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ECONOMIE ENERGETIQUE ET FONCTIONNEMENT DES BALLASTS A CIRCUIT ELECTRONIQUE/ENERGY EFFICIENCY AND PERFORMANCE OF SOLID STATE BALLASTS/ ENERGIEWIRKUNGSGRAD UND LEISTUNG ELEKTRONISCHER VORSCHALTGERAETE

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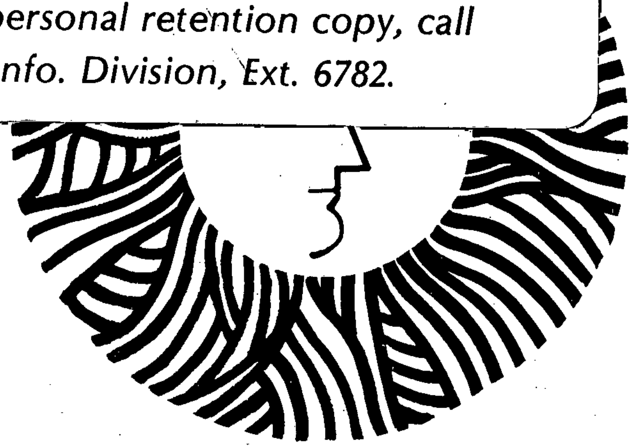

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ECONOMIE ENERGETIQUE ET FONCTIONNEMENT DES BALLASTS A CIRCUIT ELECTRONIQUE
ENERGY EFFICIENCY AND PERFORMANCE OF SOLID STATE BALLASTS
ENERGIEWIRKUNGSGRAD UND LEISTUNG ELEKTRONISCHER VORSCHALTGERAETE

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RESUME

Le fonctionnement haute fréquence des lampes fluorescentes a été compris et testé de longue date. Toutefois l'application de ce principe n'a pu se répandre que depuis l'arrivée des circuits électroniques. En réponse aux fabricants de ballasts qui prétendent obtenir une bonne efficacite énergétique, un project fut entrepris pour tester ces ballasts.

On a considére deux types de ballasts, et, à la suite d'une phase d'essais, plusieurs centaines d'unités ont remplacé les ballasts conventionnels dans les appareils d'éclairage en place sur trois étages d'un immeuble de bureaux à San Francisco, Californie. Un type de ballast à bobinage central, de bon rendement énergétique, fut inclus dans la démonstration.

Les ballasts de démonstration se sont avérés plus efficaces que les ballasts conventionnels à bobinage central qu'ils remplaçaient. Leur demande réduite a eu pour effet le plus notable une réduction considérable de la demande de puissance de pointe hebdomadaire. Avec des lampes fonctionnant à plus de 20 KHZ ils ont réduit le niveau de son audible et causé une moindre dissipation de chaleur. Les interférences d'ondes de fréquence radio, bien que passablement accrues n'ont causé aucune difficulté apparente. Comme les trois ballasts de démonstration réduisent quelque peu le rendement lumineux des lampes, ceci a partiellement réduit l'économie d'énergie réalisée grâce au project.

On a réussi à mesurer l'utilisation d'énergie dans ces ballasts au moyen de compteurs électriques couramment utilisés par la compagnie d'électricité. Cependant quelques doutes demeurent en ce qui concerne les effets des harmoniques associées au circuit électronique.

C'est pourquoi, bien qu'aucun effet défavorable n'ait été observé, on doit continuer à examiner la précision des compteurs d'électricité ainsi que l'effet de tels ballasts sur le réseau public d'électricité. Le projet de démonstration a établi que l'on peut installer en grand nombre des ballasts à circuit électonique pour le fonctionnement des lampes à haute fréquence et que l'on obtient un fonctionnement satisfaisant, sans effet défavorable, et que l'on réalise une remarquable économie d'énergie.

ZUSAMMENFASSUNG

Der Hochfrequenzbetrieb Leuchtstofflampen ist laengst verstanden und geprueft worden. Dennoch die Ankunft der elektronischen Stromkreisgeraete hat es erst ermoeglicht, dieses Prinzip in grossem Massstab zu benutzen. In Beantwortung des Anspruchs, dass Vorschaltgeraeteerzeuguer auf Energieleistung der Geraete erhebten, wurde eine Untersuchung solche Geraete unternommen.

Zwei Typen Vorschaltgeraete wurden untersucht, und, nach einer Testphase wurden ein paar Hundert Stueck in auf drei Stockwerke eines Buerogebaeude in San Francisco (California) bestehenden Lichtanlagen als Ersatz errichtet. Dazu wurde eine konventionnelle energieleistungsfaehige Kernspule auch geprueft. Es wurde bewiest, dass die zur Vorfuehrung angewandten Vorschaltgeraete leistungsfaehiger als konventionnelle Kernspulen seien.

Die Sinkung der Kraftnachfrage er gab eine bedeutend geringere Wochen-Nachtragespitze. Die mit ueber 20 KHZ betriebenen Lampen erzeugten weniger hoerbar Geraeusch und gaben geringere Waermeverluste heraus. Radiofrequenzaustrahlunginterferenzen ob auch etwas groesser, fuehrten zu keinen offenbaren Schwierigkeiten.

Die Lichtausbeute sank ein bisschen in all drei Vorshaltgeraeten, deshalb wurde die Energieerspaernis zum Teil vermindert. Der Energieverbrauch durch Vorschaltgeraete wurde mittels konventionneller elektrischer Zaehler gemasst aber es bleiben noch einige Ungewissheiten, was die Folgen der Nebentone der elektronischen Stromkreisgeraete anbetrifft.

Wenn keine widrige Folgen auch wahrgenommen wurden, muessen noch die Genauigkeit der elektrischen Zaehler sowie die Konsequenzen der Vorschaltgeraete auf die Stromversorgung untersucht worden. Die Vorfuehrung bewies, dass elektronisde Vorschaltgeraete fuer Leuchtstoff lampen in grossem Massstab erfolgreich errichtet werden koennen, das heisst:ohne widrige Folgen und mit bedeutender Energierrsparnis.

SUMMARY

High frequency operation of fluorescent lamps has long been understood and tested. However, it was not until the advent of solid-state circuitry that wide-spread use of that principle seemed possible. In response to the energy efficiency claims of ballast developers, a project was undertaken to test the ballasts.

Two ballast types were involved and, after a test phase, several hundred units were retrofitted into existing fixtures on three floors in an office building in San Francisco, California. A core-coil energy efficient ballast was demonstrated also.

The demonstration ballasts proved to be more efficient than the standard core-coil ballasts they replaced. Their demand reduction has resulted in a significantly lower weekly peak demand. Operating above 20 KHz, they have produced less audible noise. They also have lower heat dissipation.

RFI radiation, although somewhat increased, has caused no apparent difficulties. Light output has been reduced slightly by all three demonstration ballasts, a fact which somewhat offsets energy savings.

Ballast energy usage has been measured successfully with standard utility metering but there remain doubts as to the effects of the harmonics associated with solid-state circuitry. While no adverse effects have been observed, research must continue on the accuracy of electrical metering and on the effect on utility systems.

The demonstration project has shown that solid-state fluorescent ballasts providing high frequency operation can be installed successfully in large numbers without adverse effects and with substantial energy saving.

INTRODUCTION

Several organizations in the United States have developed solid state ballasts for fluorescent lighting that appear to be an economically sound replacement for the core-coil ballast now in common use. Improved efficiency in operation promises lower life cycle costs, although the initial costs of the solid state ballast are admittedly greater at this time. Other advantages are also apparent. Fluorescent lamps operated with solid-state ballasts exhibit less audible noise, have lower heat dissipation and can have an efficient dimming capacity over a broad range of light output levels. The energy cost factor, plus these additional factors, should permit, indeed encourage, lighting designers, lamp manufacturers, and fixture manufacturers to produce new, innovative lighting system concepts.

The solid state ballast provides the same primary function as the conventional core-coil ballast: It must start and then operate the lamps safely. Published solid state ballast circuit designs (1-5) convert the input 60 Hz to DC and then invert the DC to drive the lamps at high frequency. That frequency is generally in the range from 10 KHz to 30 KHz. Fluorescent lamps operated at those frequencies have a higher efficacy (6-9) than those driven at 60 Hz and, by virtue of the non-magnetic nature of the reactive circuit components, these ballasts typically have lower power losses.

In late 1976, based upon prototypical performance claims from several manufacturers and a review of the state of the development of the solid state ballast, the Lawrence Berkeley Laboratory of the University of California (LBL), with funding provided by the United States Department of Energy (DOE), initiated a development and demonstration program to assist in the commercialization of solid state ballasts for fluorescent lighting. Following a competitive procurement procedure, two ballast developers - Iota Engineering of Tucson, Arizona and Stevens Luminoptics of Danville, California - were selected to participate in the program.

