U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES • Public Health Service
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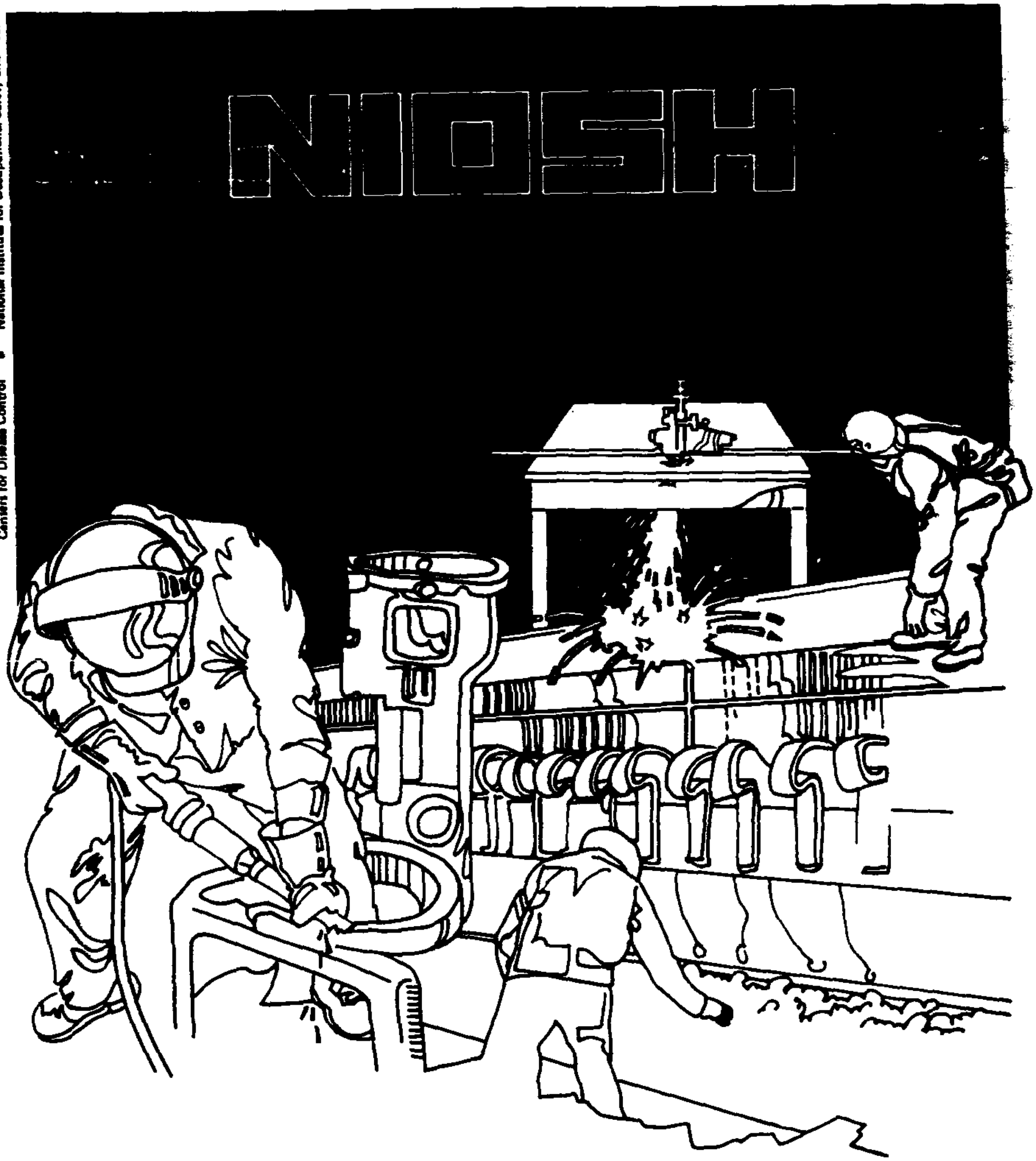

Health Hazard Evaluation Report

HETA 88-136-1945
MILLER THERMAL TECHNOLOGIES, INC.
APPLETON, WISCONSIN

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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MILLER THERMAL TECHNOLOGIES, INC.
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I. SUMMARY

On March 2-4, 1988 the National Institute for Occupational Safety and Health (NIOSH) conducted an investigation at the Miller Thermal Technology facility in Appleton, Wisconsin. This investigation was performed in response to a management request for evaluation of exposure to occupational hazards, particularly radiation emissions, to users of thermal arc spray systems.

Ultraviolet, infrared, and visible radiation exposure measurements were made of the thermal spray system under normal and simulated conditions using different operational parameters, wire types, air pressure, voltages, currents, and working distances from the target. The maximum measured levels of actinic and visible and infrared radiation levels were 22uW/cm^2 (effective), 16.7 cd/cm^2, and 170 uW/cm^2, respectively. These levels exceed the American Conference of Governmental Industrial Hygienists (ACGIH) guideline values. There are presently no applicable OSHA permissible exposure levels for optical radiation. NIOSH has developed exposure criteria only for ultraviolet radiation.

Octave band and weighted noise measurements were made on two different spraying machines and were found to represent A-weighted decibel values in excess of 101 during operation. NIOSH recommendations permit a one hour exposure time to noise levels of this magnitude. Selected environmental metal fume samples taken during the survey indicated that there is a potential for exposure to hazardous concentrations of nickel, chromium, and iron, thus pointing out a need to improve the effectiveness of the ventilation system currently in use.

These results suggest that under certain use conditions workers can be exposed to potentially hazardous optical radiation, excessive noise levels, and concentrations of several toxic metal fumes. Appropriate protective eye wear, respirators, and hearing protectors should be used. Recommendations are made for additional control measures and training to protect the worker.

KEYWORDS: SIC 3548 (Electric and Gas Welding and Soldering Equipment); optical radiation, thermal spraying, noise.

II. INTRODUCTION

On January 14, 1988, NIOSH received a request from the Miller Thermal Technologies, Inc. (MTT) to evaluate exposures of occupational hazards, particularly optical radiation, to workers who operate thermal arc spraying (TAS) systems. On March 2-4, 1988 NIOSH investigators made optical radiation, noise, and various environmental measurements under normal and simulated working conditions at the facility's TAS testing laboratory.

III. BACKGROUND

Thermal arc spraying is a method of applying metal and plastic coatings to nearly any substrate with no alteration to its structure. TAS can provide thermal barrier protection, changes in the electrical/mechanical properties of parts, improve appearance, as well as increase resistance to wear, oxidation, and corrosion. This particular investigation was limited to only evaluations of typically used metal wires, the majority being 14 gauge. The TAS equipment used to produce the spray particles (Miller Thermal model BP400 system) consisted of three major components: gun, feeder and power source. Figure 1 and 2 show the details of these components. The wire feeder carries two metallizing wires to the gun. The wires melt in the high heat zone created by the arc, and the molten particles are swept off at a high velocity by compressed air. Figure 3 shows the Miller model BP400 system. At the intersection point of the wires, an arc is formed which can produce ultraviolet, visible, and infrared radiation (hereinafter denoted optical radiation). The release of compressed air from the gun can produce high noise levels. Finally, the spray that is emitted from the gun can create a risk of elevated environmental levels of various metal fumes and powders. The parameters of voltage, amperage, and air pressure could be altered within certain settings. Voltage settings ranged from 14 to 38 volts, amperage from 70 to 450 amps, and pressure from 0 to 110 pounds per square inch.

TAS technology dates from the early 1950s, however the area is still experiencing steady and continued growth. While accurate estimates of the number of workers involved with the process are not available, discussions with experts in the field have suggested a total of about 5000 workers are directly involved with TAS. In general, most applications are performed at either many smaller machine shops having one or two workers performing TAS, or at a few larger machine shops where as many as 50 workers are involved with TAS. There are only a few manufacturers of TAS systems in the United States and the majority of these systems are produced for the metal applications.

IV. METHODS

Optical measurements were made in the test laboratory area of the MTT facility at Appleton using the system BP400 and a wide selection of wires. All measurements made on the thermal spray units were designed to characterize the typical occupational optical radiation levels that a worker would receive during a normal TAS activity. All results were obtained at a detector to gun distance of 1.0 meter. The spray was directed onto targets, located in a ventilated spray booth, as shown in Figure 4, positioned a few centimeters from the gun. Optical equipment used to measure the radiation produced by the thermal spray system was mounted on a board placed across two tripods, as shown in Figure 5, and angled at 55° from the vertical. This angle had been found to yield the optimum setting for measuring optical radiation in previous NIOSH studies (1). During the measurements all detectors were aimed toward the area immediately in front of the gun since this would be the nearest spot to the worker. Since the TAS operations produced extensive fumes and particles near the measurement area it was necessary to cover most of the optical detector systems with a plastic cover to minimize damage, except for the actual detecting element.

The following equipment was used to document levels of radiant energy produced by the various processes:

An EG&G model 555 spectroradiometer was used to measure the spectral irradiance in the wavelength from 200 to 800 nm. The unit of measurement is the watt per square centimeter per nanometer. The values obtained are summed to give the total irradiance in a particular optical region in units of watts per square centimeters. The spectroradiometer operated at a 10 nm bandpass with a ten degree field of view.

Luminance or brightness levels were measured with a Spectra Mini-Spot photometer having a one degree field of view. The values were obtained in terms of footlamberts (fL) which are converted to candela per square centimeter (cd/cm^2). The luminance of a source is a measure of its brightness when observed by an individual without eye protection, regardless of the distance from source.

An International Light model 730A radiometer with specially calibrated detectors was used to evaluate the ultraviolet radiation levels. One detector was designed to read the actinic UV radiation (200 to 315 nm) in biologically effective units of microwatt per square centimeter (uW/cm^2), while the other detector measured near UV (320-400 nm) in units of milliwatt per square centimeter (mW/cm^2) with no biologic weighting factor.

A Solar Light Sunburn meter was used to document the presence of any erythermal producing radiation in the 290 to 320 nm wavelength region. This meter reads in sunburn units per hour.

