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Development of Power System Measurements -- Quarterly Report January 1, 1982 to March 31, 1982

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Center for Electronics and Electrical Engineering
Electrosystems Division
Washington, DC 20234

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Prepared for:

Department of Energy
Division of Electric Energy Systems
)00 Independence Avenue, SW
ashington, DC 20585

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DEVELOPMENT OF POWER SYSTEM MEASUREMENTS -- QUARTERLY REPORT JANUARY 1, 1982 TO MARCH 31, 1982

R. E. Hebner, Editor

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

Foreword

This report summarizes the progress on four technical investigations during the second quarter of FY 1982. Although reasonable efforts have been made to ensure the reliability of the data presented, it must be emphasized that this is an interim report so that further experimentation and analysis may be performed before the conclusions from any of these investigations are formally published. It is therefore possible that some of the observations presented in this report will be modified, expanded, or clarified by our subsequent research.

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DEVELOPMENT OF POWER SYSTEM MEASUREMENTS -- QUARTERLY REPORT
January 1, 1982 to March 31, 1982

R. E. Hebner, Editor

This report documents the progress on four technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period from January 1, 1982 to March 31, 1982. The report emphasizes the calibration of instruments designed to measure the 60-Hz electric field in biological exposure facilities, selected errors inherent in the use of time-domain reflectometry to determine the rf characteristics of power cables, the measurement of the rate of decomposition of SF_6 in positive dc-corona discharges, and in the measurement of space charge in transformer oil between 100°C and 150°C.

Key words: cables; composite insulation; dc fields; high voltage; incipient fault; insulation; liquid breakdown; SF_6; space charge; transformer oil.

1. INTRODUCTION

Under an interagency agreement between the U. S. Department of Energy and the National Bureau of Standards, the Electrosystems Division, NBS, has been providing technical support for DOE's research on electric energy systems. This support has been concentrated in four areas -- the measurement of electric fields, the measurement of electromagnetic properties of solid insulating materials and cables, the measurement of partial discharge phenomena in gaseous dielectrics, and the measurement of interfacial electrostatic field distributions and of space charge density. The technical progress made during the quarter January 1, 1982 to March 31, 1982 is summarized in this report.

2. DC FIELDS AND ION MEASUREMENTS
Subtask No. A018

The objectives of this investigation are to develop methods to evaluate and calibrate instruments which are used, or are being developed, to measure the electric field, conductivity, the space charge density, and current density in the vicinity of high-voltage dc transmission lines and in apparatus designed to simulate the transmission line environment; and to provide electrical measurement support of DOE-funded efforts to determine the effects of ac fields on biological systems.

The performance of four electric field meters used for measuring 60-Hz electric fields in biological exposure chambers was examined at NBS during the current reporting period. A parallel plate apparatus 1 m x 1 m x 0.24 m spacing was assembled for the tests to generate a nearly uniform 60-Hz electric field. Voltages for the plates were obtained using two transformers which were configured to act as a single center-tapped transformer (center-tap grounded). An oscillator-amplifier combination energized the primary windings. The sources of error for the parallel plate apparatus can be classified into two categories, geometrical and electrical. Table 1 lists the various error sources in each category for these tests.

Parallel plates with the above dimensions will establish an electric field along the electrode axis which is within 0.01% theoretical uniform field value obtained by dividing the voltage difference by the plate spacing [1]. The use of a center-tapped transformer reduces to a negligible level perturbations of the field between the plates (along electrode axis) by nearby ground planes (e.g., walls, floor, etc.) [2]. The nearest ground plane was approximately 1 m from the parallel plates.

Measurements of the parallel plate spacing at six or more representative locations on different days indicated an average value of 24.18 cm with an uncertainty of less than ±0.1 cm. These deviations are the basis for the uncertainty estimate of ±0.5% in table 1.

The rms values of the applied voltages were determined using electrostatic voltmeters which were calibrated by applying a known dc high voltage to the meters. The uncertainty associated with this calibration was ±0.5%.

Because the frequency response of the meters was not measured, it was important to insure that the harmonic distortion of the voltage waveform was small. Using a capacitive voltage divider and spectrum analyzer, it was determined that the power frequency harmonics in the voltages applied to the parallel plates were 50 db or more below the magnitude of the fundamental for electric fields less than 100 kV/m and 40 db or more for electric fields less than 180 kV/m. These measurements are the basis for the uncertainty estimate, due to harmonic content, in table 1.

Two of the meters had dipole sensors and reportedly had a true rms detector (the frequency response of the detector was not examined during the tests). Therefore, in principle, the rms value of the electric field should have been displayed even in the presence of harmonic distortion.

These meters, which were about 4 cm high, were supported between the plates with a dielectric rod. The parallel plate spacing, noted above, is sufficiently large to prevent interactions between the field probe and the surface charge distributions on the plates [2]; i.e., the meter responded as if it were inserted into a uniform field.

The remaining two meters consisted of flat discs with guard bands and were connected to their respective circuits with shielded cables.