In the first phase of the program (10), the two subcontractors were required to complete engineering development and testing of demonstration models. Prototypes were delivered to the Lawrence Berkeley Laboratory and to an independent test laboratory to measure various performance characteristics. In the demonstration phase, approximately one thousand ballasts were retrofitted on three floors of the Pacific Gas and Electric Company (PG&E)

General Office Building in downtown San Francisco, California. This installation was created to monitor performance and reliability of the units in a large scale commercial situation.

Sufficient evidence was gathered from the first or developmental phase of this program to present a reasonable verification of the performance of the two types of solid state ballasts involved (10). One of the test ballasts is operated at 120 volts and is engineered for minimum complexity and cost. It was designed for a single level of light output, although step dimming can be added. The other test ballast is operated at 277 volts and has a built-in continuous dimming capability that allows the light output to be controlled in several different operating modes but requires more complex circuitry than single level operation and is therefore more expensive. Ballasts of the core-coil type offered as a "premium" quality energy saving device also were included as part of the demonstration control. All ballasts in this program are of the rapid start type and are designed to operate two 40 watt T-12 fluorescent lamps. Although the test ballasts are capable of operating reduced wattage fluorescent lamps, standard lamps were used to provide consistent data with usage before the installation of the demonstration units.

BALLAST DEMONSTRATION

Following successful completion of the first phase of the project and beginning in July of 1978, demonstration ballasts were installed at PG&E. Three floors were retrofitted with energy efficient ballasts. One floor was allotted to the 277 volt dimmable ballast, one floor was converted from the existing 277 volt distribution system to 120 volts and allotted to ballasts requiring that voltage, and the third floor was allotted to the energy efficient core-coil ballast which also operated at 277 volts.

The Pacific Gas and Electric Company is an investor owned public utility providing gas and electric service in the northern two-thirds of the State of California. Company engineers applied their standard metering techniques to the two main lighting input power lines on each floor. The energy usage in kilowatthours was recorded continuously as a function of time by means of magnetic tape KQ metering (11). The power in kilowatts was calculated from that in 15-minute demand intervals. This system measured the neutral line of three phase system as well as the three mains.

The solid state ballasts were designed as direct retrofits with American National Standards Institute standard color coded leads and ballast case sizes. The ballasts were installed by the lighting maintenance contractor regularly employed by PG&E, without special instructions. Except for the change to provide 120 volts on one floor, no changes were made in the electrical wiring to accommodate either of the solid state ballasts.

The Lawrence Berkeley Laboratory, one of the United States' national laboratories and a constituent part of the University of California, installed a 60 channel data acquisition system to collect: 1) detailed data for selected branch circuits on each floor, 2) data for other essential parameters such as temperature and daylighting, and 3) data from other experiments planned as a part of the over all demonstration.

Base line data were collected by both PG&E and LBL with the existing specification grade core-coil ballasts for several months before the conversion to the test ballasts was made. Prior to that the fixtures were relamped and cleaned. Any remaining ballasts from relamped fixtures were removed. All major United States fluorescent lamp manufacturers contributed lamps to the demonstration and groups of one hundred lamps were installed after the operation of the test ballasts had been established. After an appropriate number of operating hours sample numbers of lamps were returned to each manufacturer for inspection and analysis to assist in studying the effects of high frequency operation on lamp life.

The LBL monitoring installation included thermocouples in several fixtures on each floor to measure input and output air temperature, ballast temperature, and bulb wall temperature. Ambient sound level and Radio Frequency Interference (RFI) Measurements have been made and photometric measurements were made before and after the installation of the test ballasts.

RESULT OF THE BALLAST DEMONSTRATION

1. Reduction in kilowatthour usage.

Plots of the peak kilowatt reading per week are shown for one-half of each test floor (Figures 1, 2, and 3). The data prior to the numeral 1 include the connected specification grade core-coil ballasts installed when the building was constructed in 1968-1969. Prior to the installation of the test ballasts any remaining idling ballasts (those connected to delamped sockets) were removed as can be noted in the steadily decreasing curve for the 30th floor.

The data following the numeral 2 indicate use after the change to the test ballasts. Figure 1 shows the performance of the 277 volt ballasts without any operation of their dimming capacity. All were stabilized for the proper lumen output of the lamps involved. The rise in power is caused by the replacement of failed ballasts with standard core-coil ballasts.

Figure 2 shows the performance of the 120 volt ballasts on the 28th floor. The drop in power is especially dramatic since this was the only instance in which one complete half floor was refitted with electronic ballasts within a weekly data recording cycle. It is intended that these ballasts will be left in place for at least one more year so that continuing operation may be observed.

Figure 3 shows the 30th floor, where the energy efficient ballasts were used. The slight rise in power here results from additional, unexpected occupancy of the floor.

2. Thermal effect on building heat level.

The lighting fixtures in the test building are of the air handling type with cooled feed air provided through side slots. The return air is returned to the lower pressure plenum through the fixture itself so that it serves to cool the lamps and ballasts by passing over the lamps and the ballast cover. The LBL array of tests includes thermocouples placed to measure the input and exhaust air temperature on each of the test floors.

Table I shows the air temperature and the minimum bulb wall temperature in May and June while the standard core coil ballasts were still in place and in September and October with the test ballasts installed.

Table I

Bulb Wall, Input Air, and Exhaust Air Temperatures - Degrees C

	Standard Ballast				Test Ballast			
	Bulb Wall	Input	Exhaust	Heat Gain	Bulb Wall	Input	Exhaust	Heat Gain
27	39,7	23,0	29,2	6,2	37,5	22,6	28,2	5,6
28	35,9	23,4	28,7	5,3	34,2	22,4	26,4	4,0
30*	38,1	20,6	32,0	11,4	35,5	20,2	28,8	8,6

* Four lamp fixture, other all two lamp.

It can be seen that for all fixtures the temperature of the bulb walls and of the exhaust air has been reduced significantly. On the 27th floor the air heat gain is reduced by 0,6 degrees C and for the 28th floor the reduction is 1,3 degrees C. If the air returned to the plenum is being cooled and recycled this reduction provides a significant saving in the cooling energy required.

3. Effect on lamp life.

In September, 1977 the entire three demonstration floors were relamped. After three months or approximately 1,000 hours of burning, data began to be collected on the lamp failures on each floor. Table II indicates the failures. It should be noted that the lamps had nearly 3000 hours of use when the installation of test ballasts began. Because of the relatively short time involved, it does not appear possible to make a prediction about lamp life under high frequency operation. However, the data from Table II indicate that the test ballasts did not cause an undue increase in lamp failures.

At LBL a lamp life testing facility has been set up to match the requirements of the American National Standard for lamp testing. The lumen maintenance and life of the lamps provided by one of the participating lamp manufacturers have proved satisfactory under the standard testing cycle of three hours on and twenty minutes off.

Table II

Lamp Failures

Month	Burning Hours	27th Floor	28th Floor	30th Floor (1/2 Floor)	Total
1978					
Jan.	1100	3	3	2	8
Feb.		5	2	0	7
Mar.		1	2	5	8
Apr.	2030	0	2	2	4
May		0	2	0	2
June		0	1	1	2
July	2940	0	1 (102)	0	1
Aug.		1	2 (203)	6	9
Sept.		2 (27)	5 (404)	1 (169)	8
Oct.	3900	6 (257)	2	3	11
Nov.		2 (339)	1	0	3
Dec.		4	4	0	0
1979					
Jan.	4800	4	0	1	5
Feb.	4800	0	0	0	0
Mar.		15	4	2	21
Apr.	5700	1	18	0	19
TOTAL	5700	46 (339)	49 (404)	22 (169)	116

Figures in parenthesis are cumulative numbers of demonstration ballasts installed. Only one-half of the 30th floor was used in this portion of demonstration. All ballasts operate two lamps so that the total number of lamps is nearly 2000.

4. Ballast failures.

Figure 4 shows the ballast failures, by floor, during the demonstration. Electronic test ballasts have failed but the failure of some of the original core-coil ballasts and of the energy efficient core-coil ballasts can be noted.

After a short time it was apparent that there was a quality control problem in the manufacture of the 277 volt ballasts used on the 27th floor. While the number of failures was disappointing, nearly 200 units have continued to operate successfully. Failures on the 28th floor with the 120 volt ballasts were traced to an excessive open circuit voltage in some units when one of the lamps was removed. That design problem has been corrected in the continuing development of the ballasts.

In spite of the failures of the electronic test ballasts there was no evident safety hazard to personnel or damage to the building and the consequences of ballast failure did not appear to exceed those resulting from the failure of a standard core-coil ballast. From these results it appears that solid state, high frequency ballasts can provide reliable and safe operation of fluorescent lamps.

5. Electro-Magnetic Interference (EMI)

Laboratory and test site measurements of RFI (both conducted and radiated) were made by the Department of Engineering Research of PG&E (12). The results of these are shown in Figures 5 and 6 which compare the laboratory measurements with those taken on the demonstration floors.

Electronic ballasts do generate more RFI than do conventional core-coil ballasts but Figures 5 and 6 show that the amplitude differences were less at the site than those measured in the laboratory.

