HETA 91-0140-2352
September 1993
ARMCO Steel Company, L.P.
Ashland, Kentucky

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I. SUMMARY

On September 11-13, 1991, and June 2-4, 1992, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted an investigation at Armco Corporation in Ashland, Kentucky. This investigation was performed in response to a joint union/management request received on March 5, 1991. The request asked NIOSH to evaluate potential employee exposure to radiofrequency (RF) radiation at the galvaneal coating line unit and to extremely low frequency (ELF) radiation at the ladle refinery facility.

Results of measurements obtained in this evaluation in the ladle refinery area for ELF fields (30 to 800 hertz [Hz]) gave magnetic field levels varying from 0.17 to 1.34 gauss (G) and electric field levels ranging from 2.8 to 17 volts per meter (V/m) at various locations (area measurements). Personal exposure for workers in the same area using EMDEX II™ dosimeters yielded magnetic field levels ranging from 0.1 to 1.48 G. The galvaneal coating unit, which operates at 9.9 kilohertz (kHz), emitted very low frequency (VLF) magnetic field levels in excess of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).

Based on the data collected in this survey, and comparison with current occupational exposure criteria, the NIOSH investigators concluded that a potential health hazard existed on the days of measurement from exposure to magnetic fields produced by the galvaneal coating line unit. Recommendations are offered in Section VIII to further reduce exposure levels.

KEYWORDS: SIC 3325 (Steel Foundries), Electromagnetic Fields (EMF), galvaneal coating, transformer.

II. INTRODUCTION

On March 5, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a joint union/management request for a health hazard evaluation (HHE) at ARMCO Steel Company, L.P., Ashland, Kentucky. ARMCO is a limited partnership between ARMCO, Inc. of New Jersey, and Kawasaki Steel Corporation of Japan. The request concerned possible employee exposures to various types of electromagnetic radiation fields at two locations; the galvaneal unit on the #3 coating line, and the ladle refiner at the slab caster.

On September 11-13, 1991, NIOSH investigators met with management and United Steel Workers representatives to discuss the HHE request, tour the facility, and make preliminary measurements. On June 2-4, 1992, NIOSH investigators returned and made detailed occupational radiation measurements at the worksites.

III. BACKGROUND

ARMCO produces a broad range of flat-rolled steel products in its 700 acre facility. At the time of this evaluation, ARMCO employed over 1300 workers. Approximately 30 workers were involved with the galvaneal unit and over 40 different workers were associated with ladle refiner activities.

A. Galvaneal Lines

ARMCO electrogalvanizing lines use vertical gravitel cells to produce a galvanized steel product having unique surface characteristics which are needed in many industrial applications. These lines operate a high temperature annealing process that uses radiofrequency (RF) radiation at 9.9 kilohertz (kHz) to produce very high temperature levels in the material (Figure 1). The galvaneal process is operated from a control room located about 30 feet from the line. Workers are located very close to the galvaneal line during its operation. Workers near the coating unit include zinc grip operators and helpers, a utility tractor operator, a turn foreman, and various electronic and maintenance personnel. The galvaneal coating unit is somewhat portable and can be positioned at different locations. During the evaluation the unit was operated at two different sites. Workers had expressed concerns about possible RF radiation exposure from this system during its operation, since electrical arcing had been observed near the unit when activated.

B. Ladle Refinery

In Building 781 (Ladle Refinery), molten steel is tapped into the ladle and then mounted on a ladle transfer car (at temperatures around 2800 to 2900^{o}F). The steel is then transferred to the slab casting area located at the opposite end of the building. During this transfer it is necessary to reheat and stir the molten steel. In addition, various alloy materials are added prior to the steel being cast into slabs. The heating and stirring of the molten steel requires the availability of large quantities of electrical power. Workers had expressed concern about possible occupational exposure to the electric and magnetic fields produced in this operation.

The electrodes used to heat the steel operate at three phase, 60 hertz (Hz), 34.5 kilovolt (kV), 30,000 amperes per phase. The electrodes are 8.5 inches in diameter and about 16 feet long. Generally, it takes about 20 minutes to reheat the steel to the desired temperature prior to being cast. The induction stirring is performed by an electromagnet placed on the ladle's side which operates at 1200 amperes and 1.6 Hz. It was estimated that in a typical day about 10 ladles can be processed.

The ladle refinery uses a transformer to provide electrical power for its operation. The transformer is a 23.5 ton arc furnace type, TMY31, serial number 7278284, operating at three phase, 60 Hz and manufactured for ARMCO by ASEA-SKF in Sweden. The transformer is rated at 9.77 to 17 million volt-amperes (MVA) continuous, has a primary voltage capacity of 34.5 kV, and a peak secondary voltage capacity of 0.316 kV. The transformer is located about eight feet below the control room and close to the operator's position. It was installed in 1982 and operated until 1985. It was not in operation from 1985 to 1989 but was reactivated in 1990. The ladle operation runs around the clock (three shifts) and at least three workers (operator, helper, and coordinator) are in the control room during a shift.

Numerous video display terminals (VDT) were located in the control room for ladle operations. The VDTs displayed pertinent processing data and information used in the production of molten steel. However, the images formed on the cathode ray tubes were radically altered and difficult to read during the time ladle electrodes were heating the steel. This image distortion problem was thought to be a result of electromagnetic interference problems.

IV. EVALUATION DESIGN AND METHODS

Measurements of workers' exposure to the electromagnetic fields produced at both the ladle refinery facility and the galvaneal coating line were performed during the first two shifts on both evaluation dates. Measurements were performed in both a walk-around mode (area measurements) and in a personal dosimetry mode. The evaluation was designed to survey workers' actual exposure to both electric and magnetic fields while they performed their work tasks. The limited number of measurements taken in and around the facility were not intended to represent an in-depth evaluation of the radiation fields at the site, but were rather intended to approximate occupational exposure levels on the days of measurement.

Workers' exposure to the various fields were measured using the following equipment:

- Measurements were made with the EMDEX II™ exposure system, developed by Enertech Consultants, under project sponsorship of the Electric Power Research Institute, Inc. The EMDEX II™ is a programmable data-acquisition meter which measures the orthogonal vector components of the magnetic field through its internal sensors. Measurements can be made in the instantaneous read or storage mode. The system was designed to measure, record, and analyze power frequency magnetic fields in units of milligauss (mG) in the frequency range from 30 to 800 Hz.

- Holaday Industries Models HI-3600-01 and HI-3600-02 survey meters were used to document the electric and magnetic fields in the very low frequency (1 to 30 kHz) and extremely low frequency (0.1 to 1000 Hz) bands. The electric field (E-field) strength can be measured either in volts per meter (V/m) or kilovolts per meter (kV/m). The magnetic field strength (H-field) can be expressed in units of mG. The instruments also provided the ability to record the frequencies, as well as the waveforms, produced by such fields. Measurements were made at locations where personnel worked during the day.

- Holaday Industries Model HI-3624 ELF magnetic field meter was used to document root-mean-square (rms) magnetic field contributions from the magnetic stirrer. The meter has a range from 0.001 to 20 gauss (G) with a frequency range from 5 to 2,000 Hz. Discussion with Holaday representatives indicate that while the HI-3624 is rated in the 5-2000 Hz frequency region, the instrument is capable of responding at 1.6 Hz. However, the meter significantly under-responds the true reading at this frequency. Hence, readings obtained on the magnetic stirrer with the HI-3624 will be higher than what is reported.

