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CONFIDENTIAL

ELIMINATION OF PARTICLE EFFECTS IN SF₆ INSULATED
TRANSMISSION SYSTEMS

First Quarterly Report

By
S. J. Dale

Work Performed Under Contract No. ET-78-C-01-3029

Westinghouse R&D Center
Pittsburgh, Pennsylvania

U. S. DEPARTMENT OF ENERGY

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ELIMINATION OF PARTICLE EFFECTS IN SF₆
INSULATED TRANSMISSION SYSTEMS

S. J. Dale

FIRST QUARTERLY REPORT

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Westinghouse R&D Center
Pittsburgh, Pennsylvania 15235

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Department of Energy (DOE)

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Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, Pennsylvania 15235

SUMMARY

The purpose of this program is to develop methods and equipment to eliminate the adverse effect of particle contamination in SF_6 -insulated transmission systems, CGIT, so that the excellent dielectric properties of SF_6 can be fully exploited. Presently, CGIT systems are operated at about 10% of the dielectric strength capability of the SF_6 gas.

The program commenced in October 1978 and has a total duration of 21 months. The program consists of three major parts: theoretical and experimental evaluation of concepts; optimization and verification studies in CGIT systems; reliability analysis, documentation of designs and economic analysis.

The approach is based on two philosophies: that systems can be designed to tolerate the presence of contamination; that devices and materials can be incorporated in CGIT systems, and manufacturing and field installations techniques can be developed to eliminate contamination.

Progress is now being made on evaluating alternative conductor and sheath designs to minimize the effect of particles. Materials for solid insulation is being investigated for the same purpose; the effort is presently concentrated on obtaining reliable quantitative measurement techniques of electrostatic properties.

Computer calculation of particle trap configurations are being made to determine the optimum trap configurations.

A novel particle trapping technique is being investigated using adhesive materials.

Manufacture and field control technique studies has commenced with a study of mechanical vibration techniques.

An experimental test chamber consisting of a 9 m (30 foot) long 145 kV bus has been designed. This system will be used in testing of particle control concepts and in migration and optimization studies.

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SECTION 1

INTRODUCTION

1.1 Program Objectives

The purpose of this project is to eliminate the adverse effect of particles (contaminants) in SF₆-insulated transmission systems through development of improved equipment and methods so that the excellent dielectric properties of SF₆ are fully exploited.

1.2 Background

Gas-insulated equipment, such as compact substations and transmission lines, is rapidly becoming an important part of high voltage transmission systems, offering advantages of economy, savings in land space, ease of maintenance, improved safety, and freedom from pollution and radio interference problems. However, one of the most severe problems of gas-insulated systems is the presence of metal particle contaminants which can substantially reduce the breakdown voltage of the compressed sulfur hexafluoride (SF₆) gas used for the high voltage insulation between the conductor and ground. These contaminants can be introduced during assembly procedures or can be produced by abrasion between components during operation. Under the influence of the electric field these particles are lifted and if allowed to migrate to the high voltage conductor, or support insulators, can

initiate a high voltage failure -- either by breakdown in the gas or by flashover along the surface of the conductor support insulator. As a result of the risk of contamination being left or generated in the CGIT system and the depressing effect that this has on the insulation characteristics, present day CGIT systems are being operated well below the dielectric capability of SF_6 .

Typical peak 60 Hz ac operating fields of the present system ranges from about 26 to 56 kV/cm for 145 kV systems and 800 kV systems respectively, operating at 4.4 bar of pressure. For comparison, the theoretical insulation capability of SF_6 at 4.4 bar is 392 kV/cm. If the particle contamination could be eliminated from the CGIT systems, substantially higher operating stresses than presently feasible could be used thus making the CGIT systems economically more attractive than at present.

1.3 Program Philosophy and Approach

1.3.1 General

The program consists of three major parts.

- Theoretical and experimental evaluation of concepts.
- Optimization and verification studies in CGIT systems.
- Reliability analysis, documentation of designs and economic analysis.

The first part is a study of the feasibility of concepts by the evaluation of alternative solutions and designs. Two philosophies of particle control in CGIT systems will here be examined:

- Minimization of particle effects by selecting insulator materials and utilizing design concepts that provide a system immunity against particle contaminants.
- Elimination of particles and particle effects which consist of incorporating devices and adhesive materials into the system that will capture and retain particles throughout the lifetime of the CGIT system.

Both of the above philosophies will be examined and analyzed first in a theoretical and feasibility study followed by experimental prototype verification and development of design parameters.

Manufacturing and field installation techniques will also be examined for methods of improved cleanliness. Procedures for field conditioning of compressed gas insulated transmission systems will be suggested which are compatible with the improved particle control techniques.