While it is difficult to state that these increased RFI levels are "safe" and will not interfere with the normal operation of building systems, it is important to note that there is no cumulative effect from the installed ballasts on the test floors. No evidence of interference with the PG&E internal communication systems attributable to the operation of the test ballasts has been reported.

6. Comparative light outputs.

Photometric measurements at the PG&E building were made by the Lighting Group of Smith, Hinchman & Grylls Associates, Inc. (SH&G) of Detroit, Michigan. The first SH&G measurements were made after 1400 hours of lamp use. The measuring team returned to the test site following the installation of the test ballasts and at a point at which the test lamps had a total of 3900 burning hours. A fairly small sample of the luminaires involved was investigated. Field photometry was performed on five fixtures, two of each electronic ballast and one energy efficient core coil unit. Four standard electric lighting surveys were performed in selected typical offices. (13)

Both sets of measurements showed systematic and significant drops in the luminous output of the fixtures involved. These are shown in Tables III and IV.

TABLE III

Electric Lighting Survey (SH&G Report Table II)

Room 2828	14 Measured Locations	Average Decrease	-15,2%
Room 2882	8 Measured Locations	Average Decrease	-22,0%
Room 2811	9 Measured Locations	Average Decrease	-24,78%
Room 3056	9 Measured Locations	Average Decrease	-9,36%

TABLE IV

Field Photometry, Isolated Fixtures (SH&G Report Table III)

Room 2760F	Average Decrease	-15%
Room 2760K	Average Decrease	-20%
Room 2824	Average Decrease	-8%
Room 2828	Average Decrease	-16%
Room 3054	Average Decrease	-8%

These readings should be contrasted with LBL laboratory measurements shown in Table V.

TABLE V

Net Luminous Output Decrease (LBL Laboratory Measurements)

13	27th Floor Ballasts	Average Decrease	8,6%
12	28th Floor Ballasts	Average Decrease	11,6%
4	30th Floor Ballasts	Average Decrease	5,5%

Two factors contribute to the discrepencies between these measurements. Figure 10A shows the Illuminating Engineering Society of North America's lumen maintenance curves as a function of hours of operation. (14) The curves show the decrease in light output with time of operation. The hours at which the SH&G measurements were made have been plotted on these curves. It may be noted that the light output would have depreciated to about 94% at the time of the first SH&G measurements and would have dropped further to somewhat less than 88% at the time of the second measurements or a change of approximately 7% in luminous output as a function of time.

Figure 10B is the Illuminating Engineering Society of North America's curve showing light output versus minimum bulb wall temperature. (15) This curve indicates that as the minimum bulb wall temperature departs from optimum value the lumen output will fall off. Bulb wall data from LBL is shown in Table VI.

TABLE VI

LBL Blub Wall Temperature, Degrees C

Room*	30 January, 1978	9 October, 1978
2848	39,5	36,2
2760K	39,5	38,0
3054*	43,5	34,2

* Four lamp fixture

The data show that bulb wall temperature is decreased when driven with the energy efficient ballasts used in the test. The general thermal effects were discussed in Section 2 above, and indicate the same reductions. The reduction for the energy efficient core coil ballast brings the bulb wall temperature closer to the optimum operating point. In one case the solid state ballasts drop the temperature to the optimum point and in the other case drop it below that point.

It appears that the lamp lumen depreciation between the two SH&G measurement dates and the changes in bulb wall tempeature combine to make the SH&G measurements and those of LBL reach reasonable agreement.

Both laboratory and demonstration site data confirm that the increased energy efficiency of both the core-coil ballast and the solid state ballast is achieved at a small reduction in light output and in resulting illuminance. The relationship between task locations and fixtures in the measured rooms, as in most PG&E General Office locations, was such that no complaints were received because of this change.

6. User acceptance of high frequency operation.

In entering the demonstration phase of this project it was anticipated that high frequency operation somewhat above 20 KHz would cause employee complaints. Only one ballast was removed as a result of a complaint. This was a 120 volt ballast and the employee involved was adamant that he could hear the high frequency sound. Discussion with management on the involved floors indicated no further difficulties.

It was a common observation on the floors using solid state ballasts that the noise level seemed lower because of the absence of hum which many associate with standard core-coil ballasts. Sound power measurements were made by the Department of Industrial Hygiene of LBL and are shown in Figures 7, 8, and 9. (16) These three figures plot the sound level measured on the test floors of the PG&E building. The broad band sound measurements are shown under "Linear" and "A". "Linear" measures all frequencies equally and "A" responds less to low frequencies. The difference between the results from standard ballasts and the test ballasts is an increase in the higher frequencies, as was anticipated.

The broad band "A" scale is 30 to 40 dB(A) for a very quiet office and it is not uncommon for small offices to have sound levels of 50 dB(A). None of the test ballasts appears to contribute significantly to the overall effect of office noise.

7. Effect on utility systems.

The KQ metering (11) used by the Pacific Gas and Electric Company for general metering and for this demonstration has provided (computer calculations of power factor) and adequate records of the power used. Table VII shows power and power factor from the measurements of both PG&E and LBL.

TABLE VII

Power and Power Factor Measurements

Ballasts		Power in Watts PGE	Power in Watts LBL	Power Factor in % PG&E	Power Factor in % LBL
27th floor -	Standard	101	98	100	96
	277 volts	76	75	92	92
28th floor -	Standard	90	91	100	100
	120 volts	79	75	-99	94
30th floor -	Standard	97	95	100	99
	Eng. Eff.	85	84	100	97

From Table VII two things can be observed. Energy efficient ballasts, either core-coil or solid state, use less energy and, second, there are differences in power factor which may be of importance. Utility systems will welcome the reduction in use since the commercial lighting to which these ballasts are most applicable is a major contributor to daytime peak use. However, much remains to be determined about the true power factor of these devices and their actual contribution to required generating capacity. (17, 18)

The PG&E factor data are taken from the KQ metering and are the result of customary usage measuring. If one assumes that voltate and current are 60 Hz sinusoidal functions, then standard approximations such as

$$\frac{KW}{KVA} = \cos \theta$$

and

$$\text{Power factor} = \text{cosine } \theta$$

are correct. When harmonics are present the situation is different and LBL has chosen to measure "shape" power factor. Actual power factor is dependent upon the current's wave shape

$$\text{power factor} = \frac{\text{Power}}{V_{rms} \times I_{rms}}$$

The electronic ballasts used in this demonstration both have power factors in excess of 90%, as calculated by each agency. That is not true, however, of others which were investigated during Phase I of this total project. In some of these the actual power factor is different from the KQ measured value. The importance of this is two-fold. First, the KVa requirement is significantly higher suggesting a requirement for greater system generating capacity than that shown by traditional utility metering. Second, the amount of harmonics generated may be substantial. This demonstration did not produce any indication of difficulty resulting from increased harmonics and the harmonic levels found on today's power systems from all accumulated sources are still generally tolerable. The future will undoubtedly produce many more harmonic sources, primarily as a result of solid-state technology advances - such as that involved in the ballasts under test.(19)

Although the questions of accurate metering and the effects of harmonics require future study, this demonstration was conducted without any adverse effects from the solid state ballasts.

CONCLUSIONS

The assessment of system efficiency from the data collected at PG&E is difficult since that demonstration was intended to measure the commercial applicability of devices still in the developmental stage. Table VIII presents data similar to that contained in the sections above but accumulated in the LBL tests which parallel those at PG&E but conducted under laboratory circumstances with bulb wall temperature standardized at 40 degree C for each unit.

TABLE VIII

Performance of Ballasts Measured at LBL Under Controlled Conditions

Type	Number Tested	Power (Watts)	Light Output (Footcandles)	fc/W	Increase %
Standard	10	96,5	49,0	0,507	-
277 volts - 27th floor	13	70,9	44,8	0,632	25
120 volts - 28th floor	30	70,1	41,2	0,586	16
277 volts - 30th floor Eng. Eff.	4	83	46,3	0,555	9

From this table of relative performance it can be seen that the power input is reduced significantly for all energy efficient ballasts as is shown also in Figures 1, 2, and 3. However, there is a reduction in light output as discussed in 6 above. Discounting that decrease as not an inhibition to useful work, the efficiency improvements of each type of ballast compared to the standard core coil ballast range from 9% for the energy efficient core-coil ballast to 16 and 25% for the solid state, high frequency ballasts.

This demonstration has proved that complete floors of a modern office building can be equipped with high frequency ballasts without any evident difficulties and with significant savings in energy. While the ballasts of the solid state manufacturers involved and those of others not included in this test remain to be improved upon, it is apparent that a shift to high frequency ballasts would have a positive effect upon energy use for commercial offices and other locations. Surely these products will assume their rightful place among the various technological improvements in lighting which will permit designers to retain adequate levels of illumination without undue energy requirements.