- A computer based, magnetic field profiler was used to document exposure in two frequency bands, 30 Hz to 1000 Hz and 1 to 30 kHz over a range of 0.1 mG to 10 G. The monitor measures and displays the orthogonal vector components of the magnetic field and computes the rms value of the magnetic field for both frequency regions. The monitor, which was made by Electric Research and Management, Inc. of State College, PA, was designed to be used with a surveying wheel in order to map out the magnetic fields that can exist within a given area.

- Extremely low frequency (ELF) electric and magnetic fields levels were documented with the EMDEX II™ and Holaday systems throughout the facility. EMDEX II™ units were used in a walk-around mode as well as worn in pouches by workers at waist height, about 3.5 ft, from the floor. In addition, a limited number of area measurements were made with the Holaday monitors at selected work locations inside the facility. All systems were calibrated either by NIOSH or the manufacturer within six months of the date of this evaluation.

V. EVALUATION CRITERIA

At the present time there are no Occupational Safety and Health Administration (OSHA) or NIOSH exposure criteria for sub-radiofrequency (RF) fields. The American Conference of Governmental Industrial Hygienists (ACGIH) has published Threshold Limit Values (TLVs) for sub-radiofrequency electric and magnetic fields.[1] The TLV for magnetic flux density (B_{TLV}) states "routine occupational exposure should not exceed:

$$B_{TLV} \text{ (in mT)} = 60/f$$

where mT is millitesla and f is the frequency in hertz." Conversely, the electric field TLV states "occupational exposures should not exceed a field strength of 25 kV/m from 0 to 100 Hz. For frequencies in the range of 100 Hz to 4 kHz, the TLV is given by:

$$E_{TLV} \text{ (in V/m)} = 2.5 \times 10^6/f$$

where f is the frequency in Hz. A value of 625 V/m is the exposure limit for frequencies from 4 kHz to 30 kHz."

This means, for example, at 60 Hz, which is classified as ELF, the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 1 mT or 10 G. At 1.6 Hz, the electric field intensity TLV is 25,000 V/m and the magnetic flux density TLV is 37.5 mT or 375 G. At 9.9 kHz, which is classified as very low frequency (VLF), the electric field intensity TLV is 625 V/m and the magnetic flux density TLV is 0.006 mT or 4800 milliamp per meter (mA/m) (1 mT = 800 amp per meter [A/m]).

The basis of the ELF E-field TLV is to minimize occupational hazards arising from spark discharge and contact current situations. The magnetic flux density TLV addresses induction of magnetophosphenes in the visual system and production of induced currents in the body.

The Institute of Electrical and Electronic Engineers (IEEE) has promulgated a microwave/radiofrequency radiation standard that is published by the American National Standards Institute (ANSI) and is known as ANSI C95.1-(1991)[2] The IEEE committee concluded that a specific absorbed rate (SAR) of 4 watts per kilogram (W/kg) represents the threshold absorption level above which adverse health effects may arise as body temperature increases. A safety factor of 10 was then added to give a SAR of 0.4 W/kg as the maximum permissible exposure limit, averaged over the entire body. The standard uses dosimetry measurements of RF radiation to calculate the electric and magnetic field strength limit under controlled exposure conditions necessary to achieve a SAR of 0.4 W/kg and, for the 9.9 kHz frequency region, those fields are 614 V/m and 0.2 mT. The ANSI magnetic field level for this frequency region is approximately 33 times greater than the ACGIH magnetic field TLV.

VI. RESULTS

Measurement results were obtained for the ladle refinery area, galvaneal coating unit area, and several other locations within the ARMCO facility.

A. Ladle Refiner

1. **ELF Area Surveys.** The control room at the ladle refinery was divided into 12 equal three foot square zones labelled (A-L), and waist level ELF measurements were made at the center of each zone with the Holaday

meters to determine the difference in electric and magnetic fields when the ladle electrodes were in both the on (active) and the off (inactive). Table 1 shows the rms electric and magnetic field values obtained under active and inactive modes at the 12 selected sites. The magnetic field levels ranged from 0.17 to 1.34 G in the active mode and from 0.0006 to 0.0037 G in the inactive mode. The electric field levels ranged in the active mode from 3.2 to 17 V/m, and from 2.8 to 16.9 V/m in the inactive mode. These data clearly shows that the magnetic fields are several hundred times larger when the electrodes are active (i.e., heating the steel). The highest levels for the magnetic field occurred where the control room operator sat (location L). All measured levels were below the ACGIH TLV for ELF fields.

2. **Worker Personnel Exposure.** The EMDEX II™ dosimeters were worn by five ladle refiner workers around their waist during portions of the workday. The magnetic field levels recorded for these workers, who worked in the control room, ranged from 0.1 to 1482 mG. Figures 2-6 show the time-intensity distribution, by job titles, for these five employees. The peaking and temporal extent of these distributions also show that magnetic fields are at their maximum in the control room when the electrodes are active. The arithmetic average for the workers who wore the dosimeters ranged from 108 to 169 mG. Since records of ladle heating time were recorded it was possible to verify that the pattern of exposure recorded and displayed by the EMDEX II™ dosimeter correlated to the time periods when the ladle was heated and not during the ladle transmit time period. During the time the ladle was active (heated), workers were not permitted near the ladle. However, ladle samples were obtained by workers at locations near the ladle when it was not active. Average exposure levels documented by the EMDEX II™ dosimeter were below the ACGIH TLV for ELF fields.

3. **Measurements of the Stirrer's Magnetic Field.** The NIOSH investigators were informed by ARMCO personnel that the magnetic stirrer operated at a frequency of 1.6 Hz and a maximum current of 1200 amperes. These numbers were then reconfirmed with the manufacturer of the stirrer (ABB Industrial Systems, Inc). As mentioned earlier, the Holaday model HI-3624, at a 5 Hz cutoff point, under-responds the true reading. Table 2 shows the measurements collected as a function of stirrer current and distance. Since workers were located at least 20 feet from the stirrer during its on time, the magnetic field levels were quite small.

4. **Other EMF Sources.** There were other EMF sources in the control room, besides the ladle operations and magnetic stirrer. Sources such as VDTs, fans, lights, coffee pots, microwave ovens, printers, and walkie-talkies were found to be present and operational. No measurements were taken on these sources since the dominant worker exposure was due to EMF produced by the transformer.

5. **Frequency Measurements.** Waveforms were analyzed at several different times in the control room when the ladle was operating. The magnetic field waveforms, as captured by the Holaday meter and displayed on a digital oscilloscope, were found to be sinusoidal at 60 Hz. The electric field generated waveforms, as captured in the control room, were more complex in nature. Instrumentation was not available to record waveforms produced by the magnetic stirrer at 1.6 Hz.

B. Galvaneal Unit

Electric and magnetic field levels produced by the galvaneal coating units were obtained with both the Holaday ELF and VLF meters as well as the profiler. Data from these measurement are shown in Tables 3 and 4 as a function of distance and system wattage. The coating unit is in the shape of an elongated cube measuring approximately 15 x 15 x 40 feet. The unit is built in three sections which can permit workers on each section.

Unfortunately, the Holaday meter is limited to a dynamic range of 25 mG (2 A/m) for magnetic fields. This range limitation on the meter did not allow measurements to be made with this meter at distances closer than 18 feet. The profiler did record levels as high as 77.5 mG at 18 feet but instrumentation difficulty prevented the profiler from being used for the entire evaluation. Measurements made using the Holaday VLF magnetic field meter at different locations on each section of the coating units were less than 25 mG. The NIOSH investigators believe readings should be repeated when an appropriate commercial instrument is available.

