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GX 10 / 20 GENERATORS

**INCLUDING
GENERATOR & ELECTRODE
MAINTENANCE**

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SHERMAN SOLID STATE TREATER GENERATOR**GX10 / 20**

This handbook has been produced to give you every possible assistance in the installation and maintenance of your HIGH FREQUENCY SOLID STATE TREATER GENERATORS.

SHERMAN TREATERS GX20 TRANSISTORISED HIGH
FREQUENCY GENERATOR

GX10 / 20 SPECIFICATION

Input Voltage	240 Volts +/- 10%
Input Current	8 / 15 Amps R.M.S. max
Input Frequency	50/60 Hz
Generator Operating Frequency	20 kHz +/- 5%
Treatment Power	1kW / 2kW
Inverter KVA Rating	2 / 4 KVA
Maximum Output Voltage	600 Volts R.M.S.
Maximum Output Current	10 / 15 Amps R.M.S.
Cabinet Dimensions	475 (h) x 375 (w) x 225 (d)
Weight	22 kg

TRANSFORMER

HT3 20 kg

Check rating plate for operating voltage

Drawing No's.

A2.851002.01	GX10 (240V) Circuit Diagram
A2.851002.03	GX20 (240V) Circuit Diagram

SECTION 3

3.1 Description of the Equipment

The corona treatment equipment consists of three main parts

- (a) The Generator
 - (b) The High Voltage Transformer
 - (c) The Electrode Box
- (a) The Generator/Inverter converts power from the mains supply to a suitable high frequency ac for production of the corona.

The mains input to the unit is rectified to give about 300 volts dc. This is then converted to high frequency ac by the inverter and applied via an inductor and decoupling capacitor to the inverter output terminals.

- (b) The High Voltage Transformer converts the inverter output voltage to a sufficiently high voltage to produce the necessary corona discharge at the electrode. It is tapped in order to obtain optimum matching of the inverter to the electrode system.
- (c) The Electrode unit consists essentially of one earthed plane, an air gap, an insulating dielectric, such as silicone or ceramic, and a high voltage plane. The corona is formed across the air gap through which the material to be treated is passed.

3.2 Installation and Connection of Equipment

The Electrode Box must be mounted so that its rollers are exactly in line with the machine rollers. It should be free to open and be easily accessible for adjustment and maintenance. The H.T. Transformer must have all round air supply for cooling purposes and be mounted in the upright positions. (Identification label uppermost).

Idler rolls, usually mounted on top of the unit for transit purposes, should be positioned so as to guide the web through the Electrode Box without obstruction.

N.B. It is important that the electrode gap is checked prior to the electrode unit being switched on.

All electrode units have the discharge air gap set before they are despatched, however the gap may move out of alignment during transit or installation.

Do not switch the generator power on before rechecking that the air gap is correct (see Section 4).

Failure to follow these instructions could result in damage to the roll covering or the electrode and could invalidate the warranty on these items.

Pneumatically operated units should be connected to a filtered and lubricated air supply of at least 60 p.s.i. (4.0 bars).

Ozone, which is produced by corona discharge, must be removed from the area by connecting a suitable extraction fan to the ports provided on the electrode Box.

Air purged Electrode Boxes must be connected to a suitable fresh air blower by way of the inlet port provided, so that a positive pressure of 0.5mm water gauge is maintained within the unit when an ozone extraction fan is fitted and working. A pressure switch is provided, which is normally connected into the generator safety interlock system. Please refer to the circuit diagram at the rear of the manual.

All Sherman Electrode units are fitted with safety switches at all access points. All hoods, windows, etc must be closed before the generator can operate.

3.2.1 PL1 Connection to the Mains Supply

The generator requires a 220-240 Volt, single phase, 50/60 Hz supply as specified on the rating plate. The cable supplied should be connected BROWN-LIVE PIN A, BLUE-NEUTRAL PIN B, GREEN/YELLOW EARTH PIN C. The input fusing should be suitable for the protection of the cable between the supply and the inverter unit.

3.2.2 SK2 Underspeed Probe

Socket SK2 is for a 3 core cable from a speed rotation sensor. The rotation sensor consists of a rod-like device encapsulating a reed switch activated by four magnets. The four magnets, two red, two blue, must be fitted alternately (red, blue, red, blue) around the end of the roll to be monitored. These should be attached using non-ferrous fixings. The sensor must be fitted so that the magnets pass within 5mm of its flat end face.

3.2.3 SK3 Output to H.T. Transformer

The cable supplied with the equipment should be used for generator connection to the H.T. Transformer and should NOT be lengthened without reference to Sherman Treaters. The current flowing in the cable will be up to 15 Amps R.M.S. maximum and the voltage will not exceed 600 Volts ac R.M.S.