Table 1. Error sources for parallel plate apparatus

	Estimated uncertainty
I. Geometrical	
(a) Ratio of plate dimension and spacing	Less than ±0.01% in electric field value along electrode axis.
(b) Parallel plate spacing	Less than ±0.5% in electric field value.
(c) Field perturbation by nearby objects	Less than ±0.1% in electric field value.
(d) Field perturbation due to perturbation of surface charge distribution	Negligible.
II. Electrical	
(a) Voltage	Less than ±0.5%.
(b) Frequency	Synchronized with line frequency.
(c) Harmonic content	Less than ±0.3% for electric fields less than 100 kV/m and ±1.0% for fields between 100 kV/m and 180 kV/m.

The frequency response of these meters was not examined. However, both detectors contained an amplification stage which would weight signals due to their harmonic content. Thus a third harmonic content in the electric field of about 0.3% for the tests performed with the disc probes could produce a ±0.9% contribution to the meter reading.

A monopolar dc line is being configured in a high bay area for use in investigating off-ground measurements of ion density. Preliminary measurements are expected to begin during the next quarter. This effort will expand upon the exploratory measurements made last year. An optical link will be used for data acquisition, since the ion counter and related apparatus will be operated at voltages as high as 30 kV above ground.

One of the NBS staff members has been invited to participate in the development of an International Electrotechnical Commission (IEC) standard for the measurement of electric fields near ac transmission lines. He will be a member of the U.S. delegation to the IEC General Meeting in Brazil this June. With support by DOE and NBS, a U.S. (i.e., IEEE/ANSI) standard was developed and has been in force for the past few years. Because member nations are strongly urged to follow the recommendations of IEC standards, it is very desirable that the U.S. actively participate in the development of the international document to insure that the U.S. and IEC standards are technically compatible and to minimize any unwarranted disruption of present U.S. measurement techniques.

A NBS staff member will participate in the presentation of a workshop on measurement techniques for characterizing 60-Hz electric fields in small parallel plate biological exposure systems at the annual meeting of the Bioelectromagnetics Society in June. The workshop is sponsored by the IEEE/Power Engineering Society Working Group on the Biological Effects of Power-Frequency Electric and Magnetic Fields.

A NBS staff member received a Certificate of Appreciation of the IEEE/PES Corona and Field Effects Subcommittee for services rendered as Chairman of AC Fields Measurements Task Force.

For further information, contact Dr. M. Misakian, (301) 921-3121.

3. INCIPIENT FAULT DETECTION/LOCATION
Subtask No. A063

The objective of this program is to identify and, insofar as practical, remove technical barriers to the development of a successful incipient fault detector/locator for underground power transmission use. NBS responsibility includes conducting an experimental program that will aid the development of an incipient fault detection/location system by measuring the rf characteristics of power cables and evaluating the frequency content of partial discharge pulses emanating from incipient fault sites in a cable dielectric. The measurement program at NBS is essentially completed. The limitations of time-domain reflectometry (TDR) techniques for detecting incipient fault sites in transmission cables have been determined. The radio-frequency (rf) responses of these cables have also been measured. One item remains to be completed: to determine the effect of sampling-rate drift on these types of measurements.

During this past quarter, we have attempted to gain further understanding on the effects sampling-rate drift can have on the measured cable transfer functions. Our measurements involve using TDR techniques to determine the rf attenuation of various types of power cable. The TDR pulse is detected with a digital-processing oscilloscope and transmitted to a computer for processing. Basically two measurements are required. These could be the input pulse to the cable and the resulting reflected or transmitted pulse. They could also be the output pulses from two identical, but different length, cables. The problem is that these two necessary measurements are not taken at the same time. Errors can result, therefore, from sampling-rate drift in the sampling oscilloscope.

Last quarter's report demonstrated theoretically that a sampling drift in the time-domain data will result in a similar drift in the frequency domain. Therefore, the experimenter observing such drift in the transfer function can, presumably, make an allowance for it. Specifically, for measurements on power cables, this drift will cause an apparent roll-off or gain in the measured transfer function. The experimenter can multiply the transfer function by some appropriate correction function. This was the subject of a paper presented recently [3]. The problem with this approach is that it requires some a priori knowledge of the transfer function in order to make the correction (i.e., is the transfer function really supposed to be flat over a particular frequency range?). Also, the experimenter must be sure that, in correcting the function to remove the effect of sampling-rate drift, other errors are not introduced.

With these things in mind, the effort this quarter has been in correcting for sampling-rate drift in the time domain. The typical TDR waveform represents the reflections of the pulse from points along the length of the cable from the output of the TDR unit to the cable end. In our experiments, typically the first quarter of the waveform should always be the same representing the impedance of the TDR output, the cable from the TDR unit to the power cable under test, and the impedance transition to the power cable. This means that the first 100 or so points of the 512-point sampled waveform should be identical for a particular measurement. We assumed that expanding or contracting the time scale of the second of a pair of measurements until the first 100 points did agree with the first would remove the sampling-rate drift without any arbitrary assumption as to what the transfer function of the cable should be. While in principle this should work, there are problems.