Levels for ELF magnetic fields were documented in the immediate vicinity near the galvaneal unit and included the four 60 Hz induction furnaces and control rooms. These measurements were made in a walk-around mode using EMDEX II™ units held four feet off the ground. The ELF magnetic field levels around the furnaces ranged from 2 to 1100 mG with average values ranging from 30 to 50 mG. In the control room, spot readings reached 300 mG. It was observed that workers sat in chairs for prolonged periods next to areas that produced ELF levels near 150 mG.

C. Other Worksite Measurements

Measurements were made in two electrical sub-stations located on the ARMCO property. The range of electric and magnetic fields measured at either of the sub-stations was 50-1300 V/m and 20-400 mG, respectively. These measurements do not reflect a detailed evaluation of the sub-stations, but rather the levels electrical workers might be exposed to when on the sub-station walkways. If workers were to move closer to the transformers or power cables, both the electric and magnetic field levels could rapidly increase.

Levels of 2000 V/m and 800 mG were recorded on the west end (roof) of Building 601 (under electrical cables mounted 10 feet above the roof). It should be noted that only a few maintenance workers would ever be at this location.

VII. DISCUSSION

A. *Image Movement Associated with Television Sets.*

Several cathode ray tube (CRT) monitors were used in the control room at the Ladle Refinery to present information about the heating of the steel in the ladles. When the refinery's electrodes were inactive, the information on the monitor's screen was clearly readable. However, when the electrodes were active, the screens were affected by the generated electric and magnetic fields, making the images difficult to read (i.e., screen images were in a scrolling mode). In addition, when the magnetic stirrer was active, the screen images would also rock from side to side. The subject of electromagnetic imaging (EMI) on CRTs has long been recognized.[3] The problems seen in the control rooms at ARMCO can lead to health concerns such as visual tracking limitations and ergo-ophthalmology problems. One of the shift turn coordinators mentioned to the NIOSH investigators that he often felt dizzy after working for an extended time in the control room.

B. *Instrumentation Problem with VLF Measurements.*

At the time of this evaluation, there was no commercially available instrument capable of measuring the exact levels of magnetic fields at 9.9 kHz produced by the galvaneal coating unit. The measurement systems used by NIOSH at ARMCO did indicate that the levels of 9.9 kHz radiation produced by the unit were probably in excess of the ACGIH occupational exposure standard. This information is shown in Figure 7 where the shaded area indicates extrapolated magnetic field levels workers might receive if they worked at distances less than five feet from the unit. Until additional instrumentation is available that responds reliably to such fields, it may be necessary to restrict workers from working in the immediate vicinity of this unit when it is activated. This restriction may not be difficult to implement since workers are not required to remain at close distances to the galvaneal unit for extended periods of time. If workers are required to come into close contact with the system, it may be necessary to turn the power off or reduce power levels.

C. *Movement of Transformer/Workers in Control Room of Ladle Refiner.*

Due to the elevated electric and magnetic fields in the ladle refinery's control room area during active periods, NIOSH investigators suggested that either the transformer or the control room be relocated. It was noted that the original control room specifications developed by ASEA-SKF indicate that the transformer house is separated from the control room (see Figure 8). At ARMCO, the two rooms are located on the same side and in the same building. The highest ELF levels measured on the evaluation days in the vicinity of the control room were 16.9 V/m and 1.48 G. While neither of these levels are above current ACGIH occupational ELF exposure limits, it is significant that the bulk of the fields produced is due to the presence of the transformer eight feet below the control room.

In order to demonstrate the possible ELF reduction to control room personnel achievable by relocating either the control room or transformer, NIOSH investigators made ELF measurements on the platform across the aisleway from the existing control room during active ladle operations and recorded levels as high as 3 V/m and 0.43 G. These levels are significantly less than the maximum levels reported in the control room. It is anticipated that a more detailed measurement survey could find other locations that yield smaller levels.

VIII. CONCLUSIONS/RECOMMENDATIONS

Based on the results, NIOSH investigators have determined that a potential health hazard existed at the time of evaluation to workers at the galvaneal coating line unit when they were located less than five feet from the unit. The following recommendations are offered to reduce potentially significant occupational exposures and safety risks at ARMCO:

1. The Safety Office should consider purchasing appropriate ELF monitoring instrumentation to evaluate occupational exposures to electric and magnetic fields that can occur at the facility.

2. Workers at the galvaneal coating units will need to work at distances that produce VLF fields levels less than the occupational standard. The best current estimate for this distance is about five feet. When appropriate instrumentation is available to accurately assess this operation, this distance should be re-evaluated.

3. The NIOSH investigators believe the existing level of ELF exposure to control room personnel is unnecessary and could be improved by relocating either the transformer or control room. While it is true that present levels are below existing occupational standards, it is also true that very little is known about biological effects of ELF. While some exposure may have to be encountered from control room activities, it does not have to be due to unnecessary exposure.

4. Workers should be trained as to the nature and levels of electric and magnetic fields that can be found at various areas within the facility.

IX. REFERENCES

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2. ANSI [1991]. Safety levels with respect to human exposure to radiofrequency electromagnetic fields, 3 kHz to 300 GHz. The Institute of Electrical and Electronic Engineers. New York, NY: American National Standards Institute Committee C.95.1.

3. Baiswiki RS, Deno DW [1987]. Interference from 60 Hz electric and magnetic fields on personal computers. IEEE Transactions on Power Delivery. V. PWRD-1, #2, pp 558-563, April.

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1. ARMCO Steel Co., L.P., Ashland, KY
2. NIOSH
3. OSHA, Region IV

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
MEASUREMENTS OF ELECTRIC AND MAGNETIC FIELDS
AT SELECTED LOCATIONS IN THE LADLE REFINER'S CONTROL ROOM
AS A FUNCTION OF ACTIVE AND NON-ACTIVE ELECTRODES
USING THE HOLADAY METER HELD AT WAIST LEVEL

ARMCO STEEL COMPANY, L.P.
HETA 91-0140
JUNE 2-4, 1992

LOCATION	ELECTRIC FIELD (V/m)		MAGNETIC FIELD (G)		RATIO ON/OFF	
	Active	Not Active	Active	Not Active	E-Field	H-Field
A	4.4	3.42	0.17	0.002	1.3	85
B	4.8	3.6	0.25	0.002	1.3	125
C	3.1	5.8	0.33	0.0031	1.1	107
D	3.2	2.8	0.51	0.0023	1.1	222
E	5.5	6.7	0.63	0.0037	0.8	170
F	17	16.9	0.42	0.0026	1.0	162
G	6.1	11.2	0.44	0.0031	0.8	142
H	3.8	5.8	0.23	0.0025	0.7	92
I	6.8	6.5	0.36	0.0015	1.0	240
J	4.2	4.0	0.55	0.0006	1.1	917
K	4.4	4.3	0.82	0.001	1.0	820
L	8.3	10	1.34	0.002	0.8	670

TABLE 2
ESTIMATED MAGNETIC FLUX IN GAUSS
MEASURED WITH HOLADAY MODEL HI-3624 METER
USING A 5 HERTZ CUT-OFF FILTER

ARMCO STEEL COMPANY, L.P.
HETA 91-0140
JUNE 2-4, 1992

Magnetic Stirrer Current (A)	Stirrer on Ladle 20' Away	Stirrer Only 20' Away
200	0.002	0.014
400	0.010	0.020
600	0.014	0.022
800	0.019	0.029
1100	---	0.030