An Eppley model 901 calibrated thermopile with a quartz window was used to measure irradiance in units of milliwatts per square centimeters over the wavelength range from 200 to 4500 nm.

Every TAS event measured in this evaluation operated continuously for approximate 3-4 minutes. This length of time permitted all measurements to produce the maximum optical radiation output. This was necessary since the output from TAS varies with time. In addition to optical radiation levels, the voltage, current, type of metal, and pressure were also recorded for every test event. All optical radiation instruments used in this evaluation had been calibrated by their respective manufacturer within 12 months and were checked by NIOSH before and after field measurements for compliance with calibrations. In addition, photographs of the operating system during various measurement processes were taken with a 35 mm single lens reflex camera.

Area noise measurements were obtained with a GenRad Model 1982 Precision Sound Level Meter. This sound level meter has octave band measurement capabilities as well as the A, B, C, and "flat" weighting networks. Noise measurements were taken during the thermal spraying operation from a point in the center of the room, near the operators location. The sound level meter was calibrated before and after samples were taken according to manufacturers' instructions with traceable calibration sources from the National Bureau of Standards.

Full-shift area air samples to measure to amount of trace metals in the spraying fumes were collected during the day while the thermal spraying operation was in use. Three locations were chosen for sampling; one sample next to the ventilation hood, one sample on the wall next to the door, and one sample outside of the room and across an aisle from where the spraying took place. These locations were approximately 0.5 m, 3 m, and 5 m, respectively, from the TAS operations. As a result of a contaminant loading on the filter next to the ventilation hood, this filter cassette was changed three times during the sampling period.

Samples of the trace metals in the welding fumes were collected on 37 millimeter (mm), 0.8 mm pore size cellulose ester membrane filters connected to battery operated high volume air sampling pumps set at a 2.0 liter per minute (lpm) flow rate. A quantitative determination of the trace metals was made by inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to NIOSH Method 7300 (2). The filters were wet-ashed in concentrated nitric and perchloric acids. The residues were dissolved in a dilute solution of these same acids, and the resulting sample solutions were analyzed for trace metals by ICP-AES.

Additional samples were collected at the same locations for hexavalent chromium [Cr(VI)]. These samples were collected on 37 mm, 5.0 micron pore size polyvinyl chloride filters connected to air sampling pumps set at a 2.0 lpm flow rate. The sample filters were extracted in 5 milliliters (mL) of sodium hydroxide and sodium carbonate solution and transferred to 25 mL volumetric flasks. Color was developed by adding a sulfuric acid and diphenylcarbazide solution to the flasks. The samples were then diluted to a final volume of 25 mL with distilled water. The samples were analyzed for Cr(VI) by visible spectroscopy according to NIOSH Method 7600 (2).

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed without experiencing adverse health effects. It is, however, important to note that not all exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity situation.

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information about chemical and physical agents become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, 2) the ACGIH's Threshold Limit Values (TLV), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and the recommendations for reducing these levels found in the report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

At present there is limited information from OSHA on exposure criteria for workers exposed to physical agents. Criteria for physical agents come exclusively from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

A. OPTICAL RADIATION

1. Infrared Radiation (3-7)

All objects having temperatures above absolute zero emit infrared radiation (IR) as a function of temperature. In biological systems, the major insult of IR appears to occur as a result of a rise in temperature of the absorbing tissue.

The physical factors associated with temperature rise are the wavelength, heat conduction parameters, exposure time, and total amount of energy delivered to the exposed tissue. Since IR photons are low in energy, they would not be expected to enter into photochemical reactions with biological systems. Molecular interactions with radiation in the IR regions are characterized by various vibrational-rotational transitions resulting in an increase in thermal energy of the molecule.

Since the primary effect of IR on biological tissues is thermal, the skin provides its own warning mechanism by having a pain threshold below that of the burn threshold. However,there is no such adequate warning mechanism in the eye and hence additional protective equipment is often necessary. Traditionally, safety personnel consider IR to be a cataractogenic agent but recent literature (see References) has cast serious questions about the etiology of IR cataracts that could occur in the workplace from non-coherent optical sources.

Wavelengths of IR beyond 1400 nm can produce corneal and eyelid burns leading to the conditions of dry eye and skin. Figures 5 and 6 give a conceptual explanation of how near IR can produce such effects. The primary biological effect of IR on the retina and choroid is thermal in nature, with the amount of damage being proportional to the length of exposure. If the radiation intensity is low enough, however, the normal retina blood may be sufficient to dissipate any heat generated. Nevertheless, due to the focusing effect of the anterior ocular components, small amounts of IR can produce a relatively intense point energy distribution on the retina resulting in a lesion.

The present ACGIH TLV for infrared radiation is 10 mW/nm and is established to avoid possible delayed effects upon the lens of the eye (cataractogenesis).

2. Visible Radiation (3,6,8-11)

Visible radiation from either the sun or artificial sources is probably one of the more important occupational health considerations because of its major role in our daily life. When light levels are high at certain wavelength regions certain obvious retinal issues arise that require protective eye wear devices. These types of direct effect have been well known for many years and documentation exists within the scientific literature, i.e. staring at welding arcs or the sun.

Indirect effects of light, however, can occur-not-from absorption of light energy in tissues-but-from the action of chemical signals liberated by cells in the body. In many cases such indirect effects occur at much lower intensities than the direct effect. As a result such effects often are not considered a major occupational health hazard. Examples of this relationship of light to biological rhythms, include physical activity, sleep, food consumption, etc. Another well-known indirect effect is the inhibition of melatonin synthesis by the pineal gland, which in turn affects maturation and activity of the sex gland. Only within the last few years have investigators begun to discover the various subtle physiological and biochemical responses to light.

Another visible radiation issue that often arises is associated with poor room or task lighting conditions. Such conditions lead or cause aesthenopia (eye strain). Although the etiology of eye strain is debatable, it appears that repeated occurrences probably do not lead to any permanent eye damage. Workers over 40 years of age will probably encounter more symptoms of eye strain (headache, tired eyes, irritation) since they require more light to perform a similar job than younger workers.

The ACGIH TLVs for visible radiation exist to offer protection from retinal thermal injury and for photochemical injury that can occur from exposure to wavelengths in the region from 400-500 nanometers. The TLV is, at present, established at 1 candela per square centimeter (cd/cm^2).

3. <u>Ultraviolet Radiation</u> (3,6,9, 12-13)

Ultraviolet (UV) radiation is an invisible radiant energy produced naturally by the sun and artificially by arcs operating at high temperatures. Some of these sources are germicidal and blacklight lamps, carbon arcs, welding and cutting torches, electric arc furnaces, and various laboratory equipment.

Since the eyes and skin readily absorb UV radiation, these tissues are particularly vulnerable to injury. The severity of radiation injury depends on factors which include exposure time, intensity of the radiation source, distance from the source, wavelength, sensitivity of the individual, and presence of sensitizing agents.

Sunburn is a common example of the effect of UV radiation on the skin. Repeated UV exposure of lightly pigmented individuals may result in a dry, brown, inelastic, wrinkled skin (known as actinic skin). Actinic skin is not harmful in itself, but is a warning that conditions such as senile keratosis, squamous cell epithelioma, and basal cell epithelioma may develop.

Since UV is not visible, the worker may not be aware of the danger at the time of exposure. Absorption of the radiation by the mucous membranes of the eye and eyelids can cause conjunctivitis (commonly known as "welder's flash"). Lesions may also be formed on the cornea at high exposure levels (photokeratitis). Such injuries usually manifest themselves 6 to 12 hours after exposure. The injuries may be very painful and incapacitating, but impairment is usually temporary. Workers also need to be aware of the presence of certain photosensitizing agents that, upon contact with the skin, produce exaggerated sunburn when exposed to UV at certain wavelengths.

The threshold limit value for occupational exposure to ultraviolet radiation incident upon skin or eye where irradiance values are known and exposure time is controlled are as follows:

1. For the near ultraviolet spectral region (320 to 400nm) total irradiance incident upon the unprotected skin or eye should not exceed 1 mW/cm^2 for periods greater than 10^3 seconds (approximately 16 minutes) and for exposure times less than 10^3 seconds should not exceed one J/cm^2.

2. For the actinic ultraviolet spectral region (200-315 nm), radiant exposure incident upon the unprotected skin or eye should not exceed the values given in Table 1 within an 8-hour period.

3. To determine the effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), the following weighting formula should be used:

$$E_{eff} = \sum E_{\lambda} S_{\lambda} \Delta\lambda$$

   where:

   E_{eff} = effective irradiance relative to a monochromatic source at 270 nm in Wcm^2 ($J/s/cm^2$)
   E_{λ} = spectral irradiance in Wcm^2/nm
   S_{λ} = relative spectral effectiveness (unitless)
   $\Delta\lambda$ = band width in nanometers

4. Permissible exposure time in seconds for exposure to actinic ultraviolet radiation incident upon the unprotected skin or eye may be computed by dividing 0.003 Jcm^2 by E_{eff} in W/cm^2 or by using Table 2.

Table 3 shows the optical radiation exposure limits that are used by NIOSH to determine occupational insult. The levels shown are based on a 8-hour exposure level.

B. NOISE

Exposure to high levels of noise may cause temporary or permanent hearing loss. The extent of damage depends primarily upon the intensity of the noise and the duration of the exposure. There is abundant epidemiological and laboratory evidence (14-15) that protracted noise exposure above 90 dB(A) causes hearing loss in a portion of the exposed population.

The Occupational Safety and Health Administration's (OSHA) existing standard for occupational exposure to noise (29 CFR 1910.95) (16) specifies a maximum permissible exposure level (PEL) of 90 dB(A)-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard (17), and the American Conference of Governmental Industrial Hygienists (ACGIH), in its Threshold Limit Values (TLVs) (6), propose an exposure limit of 85 dB(A) for 8 hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average noise limits as a function of exposure duration are shown as follows:

Duration of Exposure	Sound Level (dB(A))	
(hrs/day)	NIOSH/ACGIH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115 *
1/8	115 *	-
		**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the time weighted average (TWA) exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. These stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o). When workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall also be implemented.