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FIGURE CAPTIONS

Figure 1. Démonstration des ballasts au 27 ème étage. Demandes de pointe

Figure 1. Ballast Demonstration, 27th Floor. Peak Demands

Bild 1. Vorfuehrung der Vorschaltgeraete am 27 ten Stock. Nachfragespitze

Figure 2. Démonstration des ballasts au 38 ème étage. Demandes de pointe

Figure 2. Ballast Demonstration 28th Floor. Peak Demands

Bild 2. Vorfuehrung der Vorschaltgeraete am 28 ten Stock. Nachfragespitze

Figure 3. Démonstration des ballasts au 30 ème étage. Demandes de pointe

Figure 3. Ballast Demonstration, 30th Floor. Peak Demands

Bild 3. Vorfuehrung der Vorschaltgeraete am 30 ten Stock. Nachfragespitze

Figure 4. Nombre de défaillances des ballasts

Figure 4. Ballast Failures

Bild 4. Defekte derVorschaltgeraete

Figure 5. Interférences d'ondes de fréquence radio, conduites

Figure 5. Conducted RFI

Bild 5. Geleitete Radiofrequenzaustrahlunginterferenz

Figure 6. Intefèrences d'ondes de fréquence radio, irradiees

Figure 6. Radiated RFI

Bild 6. Ausstrahlte Radiofrequenzaustrahlunginterferenz

Figure 7. Mesures de son, 27 ème étage

Figure 7. Sound Measurements, 27th Floor

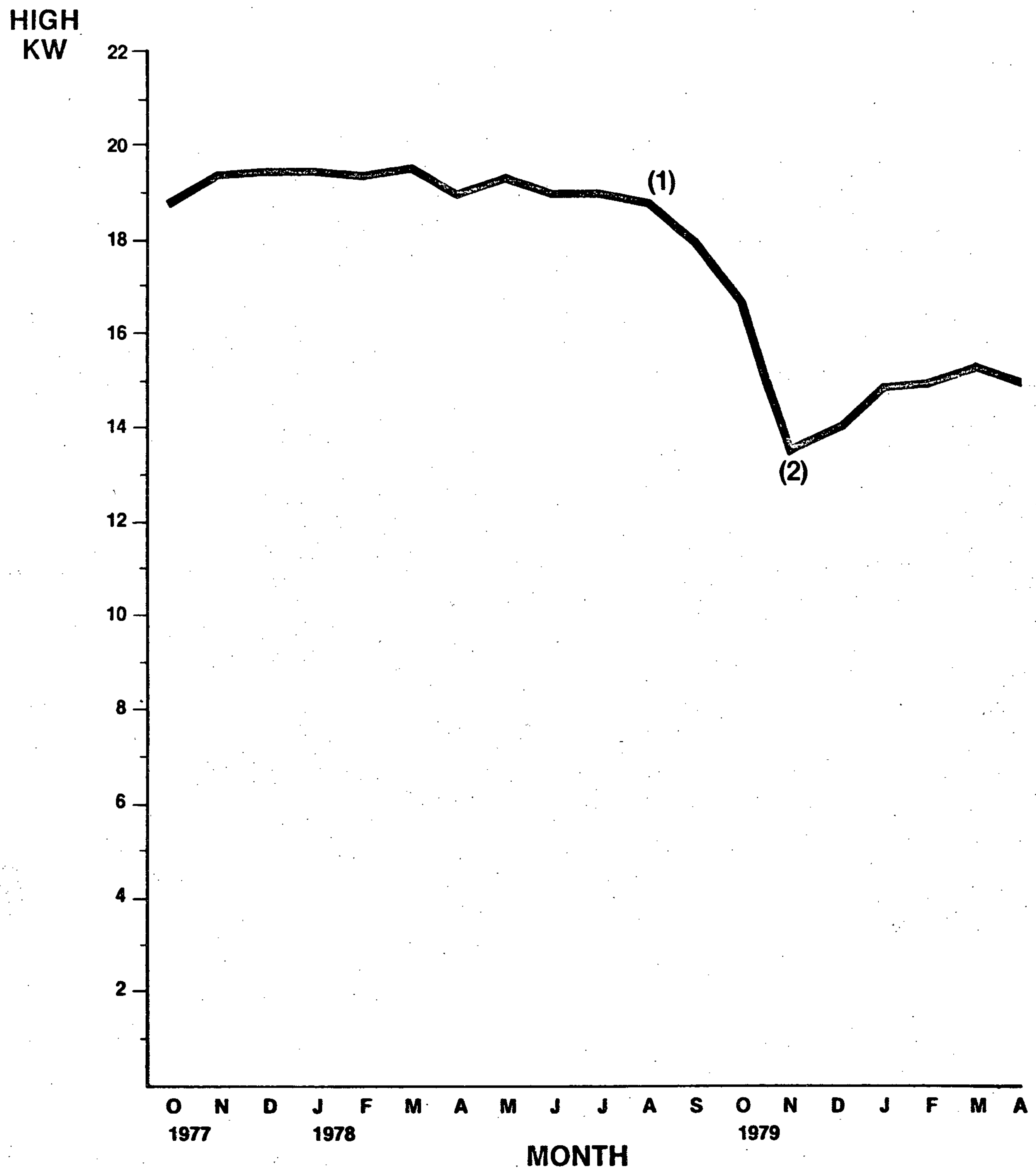
Bild 7. Tonmessungen 27ten Stock

Figure 8. Mesures de son 28 ème étage

Figure 8. Sound Measurements, 28th Floor

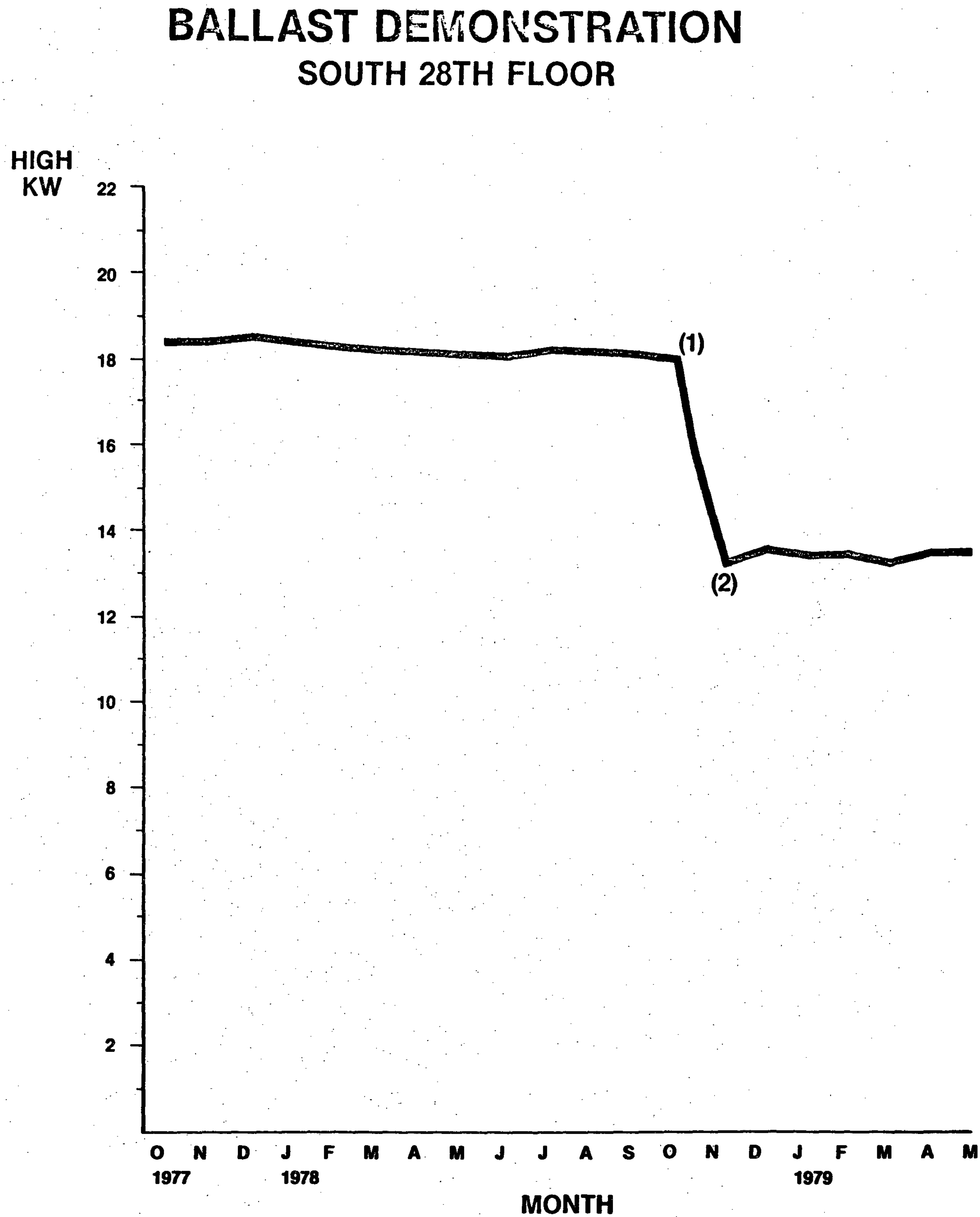
Bild 8. Tonmessungen auf dem 28 ten Stock