TABLE 3
MAXIMUM ELF/VLF FIELDS PRODUCED BY GALVANEAL LINE AT DIFFERENT LOCATIONS AND POWER SETTINGS (a) USING THE HOLADAY SURVEY METER

ARMCO STEEL COMPANY, L.P.
HETA 91-0140
JUNE 2-4, 1992

SITUATION	EXTREMELY LOW FREQUENCY		VERY LOW FREQUENCY	
	Electric (V/m)	Magnetic (mG)	Electric (V/m)	Magnetic (mG)
Standing under system, no power (background)	2.8	0.4	0.1	< 1
200,000 watts, 18 feet away	7	30	12	> 25[b]
200,000 watts, 9 feet away	10	2.5	18	> 25[b]
400,000 watts, under unit, 3' above floor	15	8	18	> 25[b]
400,000 watts, under unit, 7' above floor	--	--	80	> 25[b]
600,000 watts, under unit, 3' above floor	--	--	159	> 25[b]

a. Unit not running in normal manner, piece of metal inserted in unit to simulate production cycle.
b. Meter saturation

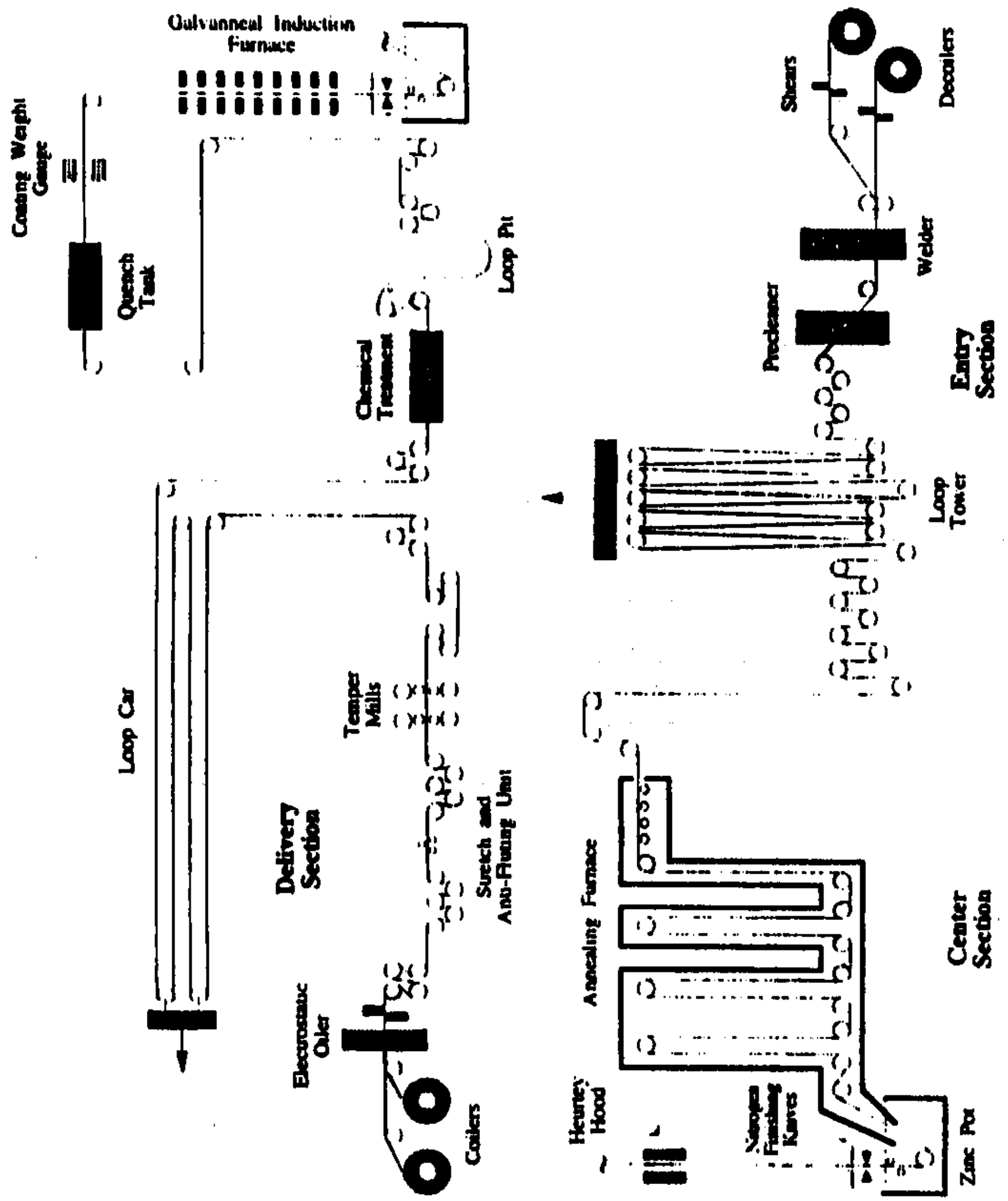
TABLE 4
RANGE OF ELF/VLF MAGNETIC FIELDS PRODUCED BY GALVANEAL LINE AT DIFFERENT LOCATIONS AND POWER SETTINGS (a) USING THE PROFILER METER

ARMCO STEEL COMPANY, L.P.
HETA 91-0140
JUNE 2-4, 1992

SITUATION	ELF (mG)	VLF (mG)
200,000 watts 18 feet	0.4 - 4.3	1.2 - 77.5
200,000 watts 9 feet	0.4 - 3.9	1.3 - 61.1
600,000 watts under unit	0.1 - 20.2	3.4 - 32.6

a. Unit not running in normal manner, piece of metal inserted in unit to simulate production cycle.

