchers. In year one of the project (2010-2011), the Welding PACT identified and rated key criteria used in the selection of welding fume control technologies. In the current grant year (2011-2012), they will use those criteria to select 3 control technologies to be evaluated in years 2-4 of the project.

This report summarizes the results of an extensive search of commercially available, portable local exhaust ventilation (LEV) systems for welding fumes, conducted by Dr. John Meeker, University of Michigan. As a result of this search, up to 10 LEV units were selected as possible candidates for future detailed assessment of their exposure control effectiveness and usability. Important selection criteria identified by the PACT were used to determine which LEV systems would be included in this subset. This report is intended to provide the CPWR Welding PACT with the information they will need for selecting three LEV systems for further study.

Selection and performance of LEV systems may be influenced by a number of considerations. These include the type of welding to be performed (SMAW, MIG, TIG, other), the type of metal being welded (carbon steel, stainless steel, other), the exposure (e.g. total fume, hexavalent chromium, manganese, other) and exposure level of concern relative to health-based or legal Occupational Exposure Limits (OELs; e.g. ACGIH, NIOSH, OSHA). The nature and location of the majority of the welds to be made determine portability needs (shop vs. site, "bench/stand" vs. "position/field", tight enclosed spaces vs. open work area, etc.). In addition, the number of

welders in the immediate area may also determine the best LEV setup (e.g. single vacuum and single hood, single vacuum and multiple hoods, multiple vacuums and multiple hoods, etc).

Other factors which may influence selection of a specific LEV technology on a job site includes cost, weight and portability, durability and material of construction, maintenance needs, impact on productivity (e.g. costs and time associated with setting up, repositioning, replacing filters, etc.), visibility and quality of work, electrical power requirements, and other factors. While all these factors are important, LEV exposure control effectiveness should be the primary factor in the decision-making process. This report provides the available information on some of these factors related to commercially-available LEV systems for use by the PACT in their determination for which systems warrant further study.

METHODS

DATA GATHERING AND EVALUATION CRITERIA

The primary method for gathering information on commercially available LEV for welding was through internet searches. This was done by first browsing websites of major welding equipment manufacturers (e.g. Lincoln, Miller, Hobart, etc.), and then through a series of detailed and thorough keyword searches on Google. In some instances the manufacturer or vendor was contacted directly for additional information. Information of interest on available LEV units was tabulated into an Excel spreadsheet, and included the following (where available):

- Company/Vendor
- LEV Name/Model Part no.
- Dimensions
- Weight
- Cost
- Warranty information
- Horsepower
- Flow rate
- Capture velocity
- Power Requirements
- Power cord length
- Duct/arm/hose diameter
- Duct/arm/hose length
- Filter type
- Filter area
- Filter efficiency
- Filter cost
- Gauges and/or indicator light (e.g. dirty filter gauge or airflow gauge)
- Pulse cleaning
- Maintenance needs/frequency
- Hood shape(s) available
- Noise/Sound level
- Optional features
- Comments related to effectiveness and/or usability
- Website URL

LEV TYPES

Early on in the search it became apparent that LEV systems for welding fall into three major categories: 1) large centralized systems with multiple hood capabilities like those found in shops and training centers; 2) mobile units weighing several hundred pounds that are set on four caster wheels for moving around and are typically fit with one or two rigid, adjustable arms with conical hoods; and 3) smaller "high-vac" portable units that typically weigh less than 100 pounds and are equipped with flexible smaller-diameter hoses like those found on regular vacuum cleaners, many with several options on hood configurations to attach to the end of the hose. The initial data gathering focused only on the mobile and portable types, characteristics of which are described in more detail below. Larger centralized systems may in fact be preferable for some operations, such as power plant overhauls where many Boilermakers are welding simultaneously in tight spaces and in close proximity to one another. But given that these systems must be designed for a specific environment and job application, it may be difficult to evaluate in a controlled setting independent of a particular job. However, the PACT will consider these centralized systems and help identify opportunities to test their effectiveness if found desirable. The characteristics of what we describe as "mobile" or "portable" systems are listed below.