First of all, besides a drift in the sampling rate, there are also drifts in the vertical amplification, the horizontal screen position, and the vertical screen position. The latter is no problem because in the software the first sampled point of the waveform is defined as zero. The effect of vertical amplification drift on the measured transfer function has been found to be negligible but horizontal screen position drift is important.

Therefore, software has been written to correct for the horizontal screen drift by "sliding" one of the waveforms left or right in integer steps with respect to the other waveform until the differences between the waveforms are minimized. After this has been completed, the sampling-rate drift correction is determined in a similar manner. While this approach works excellently with analytically generated waveforms, the results with real TDR waveforms are less satisfactory. The calculated sampling-rate drift correction is very sensitive to how well the two waveforms are aligned horizontally. A misalignment by one point in 512 can make a large difference (~100%) in the calculated sampling-rate drift correction. This, in effect, makes the current approach without some modification of limited value and additional work is required.

The work on sampling-rate drift will be completed next quarter and will be published. The completion of the final report during this same time period will conclude this project.

Plans for next quarter are to finish the above investigation and complete the final report.

For further information, contact Dr. W. E. Anderson, (301) 921-3121.

4. TECHNICAL ASSISTANCE FOR FUTURE INSULATION SYSTEMS RESEARCH
Subtask No. A053

The objective of this project is to develop diagnostic techniques to monitor, identify, and predict degradation in future compressed gas electrical insulating systems under normal operating conditions. The focus is on the fundamental information and data needed to improve test, design, and performance evaluation criteria. The investigation of partial discharges (corona) in gaseous dielectrics is emphasized. This phenomenon gives rise to degradation of the gas under high electrical stress and may lead to breakdown. Measurement of partial discharge inception in highly nonuniform fields may prove to be a preferred method to determine dielectric strength of electronegative gases.

Planned activities for FY82 include: 1) completion of an archival paper on basic mechanism of corona inception in SF_6 under ac and dc conditions; 2) investigation of the wavelength dependence of photon-induced positive corona inception in SF_6; 3) continuation of measurements of power dependence of the rates of oxyfluoride and water vapor production from corona discharges in SF_6 and report the results in a conference and an archival paper; 4) exploration of the feasibility of new methods to measure field-enhanced collisional detachment of negative ions in SF_6 and other electronegative gases; 5) improvement of the accuracy of quantitative analysis of trace gases such as H_2O in SF_6 and other gaseous dielectrics using a gas chromatograph/mass spectrometer (GC/MS), and to extend the measurements of the effects of trace H_2O on corona characteristics and relative dielectric strength of the gas; and 6) completion of an archival paper on compilation and evaluation of electron swarm data in molecular electronegative gases. In addition, we are completing an investigation remaining from FY-81, namely, the measurement of light emission from corona pulses in SF_6 and correlation of results with electrical detection of corona pulses.

Progress was made during the reporting quarter on all of the above activities except 1) and 6) which are completed. A paper entitled "Mechanisms for Inception of DC and 60-Hz AC Corona in SF_6" by Van Brunt and Misakian appears in the April 1982 issue of the IEEE Transactions on Electrical Insulation.

A paper entitled "A Survey of Electron Swarm Data in Electro-Negative Gases" is undergoing review for publication in the Journal of Physical and Chemical Reference Data.

As part of activity 2), a paper entitled "Corona-Induced Decomposition of SF_6" by Van Brunt and Leep was presented at the Third International Symposium on Gaseous Dielectrics held in Knoxville on March 10, 1982.

Work conducted during this reporting period on activity 5) resulted in preparation of a paper entitled "Effects of H_2O on the Behavior of SF_6 Corona" for presentation at the forthcoming Seventh International Conference on Gas Discharges and Their Applications.

Preliminary measurements were made of the wavelength dependence of photon-initiated positive corona discharges in SF_6, activity 2). The results appear to indicate that in pure SF_6 discharge pulses, i.e., electron avalanches or streamers, will not be initiated unless there is radiation present with a wavelength shorter than 350 nm. Further investigations of this effect are being conducted and the results will presumably be presented in our next quarterly report. In this report we highlight some of the experimental results obtained as part of activities 3) and 5).

New measurements were performed on the rate of decomposition of compressed, gaseous SF_6 in positive-dc-corona discharges. The data from these and earlier measurements were analyzed by an improved method involving determination of peak heights from single-ion chromatograms. Examples of chromatograms obtained in the quantitative analysis of oxyfluoride content in corona-degraded SF_6 are shown in figure 1. In this figure, a chromatogram from a degraded SF_6 sample is compared with a chromatogram from a standard gas sample containing 125 ppm of both SOF_2 and SO_2F_2 in SF_6 at the same pressure. The degraded gas shows the presence of SOF_4 not included in the preparation of the standard sample.