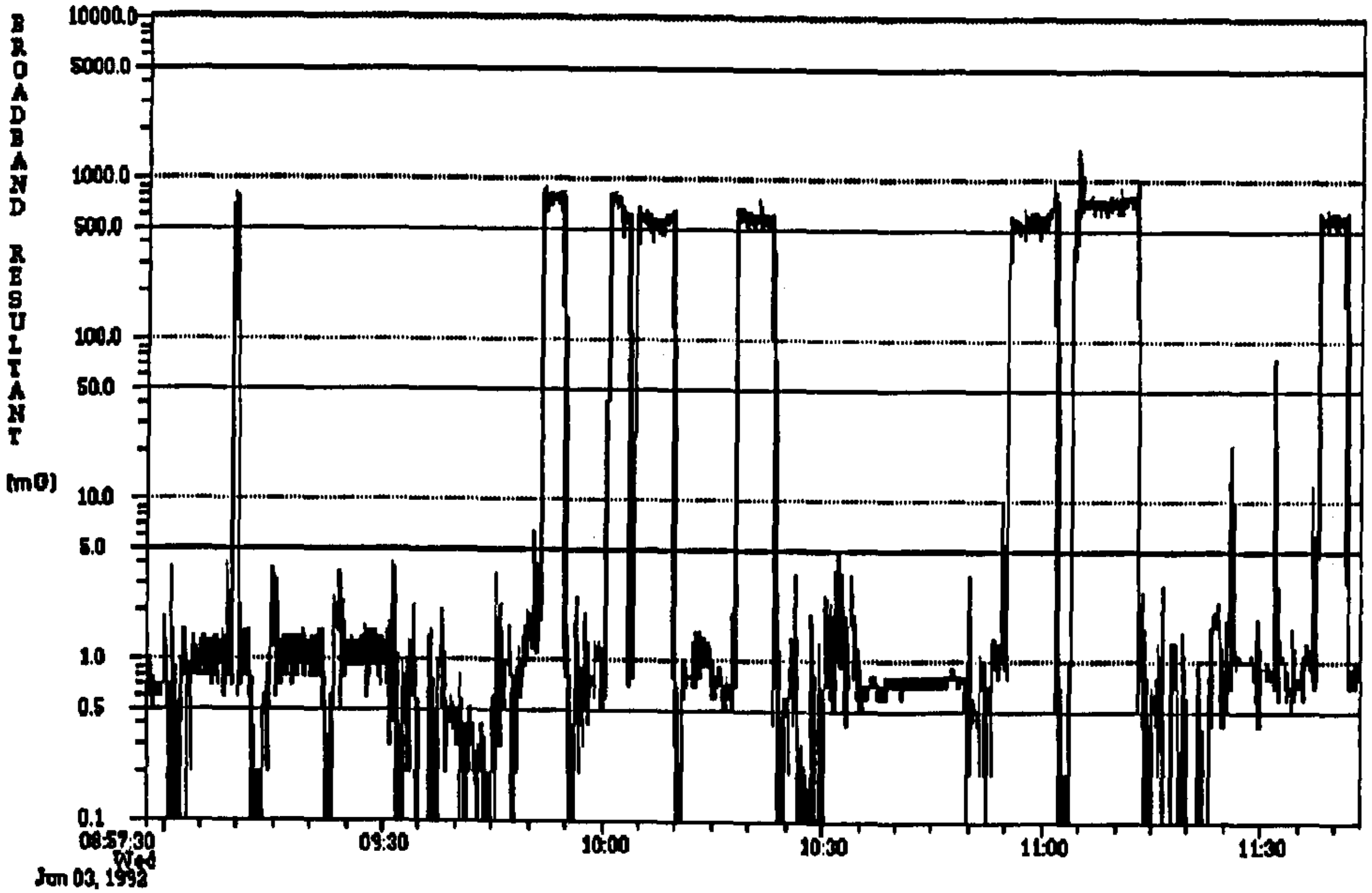
N = 6990 Geo. Mean = 2.76 mG
Fraction Exceeding 2 mg = 0.234
Mean = 127.58 mG Median =
0.9 mG 4 mG = 0.214
St. Dev = 252.59 mG 95%Tile =
705 mG 10 mG = 0.211
Sample Rate = 1.5 s mG - Hr
= 371.57 100 mG = 0.208
Min = 0.2 mG Max =
1482 mG



Operation Information

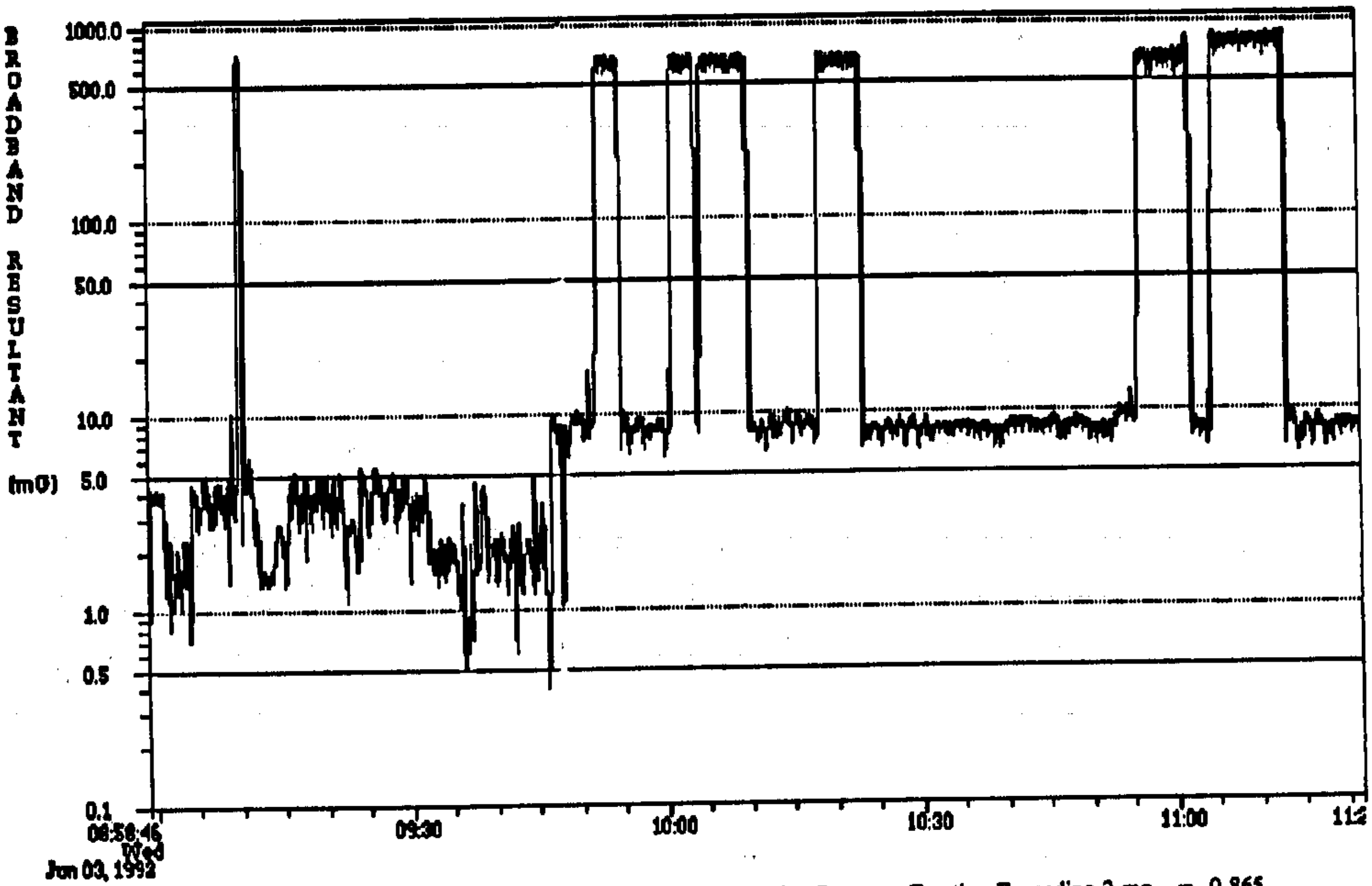
Product	**Zincgrip (Galvanized)** **Paintgrip** **HSLA** **Galvanneal**
Surface Finish	**Minispangle** **Extrasmooth** **Ultrasmooth**
Gauge	**0.017 - 0.075"**
Width	**24 - 60"**
Coil Weight	**60,000 Lbs. Max.**
Coil O.D.	**76"**
Coil I.D.	**24"**
Coating Weight	**G01 - G90, A45 - A60**
Production	**312,000 TPY**

FIGURE 1. SCHEMATIC OF GALVANEAL LINES WORK FLOW PATTERN.