C. FUMES

The health effects associated with exposure to fumes produced by the TAS process are dependent on the toxicity of the individual component metals released to the air during the process. A list of the sampled substances included in this evaluation and their applicable environmental criteria are presented in Table 4, along with a brief description of their primary health effects. For those substances which were found to be in excess of their most stringent environmental criteria, the following discussion is presented.

1. Chromium (18-19)

Chromium compounds can act as allergens in some workers to cause dermatitis to exposed skin. Acute exposure to chromium dust and mist may cause irritation of the eyes, nose, and throat. Chromium exists in chromates in one of three valence states; 2+, 3+, and 6+. Chromium compounds in the 3+ valence state are of a low order of toxicity. In the 6+ valence state, chromium compounds are irritants and corrosive. This hexavalent form may be carcinogenic or non-carcinogenic depending on its solubility. The less soluble forms are carcinogenic. Workers in the chromate-producing industry have been reported to have an increased risk of lung cancer. The known health hazards from excessive exposure to chromium welding fumes are dermatitis, ulceration and perforation of the nasal septum, irritation of the mucous membranes of the larynx, pharynx, conjuctiva, and chronic asthmatic bronchitis.

2. Copper (18, 20)

Copper fumes occur in copper and brass foundries and smelters, and in welding copper-containing metals. The health effects associated with this type of exposure consist of irritation of the upper respiratory tract, a metallic or sweet taste in the mouth, nausea, and a flu-like illness called metal fume fever. The symptoms of metal fume fever include fever, muscle aches, nausea, chills, dry throat, cough, and weakness. Most workers develop an immunity to these attacks of metal fume fever, but it is quickly lost. Attacks will tend to be more severe on the first day of the workweek. Chronic exposure to copper fumes may cause the skin and hair to become discolored.

3. Iron oxide fume (18,21)

Inhalation of iron oxide fume or dust causes an apparently benign pneumoconiosis termed siderosis. Iron oxide alone does not cause fibrosis in the lungs of animals, and the same probably applies to humans. Exposures of six to ten years are usually considered necessary before changes recognizable by x-ray can occur; the retained dust in the lungs gives x-ray shadows that may be indistinguishable from fibrotic pneumoconiosis. In one reported study, eight of 25 welders exposed chiefly to iron oxide for an average of 18.7 years (range of 3 to 32 years) had reticulonodular shadows on chest x-rays consistent with siderosis. Their exposure levels ranged from 0.65 to 47 mg/M^3. In another study, 16 welders, with an average exposure time of 17.1 years (range of 7 to 30 years), also had x-rays suggesting siderosis. Their spirograms were normal; however, the static and functional compliance of the lungs were reduced. The welders with the lowest compliance complained of breathing difficulties. Some of the welders were smokers, also.

4. Nickel (18,22)

Nickel can exist in both soluble and insoluble forms. Epidemiologic evidence suggests that the hazard presented by insoluble nickel compounds is not as great as that presented by soluble forms. Nickel has been reported to cause "nickel itch", an allergic dermatitis. An increase in nasal, sinus, and lung cancer has been noted in workers employed in nickel refineries, although the specific carcinogenic agent is still not defined. Metallic nickel introduced into the pleural cavity, muscle tissue, and subcutaneous tissue has been shown to be carcinogenic in test animals. NIOSH considers inorganic nickel to be a carcinogen.

VI. RESULTS AND CONCLUSIONS

To determine if optical radiation exposure levels to TAS operators exceed accepted occupational exposure guidelines, several measurement approaches were performed. All data obtained in these measurement exercises were produced using a Miller model BP400 thermal arc spray system and appropriate metal wires.

The first measurement approach was to evaluate the levels of occupational infrared radiation produced using three common metal wires operated at various pressure, voltage, and current parameters. The second measurement approach determined the ultraviolet radiation produced in several wavelength regions by one type of wire at a constant voltage and current, varying only the pressure. Finally, the third measurement approach provided information on visible radiation levels and basic spectral characteristics.

Table 5 shows the levels of infrared radiation produced from 11 gauge aluminum, 14 gauge stainless steel 316, and 14 gauge carbon steel 1022 wires. These results demonstrate the following:

First, levels of infrared radiation as high as $51 mW/cm^2$ are produced during this type of process. This is a factor of 5 over the recommended ACGIH TLV.

Second, the level of optical radiation is related to the amperage, high levels being produced by higher currents. Since this was considered an important finding additional data was taken, shown in Figure 6, that further supports the relationship between optical radiation and amperage. Figure 6 shows the relationship between luminance levels as a function of pressure and current for a typical metal. At a given pressure setting, the difference in luminance levels is drastically affected by the current. It should be noted that at 100 psig the luminance was quite erratic at both the low and high ampere level. Figure 6 suggests that TAS operations which operate at higher currents can present more of a optical radiation concern than lower current operations.

Third, optical radiation levels vary with the type of wire used for spraying. The limited data shown in Table 5 suggests that levels are highest for stainless steel wire.

Fourth, while the voltage level is important for the process, it was observed that a 10-20% change in voltage setting did not have much impact on either infrared radiation or luminance levels. As a result of this finding, emphasis was not placed on recording voltage settings-other than to set it on a conventional operating setting (i.e. 30-40).

In the second measurement approach, 14 gauge #25 carbon steel was sprayed onto a metal target located 17.8 cm from the gun. The pressure setting was varied while the voltage and current settings were 30 volts and 300 amps, respectively. Table 6 shows the results obtained from this exercise. Again certain observations were apparent.

First, ultraviolet radiation in the wavelength region from 200-315 nm is present as indicated both by the International Light and Sun Burn meters. The duration of exposure per day that a unprotected TAS worker could withstand before exceeding the ACGIH threshold value corresponds to approximately 5 minutes. The maximum value of 2.5 sunburn units per hour suggest that a unprotected worker would start to observe a minimal erythermal dose in about 25 minutes.

Second, higher levels of IR radiation were measured than reported in Table 5. The highest level was 170 mW/cm^2 which is 17 times over the ACGIH TLV.

Third, at lower air pressure, total optical irradiance, as measured with the Eppley radiometer, is higher than at higher air pressure.

This observation is shown also by Figure 7. One explanation for the finding is probably that more of the spray plume particles under low pressure condition remain in close vicinity of the gun nozzle for a longer time. General support for this finding is also indicated in Table 5. However, from a operational issue, low pressure settings are probably not used as much as high pressure setting due to the spray quality factor. This spray quality factor is illustrated in Figures 8-10 and is important in determining the integrity of the finished product. The more erratic the spray the less desirable is the final product.

Fourth, observation of the data indicates the presence of very low levels of near UV radiation. The levels measured were much low that 100 uW/cm^2 regardless of operating parameters. This observation of low near UV radiation has also been shown in previous studies (1).

Table 7 shows the results obtained from the third set of measurements used to evaluate visible radiation levels. The luminance range extends from 0.3 to 16.7 cd/cm^2 under various operating parameters and wire types. Knowledge of luminance levels are important for determining optical density (O.D.) requirements for protective eyewear. Using the relationship:

$$\text{Shade Number} = 7/3\ (\text{O.D.}) + 1$$

one can determine an appropriate filter shade number that would offer protection for TAS personnel. When one calculates the optical density (O.D.) and uses the above equation for the highest luminance recorded, a maximum shade number of #4 is indicated. On the day of measurement, the same shade number filter was available to all workers. However, it must be noted that calculation of shade numbers must consider the task that the worker is involved with on a daily basis. For example, in these measurements it was assumed that the worker was standing behind the gun with the spray projected away from the worker. However, there could be situations where certain groups of workers could be viewing the spray under other configurations (i.e. looking directly into the gun nozzle). Hence calculations of shade numbers must consider the worker's task.

Time-intensity plots of optical radiation produced in selected TAS operations, Figure 11, clearly indicate that radiation levels vary with time. Figure 11 also shows that the start-up portion associated with TAS can emit considerably higher levels of optical radiation than at any other time. This finding can have considerable importance in the wearing of appropriate personal protective equipment and should be emphasized in training sessions with workers.

Most of the optical data was acquired at a detector to target distance of 1.0 meter. Since occupational levels of optical radiation, in most cases, exceeded applicable exposure limits for unprotected skin and eye, it would not be unexpected to have significantly higher exposures to workers at distances less than 1.0 meter (see as a example Figure 12). Part of this increased contribution of exposure will occur because of backscatter components when close to the target. It is because of these concerns that methods should be developed that permit TAS to be done safely at close distances that do not involve the presence of workers. In considering such methods approaches such as fully or semi-automated spraying techniques and robotic controls come to mind.

The potential optical radiation hazards may be evaluated by comparing the measured TAS levels with existing ACGIH occupational guidelines. This comparison, shown in Table 8, confirms that if a worker stands 1.0 m from TAS process for the entire workday, without any protective equipment, exposure will exceed all applicable optical radiation guidelines, except for near ultraviolet. This then suggests that to work in the general work area of TAS operations control measures such as goggles, protective clothing, UV-blocking compounds, etc. will have to be utilized.

A field test performed during this evaluation involved the placement of transparent welding curtains to contain the optical radiation produced during the TAS operations. In particular, it was observed that both a orange- and yellow-tinted transparent curtain were effective in minimizing the optical radiation emission. This fact has been reported before in both radiation curing (23) and welding (24) operations. In addition to optical radiation shielding such curtains could restrict the spread of fumes and sprays, as well as attenuate some of the noise produced in TAS operations. Since such transparent barriers are readily available, easily cleaned, inexpensive, and easy to install they might be a useful and effective control measure for certain TAS operations.