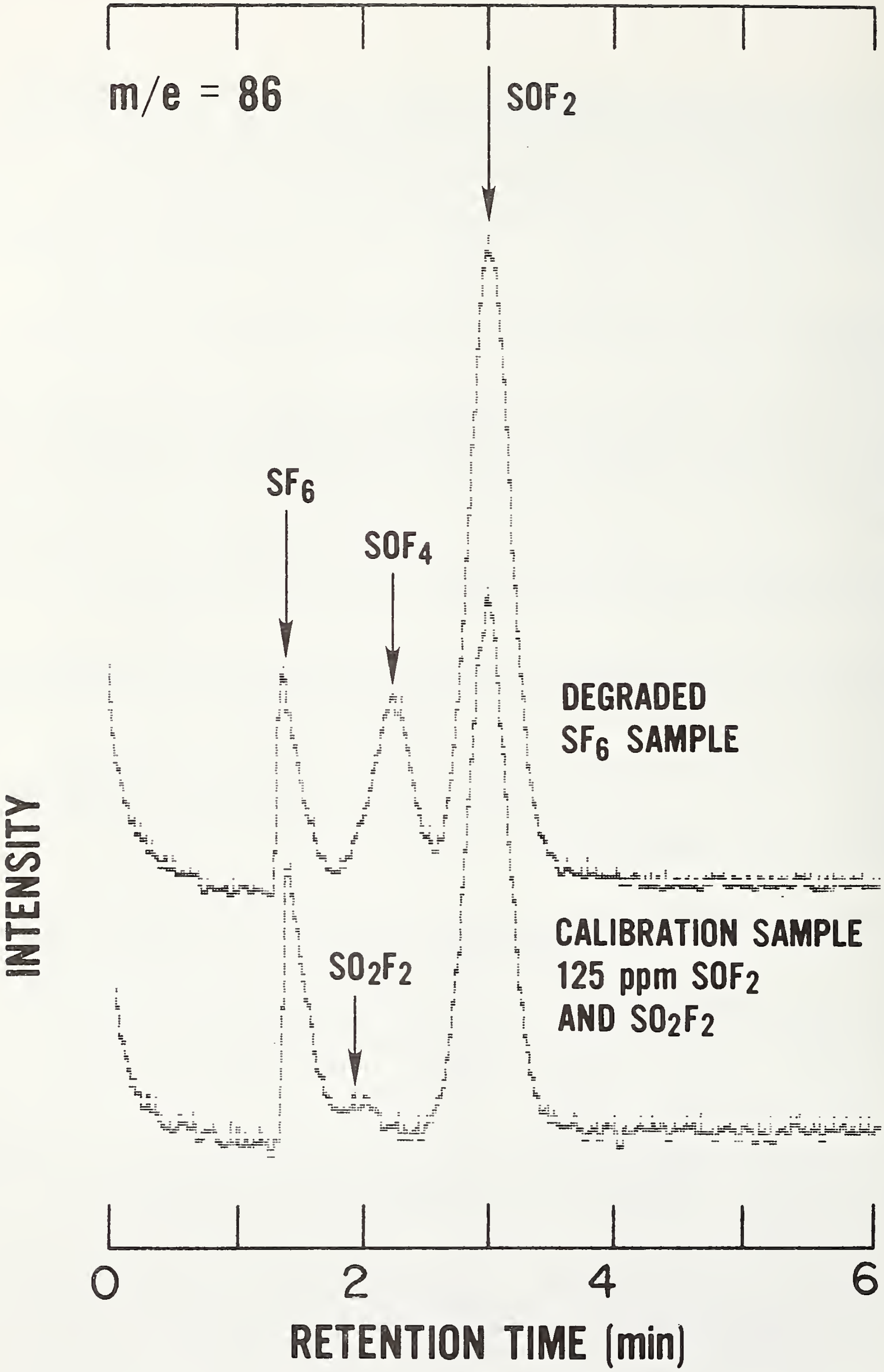

Figure 1. Single ion chromatograms of SF_6 samples for mass-to-charge ratio of 86. The chromatogram for a corona degraded SF_6 gas sample at 200 kPa is compared with a chromatogram for a standard sample at the same pressure containing 125 ppm of SOF_2 and SO_2F_2 in SF_6.

Quantitative analysis is carried out by comparing the ratio of peak height for the m/e = 86 peak corresponding to the gas of interest (SOF_2 in fig. 1) to the peak height for m/e = 19 (F^+ from SF_6) for the degraded sample with that for the standard sample. That is, the concentration in the degraded sample $[SOF_2]_\chi$ is given by

$$[SOF_2]_\chi = \{(A_{86}/A_{19})_\chi/(A_{86}/A_{19})_C\}[SOF_2]_C,$$

where A_{86} and A_{19} are respectively the peak heights of the relevant m/e = 86 and m/e = 19 peaks, allowing for background subtraction, and the subscripts χ and C correspond respectively to the unknown and standard gas samples.