N	=	6990	Geo. Mean	=	2.76 mG	Fraction Exceeding 2 mg	=	0.234
Mean	=	127.58 mG	Median	=	0.9 mG	4 mG	=	0.214
St. Dev	=	252.51 mG	95% Tile	=	705 mG	10 mG	=	0.211
Sample Rate	=	1.5 s	mG - Hr	=	371.57	100 mG	=	0.208
Min	=	0.2 mG	Max	=	1482 mG			

FIGURE 2
ELF Magnetic Field Exposure Measurements for Helper in Control Room During a Portion of Workday

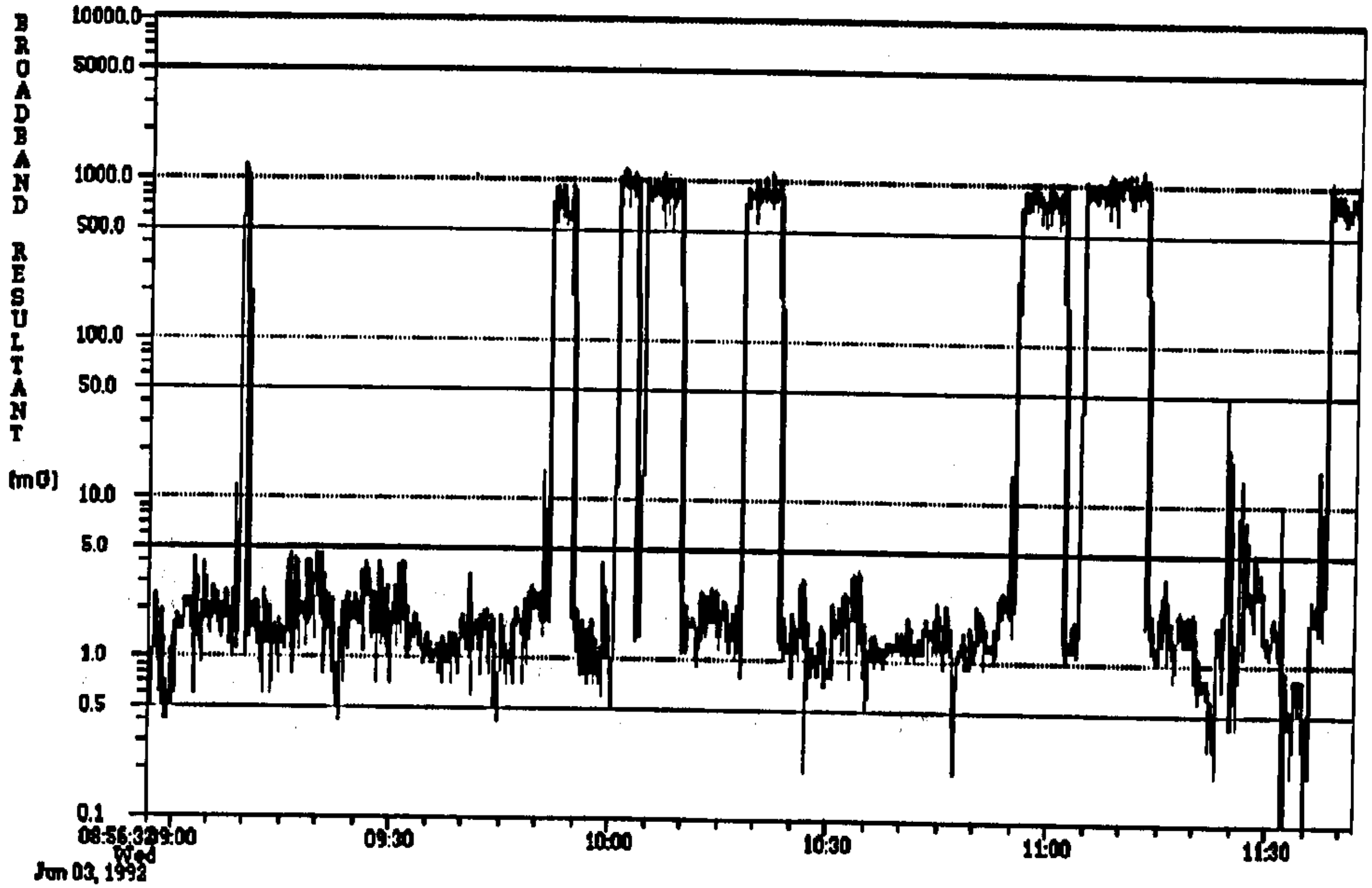


N = 5886
Mean = 138.03 mG
St. Dev = 253.06 mG
Sample Rate = 1.5 s
Min = 0.3 mG

Geo. Mean = 13.46 mG
Median = 7.8 mG
95% Tile = 689 mG
mG - Hr = 338.52
Max = 807 mG

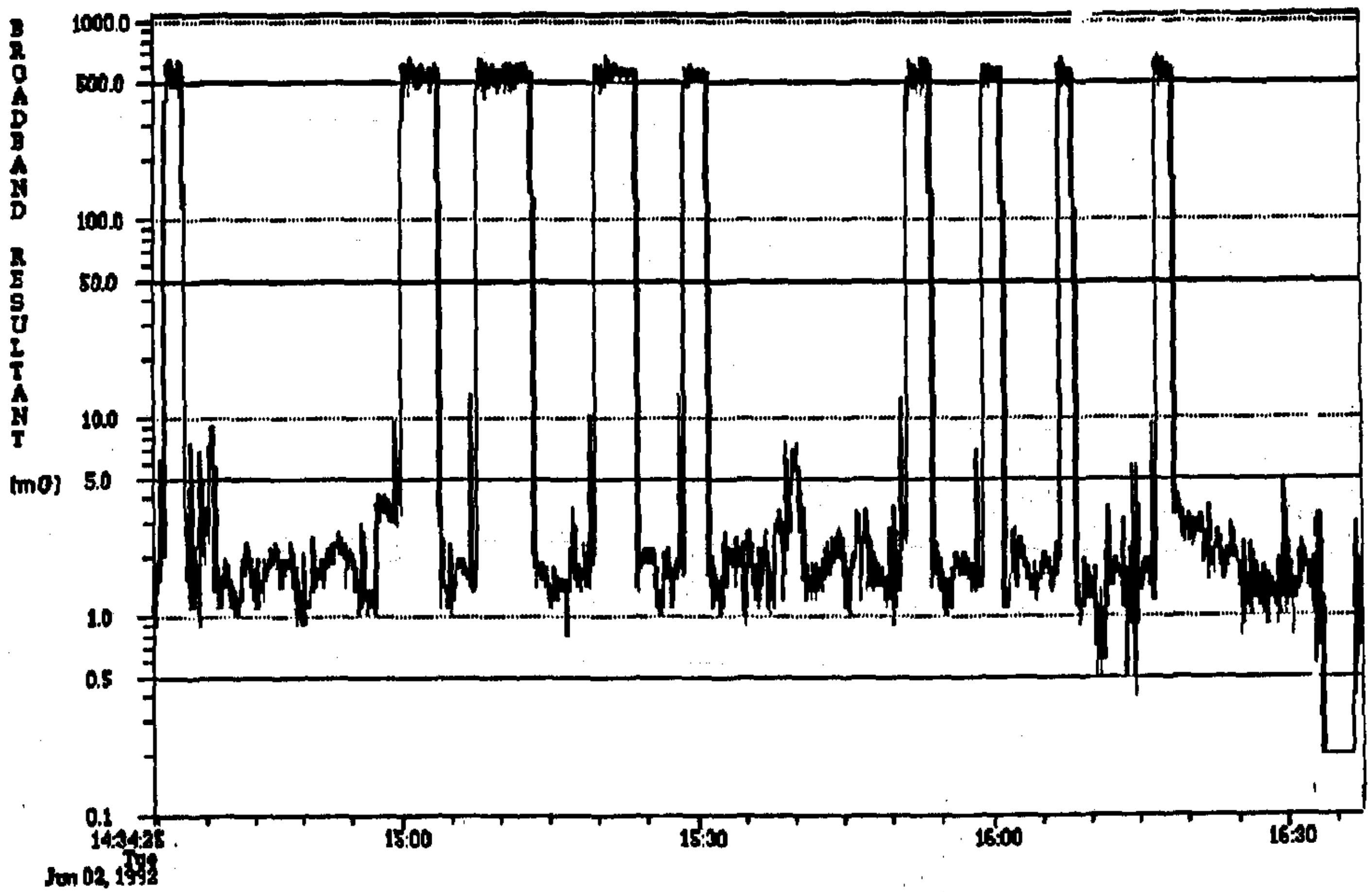
Fraction Exceeding 2 mg = 0.865
4 mG = 0.714
10 mG = 0.222
100 mG = 0.219