BALLAST DEMONSTRATION
SOUTH 27TH FLOOR



(1) END OF BASE LINE DATA, AUGUST 19, 1978
(2) ALL NEW BALLASTS INSTALLED, OCTOBER 18, 1978

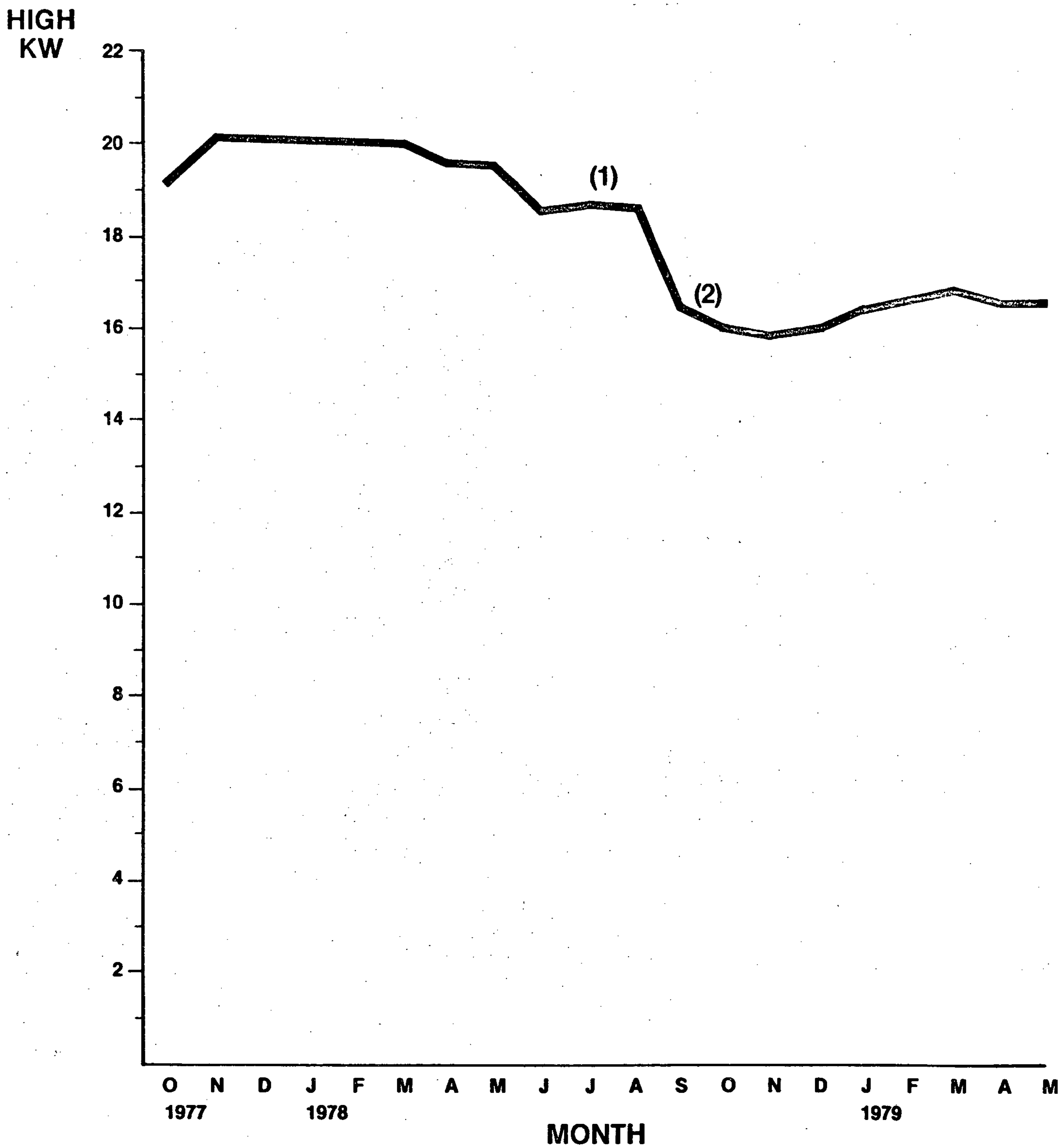
FIGURE 1



(1) END OF BASE LINE DATA, SEPTEMBER 21, 1978
(2) ALL NEW BALLASTS INSTALLED, SEPTEMBER 21, 1978

FIGURE 2

BALLAST DEMONSTRATION
30TH FLOOR

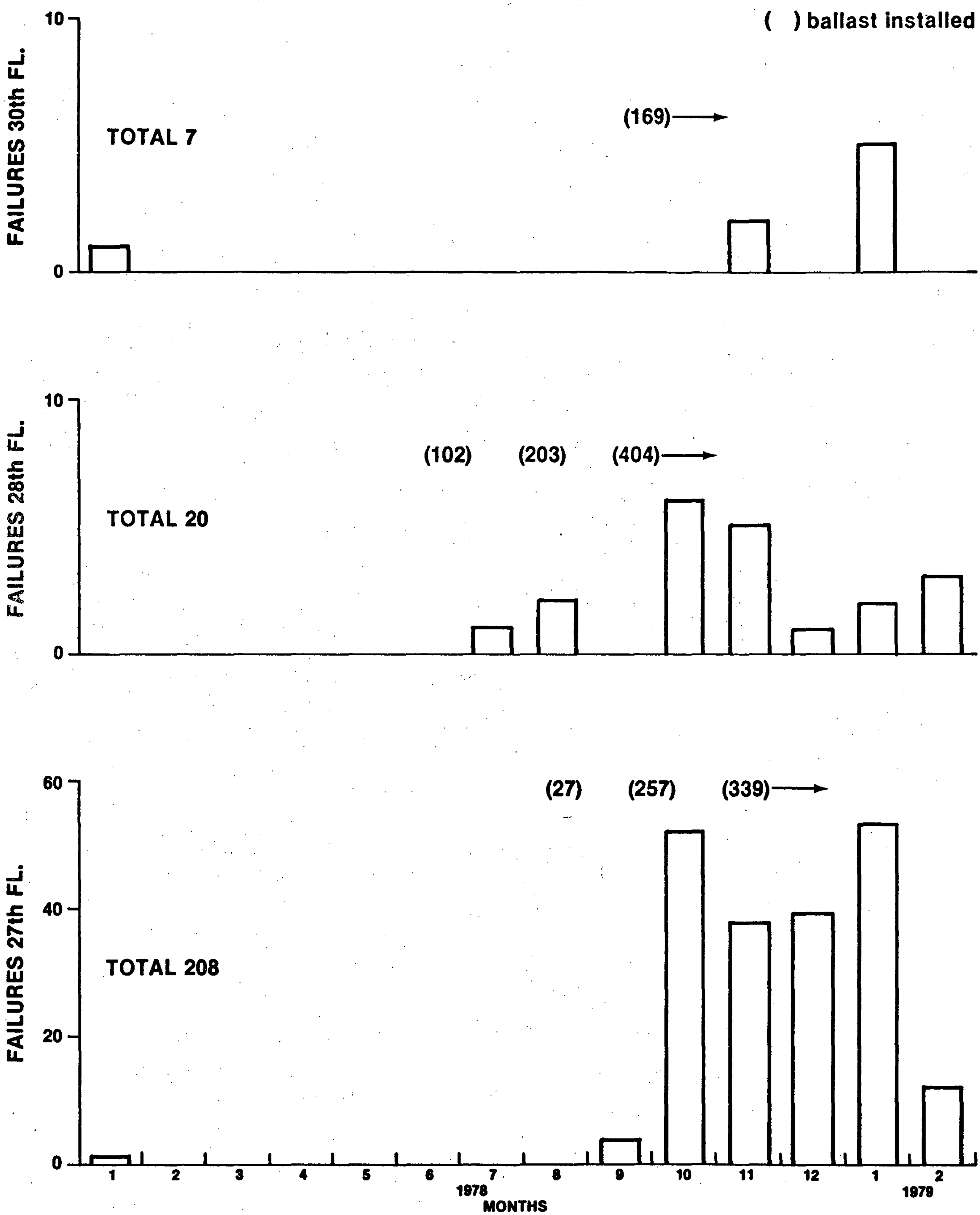


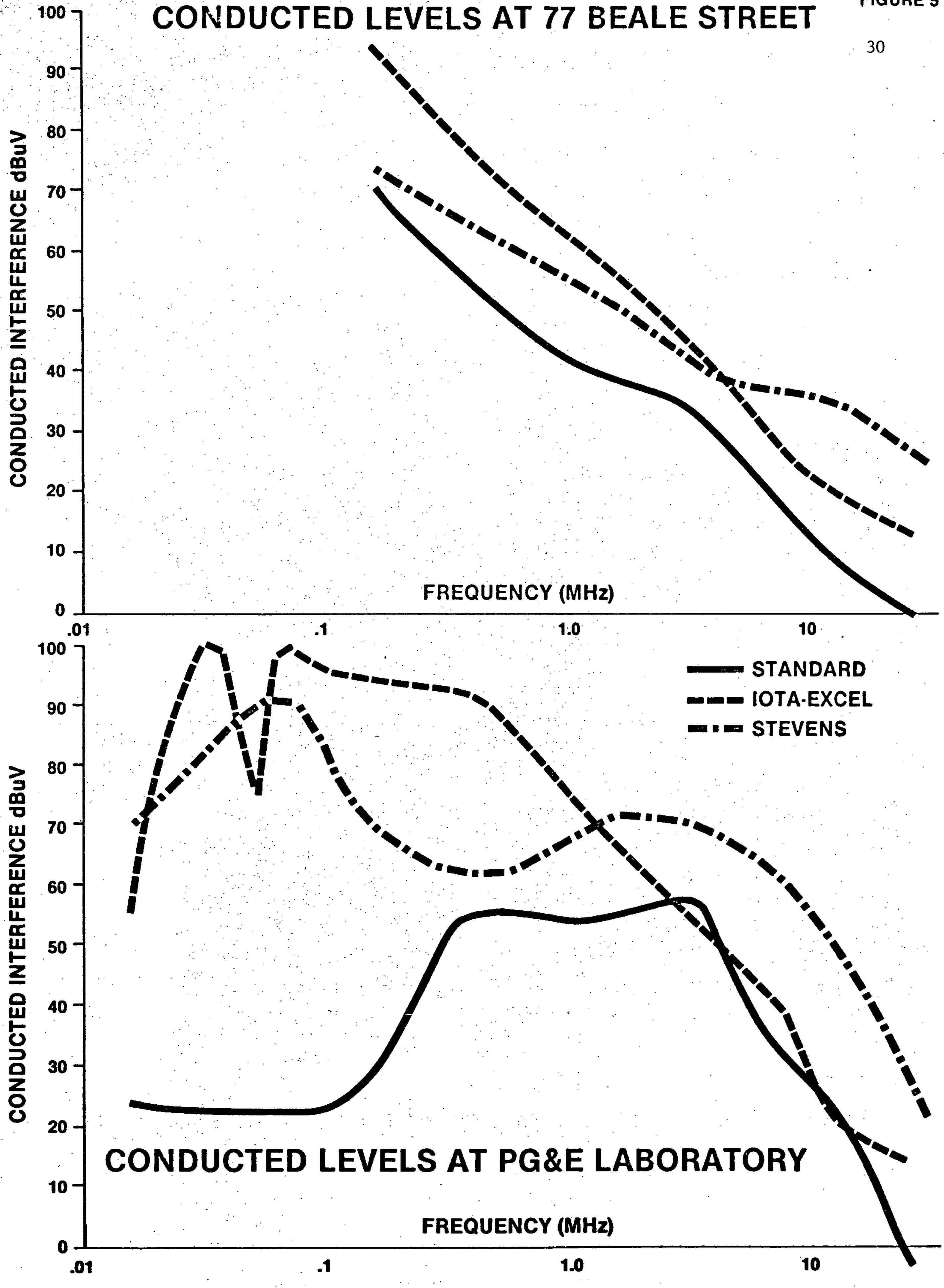
(1) END OF BASE LINE DATA, JULY 15, 1978
(2) ALL NEW BALLASTS INSTALLED, SEPTEMBER 9, 1978

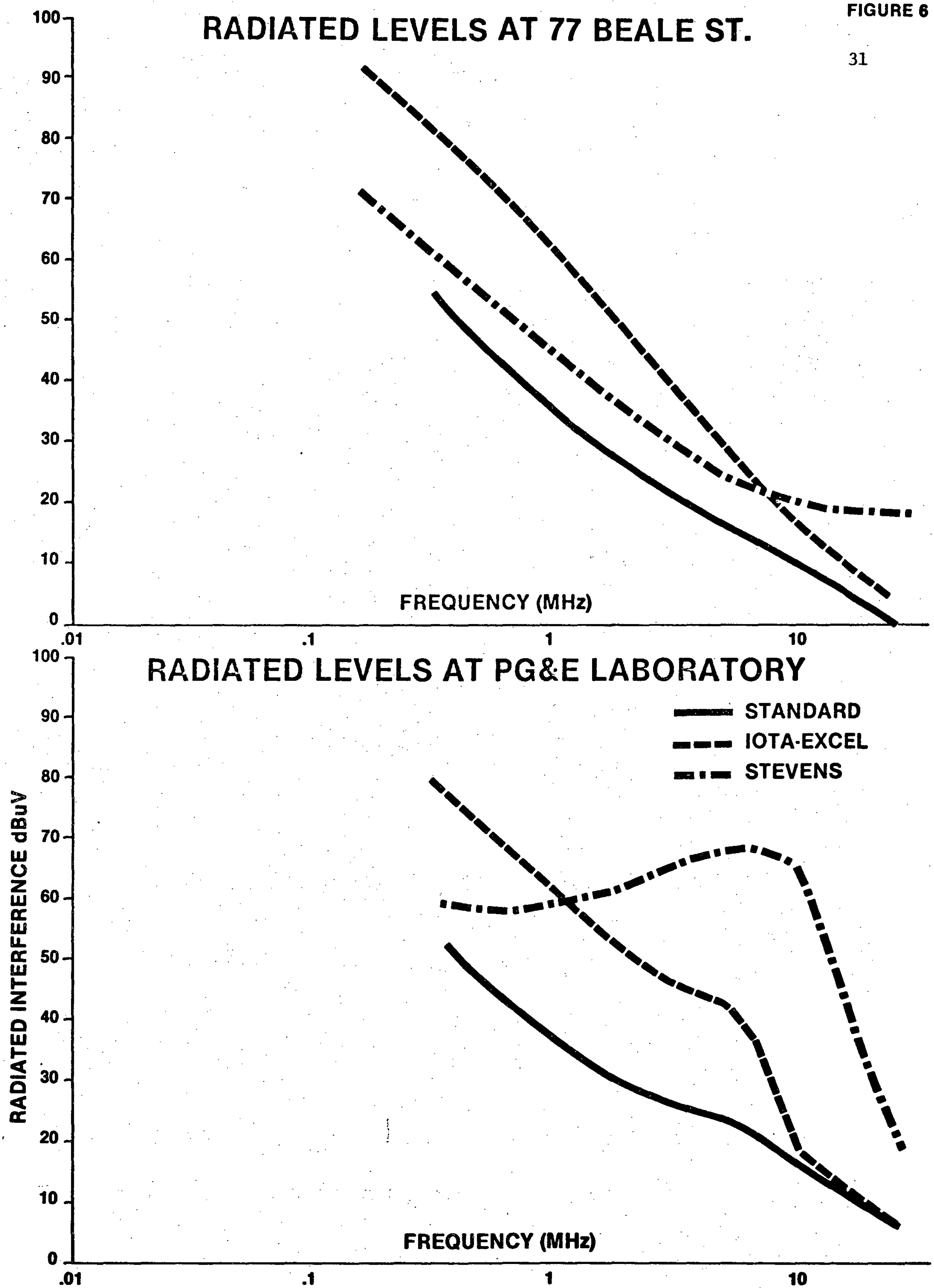
FIGURE 3

FIGURE 4

BALLAST FAILURES




CONDUCTED LEVELS AT 77 BEALE STREET
CONDUCTED INTERFERENCE dBuV
100
90
80
70
60
50
40
30
20
10
0
FREQUENCY (MHz)
.01
.1
1.0
10
STANDARD
IOTA-EXCEL
STEVENS
CONDUCTED INTERFERENCE dBuV
100
90
80
70
60
50
40
30
20
10
0
CONDUCTED LEVELS AT PG&E LABORATORY
FREQUENCY (MHz)
.01
.1
1.0
10


RADIATED LEVELS AT 77 BEALE ST.
100
90
80
70
60
50
40
30
20
10
0
FREQUENCY (MHz)
.01
.1
1
10
RADIATED LEVELS AT PG&E LABORATORY
STANDARD
IOTA-EXCEL
STEVENS
RADIATED INTERFERENCE dBuV
FREQUENCY (MHz)