Examples of results obtained by applying this analysis to the determination of SO_2F_2 concentrations in SF_6 as a function of energy dissipated by the discharge for three different discharge power levels are shown in figure 2. Contrary to the tentative conclusions drawn from some of our preliminary data, the results given here indicate that production rates for the oxyfluorides, i.e., SOF_2, SO_2F_2, and SOF_4, expressed in moles per joule of energy dissipated, exhibit a dependence on discharge power. The production rates for these species tend to decrease as power increases as can be seen by comparing the three curves shown in figure 2. This trend is most pronounced in the case of SO_2F_2. Moreover, as indicated by the fits to the data in figure 2, the production rates are not constant at a particular power level. The concentration, C, is related to the energy dissipated, U, by the expression

$$C = \alpha U^\beta,$$

where α and β are constants. The fact that $\beta>1$ indicates that the production rate, dC/dU, increases with increasing energy dissipated, i.e., initially the decomposition products build up more slowly with time. This may be due to absorption of these gases on the walls of the discharge cell. More work on the effect of surface absorption is necessary.

More measurements were performed to determine the effect of trace levels of water vapor on the electrical characteristics of positive-dc-corona in pressurized SF_6. The water was introduced by thermal desorption from a hot wire surface, and its presence was monitored with a gas chromatograph/mass spectrometer. Maximum H_2O concentrations attained were estimated to be below 300 ppm. The results showed that small quantities of H_2O enhance the corona current and corona pulse count rate by more than an order of magnitude. This is illustrated by the data for average current shown in figure 3. Consistent with earlier results [4] obtained in our laboratory, the presence of H_2O also causes a dramatic change in the charge level distribution of the corona pulses. This is indicated by the data in figure 4. The change is associated with the disappearance of burst pulses when H_2O is introduced, and it is speculated that this effect is associated with formation of ion clusters like $SF_5^+(H_2O)_n$ which reduce the mean mobility of ions in the interelectrode gap, thereby allowing a more rapid accumulation of space charge [5]. A measurement of the pulse-height-distribution of corona pulses may prove to be a very sensitive indicator of H_2O contamination in SF_6.