FIGURE 3
ELF Magnetic Field Exposure Measurements for Turn Coordinator in Control Room During a Portion of Workday



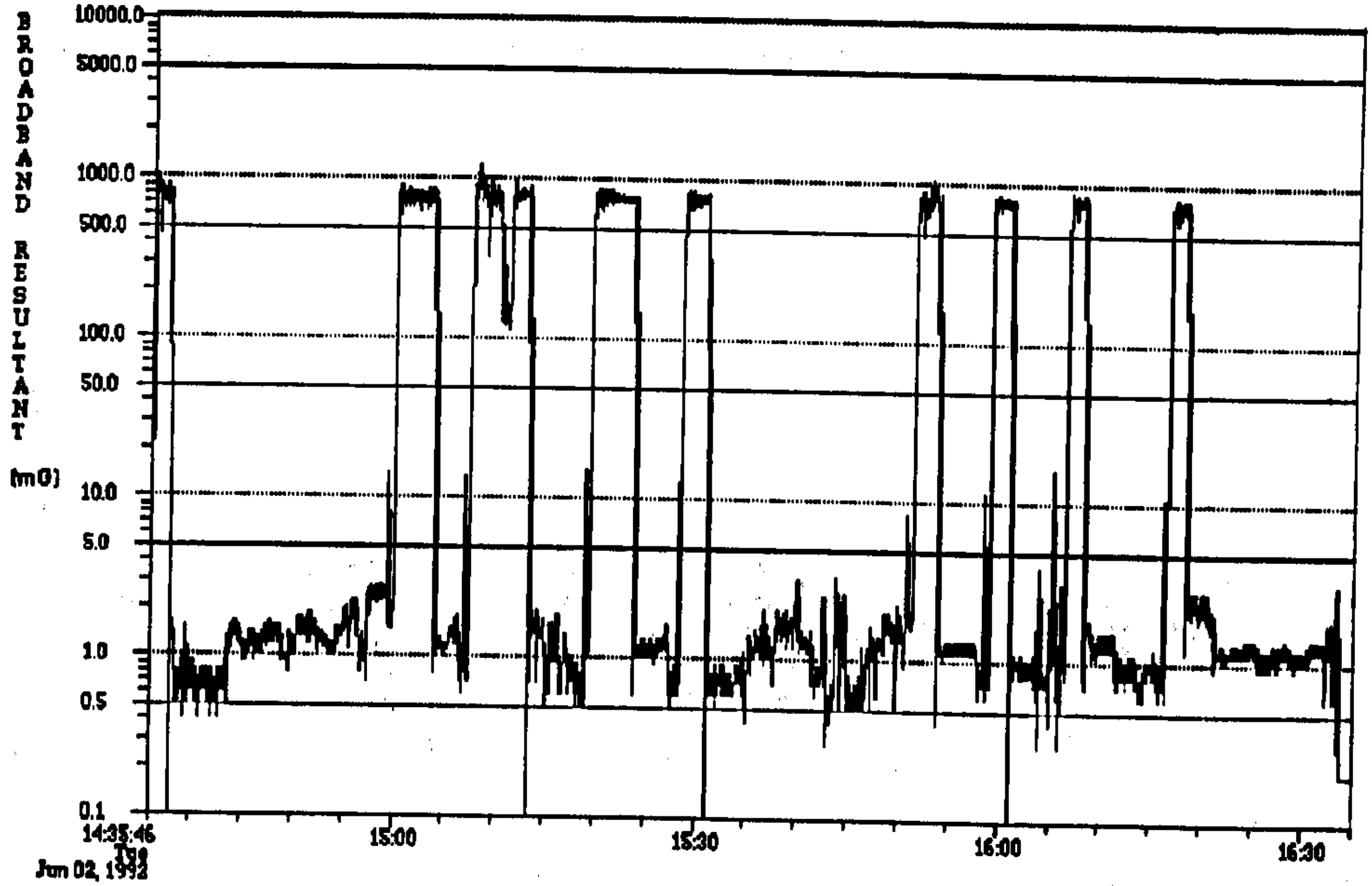
N	= 6955	Geo. Mean	= 5.19 mG	Fraction Exceeding 2 mg	= 0.366
Mean	= 168.72 mG	Median	= 1.6 mG	4 mG	= 0.220
St. Dev	= 330.02 mG	95% Tile	= 884 mG	10 mG	= 0.214
Sample Rate	= 1.5 s	mG - Hr	= 488.93	100 mG	= 0.209
Min	= 0.2 mG	Max	= 1124 mG		

FIGURE 4
ELF Magnetic Field Exposure Measurements for Ladle Furnace Operator in Control Room During a Portion of Workday



N	= 5172	Geo. Mean	= 5.68 mG	Fraction Exceeding 2 mg	= 0.437
Mean	= 107.94 mG	Median	= 1.9 mG	4 mG	= 0.234
St. Dev	= 205.12 mG	95% Tile	= 516 mG	10 mG	= 0.217
Sample Rate	= 1.5 s	mG - Hr	= 232.61	100 mG	= 0.215
Min	= 0.3 mG	Max	= 794 mG		

FIGURE 5
ELF Magnetic Field Exposure Measurements for Turn Coordinator in Control Room During a Portion of Workday



N	= 5014	Geo. Mean	= 4.22 mG	Fraction Exceeding 2 mg	= 0.287
Mean	= 146.21 mG	Median	= 1.3 mG	4 mG	= 0.209
St. Dev	= 290.82 mG	95% Tile	= 766 mG	10 mG	= 0.208
Sample Rate	= 1.5 s	mG - Hr	= 305.45	100 mG	= 0.206
Min	= 0.1 mG	Max	= 1140 mG		

FIGURE 6
ELF Magnetic Field Exposure Measurements for Ladle Furnace Operator in Control Room During a Portion of Workday

FIGURE 7. MAGNETIC FLUX INTENSITY PRODUCED BY 9.9 kHz GALVANEAL COATING SYSTEM AS A FUNCTION OF DISTANCE. DATA FOR 20% OUTPUT LEVEL.