"Mobile"

- Design/size: On wheels, but large and heavy, not moved very easily without mechanical assistance unless used on flat, smooth, and relatively unobstructed surfaces.
- Weight: >100 to 700 lbs., typically 300-400 lbs.
- Duct: Rigid, adjustable arm
- Air flow: 700 to 4,000 cfm
- Duct diameter: 4" to 8"
- Cost: $2,000 to $8,000
- Filters: HEPA or lower efficiency; many have multi-stage filter systems

"Portable"

- Design/size: Small, able to lift and move around often as needed and may fit in smaller spaces
- Weight: 35 to 100 lbs.
- Duct: Flexible hose
- Air flow: 80 to 900 cfm
- Duct diameter: 1.5" to 6"
- Cost: $1,200 to $3,000
- Filters: HEPA or lower efficiency; some have multi-stage filter systems available

PACT MEETING AND SELECTION CRITERIA

On June 13, 2011 a meeting of the AIMS Welding Partnership for Advancing Control Technology (PACT) was convened in Chicago, IL to discuss their role in the project and solicit their input on LEV characteristics likely to influence their use and adoption. The PACT has representation from various stakeholder groups, including contractors, owners, welding trade unions, government, academia, and equipment manufacturers. Those present in Chicago ranked the following selection criteria as the most important:

Most Important Criteria:

- Portability
- Ease of Use
- Impact on Productivity

Other Factors Identified that are Also Important in Selection Process:

- Presence of filter, and type
- Minimum airflow: Ideally >100 CFM for small portable units and 250 CFM for larger mobile units
- Ability to produce additional health & safety hazards (e.g. noise)
- Ideally, manufacturer sells other welding equipment (e.g. Lincoln and Miller) due to their prominence in the market, welder familiarity with these companies, and existing relationships with contractors.
- Available for lease

RESULTS

Data was collected for 81 “Mobile” and 54 “Portable” units. Due to the importance of portability identified at the June 2011 PACT meeting, selection was primarily limited to those in the smaller and lighter “Portable” group. In addition, we have selected 3 larger, mobile systems, which appear at the end of the report. The “Portable” LEV units available that met the desired criteria for weight and other factors identified at the PACT meeting were further divided into three categories based on design and style: 1) “upright”, 2) “suitcase”, and 3) “other”. The “upright” style are typically about 2-3 feet tall and sit on 2-4 wheels for moving around, though at 50 lbs or less one should also be able to pick-up from time to time as needed. The “suitcase” style LEV units are about 1 foot tall and rectangular in shape (like a short suitcase), tend to be a little lighter, and are moved around solely by lifting with a handle on the top rather than wheels. These are typically advertised for intermittent welding tasks, but their exposure control effectiveness for either light intermittent or heavier production-type welding appears to be untested to date. The “other” category was included since a couple of LEV units that did not fall into either of the other categories were identified as possibly deserving further consideration based on one or more factors that may favor effectiveness and/or usability.

SELECTED LEV EQUIPMENT

The equipment below was selected for further consideration, with a brief justification and discussion of each. For a direct comparison of some of the technical aspects of these systems, refer to TABLE 1. Weights described in equipment summaries and in Table 1 are based on empty vacuums; total weight may vary somewhat depending on other factors such as the amount of particulate matter being collected and the frequency with which filters are cleaned or replaced. For a listing of companies that offer welding LEV systems that were not selected in this exercise, as well as links to their websites, see TABLE 2 (hit CTRL + click on the equipment name to link to the website). The selected systems are not presented in any particular order.

"UPRIGHT"

1. Lincoln Electric, Miniflex (cost $1,729)

The Lincoln Miniflex (38 lbs.) is advertised as a portable, high vacuum, low volume system specifically designed for the removal and filtration of welding fumes. It is listed as 38 lbs. and provides up to 135 cfm of airflow on its "high" setting. It has a 4-stage filtration system, with the last stage being a HEPA H12 filter. The on/off switch can be operated manually or set to automatically coincide with the welding machine operation. Several nozzle/hood types are available, and there is an optional wall-mounting bracket available if floor space is limited.

We evaluated the effectiveness of the Lincoln Miniflex to reduce worker exposures to manganese and hexavalent chromium in welding fumes in previous studies that included both experimental and field settings (Meeker et al. 2007; 2010). However, the unit was only field-tested on 1 job with 2 pipe-fitters. Additional data, particularly field data, may help us better understand its performance in a variety of settings. We would also gain some insight on factors that may influence usability and indentify potential barriers to adoption, along with possible ways to address those barriers.