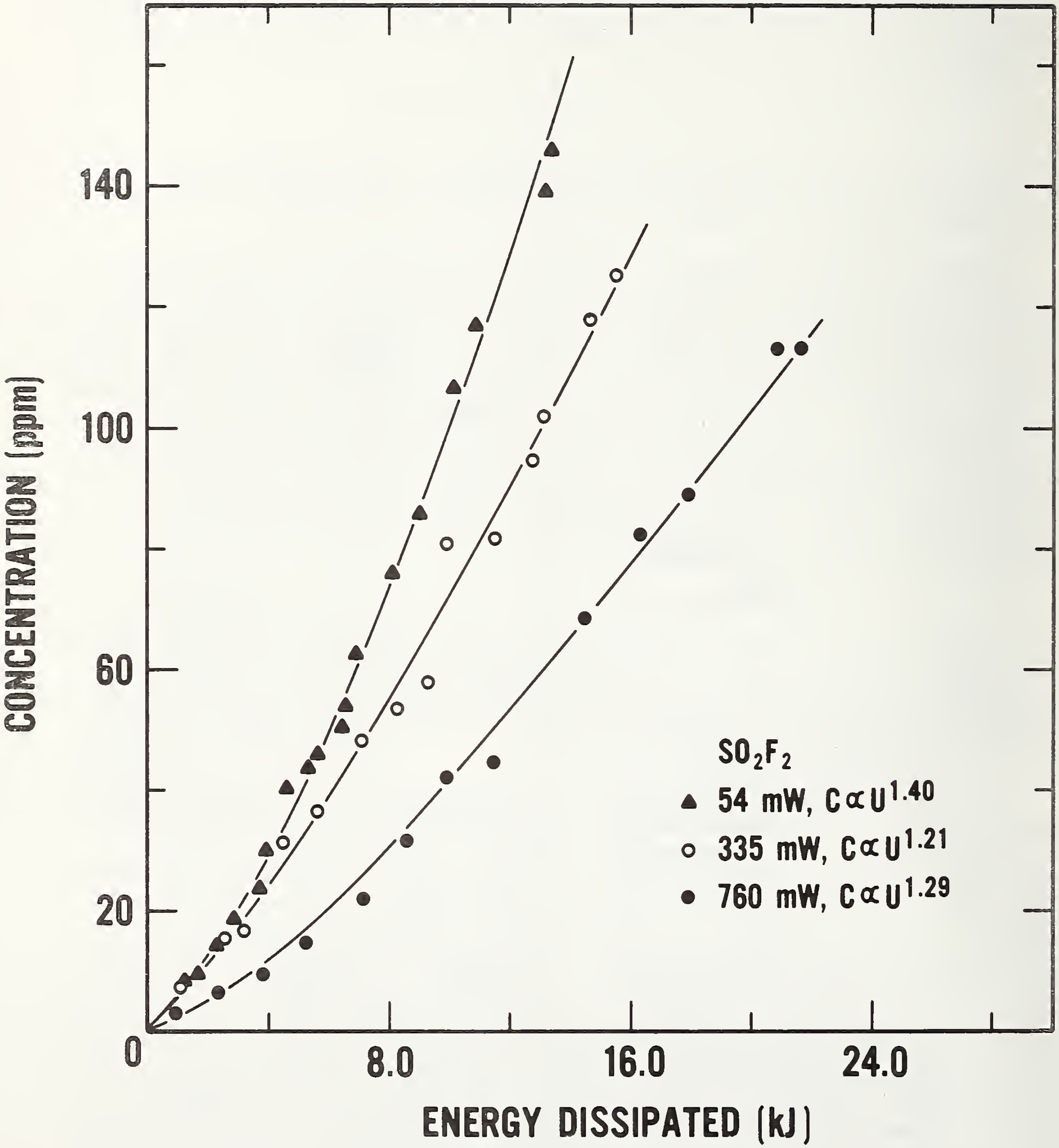

Figure 2. Measured concentration, C, of SO_2F_2 in SF_6 at 200 kPa as a function of energy dissipated, U, in corona discharges at the indicated power levels. Also shown are fits to the data.

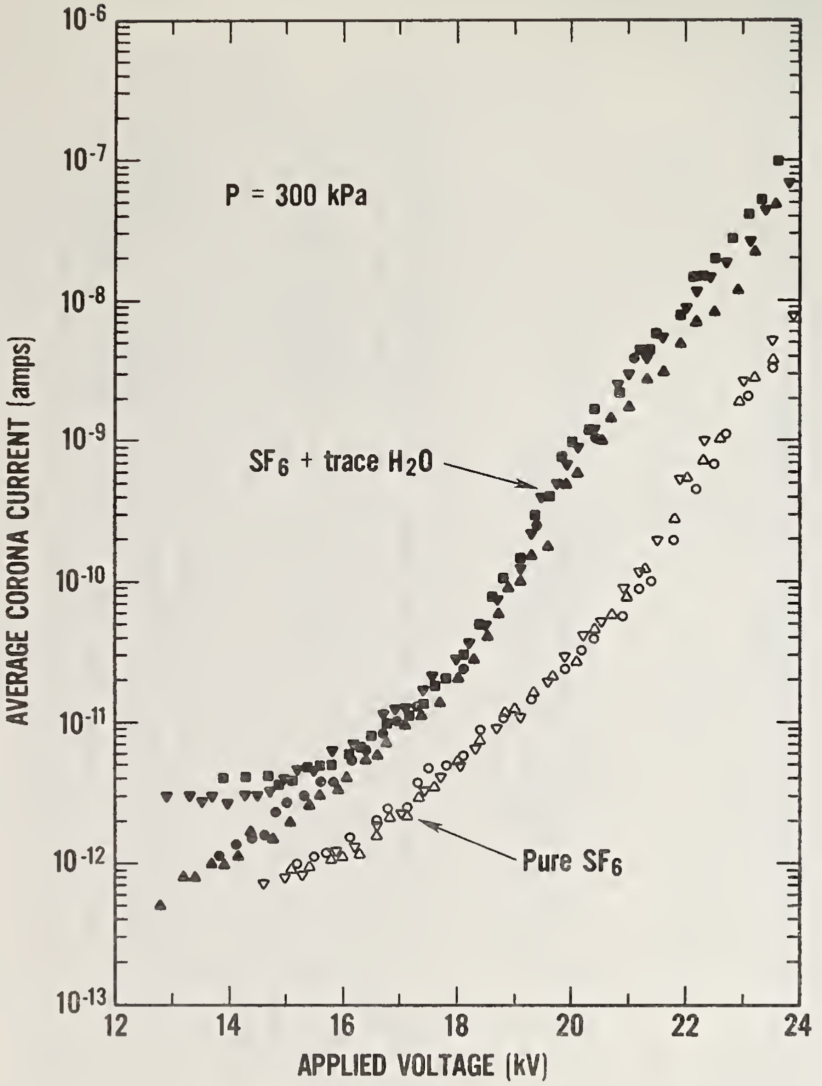

Figure 3. Measured average positive-dc-corona current versus applied voltage for pure (open symbols) and H_2O-contaminated (closed symbols) SF_6 at a pressure of 300 kPa.