27th FLOOR SOUND SURVEY

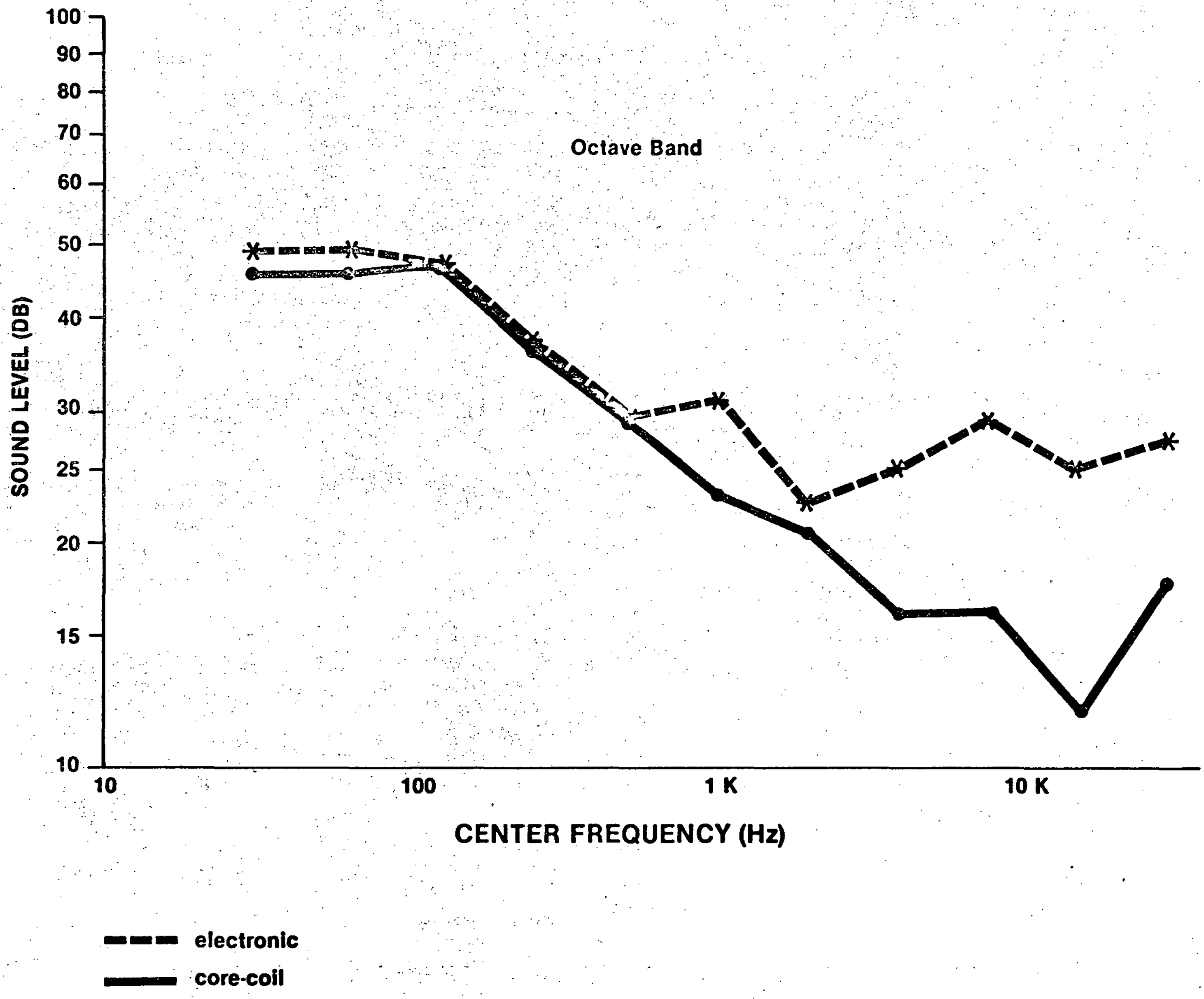


FIGURE 7

28th FLOOR SOUND SURVEY

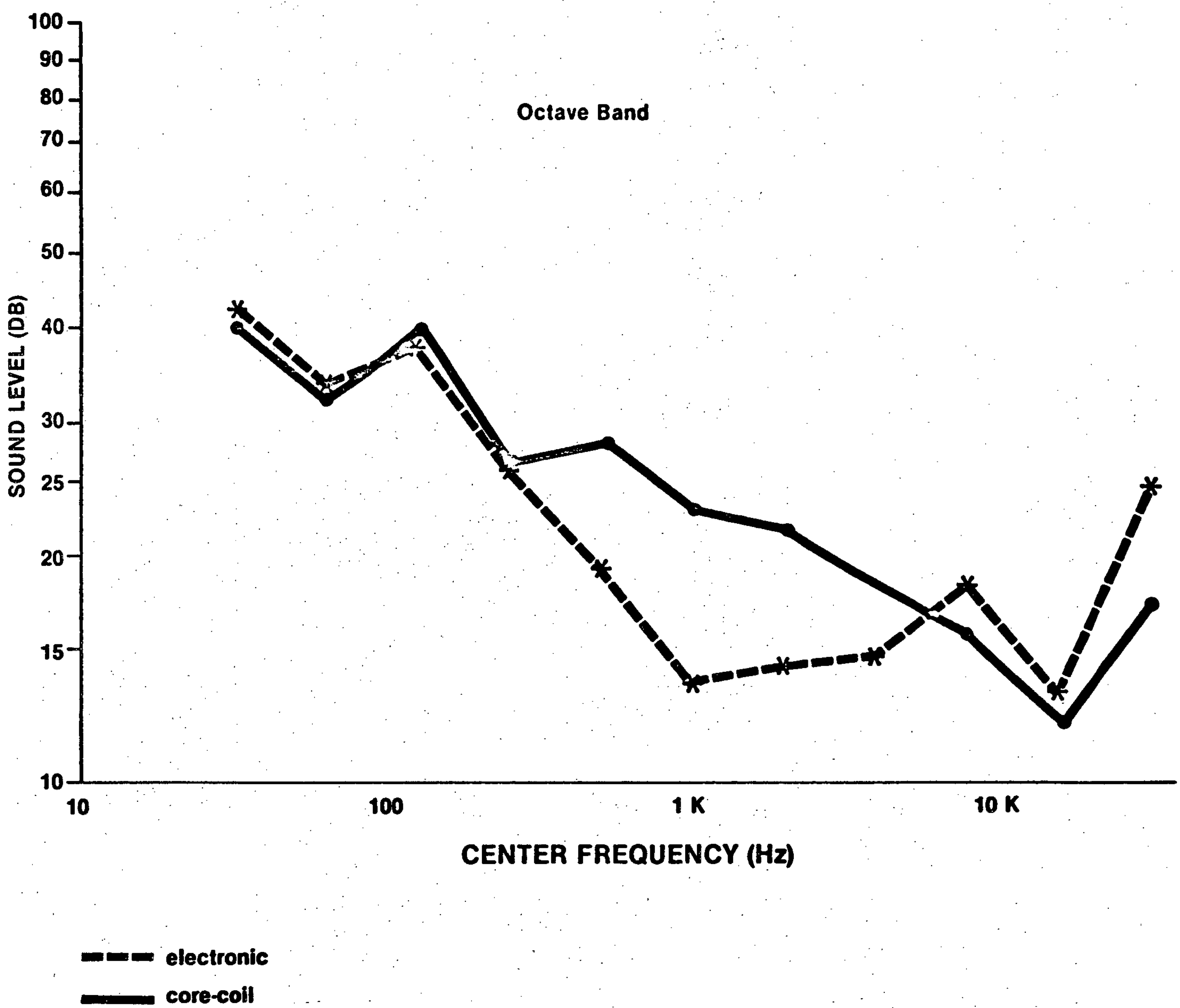


FIGURE 8

30th FLOOR SOUND SURVEY

Octave Band

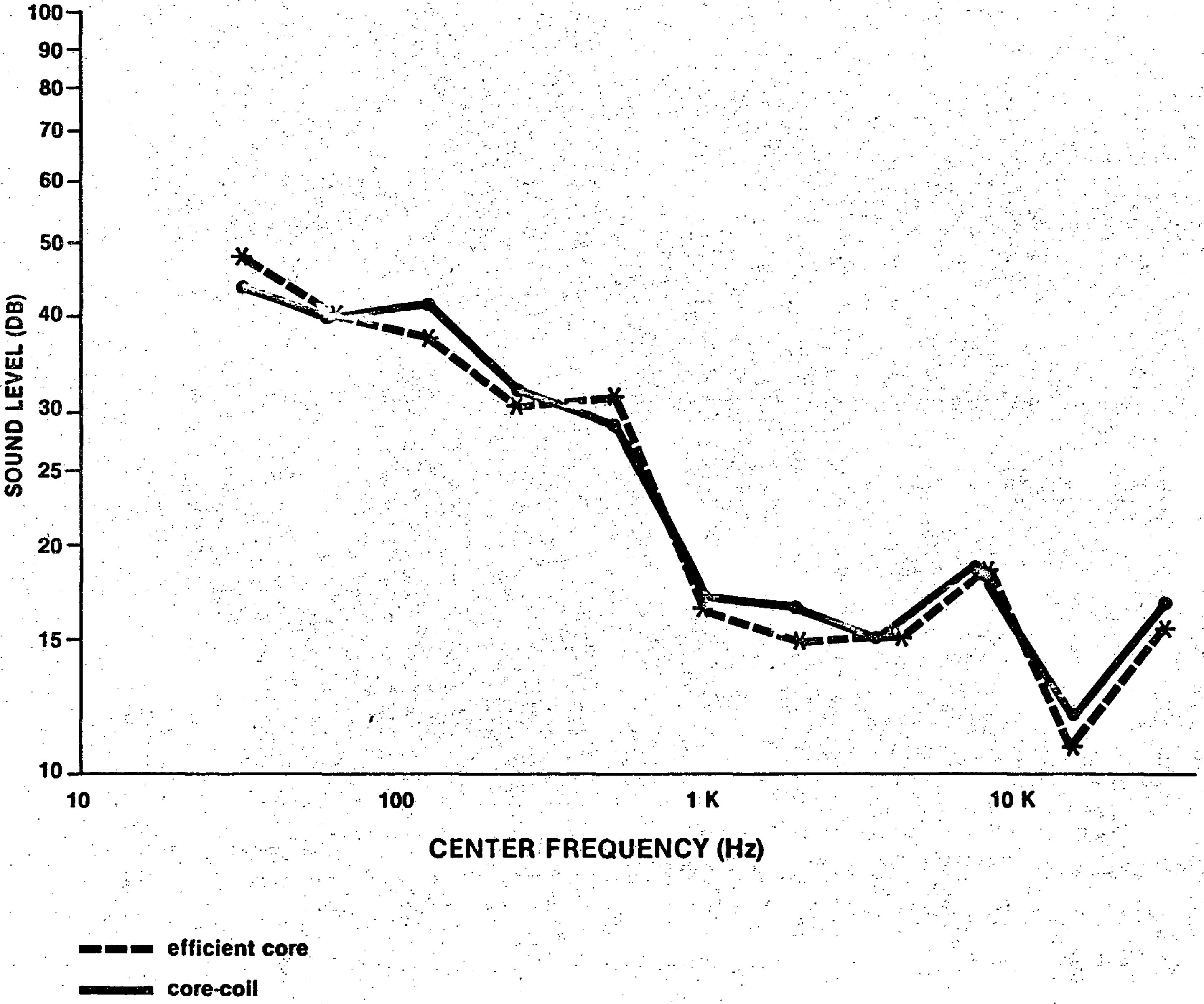
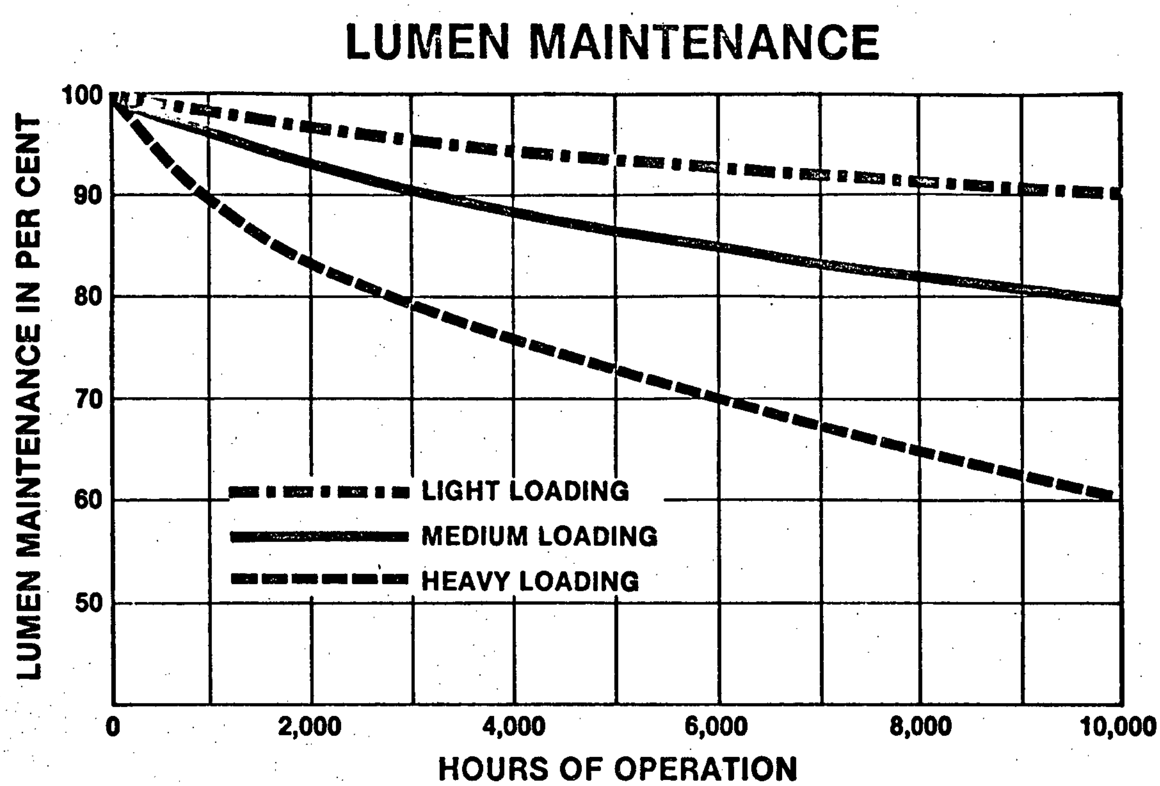


FIGURE 9


LUMEN MAINTENANCE
LUMEN MAINTENANCE IN PER CENT
100
90
80
70
60
50
LIGHT LOADING