The sound levels obtained during the TAS operation are summarized in Table 9. Octave band measurements were taken on 10 of the 12 spraying events. The median dB(A) value of these 10 events was 110 dB(A). This median value, when compared to the evaluation criteria presented earlier, represents a 0.25-hour maximum exposure time according to the NIOSH/ACGIH criteria or a 0.5-hour exposure period when using the OSHA regulation. Closer examination of the individual octave bands reveal that the TAS operation is characterized as being a high frequency noise operation. The sound levels are greatest in the 2000 and 4000 Hz octave bands. This is probably due to the sounds produced by the compressed air being released to expel the melted wire droplets onto the target. Table 10 shows a 3 dB increase in sound as a function of increasing the air pressure from 20 psig to 100 psig. The same effect occurs at both the 100 amp setting and the 250 amp setting.

It is also interesting to note that the ventilation system used by MTT presents a noise hazard to the employees. The overall level in the test room was 90 dB(A) with only one hood of the ventilation system in operation. This noise is low frequency in nature (63-500 Hz) which suggests that this noise is being produced by the fans, motors, and air movement of the ventilation system. When one views the median octave band levels of Table 9, which really represents the condition of TAS plus ventilation system, the lower frequencies (< 500 Hz) are the result of the ventilation system and the higher frequencies are from the compressed air noise.

Due to the nature of the operations on the day of measurements, some of the environmental results obtained in this survey were collected under conditions not typical of normal TAS operations at MTT. It must be noted that these samples were collected at stationary locations and do not represent personal breathing zone samples. However, the results do indicate the potential for exposure to several toxic elements. The results of the trace elements analysis (Table 11) are representative of full shift samples for the "daily total" and the two "shelf" categories. For these three TWA samples, it was found that at least one of the three evaluation criteria were exceeded for total chromium, hexavalent chromium, copper, iron, and nickel. The OSHA ceiling limit of 5.0 mg/m^3 for manganese was also exceeded during the measurements of events #1 - #4 at the ventilation hood. The grouping of the smaller number of events for analysis reveals which elements are more likely to be in the plume when certain types of metals are being sprayed. Events #1-#4 were generally types of stainless steel. The elemental analysis of the ventilation hood sample showed that relatively more chromium, iron, manganese, molybdenum, and nickel were released during these spraying operations. Events #5-#9, on the other hand, contained bronze and alcro wires (combination of aluminum, chromium, and iron). For this sampling period, the amounts of aluminum, copper, and zinc were increased while still showing measurable amounts of chromium and iron. The ICP-AES analysis used for this survey can be viewed as a general indicator of what elements are present in the collected air sample. Other analytical methods are more specific as to the character of the compound being examined. The toxicity data for several of the trace elements found in the air samples are dependent on the valence of the material, its solubility, and whether the compound is organic or inorganic. This survey points to the need for further analysis on particular elements (e.g. hexavalent chromium) for employers who plan on using TAS technique with a particular set of wire or wires.

The company provided the employees with 3M model 9925 welding fume respirators for personal protective equipment. This particular brand of respirator has NIOSH/MSHA approval (approval number TC-21C-348) for dust, fume, and mist. During the survey period, most employees were observed not wearing the equipment. The respirators were seen lying on tables outside of the plastic bags in which the respirators came from the company. No written respiratory policy/was available. Additionally, it was observed that the company also provided the workers different types of hearing protection devices, but their use was only sporadic.

Visual inspection of the two ventilation hoods revealed that the systems were not operating at optimum efficiency. Both ventilation systems are water cascade systems which direct the captured contaminated air through a water curtain and out of the buildings through a roof duct. The roof ducts were partially clogged with materials (probably due to the action of the thermal spray with the ventilation system), drastically reducing the area of airflow. Also the only provision for make-up air to the testing room (without opening the entry door) was through a vent cut in the wall of the room located directly above a small heating plate where solvents were being used in other operations.

VII. RECOMMENDATIONS

The following recommendations are offered as methods to further reduce occupational exposure at MTT based on observations made on the days of measurement:

1. A pair of impact goggles with an optical density value of at least 4 should be worn. The actual shade number value would depend on the level of optical radiation being produced and the work task.

2. The door leading into the TAS area should be posted with a warning sign and/or interlocked to further reduce inadvertent exposure to occupational hazards during TAS operations. Another alternative would be the use of transparent welding curtains as a method to confine optical radiation, noise, and spray particles produced in and around this area. References 23 and 24 discuss in detail the advantages of such barriers.

3. Those workers who are in close proximity to the TAS operation, should consider using gloves and tight woven protective clothing having a tightweave in order to minimize skin exposure from the ultraviolet radiation.

4. It was observed that all TAS units at MTT contained a Miller warning label shown in Figure 13. It is recommended that the wording that refers to "arc welding" be changed to reflect "TAS"

operations. The wording "optical radiation produced by TAS can damage eye and skin" should be used. Perhaps the warning label should also refer to the potential for production of metal powder during the TAS process.

5. Single use (disposal) respirators should not be used by employees engaged in any of the spraying operations. These respirators should be replaced by half-mask or full-face respirators with high efficiency particulate filter canisters which offer a higher degree of personal protection. If any of the elements which are suspected carcinogens (e.g. chromium [VI] or nickel) are measured above the NIOSH REL's for that compound (See Table 4), then self-contained breathing apparatus with full-facepiece, operated in a positive pressure mode are required until such time as engineering controls are implemented to reduce employee exposures below the NIOSH REL.

6. A respiratory policy must be formulated by the employer with written standard operating procedures governing the selection and use of respirators. This policy shall meet the requirements set forth in the Department of Labor's regulation for respiratory protection (29 CFR 1910.134) (16).

7. Full-shift breathing zone air samples should be periodically made for employees who work in TAS area to assess the worker's exposure due to the potential for exposure to regulated agents.

8. Because of the high noise levels recorded during the TAS operations, a hearing conservation program which meets OSHA's hearing conservation amendment (29 CFR 1910.95, paragraph (c) to (o)) must be implemented. This program must include audiometric testing, noise monitoring, hearing protection devices, training, and recordkeeping.

9. Noise from high pressure air movement through restricted areas has been reduced through the use of special air nozzles in other industrial situations. Perhaps this approach could be used in TAS operations to reduce the high noise levels produced by the spraying of molten metal with compressed air. It may prove helpful to employ the services of a noise engineer who is familiar with noise reduction techniques.

10. The ventilation systems that operate in the TAS area must be thoroughly cleaned and serviced to return them to their optimal operating efficiency. A routine service and maintenance program must also be implemented to insure that the systems do not become clogged or sealed in the future.

11. A fire extinguisher with a multiple class extinguishment rating should be installed in a convenient location in the room where the TAS operations occur.

12. The electrical connectors mounted on the ventilation hood should be covered to reduce the potential for electrical shock.

13. The ladder leading to the roof should be permanently mounted to eliminate the fall potential that existed on the day on visit.

14. The portable eye wash station located behind the wire storage rack should be moved to a more accessible position. The eye wash station should be replaced with a permanent station which supplies the copious amount of water necessary to flush the eyes upon exposure to chemicals or particles.

VIII. REFERENCES

1. Moss, C. E. and Murray, W. E. Radiation levels produced in gas welding, torch brazing, and oxygen cutting. Welding Journal 58(9):37-42, 1979.

2. National Institute for Occupational Safety and Health. NIOSH manual of analytical methods. 3rd ed. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977 (DHHS publication no. (NIOSH) 84-100).

3. Occupational Diseases: A Guide to Their Recognition, USPHS, CDC, NIOSH Publication #77-181, Revised June 1977.

4. Infrared Radiation, in Manual on Health Aspects of Exposure to Nonionizing Radiation by Moss, C. E. (et.al) World Health Organization, Regional Office, Copenhagen, Denmark, 1980.

5. Determination of Ocular Threshold Levels for Infrared Radiation Cataractogenesis, by Pitts, D. G. (et.al.) NIOSH Publication #80-121, June 1980.

6. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values (TLV) for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1987.

7. Moss, C. E., et. al. Biological Effects of Infrared Radiation, NIOSH Publication #82-109, September 1982.

8. Moss, C. E. Radiation hazards associated with visible radiation curing processes. Radiation Curing 9(3):24-28, 1982

9. Optical Radiation and Visual Health , edited by Waxler, M. and Hichins, V. M., CRC Publications, Inc. Boca Raton, Florida 1986.

10. IES Lighting Handbook, Reference Volume, edited by Kaufman, J. E., Illuminating Engineering Society of North America, New York, N.Y., 1981.

11. Safety with Lasers and other Optical Sources by Sliney, D. H. and Wolbarsht, M., Plenum Press, ew York, N. Y., 1980.

12. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to ultraviolet radiation. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1973. DHEW (NIOSH) publication 73-11009.

13. Roofing asphalts, pitch, and UVL carcinogenesis. NIOSH Contract 210-78-0035, 116 pages, 1978. Available from NTIS as No. PB-83-134-767/A06.

14. Kryter, K.D. The effects of noise on man. New York and London: Academic Press, 1970.

15. Berger, E.H., Ward, W.D., Morrill, J.C., and Royster, L.H. (Editors) Noise and hearing conservation manual (Fourth Edition). Akron, Ohio: American Industrial Hygiene Association, 1986.

16. Occupational Safety and Health Administration (OSHA). Code of Federal Regulations, Labor, 29, Parts 1900 to 19190, revised as of July 1, 1985.

17. National Institute for Occupational Safety and Health. Criteria for a recommended standard. Occupational exposure to noise. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1973. (DHEW publication no. (NIOSH) 73-11001).

18. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values and Biological Exposure Indices. Fifth Edition. Cincinnati, Ohio: ACGIH, 1986.

19. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to chromium VI. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976 (DHHS publication no. (NIOSH) 76-129).

20. National Institute for Occupational Safety and Health. NIOSH/OSHA occupational health guidelines for chemical hazards. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981. (DHHS (NIOSH) publication no. 81-123).

21. Proctor, NH and Hughes, JP. Chemical hazards of the workplace. Philadelphia: J.B. Lippencott Co., 1978.

22. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to inorganic nickel. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977 (DHHS publication no. (NIOSH) 77-164).