Due to the high operating frequency of the inverter this cable MUST NOT be run in steel conduit or clipped to steel trays as the eddy current losses in the steel will cause heating, reducing the effective inverter treatment power.

3.2.4 SK4 Remote Control and Skip/Treat Functions

- (a) Skip/Treat. In order to treat only limited segments of material it is possible to fit a volt free contact between pins A and B of this plug. When this contact is closed treatment will take place. If option is not used A and B should be linked.
- (b) Where no rotation sensor is fitted Pins A and B will/may be connected to a customer's volt free contact in order to put the generator into standby when the customer's line stops.
- (c) Remote Control. To switch the generator off remotely a contact can be fitted across pins E & F of PL4 (The link between pins E & F being removed first).

3.2.5 H.T. Transformer

Ensure that the cable from the generator is correctly connected to the transformer. Check that the transformer case is firmly connected to the electrode case (which is earthed) and that the high voltage connection is made from the transformer to the electrode. An adaptor is supplied in order that an H.T. probe with a 3mm thread may be used to make the high voltage connection of Sherman units. This may be discarded when the transformer is used with other electrode systems. The breather screw should be fitted before use.

N.B. The transformer should only be operated in an upright position as indicated on the label.

SECTION 4

Operating the Equipment

In order to obtain optimum treatment from the system it is necessary to correctly match the generator to the electrode system. This is done by the selection of the correct tap on the H.T. Transformer and the correct setting of the choke in the inverter for the electrode type (Section 4).

(a) Setting up Electrodes

For single sided treatment, the flexible link that connects the H.T. Transformer to the unused discharge bar should be removed at the H.T. end and securely stowed. The length of the electrode (bar) may then be adjusted so that corona only occurs coincident with the area of the film to be treated. 'U' section electrodes may be adjusted by loosening the wing nuts on each adjustable section and sliding the sections to the required position. Segmented electrodes may be adjusted to give strip treatment. Segments in use should be turned fully down and those not in use fully up.

Sherman standard electrode units are fitted with calibrated dials which indicate directly and the gap setting. Some special units do not have this facility and the gap must be set using a suitable feeler gauge. Gap setting mechanisms must be locked after use to prevent inadvertent maladjustment. Careful setting of the gap is essential if even and effective treatment is to be obtained.

N.B. It is important that the electrode gap is checked prior to the electrode unit being switched on.

All electrode units have the discharge air gap set before they are despatched, however the gap may move out of alignment during transit or installation.

Do not switch the generator power on before rechecking that the air gap is correct (see Section 4).

Failure to follow these instructions could result in damage to the roll covering or the electrode and could invalidate the warranty on these items.

(b) Initial Switch On

It is assumed that all connections have been made as described previously. Ensure the Output Power Control Potentiometer is turned fully anticlockwise (minimum).

Turn the circuit breaker on the front panel to the on position. The 'Mains On' lamp, 'Up to Speed' lamp and 'Interlocks Closed' lamps should light.

If the 'Up to Speed' lamp fails to light then check:

- i. that a probe is fitted
- ii. that the electrode rolls are turning
- iii. that the circuit has been correctly adjusted
- iv. that the circuit is switched out (SW1) if not required on the control circuit card, ie, SW1 is in the down position.

If the 'Interlocks Closed' lamps fails to light then check electrode safety switches by removing PL4 and checking continuity between pins F and G on PL4. Check also that this interlock light extinguishes if the interlock circuit is broken.

Press the Start/Stop switch and after a brief delay the 'Treat On' lamp should light when corona discharge takes place.

Increase the treatment power by turning the Power Control potentiometer slowly clockwise. The Treatment power is indicated by the meter on the front panel and is adjustable between 0 and 1kW / 2kW. If the full power range is not available, then it is probable that the electrode is incorrectly matched to the generator (Section 8).

If, as the power increased the red 'Trip' light comes on it is possible that

- i. there is a matching problem (Section 8)
- ii. there is fault on the dielectric sleeve on the electrode roll
- iii. the high voltage connections have flashed over

(c) Normal Operation After Initial Checks

- i. Turn on Mains Circuit Breaker
- ii. Depress Start Button
- iii. Set Power Demand Potentiometer to required level
- iv. Press Stop button to stop treatment

N.B. ALWAYS use Start and Stop buttons for all normal Starting and Stopping. Use mains on switch only as an isolator for prolonged shutdown.

SECTION 5

Routine Maintenance

All maintenance should be carried out with the mains supply disconnected from the system.

(a) Generator - Clean air filter periodically. Change any defective lamps. Clean inside of generator.

(b) Electrode System

Examine electrode box or roller unit periodically and remove accumulations of dust and dirt. Clean dielectric sleeves using a suitable cleaner. Replace any high voltage insulators which show signs of severe discoloration, or damage. Regrease all adjusting mechanisms with silicone grease. Confirm that all safety interlocks are working correctly and that the ozone extraction system is effective.

