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ATMOSPHERIC CONTAMINATION ASSOCIATED WITH INERT-GAS-SHIELDED, CONSUMABLE ELECTRODE ARC WELDING

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INTRODUCTION

Apparent excessive concentrations of atmospheric contamination which were reported to be associated with an inert-gas-shielded consumable electrode arc welding operation were studied to evaluate the potential health hazards. A study was made of the concentrations of metal fume and gaseous products of the operation as well as the spectrum of ultraviolet radiation. Recommendations for necessary controls were made.

TYPE OF OPERATION

This investigation was concerned with an inert-gas-shielded arc welding operation using a 0.045" diameter, type 347 stainless steel consumable electrode fed through the torch at a rate of 266 inches per minute. This electrode contained 17 - 19% chromium, 9 - 12% nickel, 0.8% niobium (columbium) and 0.08% carbon.

The inert gas mixture, composed of 95 - 100% argon with 5 to 0% oxygen, was supplied to the torch at a rate of 50 cubic feet per hour. Power was supplied from a welding machine operated at 210 amperes which produced a current density of about 166,000 amperes per square inch of welding wire.

The welding room was approximately 15 ft. by 20 ft. by 10 ft. high, with a 6 ft. door 10 ft. high opening into the main bay of the building. A canvas curtain was hung over the door opening. The main building was approximately 200 ft. long by 100 ft. wide, with most of the building open to the 40 ft. peak roof with the exception of an office area, a glass shop and the welding room, which had 10 ft. ceilings and were enclosed.

Two flexible exhaust ducts were suspended from the ceiling of the welding room in such a manner that they could be placed at the welding operation. The ducts were connected to a common blower. One exhaust duct opening was enlarged and had an area of 0.5 sq. ft. with a face velocity of 1350 fpm; the other exhaust duct opening had an area of approximately 0.2 sq. ft. with a face velocity

OF 2200 FPM. A TOTAL AIR VOLUME OF 1090 CFM WAS REMOVED FROM THE ROOM BY THE TWO DUCTS.

A TRICHLORETHYLENE DEGREASER WAS LOCATED ABOUT 100 FT. FROM THE WELDING ROOM ON THE SAME SIDE OF THE BUILDING. AN OVERHEAD SUPPLY VENTILATION SYSTEM WAS OBSERVED BLOWING DIRECTLY AT THE TOP OF THE DEGREASER AND, WHEN THE DEGREASER COVER WAS OPEN, HEAVY CONCENTRATIONS OF SOLVENT VAPOR ESCAPED INTO THE ROOM ATMOSPHERE. SOME OF THIS VAPOR WAS REPORTED CARRIED TO THE WELDING OPERATIONS WHERE IT COULD HAVE BEEN DECOMPOSED BY THE HEAT OF THE ARC TO PRODUCE PHOSGENE.

SAMPLING METHODS

OZONE WAS COLLECTED IN THE BREATHING ZONE OF THE WELDER WITH FRITTED GLASS BUBBLERS CONTAINING 40% POTASSIUM IODIDE SOLUTION. THE OZONE WAS DETERMINED BY TITRATION OF THE LIBERATED IODINE WITH 0.01 N SODIUM THIOSULFATE SOLUTION(1). ADDITIONALLY, OZONE SAMPLES WERE OBTAINED BY SUSPENDING GROUPS OF 3, 4 AND 5 AIR-FILLED POLYETHYLENE BAGS AT DISTANCES OF 19, 34, AND 44 INCHES, RESPECTIVELY, FROM THE ARC, DURING A 10 MINUTE WELDING PERIOD. THESE BAGS, WHICH WERE 0.002" THICK, CONTAINED AN AVERAGE VOLUME OF 28 LITERS OF AIR EACH. THE OZONE WAS SUBSEQUENTLY COLLECTED BY PASSING THE AIR FROM THE PLASTIC BAGS THROUGH THE POTASSIUM IODIDE SOLUTION AT A MEASURED RATE, AND DETERMINED AS STATED ABOVE. THE PURPOSE IN USING THE PLASTIC BAGS WAS TO DEMONSTRATE WHETHER THE OZONE, NOTICED SUBJECTIVELY THROUGHOUT THE ROOM IMMEDIATELY AFTER STRIKING THE ARC, WAS PRODUCED BY THE ULTRAVIOLET RADIATION AT DISTANCES OF SEVERAL FEET FROM THE WELDING ARC.