23. Wilson, D.S. and Wilson, D. R. Protective curtain for radiation curing Radiation Curing 10(2):35-39, 1983.

24. Sliney, D. H., Moss, C. E., Miller, C. G., and Stephens, J. P. Semitransparent Curtains for Control of optical radiation hazards. Applied Optics 20(14):2352-2361, 1981.

25. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to zinc oxide. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1976 (DHHS publication no. (NIOSH) 76-104).

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

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Copies of this report are currently available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Miller Thermal Technologies, Inc.
2. NIOSH, Cincinnati Office
3. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1

Relative Spectrial Effectiveness by Wavelength

Wavelength (nm)	TLV mJ/cm^2	Relative Spectral Effectiveness S
200	100	0.03
210	40	0.075
220	25	0.12
230	16	0.19
240	10	0.30
250	7.0	0.43
254	6.0	0.5
260	4.6	0.65
270	3.0	1.0
280	3.4	0.88
290	4.7	0.64
300	10	0.30
305	50	0.06
310	200	0.015
315	1000	0.003

Table 2

Permissible Ultraviolet Exposures

Duration of Exposure Per Day	Effective Irradiance, E_{eff} (uW/cm^2)
8 hrs	0.1
4 hr	0.2
2 hrs	0.4
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5
5 min	10
1 min	50
30 sec	100
10 sec	300
1 sec	3,000
0.5 sec	6,000
0.1 sec	30,000

TABLE 3

Optical Radiation Evaluation Criteria
and Health Effects Summary

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Physical Agent	Evaluation Criteria* NIOSH REL	OSHA PEL	ACGIH TLV	Primary Health Effects
Ultraviolet (200-315 nm)	0.1 eff uW/cm^2	-	0.1 eff uW/cm^2	photokeratitis and erythema
(315-400 nm)	10 mWcm^2	-	1 mW/cm^2	erythema
Visible (400-760 nm)	-	-	1.0 cd/cm^2	retinal burns
Infrared (760 nm-1.0 nm)	-	-	10 mn/cm^2	cataractogenesis

*Values represent 8-hour exposure, but higher exposures are permitted shorter time intervals.

TABLE 4

Evaluation Criteria and Health Effects Summary

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Substance	Evaluation Criteria[1] (mg/m³) NIOSH REL	OSHA PEL	ACGIH TLV	Primary Health Effects	References
Chromium (VI) (insoluble)	0.001	1.0	0.05	Lung cancer, dermatitis, irritation of nose, eyes, and throat.	3,5,b,c
Cobalt metal, fume, and dust	-	0.1	0.05	Cobalt exposure has been associated with allergic dermatitis and irritation of the nose and throat. It also has a potential for pulmonary fibrosis.	3,5,b,d
Copper Fume	-	0.1	0.2	Copper fume causes irritation of eyes, nose and throat. Also is associated with metal fume fever.	3,5,b,d
Iron Oxide Fume	-	10.0	5.0	Siderosis; a benign pneumoconiosis associated with inhalation of a particulate.	3,5,a,b
Manganese fume (as Mn)	-	5.0 (C)	1.0 (3.0 STEL)	Central nervous system effects; metal fume fever.	3,5,a

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TABLE 4 (continued)

Evaluation Criteria and Health Effects Summary

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Substance	Evaluation Criteria[1] (mg/m³) NIOSH REL	OSHA PEL	ACGIH TLV	Primary Health Effects	References
Molybdenum (insoluble)	-	15.0	10.0	Fume from arcing molybdenum causes respiratory irritation and liver damage in animals.	3,5,d
Nickel, inorganic	0.015	1.0	1.0	Lung and nasal cancer; respiratory irritant; allergic dermatitis.	3,5,b,d
Phosphorus (yellow)	-	0.1	0.1	Yellow phosphorus fume causes irritation of the respiratory tract and eyes.	3,5,d
Tin, inorganic	-	2.0	2.0	May cause irritation of the eyes, nose, throat, and skin.	3,5,d
Zinc Oxide Fume	5.0 (15.0 STEL)	5.0	5.0 (10.0 STEL)	Metal fume fever.	3,5,d,g

1. Values are in milligrams per cubic meter of air (mg/m^3) and represent time-weighted average (TWA) exposure limits for up to a 10-hour workday.

(C) Ceiling limit; exposure shall not exceed this concentration.

(STEL) Short Term Exposure Limit: a 15-minute TWA exposure which should not be exceeded during the workday.

TABLE 5

First set of optical radiation measurements. Detector-gun distance is 1.0 m; gun-target distance is 46 cm.

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88 - 136
March 3, 1988

TEST NO.	WIRE TYPE	AIR PRESSURE (PSIG)	CURRENT (A)	1R (mW/cm^2)	LUMINANCE (cd/cm^2)
1	Aluminum	110	200	3.0	1.0
2	Aluminum	110	380	3.5	1.0
3	Aluminum	55	380	5.5	1.0
4	Aluminum	55	300	13.3	1.7
5	Aluminum	110	300	7.4	0.7
6	S. Steel	110	300	-	6.7
7	S. Steel	110	300	-	6.7
8	S. Steel	110	58	3.5	0.7
9	S. Steel	110	330	51.0	6.7
10	S. Steel	55	330	38.0	6.7
11	C. Steel	110	310	-	3.3
12	C. Steel	110	400	-	1.7

TABLE 6

Second set of optical radiation measurement. TAS system set at 300 Amperes, 30 Volts with carbon steel as metal type. Detector-gun distance is 1.0 m and gun-target distance is 17.8 cm.

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

TEST NUMBER	AIR PRESSURE (PSIG)	IR (mW/cm^2)	SBM (SBU)	I.L.-FAR (eff. uW/cm^2)
13	20	121	0.8	10
14	40	170	0.8	10
15	60	66	1.3	15
16	80	38	2.5	22
17	100	31	1.3	10

TABLE 7

Third set of optical radiation measurements. Luminance levels as a function of wire types, pressure, and current settings. Detector-gun distance is 1.0 m; gun-target distance is 71 cm.

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

EVENT NO.	WIRE TYPE	AIR PRESSURE (PSIG)	CURRENT (A)	LUMINANCE (CD/M^2)
1*	Carbon Steel 20	110	250	3.3
2*	Stainless Steel	60	250	16.7
3*	" "	60	250	10.
4*	" "	100	350	10.
5.	Alcro	60	250	6.7
6.	"	100	300	13.3
7.	Tobin Bronze	60	250	0.3
8.	A. I. Bronze	60	250	3.3
9.	" "	60	250	-
10.	Mogul-580/T. Bronze	60	250	1.0
11.	Mogul	60	250	1.7
12.	Stainless Steel	60	250	3.3

* originally the gun-target distance was 13 cm. but the close distance caused the target to be destroyed so the distance was changed to 71 cm for event 5.

TABLE 8

Comparison of maximum TAS radiation levels at 1.0 m with optical radiation occupational exposure limits.

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Optical Indicator	Maximum measured value	Occupational exposure limit
Actinic UVR (200-315 nm)	22. eff uW/cm^2	0.1 eff uW/cm^2 in 8-hour day.
Near UVR (320-400 nm)	<0.1 mW/cm^2	1.0 mW/cm^2 for time periods > 16 minutes.
Luminance (400-760 nm)	16.7 cd/cm^2	1.0 cd/cm^2 in 8-hour day.
Infrared Radiation (760 - 1400 nm)	170 mW/cm^2	10 mW/cm^2 in 8-hour day.

TABLE 9

Results of Area Octave Band and Overall Sound Level Measurements

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Sound Measurement Condition*	A**	C***	Octave Band Center Frequencies: Hertz (Hz)									
			31	63	125	250	500	1000	2000	4000	8000	16000
Spray Operation: (number = 10)****												
Median	110	109	78	84	90	91	89	97	105.5	106.5	102.5	98.5
High Range	119	117	82	87	91	93	93	106	114	114	105	101
Low Range	107	106	76	82	89	90	86	92	101	103	100	96
Ventilation Hoods Only	90	95	80	85	90	90	85	82	74	77	85	89

* Values are instantaneous levels in decibels (re. 20 micro Pascals [uPa]) with the sound level meter in the slow weighted position.

** Values are the overall sound pressure level on the A-weighted network. The A-weighting mimics the human ear at threshold by emphasizing the mid-range frequencies and deemphasizing the low and high frequencies.

*** Values are the overall sound pressure level on the C-weighted network. The C-weighting allows all sounds to be combined with relatively little weighting correction.

**** Octave band analyses were conducted on only 10 of the 12 different events or welding wire combinations.

TABLE 10

Noise Levels as a Function of Arc Amperage and Air Pressure

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

Air Pressure (psig)	100 amps	250 amps
20	103.4*	105.6
40	104.6	106.3
60	105.5	107.3
80	105.4	107.9
100	105.9	108.8

* Values are in overall decibels, a-weighted, slow scale (dB[A]).