Pinholes that may occur in silicone rubber sleeves may be repaired using silicone rubber compound. The area around the pinhole must first be removed using a 1mm punch. Allow sufficient time for compound to harden after application.

If sleeves are badly worn, or damaged they must be replaced. Silicone rubber sleeves may be removed by inserting the nozzle of a compressed air line between the sleeve and the metal roller. The roller should be cleaned and about 50mm of the new sleeve pulled over it. The air line nozzle should then be reinserted and the sleeve pulled along the roller. The sleeve should overlap the roller by 50mm at each end.

SECTION 6

Description of Circuit Operation

- 6.1.1 Circuit Overview
- 6.1.2 Power Supply and Interlock Circuit
- 6.1.3 Inverter Operation
- 6.1.4 Inverter Control Card
- 6.1.1 Circuit Overview

Referring to circuit diagram A2.851002.01 / 03 the input power is fed in through CB1 and mains filter MF1. On closure of CB1 power is fed to the inverter power supply card and the fan via FS1 and FS2. The mains is rectified by BR1, filtered by C1 and fed via fuse FS3 to the inverter bridge assembly. The inverter assembly, controlled by the inverter control card produces high frequency ac which is fed via L1 and decoupling capacitor C2 to the inverter output. Monitoring and control is provided by CT1 (metering), CT2 (power control), CT3 (inverter current control) and T1 (inverter voltage limiting).

6.1.2 Power Supply and Interlocks

The power supply is fed from one toroidal transformer to give two independent supplies, one for the electronics (E) and one for the auxiliaries (A). Each supply is floating (i) with respect to each other and (ii) with respect to the mains input and inverter output.

The electronics supply is used solely for feeding the electronics control card for the inverter.

The auxiliaries supply is used for feeding the metering, indication and items external to the unit such as the speed rotation sensor and the interlock circuit.

Each supply is independently fused on the power supply card. The Interlock CCT runs from the +24V (A) supply to pin F on SK4. From pin E on PL4 through any microswitches on the electrode unit, back to pin G on PL4. PL4 pin E being linked to pin F to complete the CCT. Indication of circuit continuity is given by LP5 the interlock closed lamp.

SK4 Pins A and B are linked. When skip treatment is required the link should be removed.

6.1.3 Inverter Operation

The Inverter consists essentially of eight transistors (GX20) (Q1 - Q8) connected in bridge configuration with various auxiliary components to aid satisfactory power circuit operation. (Diagram A2/200002.02).

Regarding these transistor (Q1/5, Q2/6, Q3/7, Q4/8) purely as switches, Q1/5 and Q2/6 switch in opposition - ie, Q1/5 is on the Q2/6 is off and vice-versa. The same is true for the switching of Q3/7 and Q4/8.

If Q1/5 is switched on at the same time as Q3/7 (and therefore Q2/6 at the same time as Q4/8) then the overall voltage at the inverter output O1 and O2 will be zero. If Q2/6 is switched on at the same time as Q3/7 (and therefore Q1/5 at the same time as Q4/8) then the overall voltage at the inverter output will be a square wave with a peak to peak value of twice the dc voltage applied to the inverter.

By altering the switching of Q1/5 and Q2/6 relative to the switching of Q3/7 and Q4/8 (ie, the phase) it is possible to vary the effective inverter output voltage between the two points defined in the paragraph above.

This voltage is applied via choke L1 and decoupling capacitor C2 the H.T. Transformer (Drawing A3.200001.04). The secondary of the H.T. Transformer supplies the electrode.

The capacitance of the electrode will form a resonant circuit with the inductance L1 in the inverter and dependent upon where the inverter frequency (fixed) lies relative to the resonant frequency of this circuit determines the KVA the inverter has to provide to give the required treatment power (kW).

The KVA rating of the inverter is twice the rated treatment power (kW). If the full KVA rating of the inverter is exceeded, the trip light LP3 will come on. To overcome this problem it will be necessary to change the tapping on the transformer, or in extreme cases the value of L1, in order to obtain full treatment power.

N.B. The trip light will also operate if there is a fault on the electrode system, or with the H.T. Transformer itself.

6.1.4 Inverter Control Card

The main printed circuit card contains all the functions for the control and protection of the inverter (Drawing A1/100007.05). All interfacing with the card ensures that the card is electrically independent from other supplies and signals within and outside the inverter.