2. Plymovent, PHV (cost N/A)

The Plymovent PHV (41 lbs.) looks identical to the Lincoln Miniflex and has the same technical specifications (TABLE 1). Though the cost was not available on the Plymovent website, it is likely similar to that of the Lincoln Miniflex. However, since Plymovent is a Dutch company its availability in the US would need to be determined; also, based on Plymovent's branding agreement with Lincoln and similarity to Miniflex only one of the two should be selected for further testing.

3. Miller, Filtair 130 (cost $1,937)

The Miller Filtair 130 is similar in size, weight (46 lbs.) and flow rate to the Lincoln Miniflex and Plymovent PHV. It is also similar in cost to the Lincoln Miniflex. Information on the type of filter system included was somewhat vague, the website and spec sheet just state, "Highest performing filter in the industry will last longer and capture the smallest submicron (<1 micrometer) particles. Miller's filter is manually cleanable and the unit features a fume collection tray to minimize maintenance". Hose can be connected to various magnetic nozzles/hoods or a fume extraction gun (for MIG welding) which are also offered by Miller. The Filtair appears to have smaller wheels compared to Lincoln and Plymovent, which may make it more difficult to maneuver.

4. Aero Filter Systems/TEKA, Handycart (cost N/A)

The Aero/TEKA Handycart is similar in appearance and technical specifications (shape, weight [50 lbs.], noise level, etc.) to the Miller Filtair 130. However, it is listed as having a substantially greater flow rate (190 cfm). This information needs to be interpreted somewhat cautiously because the methods and test conditions (e.g. hose, hood attached or not) could influence the flow rate reported. Another reason this system was selected is because it includes a digital reading for turbine speed and filter monitoring. It also has an option for automatic pneumatic hands-free filter cleaning. The filtration system on this unit also differs from the others listed above; it is a PTFE coated cartridge listed at >99% efficient. It is unclear how this differs from the 4-stage filter systems offered by Lincoln and Plymovent (or the Miller filter) with regards to performance and cost of replacement.

"SUITCASE"

5. Lincoln Electric, X-Tractor (cost $2,875)

In addition to the Miniflex, Lincoln also offers the X-Tractor which weighs slightly less (37 lbs.) and may be somewhat more portable. However, it offers a lower flow rate (115 cfm) and also costs about $1,000 more than the Miniflex. It is equipped with a cleanable high efficiency polyester filter, and has an internal and self-contained filter cleaning system that extends the life of the filter. Like the Miniflex, on/off switch can be automatic; also, the hose can be attached to a variety of available nozzles/hoods or a fume extraction gun.

6. Nederman, Fume Eliminator (cost N/A)

The Nederman Fume Eliminator is lightweight (35 lbs.) and looks like the other systems in this "suitcase" grouping. Airflow is listed as 88 cfm, which is lower than the other "suitcase" systems. However, it states that this is the flow rate when an 8-foot hose is attached. It comes with a disposable cellulose filter that is listed as being 99.7% efficient. It also has an optional auto start/stop option as is found on the Lincoln products, and, like the other products listed, the hose can be attached to a variety of available nozzles/hoods or a fume extraction gun. In addition to this small Fume Eliminator LEV system Nederman also offers the WeldFilter and the FilterCart Series, though at 160-180 lbs they exceeded our weight guideline for portability.

7. Trion, Air Boss One Man Portable (cost N/A)

The Trion Air Boss One Man Portable (45 lbs.) is also similar in appearance to the Lincoln X-tractor and Nederman Fume Eliminator. However, the advertised airflow is substantially higher (220 cfm). As mentioned above, it is difficult to compare flow rates between systems since the methods and test conditions may vary. The Air Boss includes a 35% ASHRAE prefilter and a HEPA main filter. It is also equipped with a light signal notifying the operator when the filters need to be replaced.

8. Enviroflex, Portable Welding Smoke Extractor (cost N/A)

The Enviroflex Portable Welding Smoke Extractor (43 lbs.) is similar in appearance to the Lincoln, Nederman, and Trion systems listed above. The flow is listed at 160 cfm for nozzle applications (as opposed to fume extraction gun applications listed at 210 cfm), and they offer a “Y” connector to enable use by more than one welder at a time. Several filter configurations available including a single washable filter or a dual filter system that includes a throwaway HEPA filter.