TABLE 11

Area Air Sample Results for Welding Fumes

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136
March 3, 1988

			Environmental Concentration (mg/M^3)					
Location	Sampling Duration	Sample Volume (Liters)	Aluminum	Cobalt	Total Chromium	Hexavalent Chromium	Copper	Iron
Face of Ventilation Hood Event #1 - #4	0832-1006	190	0.17	0.02	2.22	0.34	0.55	22.10
Event #5 - #9	1009-1356	462	2.77	Trace	1.75	0.12	0.98	4.22
Event #10-#12	1400-1602	246	0.02	ND	1.63	0.18	0.40	11.34
Daily Total	0832-1602	898	1.47	Trace	1.82	0.18	0.73	9.96
Shelf; next to door, inside room	0832-1603	912	1.18	ND	0.22	0.03	0.31	1.57
Shelf; across aisle, outside room	0832-1601	908	0.01	ND	Trace	Trace	Trace	0.03
Environmental Criteria		NIOSH REL	-	-	-	0.001	-	-
		OSHA PEL	-	0.1	1.0	1.0	0.1	10.0
		ACGIH TLV	5.0	0.05	0.5	0.05	0.2	5.0

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TABLE 11 (continued)

Area Air Sample Results for Welding Fumes

Miller Thermal Technologies, Inc.
Appleton, Wisconsin
HETA 88-136

March 3, 1988

Location	Sampling Duration	Sample Volume (Liters)	Environmental Concentration (mg/M^3)					
			Manganese	Molybdenum	Nickel	Phosphorus	Tin	Zinc
Face of Ventilation Hood Event #1 - #4	0832-1006	190	1.96	0.45	1.68	0.04	0.03	0.01
Event #5 - #9	1009-1356	462	0.04	0.01	0.03	0.02	0.02	0.16
Event #10-#12	1400-1602	246	0.29	ND	0.04	0.02	0.01	0.43
Daily Total	0832-1602	898	0.52	0.10	0.38	0.03	0.02	0.20
Shelf; next to door, inside room	0832-1603	912	0.08	0.01	0.04	0.01	0.01	0.07
Shelf; across aisle, outside room	0832-1601	908	Trace	ND	Trace	ND	Trace	Trace
Environmental Criteria		NIOSH REL	-	-	0.015	-	-	5.0
		OSHA PEL	5.0 (C)	15.0	1.0	0.1	2.0	5.0
		ACGIH TLV	1.0	10.0	1.0	0.1	2.0	5.0

Trace - Less than 0.01 mg/M^3 for this sample set.
ND - Not Detected: Less than 0.001 mg/M^3 for this sample set.

The following elements were analyzed for in the method but not detected on any sample: antimony, arsenic, barium, beryllium, cadmium, calcium, lead, lanthanum, lithimm, magnesium, sodium, platinum, selenium, silver, strontium, tellurium, thallium, titanium, vanadium, yttrium, and zirconium.

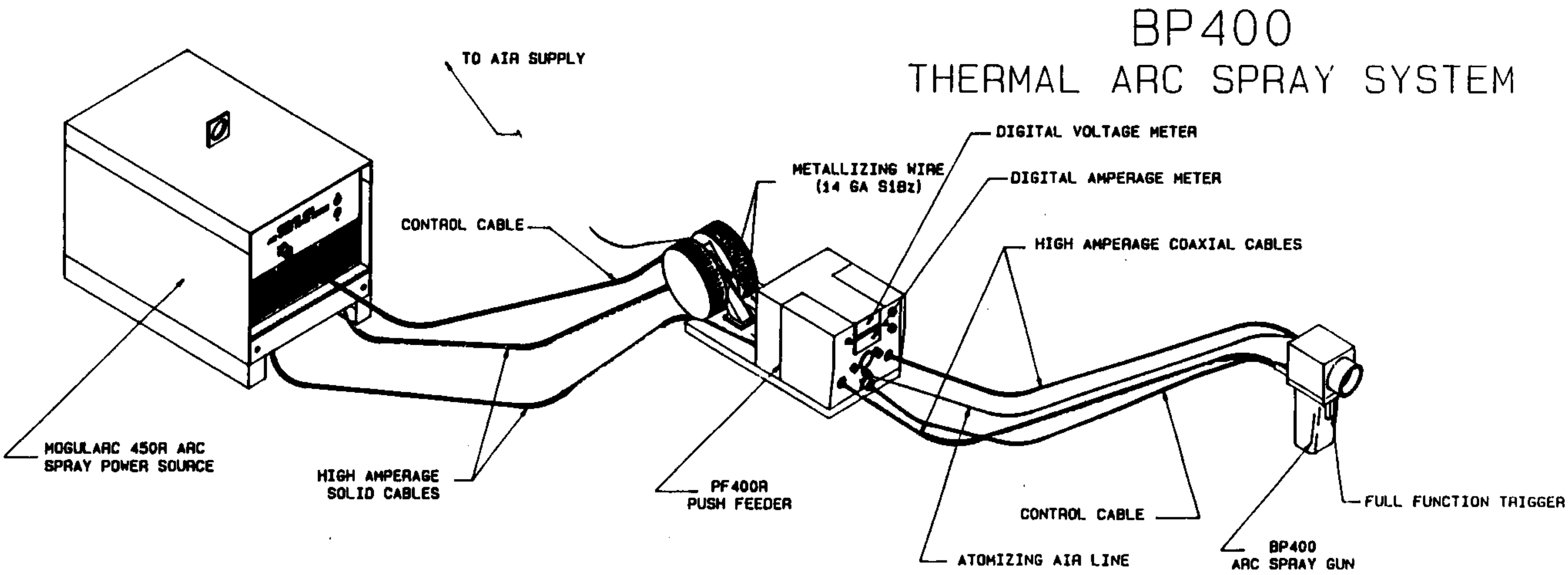

Figure 1. Miller model BP400 thermal arc spray system.

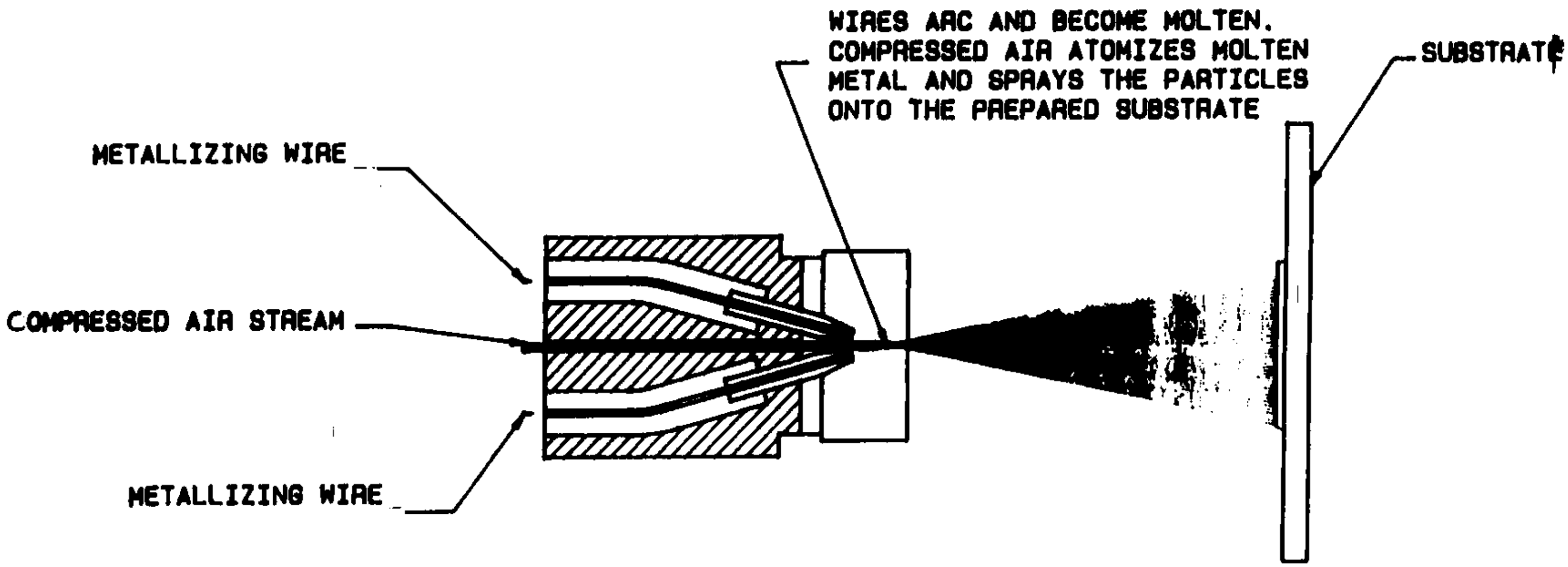

Figure 2. Gun details of model BP400 TAS system.

Figure 3. Photograph of model BP400 TAS system.

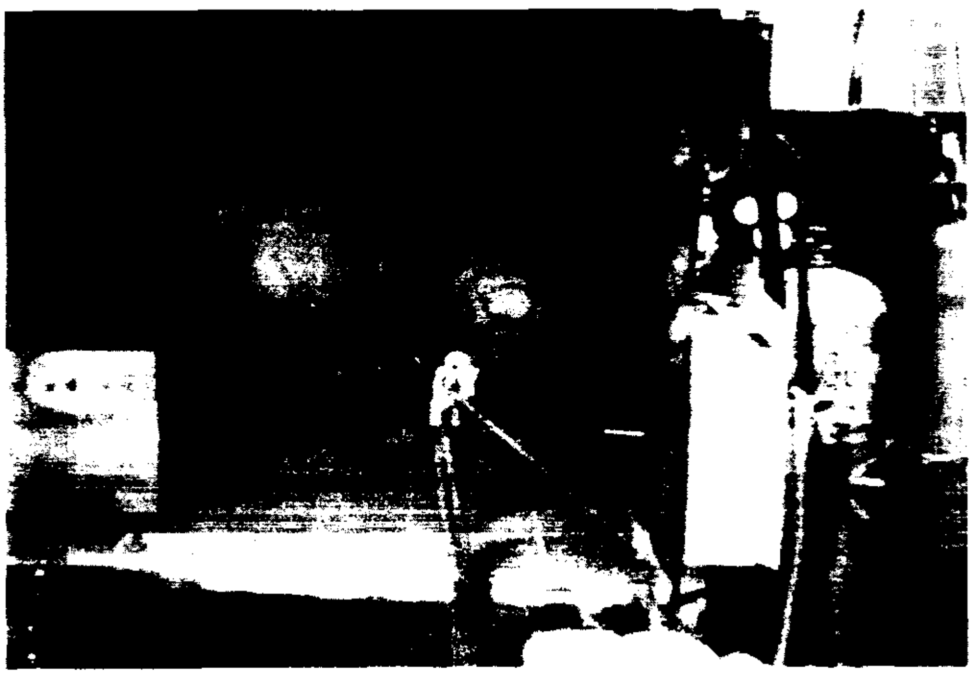

Figure 4. Spray booth where optical radiation measurements were recorded during field evaluations.