TOTAL METAL FUME WAS DETERMINED GRAVIMETRICALLY. TARED NO. 41 WHATMAN FILTER PAPERS WERE USED TO COLLECT THE FUME, SAMPLING AT A RATE OF 1.5 CFM. ADDITIONAL METAL FUME SAMPLES FOR CHEMICAL ANALYSIS WERE COLLECTED ON TYPE S, MSA PLEATED FILTERS WITH A HI VOLUME SAMPLER.

OXIDES OF NITROGEN SAMPLES WERE COLLECTED BY MEANS OF EVACUATED GAS BALLOONS, AND DETERMINED BY THE PHENOLDISULFONIC ACID METHOD(2).

(1) C. E. THORP., IND. AND ENG. CHEM. ANAL. ED. 12, 209 (1940).
(2) BEATTY, BERGER, AND SCHRENK U.S.B.M. R. I. 3687.

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FINDINGS

OZONE CONCENTRATIONS FOUND IN THE WELDING ROOM ARE SHOWN IN TABLE I.

TABLE I

OZONE

SAMPLE NO.	OXYGEN CONTENT OF INERT GAS %	TYPE OF AIR SAMPLE	SAMPLING DISTANCE (FROM ARC)	OZONE* PPM
1	5	ROOM AIR	18"	1.6
2	5	ROOM AIR	18"	0.6
3	5	ROOM AIR	18"	1.1
4	2	ROOM AIR	18"	0.6
5	0	ROOM AIR	18"	0.4
6**	0	PLASTIC BAG	19"	1.1
7	0	PLASTIC BAG	34"	0.3
8	0	PLASTIC BAG	44"	0.1
9	0	ROOM AIR	18"	2.4
10	0	ROOM AIR	96"	0.3

* MAC FOR OZONE = 0.1 PART PER MILLION PARTS OF AIR.
** SAMPLES 6 THROUGH 10 WERE COLLECTED CONCURRENTLY.

SAMPLES 1 AND 2 WERE COLLECTED IN THE BREATHING ZONE OF THE WELDER, USING 5% OXYGEN IN THE INERT GAS SUPPLY. BOTH SAMPLES WERE WELL ABOVE THE MAC OF 0.1 PPM FOR OZONE. SAMPLES 3, 4 AND 5 WERE COLLECTED CONSECUTIVELY, USING 5%, 2% AND 0% OXYGEN, RESPECTIVELY, IN THE INERT GAS SUPPLY. THE CONCENTRATIONS WERE IN THE SAME RANGE AS SHOWN BY THE FIRST TWO SAMPLES BUT THEY SHOW A DEFINITE RELATIONSHIP TO THE OXYGEN CONCENTRATION IN THE INERT GAS SUPPLY. VENTILATION WAS FOUND TO HAVE NO DEMONSTRABLE EFFECT ON OZONE CONCENTRATIONS IN SAMPLES COLLECTED AT 18 INCHES FROM THE ARC. THE OXYGEN IN THE INERT GAS SUPPLY WAS NOT THE ONLY SOURCE OF OZONE, AS SHOWN BY SAMPLE NO. 5, WHICH WAS REPRESENTATIVE OF CONDITIONS WITH NO OXYGEN SUPPLIED WITH THE INERT GAS. SAMPLES #6, 7 AND 8, TAKEN FROM PLASTIC BAGS EXPOSED TO THE ULTRAVIOLET RADIATION OF THE WELDING TORCH FOR A PERIOD OF 10 MINUTES SHOWED OZONE CONCENTRATIONS THAT WERE APPROXIMATELY INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE FROM THE ARC. THIS INDICATES A DIRECT RELATIONSHIP BETWEEN THE INTENSITY OF THE ULTRAVIOLET RADIATION AND THE OZONE CONCENTRATION, AND SUGGESTS THAT THE ULTRAVIOLET RADIATION GENERATES OZONE THROUGHOUT THE ROOM. SAMPLES 9 AND 10 WERE COLLECTED DIRECTLY