The basic inverter control is performed by IC1, IC4, IC7 and IC5. The master oscillator is within IC1, which produces the drive pulses (TP9 and TP20) for output transistors Q1/5 and Q2/6, via T1 and T2. IC7 produces the drive pulses (TP15 and TP18) for Q3/7 and Q4/8. The main control amplifier is within IC4 and the width of the pulse on TP11 determines, via the logic in the IC5 the phase shift between the switching of Q1/5 and Q2/6 and Q3/7 and Q4/8. This determines the output voltage from the inverter.

The heart of the control lies on IC4 and the following parameters are used to achieve it.

- i. Power Demand derived by IC11 from the treatment power demand potentiometer and the real current feedback from CT2 via D20-D23.
- ii. Inverter Voltage feedback from T1 via D2-D5.
- iii. Inverter Current feedback from CT3 via D6-D9.
- iv. Clamping due to the various alarm and control functions (described later).

The Power Demand is fed in via R67 to pin 2 of IC4. This is offset by the inverter current feedback through R82 and R83. Under normal operating conditions the amplifier in IC4 will now control so that the power demand is met.

Should the inverter output voltage exceed 600 volts ac then the voltage feedback signal will overcome the zener voltage of ZD1 and feed via R9 into pin 2 of IC4 to limit this voltage thus restricting the power demand.

The board contains various alarm and control circuits as follows:

- i. Up to Speed. This is sensed externally as described in section 1.2 (SK2). The signal (TP3) is fed into a monostable (IC6) and into level comparator (IC8). This signal is fed into the trip circuit logic (IC9). External indication is given via RL2.
- ii. Start/Stop. The signal (TP4, 0 volts = Start) is fed directly into the trip circuit logic (IC9).
- iii. Overtemperature, sensed by a thermostat on the inverter heatsink (TP5, 1 = Overtemperature), feeds directly into the trip circuit logic (IC9).
- iv. Skip/Treat. This signal (TP6, 0 = Treat) is fed directly into the trip circuit logic (IC9).
- v. Instantaneous Current Trip (IC2). The inverter current feedback signal is compared with a threshold level set on RV2. Should the comparator toggle on an overcurrent this triggers a monostable (IC6), the output of which feeds into the trip circuitry (IC9).

The pulse from the monostable will inhibit the inverter output for 1.5 seconds, after which the inverter will restart. CONTINUAL OVERCURRENT WILL PRODUCE A REPEATED TRIP SIGNAL AND THE TRIP LAMP WILL NOT BE SEEN TO EXTINGUISH. External indication is given via RL3.

vi. Power Supply Prime is achieved with C15 and R47.

All of the above six functions inhibit the output of the inverter via logic contained in IC9 and IC10, by clamping the amplifier on IC4 with TR1. In addition the contactor will open (controlled by RL1) if:

- i. Start button not depressed.
- ii. Power supply prime not present.
- iii. Unit overtemperature.
- iv. Interlocks open - This function is hard wired into the contactor circuit.

IC3 detects a low level of inverter current which gives indication of 'Treat On' via RL4.

NOTE: With the exception of RV5 all the potentiometers on the card are factory set and sealed. They MUST NOT be tampered with.

SECTION 7

Trouble Shooting

In the event of a problem, follow carefully the procedures listed below. Bear in mind that high voltages exist within the inverter cubicle and any checks within the cubicle must be carried out with the MAINS SUPPLY ISOLATED. 30 SECONDS SHOULD BE ALLOWED AFTER ISOLATION OF SUPPLY FOR THE DISCHARGE OF CAPACITORS WITHIN THE UNIT.

SYMPTOM

Inverter gives no treatment, but 'Mains On' lamp lit.

CHECKS

- i. Check 'Up to Speed' and 'Interlocks Closed' lamps are lit. If not, investigate cause.
- ii. Check that Skip/Treat contact is closed if fitted, or that pins A and B of PL4 are linked.
- iii. ISOLATE INVERTER. Check electrode system for visible signs of trouble and for continuity of connections.
- iv. With inverter isolated, open the inverter cubicle and with a suitable measuring instrument check continuity of inverter fuse FS3 (Drawing A2.851002.01 / 03). If open circuit, consult Sherman Treaters, as there is probably a fault on the inverter stack. Check both fuses on the Power Supply card. Replace if blown and investigate cause.
- v. Remove RL1 and check resistance of coil (350 ohms).

SYMPTOM

Inverter gives no treatment, no lamps lit.

CHECKS

- i. Check that mains supply is present to the unit and that CB1 is closed.
- ii. Isolate mains supply. Check the two fuses on the power supply card and the fuse feeding the power supply FS2.

SYMPTOM

Inverter 'Trip' light comes on.

CHECKS

This will be due to a fault on the electrode system, or on the H.T. Transformer, assuming that the system has been correctly matched.

Examine the electrode system and the dielectric sleeve for signs of burning, or other damage.