"OTHER"

9. Eurovac, Eurovac II Welding Portable (cost $1,575)

The Eurovac II Welding Portable was selected for further consideration due to its unique design; it includes a cyclonic pre-selector as well as a HEPA filter, where larger particles are removed before getting to the filters which can improve performance and reduce maintenance needs. This system is heavier than the other units listed here since it is 115 lbs.; however, it is likely lighter than common compressed gas cylinders used in welding and comes attached to a 2-wheeled hand cart (instead of on 4 caster wheels like the 300 + lb. "mobile" units) which may facilitate maneuverability. The unit has two take-offs for use with one or two hoses/hoods/welders at a time. The hose inner diameter is only 1½" (compared to most others which are 1¾") which may increase velocity and capture velocity, but potentially may also restrict flow and reduce the effective capture area; In addition, the hood shapes offered by Eurovac may not be optimal to minimize entry losses. The company offers three hood styles under the "High Vacuum Source Capture Welding Guns & Fume Attachments" page on their website. However, all three options are variations of slot-style designs, whereas a bell-shaped hood allows for the most efficient transition of air from the workspace into the duct. Thus, a higher volumetric airflow is achieved with the same degree of fan power compared to other hood designs. It is possible that the unit could be easily retrofitted with an alternative hood obtained from a different vendor.

10. Sentry, Dual Arm Fume Extractor (cost $2,311)

The Sentry Air Systems Dual Arm Fume Extractor was also included in this list due to its unique design that includes two take-offs as well as larger diameter ducts (4") that are rigid/adjustable and typically found only on the much heavier mobile LEV units. However, it is unclear how these features may impact performance. The larger diameter ducts that come with this system may provide added volumetric air flow, but could result in lower capture velocity. It is listed as providing 175 cfm per arm. It would be possible to cap one of the take-offs when only in use by a single welder which would provide a

higher flow rate to that single hood. In addition, it may be possible to replace the self-supported flex arms with 12-foot "python" flex hoses Sentry offers for harder-to-reach weld locations. Thus, this system may offer good flexibility in options for differing worksite characteristics. Several filter options are available, including a HEPA filter. Also, an optional magnehelic gage can be mounted to monitor flow. Finally, this was one of the few, if not the only, website to also offer some information and data on their equipment's ability to control worker exposures to welding fumes. However, data were not available on this particular model.

CONCLUSION

Ten portable LEV units for welding fumes have been selected for further consideration by the CPWR Welding PACT. Stakeholder input on the potential advantages and disadvantages of each of these units and a systematic selection and rating process will be used to choose three systems to be evaluated in years 2-4 of this project. In addition, guidance from the Welding PACT and industry stakeholders, as well as the information gleaned from this project, will be used in shaping strategies aimed at encouraging greater use of LEV for welding fumes in construction.

REFERENCES

Meeker JD, Susi PL, Flynn MR. Hexavalent chromium exposure and control in welding tasks with an emphasis on construction. *J Occup Environ Hyg*, 2010; 7(11):607-615. PMID: 20845207

Meeker JD, Susi P, Flynn MR. Manganese and welding fume exposure and control in construction. *J Occup Environ Hyg*, 2007;4(12):943-51. PMID: 17963139

Flynn, M.R.; Susi, P; *Local Exhaust Ventilation for the Control of Welding Fumes in the Construction Industry--A Literature Review.* Annals of Occupational Hygiene 2012; DOI: 10.1093/annhyg/mes018, March 2012