MEDIUM LOADING
HEAVY LOADING
0
2,000
4,000
6,000
8,000
10,000
HOURS OF OPERATION

(A)

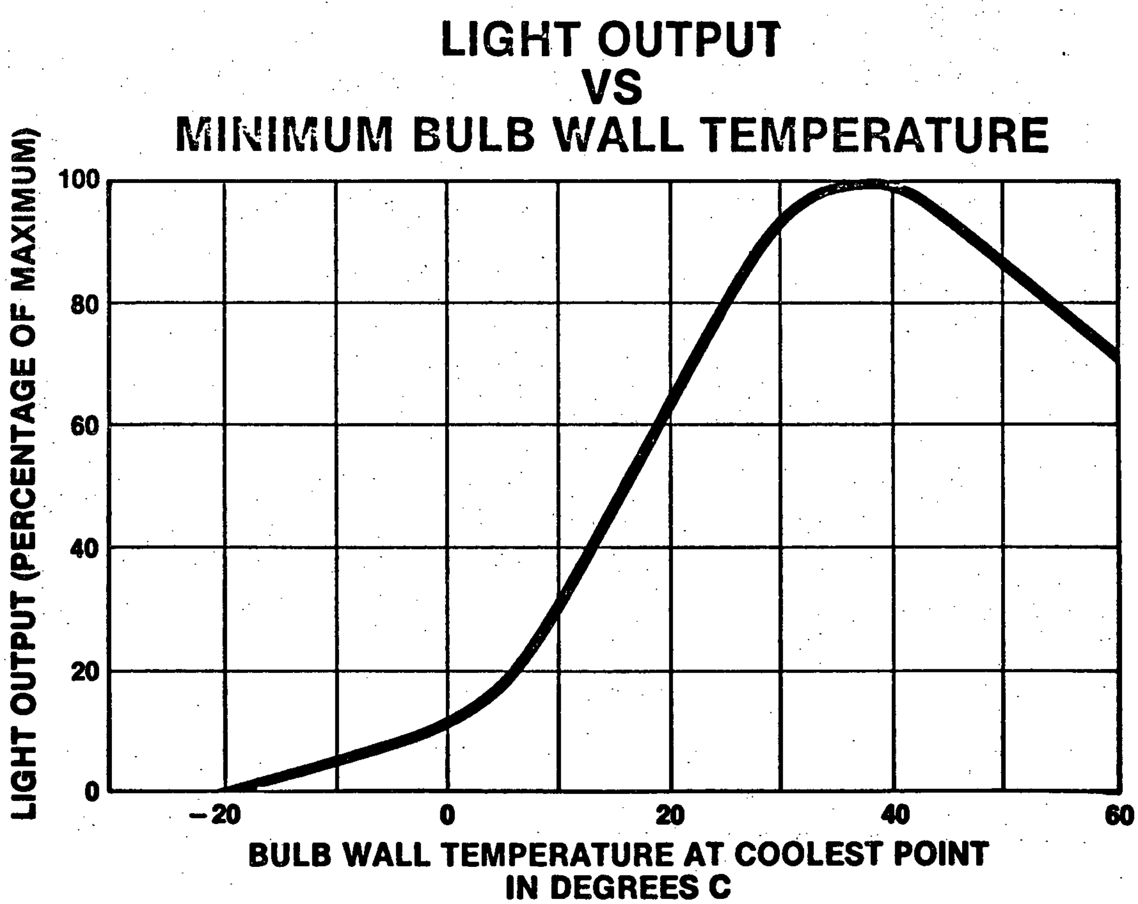

LIGHT OUTPUT
VS
MINIMUM BULB WALL TEMPERATURE
LIGHT OUTPUT (PERCENTAGE OF MAXIMUM)
100
80
60
40
20
0
−20
0
20
40
60
BULB WALL TEMPERATURE AT COOLEST POINT
IN DEGREES C

FIGURE 10

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