SYMPTOM

Mains Input Circuit Breaker trips

CHECKS

This will be due to either a faulty bridge rectifier BR1, or a problem with the capacitor precharge circuit A3/100005.05.

SYMPTOM

Inverter Overtemperature

CHECKS

- i. The fan is operating and all air inlets and outlets are clear.
If the fan has failed, check fuse FS1 on Drawing
A2.851002.01 / 02
- ii. The generator is not being exposed to excessive heat.

If the problem persists, consult Sherman Treaters Service Department for advice.

SECTION 8

Matching the Generator to the Electrode

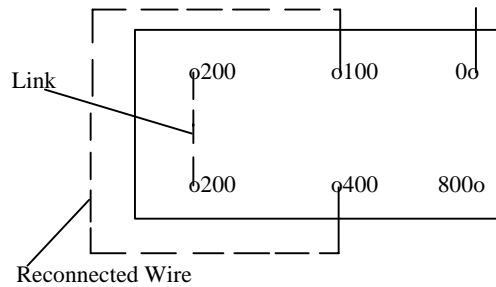
The choke L1 contained within the inverter cubicle is adjustable to suit various electrode systems, but will have been factory set to best suit your electrode system.

It should be possible to obtain satisfactory matching of the generator to the load simply by selecting the correct tap on the H.T. Transformer.

The generator has been designed to operate within certain parameters, covering inverter voltage, current and frequency. The inverter will operate within these and, if the matching is incorrect, limit the treatment to the load.

No adjustments are required, or should be made to, the inverter itself.

With this generator the highest tap where full treatment power can still be obtained from the generator should be selected (ie, start off with the generator connected to the highest tap and reduce the tap setting until full treatment can be obtained). It is possible that if the electrode gap, or configuration is altered the tap setting on the transformer will also have to be changed.



NOTE

The inductance must be selected on Choke L1 according to dielectric.

For Silicone: GX 10 800 μ H
 GX 20 400 μ H

For Ceramic: GX 10 200 μ H
 GX 20 100 μ H

The above diagram shows connections for a GX20 on Silicone
 For Ceramic remove link and reconnect wire to 100.

These connections are recommended settings. In the case of different electrode discharge areas and dielectric materials, these settings may vary, as this forms part of the matching circuit.

SECTION 09**Parts List****GX10 / 20 - 240V****CABINET ASSEMBLY**

CCT REFERENCE	CCT DESCRIPTION	PART NO
	Inverter Control PCB	301.3004
	Voltage Feedback PCB	301.3008
	Power Supply PCB	301.3009
	GX10 Heatsink Assembly	301.3005
	GX 20 Heatsink Assembly	301.3006
L1	Inductor	111.0087
C1	Capacitor 1500 uf	102.0044
C2	Capacitor 10 uf	102.0055
C3	Capacitor 0.1 uf 1000v	102.0065
CT1,2,3	Current Transformers	111.0085
BR1	Rectifier Bridge	103.0093
	Mains Filter	103.0106
	Fan 240V	124.0046
	Fan Filter	124.0047
RL1,2,3,4	Relay LY4	122.0096
FS1,2	Fuse Holder	123.0031
	Fuse 500mA	122.0068
FS3	GX20 - 10CT Fuse	123.0054
	GX10 – 6CT Fuse	123.0051
R1	Resistor 10R	101.0097
R2	Resistor 10k	101.0098
TH1	Thermal Switch 70C	122.0011

GX10 / 20 - 240VDOOR ASSEMBLY

CCT REFERENCE	CCT DESCRIPTION	PART NO.
LP2,4,5,6	Green LED	123.0067
LP3	Red LED	123.0066
LP1	Green LED	123.0069
S1	Start/Stop Button	122.0144
	Start Contact	122.0118
	Stop Contact	122.0119
CB1	25 Amp Circuit Breaker	122.0050
RV1	5k Potentiometer/ Power Control	101.0089
	Dial Mechanism	202.0049
DM1	Digital Meter	125.0007
	Meter Interface PCB	301.3010

COMPONENTS USED ON HEATSINK ASSEMBLY / INVERTER
CCT

CCT REF	CCT DESCRIPTION	PART NO	QTY USED	
			GX10	GX 20
Q1 - 8	Mosfet (MTM 15N50)	103.0100	4	8
D1, 3, 5, 7	Diode (BYW81P1150)	103.0099	4	4
D2, 4, 6, 8	Diode (BYT12P1600)	103.0098	4	4
ZD1 - 16	Zener Diode (BZX61C15)	103.0025	16	8
R1 - 8	Resistor 22R	101.0004	8	4
C1 - 2	Capacitor 0.47 uf	102.0028	2	2

Section 10

MACHINERY SAFETY

1. Corona treatment equipment operates at very high voltages (up to 15000 volts) at electrodes. It is essential that the utmost caution is taken when operation and maintaining equipment, where dangerous voltages are present they are indicated by the hazardous voltage warning label ISO 3864 No. B.3.6.
No access is permitted to the area indicated by this symbol **UNLESS** the power supply is isolated.