TABLE 1. COMPARISON OF SELECTED PORTABLE LEV UNITS FOR WELDING FUME

Design/Type	Company	Product Name	Weight	Airflow (listed)	Filter(s)	Hose diam	Hose length	Noise	Comments
"Upright"	Lincoln	Miniflex	38 lbs.	135 cfm	HEPA	1 ¾"	8 – 24 ft	<70 dBA	Automatic or manual on/off; We've evaluated the Miniflex in previous studies.
	Plymovent	PHV	41 lbs.	135 cfm	HEPA	1 ¾"	8 – 24 ft	70 dBA	Seems identical to Miniflex – same thing?
	Miller	FILTAIR 130	46 lbs.	132 cfm	See comments		8 – 34 ft	69 dBA @ 5 ft	"Highest performing filter in the industry will last longer and capture the smallest submicron (<1 micron) particles. Miller's filter is manually cleanable and the unit features a fume collection tray to minimize maintenance"
	Aero/TEKA	Handycart	50 lbs.	190 cfm	Cartridge, PTFE coated, >99% efficient	1 ¾"	8 – 33 ft	62 dBA	Digital interface; optional automatic pneumatic dusting module permits hands-free filter cleaning
"Suitcase"	Lincoln	X-TRACTOR 1GC	37 lbs.	115 cfm	High efficiency polyester	1 ¾"	8 – 45 ft	74 dBA	Cleanable filter. Automatic or manual start/stop; filter cleaning system; "best for 'light duty' welding operations"
	Nederman	Fume Eliminator	35 lbs.	88 cfm	Cellulose, 99.7% efficient	1 ¾"	8 – 50 ft	73 dBA	Disposable filter cartridge. 88 cfm is with 8-ft hose attached. Optional automatic start/stop and indicator for filter change
	Trion	Air Boss One Man Portable	45 lbs.	220 cfm	HEPA		10 ft	85 dBA @ 5 ft	Light signals when filters need to be replaced
	Enviroflex	Portable Welding Smoke Extractor	43 lbs.	160 cfm	HEPA	1 ¾"	15 - 50 ft		Model ESE 202A. Other models w/washable filter or lower power/flow rates also available
Other	Eurovac	Eurovac II Welding Portable	115 lbs	103 cfm	Cyclone + HEPA	1 ½"	25 ft +	"quiet"	Can accommodate 2 hoses/hoods; Cyclone preseparator may reduce maintenance in dusty work environments
	Sentry	Dual Arm Fume Extractor	55 lbs.	175 cfm per arm	HEPA	4"	4 – 20 ft	66 dBA	Optional magnehelic airflow gage; cap unused portal if only 1 welder; interchangeable flexible arms or hose

TABLE 2. ADDITIONAL COMPANIES IDENTIFIED THAT OFFER PORTABLE LEV FOR WELDING BUT WERE NOT SELECTED (Listed Alphabetically):

COMPANY	**WEBSITE**
Ace Industrial Products	http://www.aceindustrialproducts.com/portableextractors.html
AER Control Systems	http://www.aercontrolsystems.com/dustfume.htm
Air Impurities Removal Systems	http://www.airsystems-inc.com/product_981-air-cleaning-system.html
Air Quality Engineering	http://www.air-quality-eng.com/portable.php
Airsystems	http://www.airsystems.com/product_pages/environmental_control/portable_fume_extractor.htm
Clean Air America, Inc	http://www.clean-air.com/prod_Portable%20collector.php
Diversi-tech, Inc.	http://diversitech.ca/product-line/dust-smoke/fred-mini-vac.aspx
Donaldson Torit	http://www.donaldson.com/en/industrialair/fume/index.html
Electrocorp	http://www.electrocorp.net/welding_fume_extraction.php
Enviroflex	http://www.enviroflex.com/products.html
Fume Fighter	http://www.mist-dust-collection.com/fume-extraction/FumeFighter-soldering.htm
Fumex	http://fumeextraction.fumexinc.com/compare/all-categories/welding-fume-extraction
Hitec Engineering Co.	http://www.hitecengineering.com/fume_extraction_heavy_duty.htm
Horizon International	http://www.horizon-int.com/portable-fume-extraction.shtml
Industrial Maid	http://www.industrial-maid.com/portable&portabledowndrafts.htm
Kemper	http://www.kemperamerica.com/mini-weldmaster.html
LEV-Co	http://www.lev-co.com/products.asp?CatID=1&sCatID=119&SolutionID=6
Max MobilAir	http://www.texaselec.com/MaxMobilair/MaxMobilair.htm
Micro Air	http://www.microaironline.com/products/maportableprod.html
Oskar	http://www.oskarsales.com/pages/portable_collectors.html
Robovent	http://www.robovent.com/products/per4mer.html
TEKA	http://www.teka.me/teka/produktliste.html?parcat=1000000&cat=1000000
Tweco	http://www.brweldingsupplies.com/shop/products/tweco-smoke-master-fume-extractor-tsc-96-4500-1010.cfm
Vent-A-Kiln Corp.	http://www.ventafume.com/content/pages/pav-portable
Weller	http://www.wellerzerosmog.com/volume_extraction/index.cfm