FROM THE ROOM AIR AT THE SAME TIME THE PLASTIC BAG SAMPLES WERE COLLECTED. SAMPLE NO. 9, COLLECTED 18 INCHES FROM THE ARC, SHOWED A CONCENTRATION MORE THAN TWICE THAT FOUND IN A PLASTIC BAG PLACED AT APPROXIMATELY THE SAME DISTANCE FROM THE SOURCE. SAMPLE NO. 10 COLLECTED FROM THE ROOM AIR 8 FT. AWAY FROM THE TORCH SHOWED A CONCENTRATION OF 0.3 PPM.

THE PRODUCTION OF OZONE BY ULTRAVIOLET RADIATION WAS ASSESSED FURTHER BY MEANS OF A MEDIUM QUARTZ SPECTROGRAPH THAT WAS SET UP AT THE WELDING OPERATION. BY UTILIZING PHOTOGRAPHIC EMULSIONS ESPECIALLY SENSITIVE TO THE RED END OF THE SPECTRUM AS WELL AS THOSE SENSITIVE TO THE LOW ULTRAVIOLET REGION, IT WAS POSSIBLE TO INVESTIGATE THE WAVELENGTH RANGE BETWEEN 2000 A AND 9000 A.

DUE TO THE HIGH CURRENT DENSITY, THE RELATIVE INTENSITY OF THE EMISSION ULTRAVIOLET RADIATION BY THIS INERT-GAS, CONSUMABLE ELECTRODE PROCESS WAS SEVERAL TIMES GREATER THAN THAT PRODUCED BY HELIARC WELDING WITH A TUNGSTEN ELECTRODE OR BY CONVENTIONAL ARC WELDING AT ALL WAVELENGTHS BETWEEN 2000 A AND 5000 A. THE ADDITION OF 5% OXYGEN TO THE ARGON WAS FOUND WAS FOUND TO INCREASE THE INTENSITY IN THE ULTRAVIOLET RANGE BY ABOUT 50%.

THE PRODUCTION OF OZONE BY ULTRAVIOLET RADIATION OCCURS MAINLY IN THE REGION 1400 A - 1900 A(3). CONVERSELY, OZONE IS DECOMPOSED BY ULTRAVIOLET RADIATION BETWEEN 2000 AND 3000 A. ALTHOUGH THE SPECTROGRAPHIC EQUIPMENT EMPLOYED PERMITTED ANALYSES DOWN TO ONLY 2000 A IT IS CONJECTURED THAT IN VIEW OF THE RELATIVELY HIGH INTENSITY IN THE 2000 - 3000 A REGION AND THE HIGH OZONE CONCENTRATIONS ENCOUNTERED, THE INTENSITY IN THE 1400 - 1900 A RANGE WAS CORRESPONDINGLY HIGH.

(3) MELLOR, J. W., INORGANIC AND THEORETICAL CHEMISTRY, 1, 880 - 881, (1922).

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METAL FUME CONCENTRATIONS ARE SHOWN IN TABLE II.