2. The treatment process produces ozone gas as a by product. It is the customer's responsibility to ensure that the unit is connected to a suitable extraction system and or catalytic converter constructed from corrosion resistant materials.
Ozone extraction outlets are identified by the above label.
(See Appendix 1.)



3. The Generator is equipped with a dust filtration system indicated by the caution symbol ISO 3864 No B.3.1 symbol. If this system blocks see routine maintenance section, as the unit may overheat
4. When isolating the Generator supply a small time delay of <5 seconds is needed for power to drain from capacitors via leakage resistors. Service engineers opening the doors should be aware of this.
5. Care must be taken to avoid injury from moving parts, such as rotating rolls, moving electrode assemblies and sensor probes at roll ends. Where risk is considered high guards are fitted.
6. Some machines are designed to be 'open' construction. It is the customer's responsibility to ensure access is safe. Fence type guards or other protection can be ordered separately at order placement or subsequently.

NB Sherman Treaters cannot specify guarding of interfaces between their machinery and the machinery into which it is to be incorporated because of the unique requirements of each installation. Therefore, Sherman Treaters have supplied machinery with residual mechanical and electrical risks which must be safe-guarded by the user. Access to Sherman Treaters machinery must be prevented at all times when the HT electrodes are energised.



11 Ozone: Health Hazards and Precautionary Methods

Guidance Note EH38 from the Health and Safety Executive

OZONE : Health Hazards and Precautionary Measures

Environmental Hygiene Series 38 (July 1983)

These Guidance Notes are published under five subject headings: Medical, Environmental Hygiene, Chemical Safety, Plant and Machinery and General.

INTRODUCTION

1. This guidance note contains information on the principal hazards to health from ozone and on potential sources of exposure. General advice on precautionary measures, control techniques and legal requirements is given.
2. Ozone, O₃, is a toxic gas possessing a distinctive odour and is a normal constituent of the earth's atmosphere. Ozone is produced deliberately for a variety of industrial purposes and is also produced naturally from oxygen whenever ultra-violet radiation or electrical discharges occur, e.g. at high altitudes or by the action of lightning. Such natural occurrence is unlikely to produce concentrations hazardous to man.
3. Because of its strong tendency to decompose and to release oxygen, ozone is extremely reactive and is a powerful oxidising agent which reacts explosively with oil and grease. Nevertheless it can be used with safety in industry. For example, since it readily oxidises organic matter, it is used as a bactericide and algacide.
4. Ozone itself is a distinctly blue coloured gas (bp – 111.9°C) and is about one and a half times heavier than air (density 2.144g/l). Ozone is used as "ozonised air", a colourless gas produced when ozone is generated from part of the oxygen in air (see para 13). Ozone cannot be stored or transported in vessels because it decomposes spontaneously in the presence of oxidisable impurities, humidity and solid surfaces. The rate of decomposition increases with temperature.
5. Background concentrations in our immediate atmosphere vary as a function of season, weather conditions, altitude and humidity

EFFECTS OF OZONE

6. Low concentrations of ozone have a significant effect upon textiles, fabrics, organic dyes, metals, plastics and paints and cause the characteristic cracking of stressed rubber, commonly called "weathering". A few substances, however, are resistant to the oxidising effect of ozone and these include glass and some stainless steels.

7. The acute toxicity of ozone to man has long been recognised and is well documented¹⁻⁸. The symptomatic and clinical effects of ozone at various concentrations are summarised in Table 1. Ozone is irritant to mucous membranes of eyes and respirator tract, and high concentrations can cause pulmonary oedema.

8. It is possible that there are secondary sites of reaction to ozone characterised by a defect in oxygen dissociation from oxyhaemoglobin in the tissues. Even at an exposure level of 0.1ppm ozone, premature ageing may result in man if exposure is sufficiently prolonged.

EXPOSURE LIMITS

9. The Health and Safety at work etc Act 1974 requires every employer to ensure, so far as is reasonably practicable, the health of all his employees and others who may be affected by the work he undertakes. The Act also places duties in respect of health and safety matters on the self-employed. The Factories Act 1961 requires factory occupiers to take all practicable measures to protect employed persons against inhalation of fume. The general policy adopted by the Health and Safety Executive is that exposure to hazardous substances should be kept at low as is reasonably practicable and in any case exposure should be kept within published standards by the application of engineering controls or other suitable control techniques. The Health and Safety Executive publishes, in guidance notes in the RH series, information on exposure limits applied in the UK.