The second part of the program deals with optimization and verification tests of selected concepts in full scale CGIT systems:

- First, a 30 foot 138 kV test section will be employed for optimizing the particle control concepts and in studying of particle migration. This test includes a combination of ac, dc and switching impulse tests.
- Second, a scaled up particle trapping technique will be laboratory tested in a 550 kV system size for verification of scaling parameters with higher system voltages.

- Third, factory assembled standard 60 ft CGIT sections for 242 kV incorporating the optimized new techniques for particle control will be subjected to breakdown voltage tests. These data will be analyzed and compared with existing Westinghouse data on identical CGIT sections for improvement and reliability of the new concepts.

Finally a reliability analysis of the system will be performed based on the experimental results. All manufacturing and field assembly procedures will be documented and the economic benefit of being able to operate CGIT systems at higher stresses will be analyzed.

A flow diagram is shown in Figure 1.1.

1.3.2 Theoretical and Experimental Evaluation of Concepts

1.3.2.1 Minimization of particle effects

CGIT systems can be designed such that a certain degree of immunity is achieved against particle contaminants. Alternative designs and concepts will be studied in terms of major CGIT components:

- conductor
- sheath
- insulators

Alternative conductor and sheath designs will be investigated that can give lesser sensitivity to the presence of particles during operating conditions.

1-5

Figure 1.1. Flow diagram for particle elimination program.

Insulator materials will be studied that offers reduced particle attraction and adherence to the surface. This study will include surface coatings and insulator shapes will also be included. Another concept is the use of thin wall barriers around the insulators to prevent particle interaction. This latter concept is depicted in Figure 1.2.

1.3.2.2 Elimination of particles and particle effects

The major part of this program will be concentrated on developing methods to eliminate or render harmless particle contaminants in CGIT systems. Major concepts that will be studied are:

- Electrostatic trapping techniques
- Adhesive materials for particle trapping
- Manufacturing and field installation techniques

Electrostatic trapping techniques include studies of electrostatic particle traps with the aim to develop traps which provide rapid capture of particles with positive retention characteristics. Studies will include edge contours of slots, optimization of slot width, trap area and cavity configurations, effectiveness to capture particles once they have reached the trap, and retention characteristics of the trap under various electrical stresses and mechanical conditions (e.g., slope, vibration, etc.).

Optimum design parameters will be developed using computer field calculations. Prototype trapping designs will be experimentally verified using coaxial electrodes. The trap performance will be tested with 60 Hz, dc and switching impulse voltages as well as under simultaneous mechanical vibration.

Dwg. 6441A15

Figure 1.3 — Barrier particle control concepts.

Other concepts that will be investigated are control methods for particles in long vertical bus lengths.

Particle migration is an important part of any trapping technique and will be included in this study.

Adhesive material for particle traps. In this study most emphasis will be placed on developing permanently tacky adhesive for use in combination with electrostatic particle traps. Figure 1.3 shows one solution using an electrostatic trap together with an adhesive layer. This hybrid form of particle trap is expected to have superior retention characteristics.

Manufacturing and field installation techniques. In this part of the program methods which can significantly reduce the contamination in CGIT systems will be developed. These include:

- Mechanical vibration techniques
- Cleaning techniques
- Field jointing
- Field conditioning

Mechanical vibration techniques will be improved and developed to remove particles from CGIT sections in the assembly stage, and as part of the field conditioning process this method can be used to move particles into traps.

Cleaning techniques will be evaluated and tested to further eliminate particles from the factory assembled CGIT sections.

Dwg. 6441A20

(a) Adhesive layer in conjunction with electrostatic trap

(b) Practical method of using adhesive layer

Figure 1.2 — Adhesive layer for improving electrostatic traps.

Field jointing techniques will be developed to minimize the contamination of CGIT systems during field assembly. This may result in a different design philosophy for CGIT systems. Concepts like completely sealed factory assembled units and inside coating of joint sections or total CGIT sections to trap and embed any contamination will be considered.

Field conditioning methods. Based on analysis of tests and the CGIT design with improved particle control techniques, procedures for conditioning in the field will be recommended.

1.3.3 Optimization and Analysis of Particle Control in CGIT Systems

Experimental tests and verification studies of the most promising particle control techniques developed in the first part of the program will be conducted. The control techniques will be integrated in a full scale CGIT 138 kV test section. Tests of particle traps at 550 kV system size will also be made for such verification.

The final particle control techniques will be incorporated into the CGIT designs and assembled in the factory on the standard "shop floor" under conditions that are considered practical and suitable for mass production techniques: A 242 kV 60 ft rigid section of CGIT bus will be assembled and tested in the factory. The section would be assembled using the new developed design and assembly techniques. It would then be ac tested to breakdown, using partial discharge tests and acoustical techniques to study particle motion and trapping. After each test the length would be fully disassembled and passed through the factory cleaning and assembly

techniques again. Care would be taken that the section would not be ultracleaned by this repeated process, e.g., the system would be deliberately contaminated before cleaning.