TABLE II

METAL FUME

VENTILATION	TOTAL FUME* mg/m^3
NO	50
NO	70
NO	17
NO	38
YES	15
AVERAGE	38

* MAC = 15 mg/m^3

TOTAL FUME CONCENTRATIONS WERE AT OR ABOVE THE MAC OF 15 mg/m^3. FIVE SAMPLES RANGED FROM 15 TO 70 mg/m^3. ANALYSIS OF THE FUME SHOWED IT TO BE 84.4% IRON OXIDE, 6.4% NICKEL OXIDE, 9.1% INSOLUBLE CHRONIC OXIDE, AND ONLY 0.003% OF THE SOLUBLE HEXAVALENT CHROMIUM TRIOXIDE.

TABLE III

OXIDES OF NITROGEN

SAMPLE No.	PPM	SAMPLE No.	PPM	SAMPLE No.	PPM	SAMPLE No.	PPM
1	0	5	5	9	5	13	1
2	2	6	2	10	2	14	2
3	3	7	0	11	5	15	4
4	4	8	5	12	10	16	2

OXIDES OF NITROGEN CONCENTRATIONS WERE RELATIVELY LOW, AVERAGING 3.2 PPM, WITH ONLY ONE OUT OF 16 SAMPLES ABOVE THE MAC OF 5 PPM FOR NO_2. EXHAUST VENTILATION WAS OPERATING ONLY DURING THE COLLECTION OF SAMPLE NO. 5. THE ONE ELEVATED CONCENTRATION WAS 10 PPM. ACCORDING TO ELKINS[4] THE OXIDE PRODUCED AT THE ARC DURING WELDING IS NITRIC OXIDE, WHICH IS OXIDIZED VERY SLOWLY, AT THE

(4) ELKINS, H. B. J. IND. HYG. AND TOX., 28, 37, (1946)

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LOW CONCENTRATIONS FOUND HERE, TO NITROGEN DIOXIDE. OXIDES OF NITROGEN DO NOT CONSTITUTE A HEALTH HAZARD UNDER THE CONDITIONS STUDIED.

CONCLUSIONS AND RECOMMENDATIONS

OZONE AND METAL FUME PRODUCED IN THIS OPERATION REQUIRE CONTROL. EXHAUST VENTILATION AT THE ARC CAN PROVIDE ADEQUATE CONTROL OF THE METAL FUME, BUT ADDITIONAL CONTROL WILL BE NECESSARY TO ELIMINATE THE OZONE PROBLEM. IT HAS BEEN SHOWN THAT THE ULTRAVIOLET RADIATION PRODUCES OZONE AT DISTANCES AS FAR AS SEVERAL FEET FROM THE SOURCE. THIS INDICATES THAT THE OPERATION SHOULD BE SHIELDED IN SUCH A MANNER THAT THE VOLUME OF IRRADIATED AIR IS MINIMIZED.

IT IS SUGGESTED THAT AN EXHAUST BOOTH BE PROVIDED THAT WILL ENCLOSE THE WELDING TABLE AND BE SUFFICIENTLY LARGE THAT THE WELDER CAN WORK INSIDE. THE MINIMUM CONTROLLING AIR VELOCITY AT THE ENCLOSURE'S OPENINGS SHOULD BE 150 FPM. SUCH A CONTROL SHOULD REMOVE MOST OF THE AIR EXPOSED TO ULTRAVIOLET RADIATION BEFORE IT CAN BE BREATHED BY THE WELDER AND PREVENT IT FROM ESCAPING INTO THE ROOM. ACTUAL TRIAL AND AIR SAMPLING WILL BE NECESSARY TO ASSURE ADEQUACY OF AIR FLOWS AND SUITABILITY OF DESIGN OF THE EXHAUST BOOTH.

IT IS UNDERSTOOD THAT THE DEGREASER VENTILATION WILL BE CORRECTED, SO THAT NO DRAFTS WILL REMOVE SOLVENT VAPOR FROM THE DEGREASER. THIS SHOULD ELIMINATE THE POSSIBILITY OF PRODUCING PHOSGENE IN THE WELDING AREA.

/S/
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