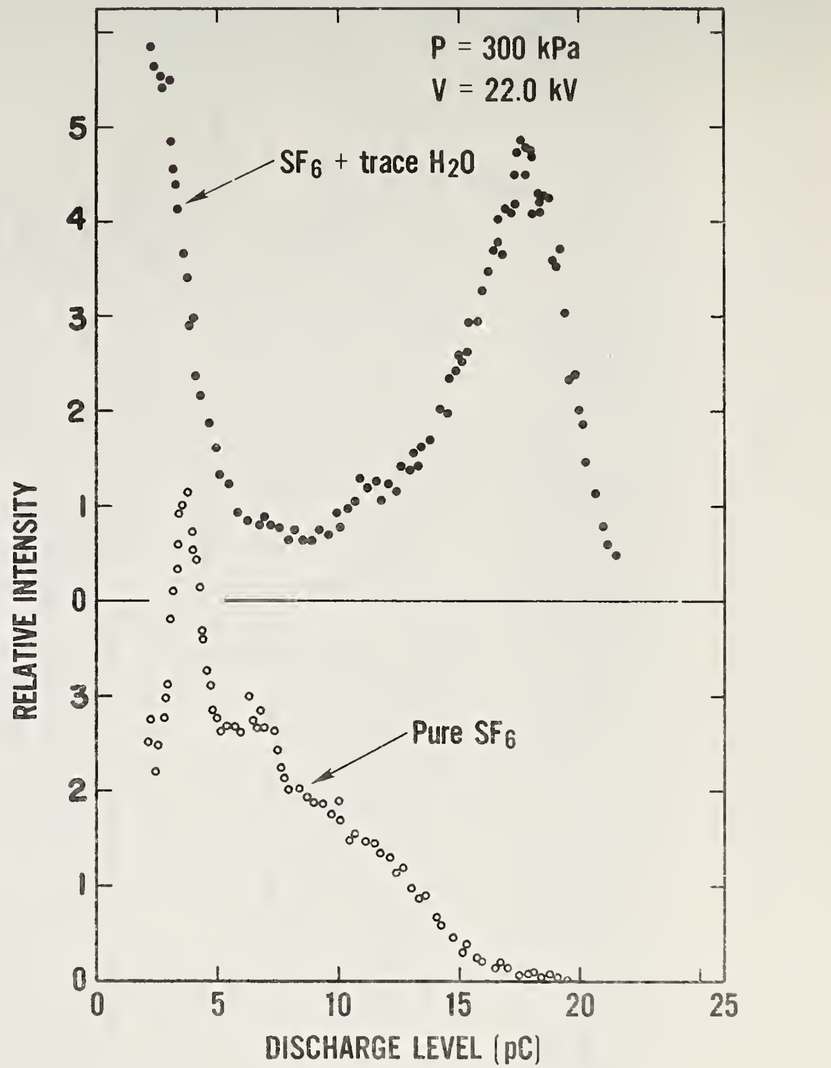

Figure 4. Measured relative number of discharge pulses versus their charge for pure and H_2O-contaminate SF_6 at 300 kPa and applied voltage of 22.0 kV.

Although the introduction of H_2O in small quantitites greatly enhances corona, it appears to degrade the overall dielectric strength of SF_6 only slightly. This was made most evident from comparisons of the measured inception voltages for negative corona. Our measurements yielded negative corona inceptions for H_2O-containing SF_6 that were less than 5% below those for pure SF_6. The inception results which we obtained, therefore, suggest that the sparking potentials for pure and H_2O-contaminated SF_6 in uniform fields should not differ appreciably. However, the enhancement of corona when H_2O is present could conceivably influence nonuniform field breakdown in the region where corona stabilization occurs. The effect of H_2O may, in fact, be to increase the breakdown voltage for corona stabilized breakdown in SF_6. More investigation of the effect of H_2O on nonuniform field breakdown in SF_6 seems desirable.

During the next quarter, a conference paper dealing with the above-mentioned effects of H_2O on SF_6 corona will be submitted for inclusion in the Proceedings of the Seventh International Conference on Gas Discharges and Their Applications, to be held in London, August 31 to September 3, 1982. Our measurements on the power dependence of gaseous by-product production rates from corona in SF_6 will be extended to higher discharge powers to determine power dependence and to examine possible effects of absorption on the walls of the discharge cell. It is expected that improvements will also be made to speed up the analysis of data from the gas chromatograph/mass spectrometer and to perform calibrations for quantitative analysis more efficiently and more reliably. Measurements of effects of changing polarity on corona-induced decomposition will also be considered, together with extensions to other gas mixtures, especially SF_6-N_2 mixtures. Special emphasis will be given during the next quarter to investigating photon-initiated positive point-plane discharges in SF_6 and possibly also O_2-N_2 mixtures at relatively high pressures (>100 kPa). The proposed investigations will be carried out using both a tunable dye laser and a filtered mercury discharge lamp. The purpose of this activity is to investigate the possible role of photodetachment of negative ions in initiating and sustaining high-voltage corona discharges in irradiated gaps.

For further information, contact Dr. R. J. Van Brunt, (301) 921-3121.

5. OPTICAL MEASUREMENTS FOR INTERFACIAL CONDUCTION AND BREAKDOWN IN INSULATING SYSTEMS
Subtask No. A057

The objectives of this investigation are to develop apparatus and appropriate procedures for the optical measurement of interfacial electric field and space charge density in materials for electric power equipment and systems, to understand the interfacial prebreakdown and breakdown processes in specific insulating systems, and to demonstrate the applicability of the developed instrumentation and the procedures in the development and design of future systems.

A new system to measure the electric field in transformer oil using the electro-optic Kerr effect has been constructed and tested as a portion of this investigation. This new system is designed to perform experiments above 100°C. Measurements were made over the range of 100°C to 150°C. In this range, space charge was observed at dc and to a lesser extent at ac.