Analysis of the new breakdown voltage distribution and comparison with existing Westinghouse data on identical 242 kV sections using the present trapping techniques will allow evaluation of improvement due to the new trapping and assembly techniques. These new data will enable a statistical analysis to be made of the reliability of long length CGIT lines in the field.

1.4 Program Organization and Schedules

The duration of the program is twenty months. Tasks and schedules are shown in Figure 1.4 with milestones detailed in Table 1.1.

1.4.1 Summary of program tasks

Task 1. Theoretical analysis and experimental investigation. Perform theoretical investigation and analysis needed to prove the effectiveness of designs and methods proposed.

Task 2. Major experimental system and verification studies. Perform experimental investigation involving prototypes built according to proposed designs and methods.

Task 3. Reliability analysis. Perform statistical analysis of experimental data to insure that the proposed methods and designs will provide reliable

U.S. DEPARTMENT OF ENERGY
MILESTONE SCHEDULE AND STATUS REPORT

PAGE 1 OF 1

1. Contract Identification Elimination of Particle Effects in SF ₆ Insulated Transmission System		2. Reporting Period through		3. Contract Number ET-78-C-01-3029																					
4. Contractor (name, address) Westinghouse Electric Corporation Research and Development Center 1310 Beulah Road, Pittsburgh, PA 15235		5. Contract Start Date 9/28/78		6. Contract Completion Date 6/26/80																					
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months												10. Percent Complete											
		FY 78			FY 79					FY 80				a) Planned	b) Actual										
		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J			
1	Theoretical and Experimental Investigation																								
.1	Electrostatic Traps				▽ A						▽ B														
.2	Adhesive Trap Materials				▽ A						▽ B														
.3	Solid Dielectric Insulation										▽ A														
.4	Manufacture and Field Control Methods										▽ A														
2	Major Experimental System and Verification Studies										▽ A														
3	Reliability Analysis																								
4	Documentation																								
5	Economic Benefit Analysis																								
6	Final Report																								
7	Program Management and Technical Report Schedule				▽			▽			▽			▽				▽							
11. Remarks																									
12. Signature of Contractor's Project Manager and Date Steinar J. Dale													13. Signature of Government Technical Representative and Date												

Figure 1.4. Milestone Schedule and Status Report

Table 1.1. MILESTONE LOG

ET-78-C-01-3029

Contract No.

IDENTIFICATION NO.	DESCRIPTION	PLANNED COMPLETION DATE	ACTUAL COMPLETION DATE	COMMENTS
1.1.A	Concept Studies Complete	02/79		
1.1.B	Prototype Tests Complete	07/79		
1.1	Particle Trap Design Finished	09/79		
1.1.C	Vertical CGIT Trap Concept Studied	12/79		
1.2.A	Adhesive Trap Concept Tested	01/79		
1.2	Adhesive Material Major Candidate Selection	02/79		
1.2.B	Material Selection and Application Methodology for Factory Test Complete	09/79		
1.2.C	Aging Tests Complete	05/80		
1.3.A	Material Selection Complete	05/79		
1.3	Small Prototype Tests Complete	09/79		
1.4.A	Elimination Methods, Factory Study Complete	07/79		
1.4	Improved Factory Control Methods Complete	09/79		
1.4.3	Field Joint Techniques Complete	12/79		
1.4.6	Field Conditioning Study Finished	04/80		
2.A	138kV Test Section Delivered	05/79		
2.	Optimized Particle Control Package (OPCD) for Factory Tests Decided.	9/79		
2.B	Is OPCP Satisfactory	11/79		
2.C	Vertical CGIT Tests Complete	01/80		
2.D	550kV Test Complete	02/80		
2.E	242kV Factory Verification Tests Complete	03/80		
2.F	Particle Migration(138kV System) Complete	04/80		
3.	Reliability Analysis Complete	04/80		
4.	Documentation Complete	04/80		
5.	Economic Benefit Analysis Complete	04/80

Figure 1.5 — Project organization showing key contributors to Particle Elimination Program.

operation on long transmission systems particularly with respect to contaminants.

Task 4. Documentation. Provide documentation of manufacturing and field installation procedures of those designs and methods which will help reduce the adverse effects of free conducting particle contamination.

Task 5. Economic benefit analysis. Provide an analysis and documentation of the savings that could be realized by fully exploiting the dielectric properties of the gas or gas mixture and to the extent possible, provide an outline of follow-on work.

Task 6. Final report. Prepare a final report documenting in detail all the work performed under the project.

1.4.2 Program organization

The program organization is outlined in Figure 1.5. The program management is with the Westinghouse Research and Development Center with work being performed by several specialist groups. Extensive work is also being performed at the Westinghouse CGIT Laboratory in Westborough, Massachusetts.