10. The recommended exposure limit for ozone is 0.1ppm (0.2mg/m³) calculated as an 8-hour time-weighted average concentration. There is also a short-term exposure limit for ozone of 0.3ppm (0.6mg/m³) calculated as a 15-minute time-weighted average concentration.

SOURCES OF EXPOSURE

11. Ozone is made using ultra-violet radiation or electrical discharge either intentionally for the purpose of a specific process or incidentally to a process. It is an unstable substance but its rate of decomposition varies widely according to temperature and humidity. A given ozone output yielding a faint trace of ozone in a workroom atmosphere on a humid day may create an undesirable concentration on a dry day.

INTENTIONAL PRODUCTION

12. Ozone is usually produced intentionally by silent electrical discharge in air. Alternative means of production such as bombardment of air with ultra-violet or ionising radiation, or electrolysis of cooled sulphuric acid, are uncommon in practice.

13. There are basically three types of ozone generator in use, working at:

- (a) Atmospheric pressure – typically a box through which material to be treated with ozone is passed, and in which a silent electrical discharge is initiated through the air by means of metal electrodes. This system is often used for surface treatment of plastic film.

- (b) Reduced pressure – found in swimming pool disinfection plants whereby dried air is drawn through glass tubes across which a silent electrical discharge is struck. The reduced pressure is generated by a sidestream from the circulating pool water forming a venturi vacuum.
- (c) Positive pressure – found in potable water treatment plants and throughout industry generally. Dried air is blown through glass tubes across which a silent electrical discharge is struck and this ozonised air emerges at positive pressure.

14. The processes for which ozone is produced are outlined below.

SURFACE TREATMENT

15. Various industries which manufacture or use plastic packaging in its various forms use ozone to pre-treat the plastic surface immediately before printing.

ELECTRICAL DISCHARGES

16. Ozone is generally produced around high voltage equipment and by electrical discharges in specific processes e.g.

- (a) Arc welding – reactive metals such as aluminium and titanium, and also stainless steel are arc welded in an inert shield of argon or carbon dioxide. The intense radiation from the arc produces significant quantities of ozone.
- (b) Static eliminators are often used in industry to remove static electricity from recently moulded plastic articles, and continuous use of them in a poorly ventilated room could lead to the build-up of an irritating level of ozone above the recommended exposure limit. The main factor which determines the amount of ozone produced is the voltage across the collector plates; the higher the voltage the more ozone is produced.
- (c) Electrostatic precipitators are used to remove dust and some airborne contaminants from the air and they produce ozone also. More ozone is produced if there are rough or sharp edges on, for example, new metal parts since intense local voltage gradients are produced.

VENTILATION

17. Areas into which ozone may escape must be equipped with adequate ventilation and extraction facilities. In ozone plant rooms, it is recommended that ten changes of room air per hour be achieved to enable dangerous accumulations of gas to be dispersed within a few minutes.

18. Ozone should be prevented from entering the workroom air by the use of exhaust appliances placed close to the source of emission. The ozone may then be passed through appropriate filters before discharge to a safe place in the open air. In the case of ozonators operating under negative pressure, the process acts as its own exhaust ventilator. In the case of atmospheric pressure ozonators, effective local exhaust ventilation is necessary because the ozonators are not enclosed. Cinema projection lamps should present no ozone hazard provided adequate mechanical exhaust ventilation is fitted to the lamp housing and the exhausted air is vented to a safe place. Many processes incidentally producing ozone (e.g. welding, ultra-violet curing inks) will have some ventilation provided to deal with other problems from process.

SAFE SYSTEMS OF WORK

19. In order to ensure that plant and processes are properly operated and controlled to minimise risk to health, satisfactory safe systems of work need to be established and maintained by means of appropriate training and supervision.
20. All people operating ozone plant should be given full training in all aspects of the operation of the ozonator and associated equipment and should be trained in emergency and first aid procedures. Emergency action plans should be prepared for all sites where ozone is generated deliberately in potentially hazardous quantities.
21. Special care may be required when opening sealed plant for maintenance purposes. Guidance Note GS5¹⁰ should be consulted for detailed advice on permit-to-work systems and precautions on entry into confined spaces.
22. Work on ozone plant should only be undertaken by a person specifically authorised to do the work. Such a person should be trained and be competent to do the work in a safe manner. When carrying out repairs or maintenance work on an ozonator, the ozonator transformer must be isolated and locked off, and a permit to work must be issued, to avoid risks from ozone and from electrical hazard.
23. The cleaning materials used for cleaning ozone units and pipework must be free from oil or grease.
24. In the event of an ozone leak a plant restart should not be attempted until the source of leakage has been investigated and rectified. Leak detection by nose is not satisfactory because even slight leaks cause the sense of smell to be numbed and lead to the false conclusion that a leak no longer exists.
25. Appropriate warning signs indicating the presence of a potential toxic gas hazard should be displayed on ozone plant access doors or in passageways leading to the plant room.