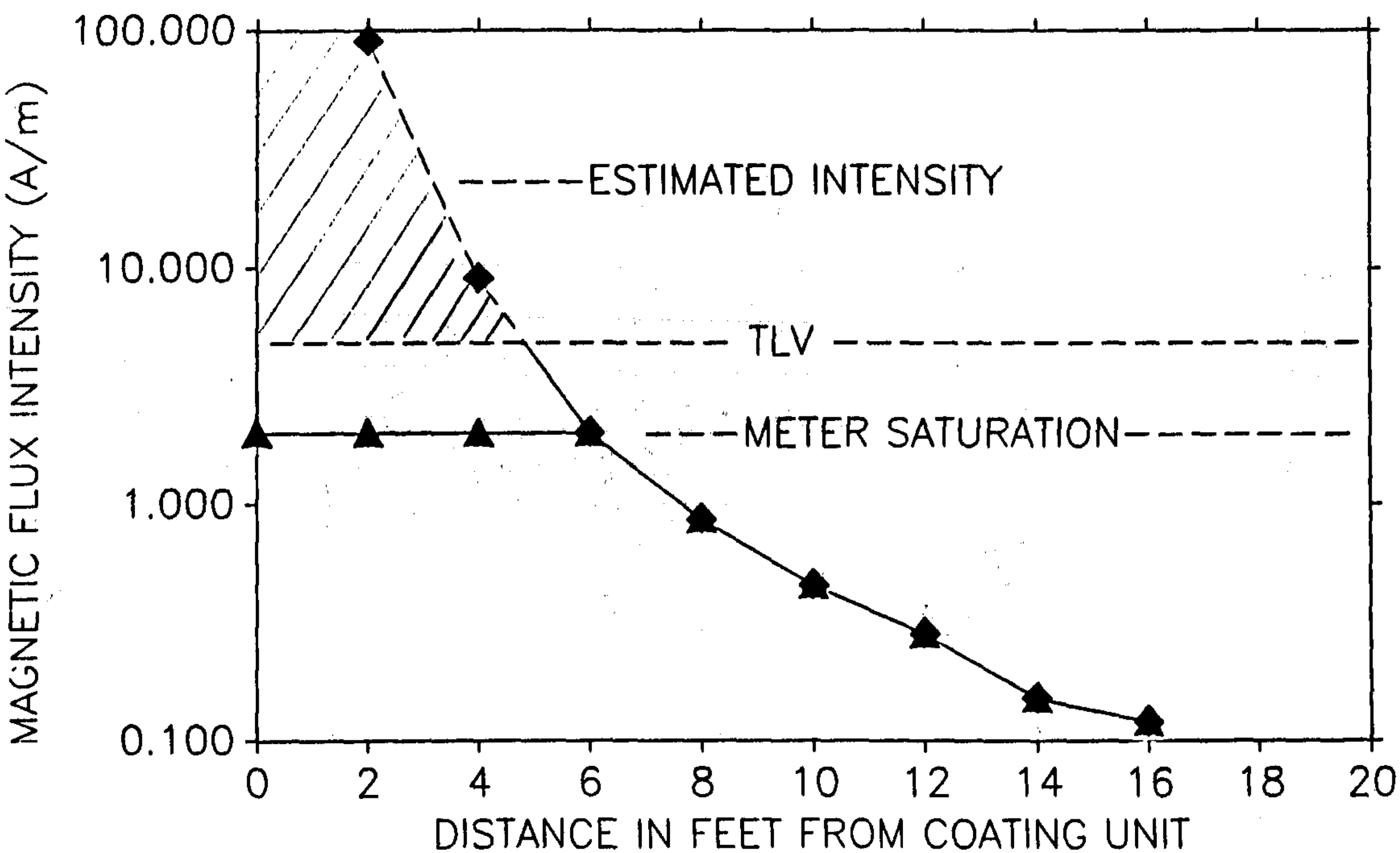
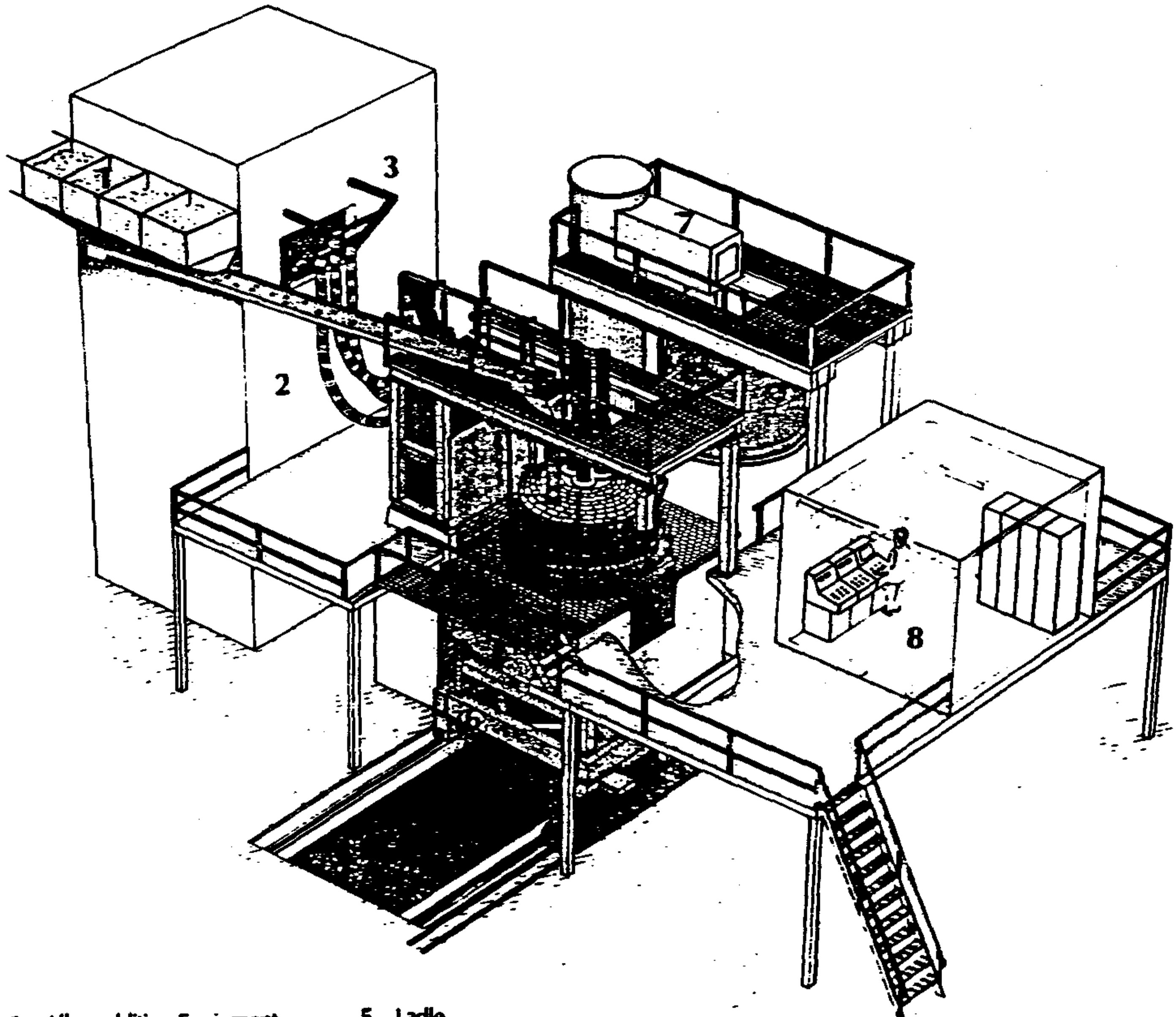


FIGURE 8. CONTROL ROOM CONFIGURATION ORIGINALLY SUGGESTED BY MANUFACTURER OF TRANSFORMER SYSTEM.



1 Alloy addition Equipment
2 Hydraulic and electric rooms
3 Transformer house
4 Heating station
5 Ladle
6 Ladle transfer car
7 Degassing station
8 Main control room