Figure 5. Optical radiation detector stand positioned 1.0 m from gun of TAS system (rear view).

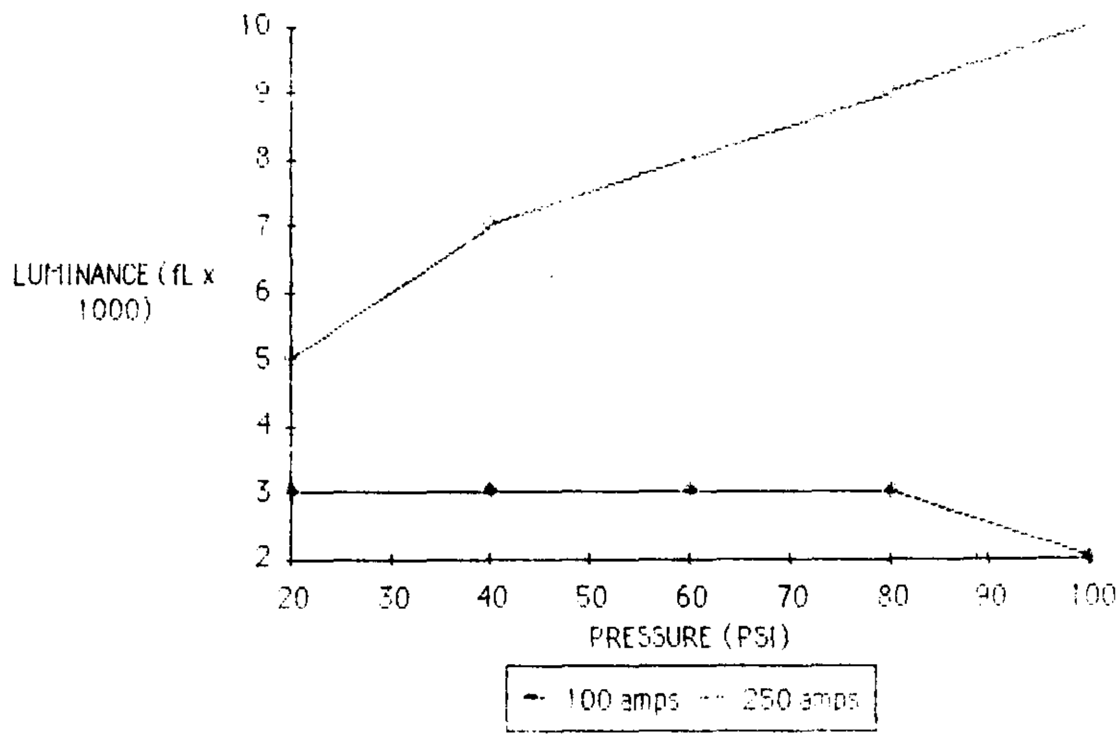

Figure 6. Thermal arc spray luminance levels as a function of pressure (PSI) and current (A) produced during spraying of stainless steel #2 wire.

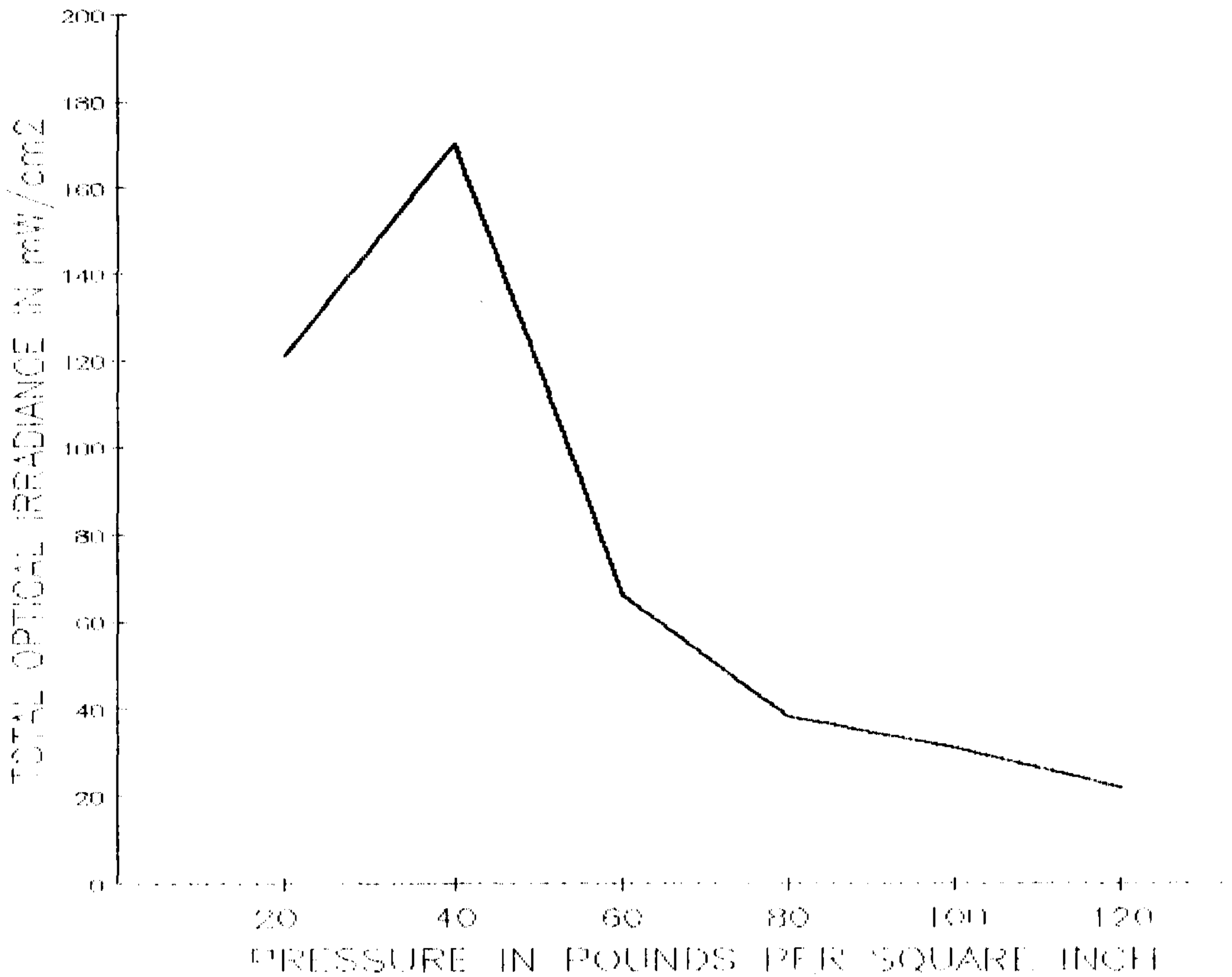

Figure 7. Total optical irradiance levels as a function of pressure.

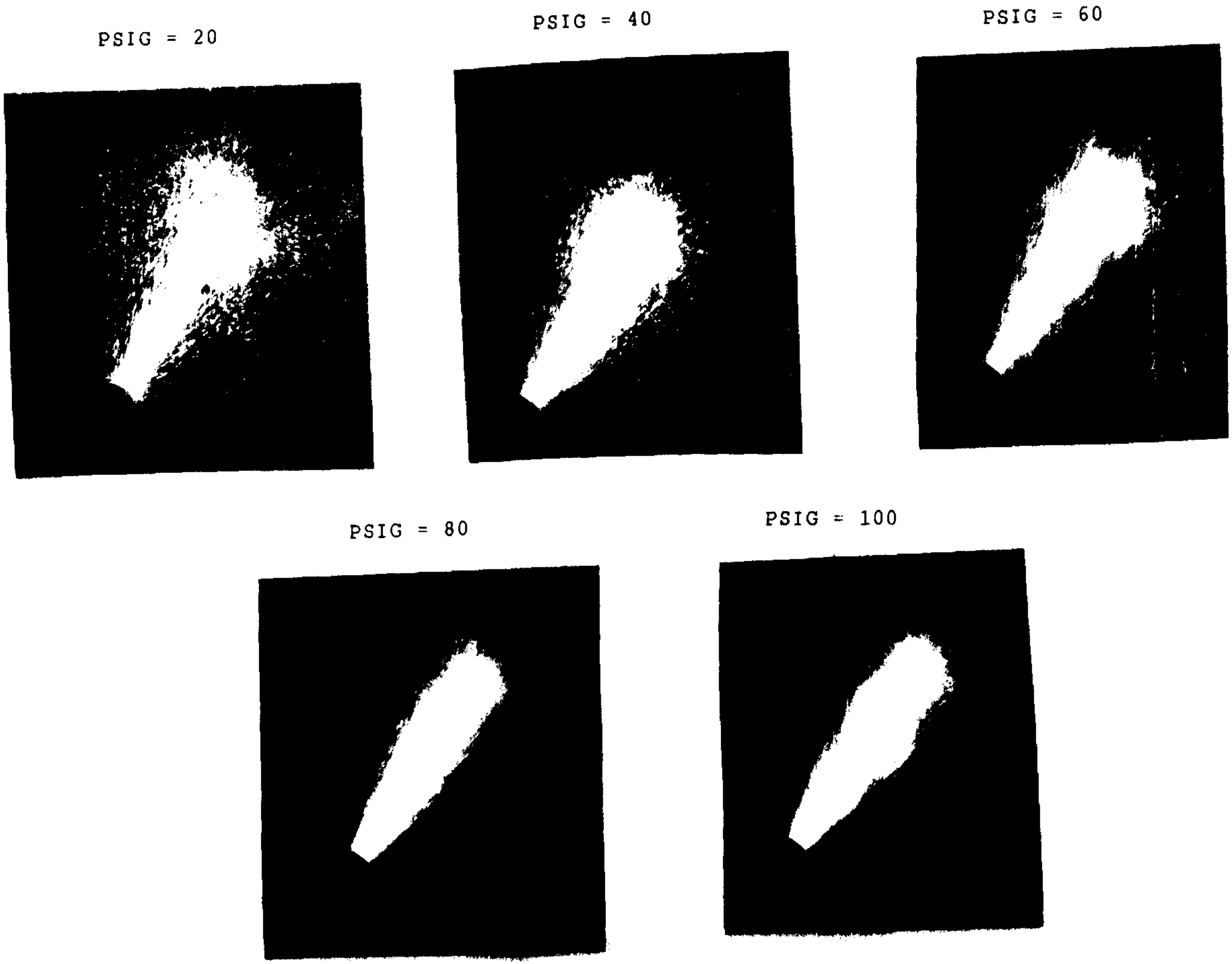

Figure 8. Thermal arc spraying of stainless steel wire at 250 A and 37 V.