MONITORING

26. Ozone detectors may be used to provide audible and visual warnings of ozone leaks. Such alarm signals may be used to initiate emergency procedures, or to automatically turn on plant room ventilation and shut down the ozonator. Ozone-in-air monitors are essential in plant rooms where ozonators and associated equipment operate under positive pressure, because of the greater risk of ozone leakage outward. The monitors in such situations should actuate automatic ozonator shut down at 0.3ppm ozone or less, while actuating warning alarms at 0.1ppm or less.
27. Minor ozone leaks can be detected and located by means of moist starch/potassium iodide paper which turns blue on exposure to ozone.
28. It is essential to carry out regular testing and calibration of all sensor equipment used.

EXHAUST EMISSION

29. Process gas venting to atmosphere should pass through an ozone destructor device or be released in such a way as to present no hazard. A destructor is a catalyst filter or other device which causes ozone to decompose in a controlled manner to oxygen. Provided the discharge point allows adequate dilution a destructor device may not be necessary. If a catalyst bed, for example activated carbon, is used as an ozone destructor it is possible that the bed could become exhausted during a period of operation and this should be borne in mind when arranging maintenance schedules.

30. Deflection weather caps are not recommended for discharge stacks since these hinder dispersal. Vertical discharge stacks are recommended with a discharge velocity of 15-20m/s to aid dispersal and avoid re-circulation into buildings. Stacks and extraction vents should be carefully sited so that they do not feed fresh air ventilation intakes.

31. The control of ozone input to a process is crucial since excess ozone can lead to high levels of vented ozone.

32. Activated carbon filters must under no circumstances be exposed to ozone concentrations higher than 20g/m³ since the reaction may become auto-accelerated and lead to an explosion. The automatic shutdown is a safeguard against this risk.

FIRST AID

33. If a person is overcome by ozone, the following precautions should be adopted:

- (a) Remove the patient to a warm uncontaminated atmosphere and loosen tight clothing at the neck and waist.
- (b) Keep the patient at rest.
- (c) If the patient has difficulty in breathing, oxygen may be administered provided that a suitable apparatus and a trained operator are available.
- (d) If breathing is weak or has ceased, artificial respiration should be started. The mouth-to-mouth or mouth-to-nose methods are preferred.
- (e) Seek medical aid.

34. Ozone poisoning should be treated symptomatically. This may include bed rest, analgesics to relieve pain, and antibiotics as may be prescribed by a medical practitioner.

SAMPLING AND ANALYTICAL METHODS

35. Sampling strategies to monitor the extent of exposure to ozone or to assess compliance with exposure limits should be carefully planned and the advice of an occupational hygienist may prove useful. Short-term sampling may be used to identify peak exposures and to assist in the prevention of acute gassing incidents. It may not be valid, however, to use the results of such sampling for the determination of time-weighted average long-term exposures. Personal atmospheric sampling is to be recommended when assessing the actual pattern and duration of exposure. (Further information is contained in Health and Safety Executive guidance notes on Exposure Limits).

36. The traditional method of determining ozone in air may be used¹² but continuous ozone monitors are now available which use a variety of techniques including chemiluminescence, ultra-violet photometry and electro-chemical cells. Relatively inexpensive gas detector tubes are also available. These are ideal for spot check, provided that interfering gases, such as oxidising agents, are known to be absent.

STATUTORY REQUIREMENTS

37. The general duties of employers, the self-employed, manufacturers, suppliers and of employees at work are contained in the Health and Safety at Work etc Act 1974. Other relevant statutory provisions include the Factories Act 1961, the Offices, Shops and a Railway Premises Act 1963 and the various regulations and orders made under these Acts. The following is a brief summary of the principal requirements with regard to potential ozone health risks:

(a) Health and Safety at work etc Act 1974

- s.2 & 3 general duties of employers and the self-employed
- s.6 general duties of manufacturers
- s.7 general duties of employees

(b) Factories Act 1961

- s.4 provision of ventilation
- s.30 dangerous fumes
- s.63 removal of dust of fumes

(c) Offices, Shops and Railway Premises Act 1963

- s.7 provision of ventilation

(d) The Shipbuilding and Ship-Repairing Regulations 1960 – Regulation 53

- The Iron & Steel Foundries Regulations 1953 – Regulation 7
- The Non-Ferrous Metals (Smelting and Founding) Regulations 1962 – Regulation 11
- The Electricity (Factories Act) Special Regulations 1944
- The Notification of Accidents and Dangerous Occurrences Regulations 1980
- The Health and Safety (First Aid) Regulations 1981.

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