During this reporting period, a paper [6] describing earlier work was prepared, accepted for presentation at the IEEE Power Engineering Society's 1982 Summer Power Meeting, and for publication in the IEEE Transactions on Power Apparatus and Systems. This previous work generally emphasized measurements below 100°C. At those temperatures, the space charge was undetectably small.

The new NBS test system is a thermally insulated aluminum cube, approximately 60 cm on a side, with an acetal-plastic top and is filled with silicone fluid. The stainless steel test cell, filled with transformer oil, is placed in the silicone fluid bath and the silicone fluid is heated using resistance heaters on the outside of the tank as well as immersion heaters in the fluid. The stainless steel cell is equipped with an oil circulation system, including a copper heat exchange coil, to minimize any temperature difference between the silicone fluid and the oil under test.

As before, no space charge was detected at room temperature. At elevated temperatures, field distortions due to space charge were evident. The data taken under direct voltage are summarized in table 2. Negative space charge was observed near the anode producing a more intense electric field near the anode. The system was initially heated to 125°C. At this temperature, the space charge density in the vicinity of the anode was -14 nC/cm^3. As a consistency check, the polarity of the high-voltage power supply was reversed. Space charge of about the same density again formed at the anode which was now the opposite electrode. For a period of three days, the system was maintained at 100°C or above and measurements were taken at temperatures up to 150°C.

The system was returned to room temperature and no space charge was detected. The system was then reheated and measurements of the space charge density between 100°C and 150°C were again recorded. As shown in table 2, the space charge density at 125°C was approximately the same for this set of data as it was for the previous measurements.

The system was then cooled to 43°C and reheated. At 127°C, the field distortion was significantly smaller--the space charge density was calculated to be about -5 nC/cm^3. Presumably the high temperature operation or the temperature cycling was reducing the space charge density. Since it was suspected the space charge density was influenced by the density of water in the cell, 30 ml of transformer oil which was saturated with water at room temperature was added to the approximately 3 liters of oil at 127°C. It is estimated that this process increased the water content by about 1 ppm. The addition of this amount of water increased the space charge to -15 nC/cm^3.

Measurements were also made using 60-Hz alternating voltage. In general, the space charge density was less with ac than with dc. Further measurements will be required, however, to characterize adequately the 60-Hz behavior. Accurate measurements of the space charge density require a determination of the functional dependence of the Kerr coefficient on temperature and on the wavelength of the illuminating light. These

Table 2. Space charge density vs thermal history

Temperature (°C)	Space charge density near anode (nC/cm^3)	Comments
125	-14	Temperature maintained above 100°C for three-day period. Increased to 150°C before allowing system to cool to room temperature (24°C).
106	- 5	Temperatures maintained above 100°C for two-day period. After 150°C data, system cooled to 43°C overnight.
113	- 9	
125	-15	
150	- 7	
127	- 5	The smaller reading was taken just before water-contaminated oil was added; the larger reading shows the effects of adding the water-contaminated oil sample.
	-15	

functional dependences were estimated for the present data, so it is possible that the value of the space charge densities could be in error by as much as ±40%. It should be emphasized, however, that comparisons at the same temperature should agree within a few percent as should comparisons over the temperature range of interest in this work (106°C - 150°C).

These measurements will be extended during the next quarter. The temperature and wavelength dependence of the Kerr coefficient will be measured so that absolute measurements of the space charge can be made. Additional data as a function of water concentration will be taken under ac excitation to compare the space charge density under ac with that under dc excitation. Finally, we anticipate the initiation of measurements using an oil-paper or oil-pressboard system. These measurements, which will be an extension of previous work [7], should provide more fundamental insight into the processes responsible for the results of the model study presented in [8]. The latter study at the General Electric Company, sponsored by the Electric Power Research Institute, suggested that the dielectric strength of power transformers may deteriorate in the temperature range from 100°C to 150°C. That project tested model structures to determine the effect of operation under overloaded conditions and concluded that insulated conductors deteriorate moderately over the 100°C to 150°C temperature range. The deterioration was accompanied by evolution of visible gas bubbles containing water vapor at conductor temperatures as low as 140°C. The results of those tests prompted the present investigations above 100°C.

For further information, contact Dr. E. F. Kelley, (301) 921-3121.

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Washington, D.C. 20585

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This report documents the progress on four technical investigations sponsored by the Department of Energy and performed by the Electrosystems Division, the National Bureau of Standards. The work described covers the period from January 1, 1982 to March 31, 1982. The report emphasizes the calibration of instruments designed to measure the 60-Hz electric field in biological exposure facilities, selected errors inherent in the use of time-domain reflectometry to determine the rf characteristics of power cables, the measurement of the rate of decomposition of SF_6 in positive dc-corona discharges, and in the measurement of space charge in transformer oil between 100°C and 150°C.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

cables; composite insulation; dc fields; high voltage; incipient fault; insulation; liquid breakdown; SF_6; space charge; transformer oil.

13. AVAILABILITY

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