EVENT # 8 (A.I. BRONZE) — EVENT # 11 (MOGUL) — EVENT # 12 (S. STEEL)

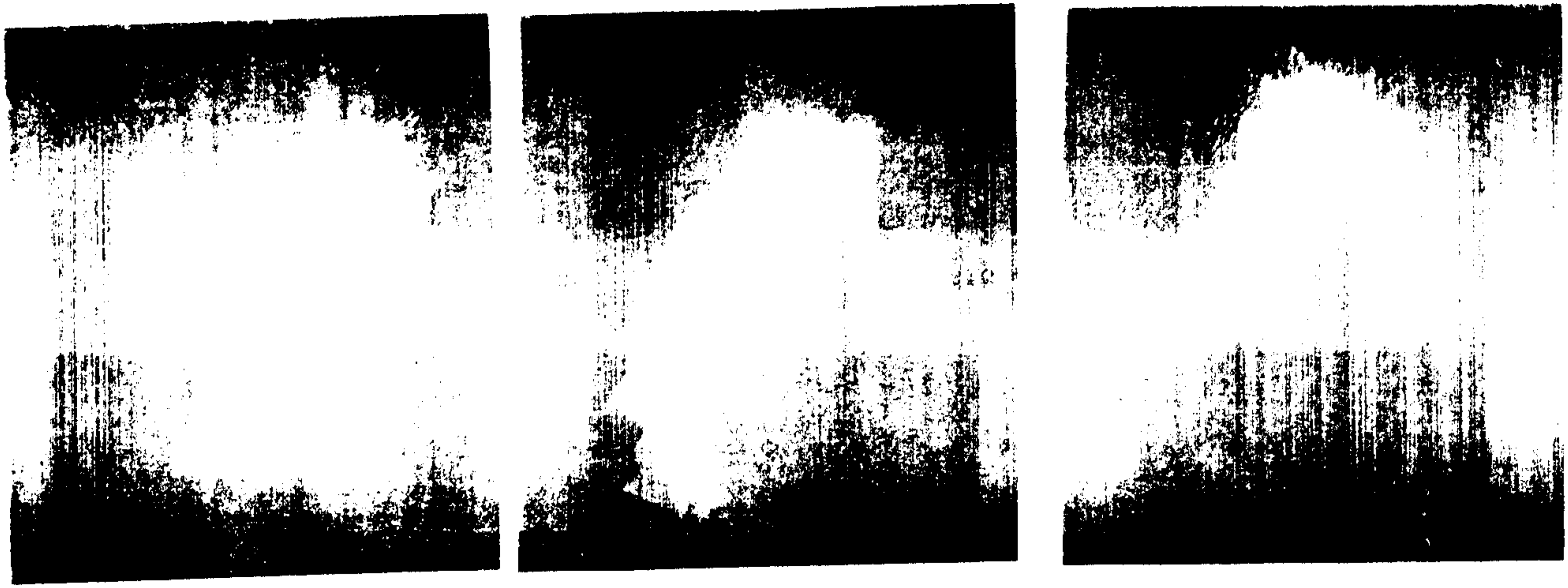

Figure 9. Spray patterns of three different TAS events. All events performed at same pressure, current, and voltage level.

PSIG = 20

PSIG = 100

Figure 10. Spray patterns from [illegible] wire operating at 100 A and 37 V.

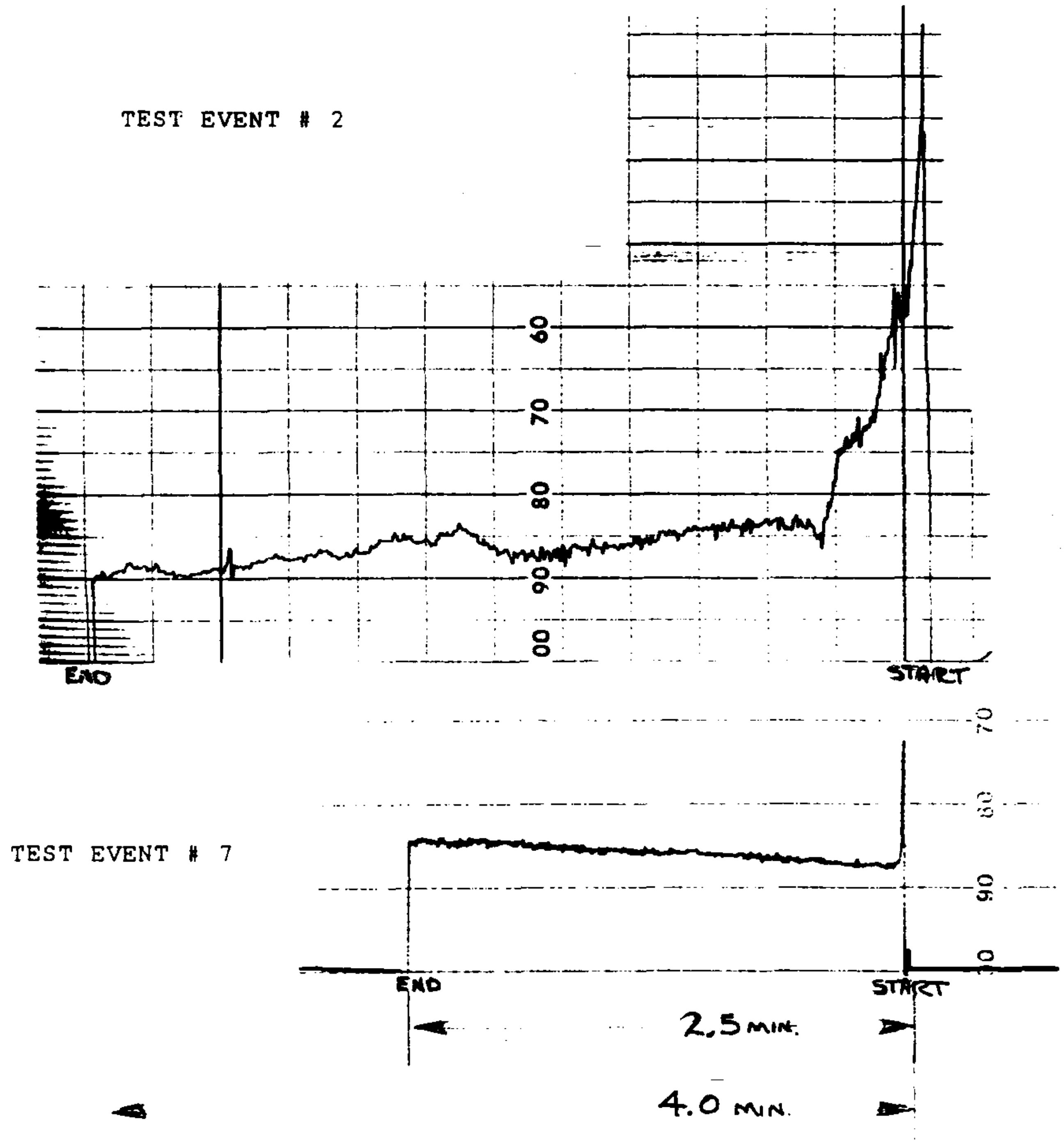

Figure 11. Time-intensity relationships of two typical TAS events.

Figure 12. TAS operators working at close distances (<1.0 m).

WARNING: ARC WELDING can be injurious to operator and persons in the work area.

- Protect yourself and others. Read and understand this label. For more detailed information, read and understand the instruction manual accompanying this equipment. Additional manuals and labels available from manufacturer. Only qualified persons are to install, operate, and maintain this equipment in accordance with applicable codes, safety practices, and manufacturer's instructions.

ELECTRIC SHOCK can kill.

- Install and ground unit according to national, regional, and local codes.
- Do not touch live electrical parts.
- Keep all panels and covers in place while energized.
- Protect yourself with dry insulating gloves and clothing.
- Disconnect input power before removing any panels and covers.
- Shut down the welding power source before touching the drive assembly, welding wire, wire reel, or any metal parts in contact with the welding wire.

ARC RAYS can burn eyes and skin; NOISE can damage hearing.

- Wear correct eye, ear, and body protection.

FUMES AND GASES can seriously harm your health.

- Ventilate to keep from breathing fumes and gases.
- If ventilation is inadequate, use approved breathing apparatus.

HOT METAL, SPATTER, AND SLAG can cause fire and burns.

- Watch for fire; have fire extinguisher nearby and know how to use it.
- Allow equipment and work to cool before handling.

MAGNETIC FIELDS FROM HIGH CURRENTS can affect pacemaker operation.

- Wearers should consult with their doctor before going near arc welding operations.

AVERTISSEMENT: LA SOUDURE A L'ARC comporte des risques de blessures pour l'operateur ou les personnes dans la zone de travail.

- Consulter la notice technique avant utilisation.

UN CHOC ÉLECTRIQUE peut être mortel.

- Couper l'alimentation au poste de soudage avant de toucher à l'ensemble d'entrainement, au fil de soudage, au dévidoir ou á toute autre pièce métallique en contact avec le fil de soudage.

070 634

Do Not Remove, Destroy, Or Cover This Label

Figure 13. Warning label on model BP400 TAS system.