1.4.3 Milestone schedule and status report

The Milestone Schedule and Status Report is shown in Figure 1.4. A milestone log is given in Table 1.1.

Work has commenced in the four major control concept areas listed under Task 1.

SECTION 2

TASK 1. THEORETICAL ANALYSIS AND EXPERIMENTAL INVESTIGATION

2.1 Task 1.1. Electrostatic Particle Elimination Concepts

The experimental work in this part of the program will be made using the test vessel shown in Figure 2.1.

1.1 Conductor and Sheath Concepts

Sheath

A corrugated sheath section has the characteristics of electrostatic particle traps since the field in the bottom of a corrugation is only about 15% at the corrugation top. In comparison, a smooth sheath section with the same inner diameter has a field at the sheath of three times that in the corrugation bottom (for the specific corrugated pattern shown in Figure 2.2).

Tests made at Westinghouse on another DOE sponsored contract, ET-78-C-01-2870, showed that particles could be temporarily trapped or "trapped" with respect to a given voltage range in a corrugated sheath section which were 12.5 mm deep and had a 70 mm separation. This is shown in Figure 2.3 where increasing voltage levels are required to "untrap" particles. The corrugations did not therefore have the positive retention characteristics

Figure 2.1. Test vessel with coaxial electrode test section for particle trap development studies

1 Pressure Vessel	5 Support Insulator
2 242 kV Bushing	6 Conductor
3 Observation Windows	7 Particle Trap
4 Sheath Test Section	

$$a = 38 \text{ mm}$$

$$b = 6.4 \text{ mm}$$

$$r = 7.5 \text{ mm}$$

Figure 2.2. Corrugated pattern of sheath section.

Figure 2.3. Particle initiated breakdown in 302/102 mm diameter coaxial electrodes with corrugated sheath.

Figure 2.4. Stranded type conductor with four rods

needed for reliable particle traps. This concept will be investigated further.

Conductor

A conductor consisting of four separated electrodes at the same potential has been designed and made. The conductor design is shown in Figure 2.4. Tests will be made to determine if particle initiated breakdown is less severe with this configuration than with the conventional cylindrical electrode. Similar conductor designs are being considered in DOE Contract ET-78-C-01-2870 for semiflexible cables.

1.2 Electrostatic Trap Techniques

One method presently being used as particle control in CGIT systems is the electrostatic particle trap, where a region of low or zero electric field is provided at the sheath (outer electrode of a coaxial system) by slots or a slightly elevated metal shield. In the latter, particles can enter the low field region created on the sheath through slots in the shield.

There are several important factors that must be considered for particle control with such traps:

- Particle contaminants must be migrated through the CGIT system to the location of the traps. This must be achieved without risking damage to the system from flashovers or contamination of solid insulators which can cause flashover at later times.

- Once the particles have arrived at the trap, the trap must provide rapid and positive capture of the particles and must not discriminate on particle size and shape.
- The trap must have positive retention characteristics under 60 Hz, dc and transient voltages as well as mechanical vibration and on-slopes.

The first of the above factors determines the number of trap units per unit length of the system and also the position of the traps in the system; e.g., at insulator.

The second factor deals with the trap areas, the aperture ratio and the trap configuration such as edge contours, aperture or slot length and width, profile of the metal parts: whether curved or flat, etc. The field intensification caused by the trap must be minimized since the particle activity increases with field. The trap should not promote firefly motion of particles on the trap because this decreases the trapping efficiency per unit time.

The trap cavity and apertures must be designed such that particles cannot escape from the trap once they are inside. For example, particles which fall into the trap through a slot should not bounce back out again. This factor may be more important in determining the depth of a trap than the electrostatic field reduction at the trap bottom. Particles can also be ejected from trap cavities by gas movement resulting from corona discharges in a system. This can be particularly serious with dc voltages.

Calculations using a finite-difference over-relaxation computer program have been performed to determine the field distribution of a trap configuration consisting of parallel wires. There are three parameters which characterize this type of trap: the wire diameter d , the spacing s between the centers of adjacent wires and the depth from the top of the wires to the bottom of the trap. If the trap is sufficiently small compared to the conductor-to-sheath spacing, these parameters completely determine the field distribution on the trap. The maximum field in such a grating-type particle trap is at the top of each wire and is a function of s/d where s is the wire separation (center to center) and d is the wire diameter. Maximum fields as a function of s/d is shown in Figure 2.5. The field is normalized to a uniform far field in which the system is submerged. As s/d is increased, viz., the separation is increased, the field at the top of the wires are also increased. Note, for example, that for a coaxial cable with a conductor to sheath field ratio of e , $s/d = 3$ results in a sheath field enhancement of 75% or: the maximum field on top of a wire is 64% of the conductor field. Since the particle activity increases with electric field it is important that the field on top of a particle trap is minimized.

The electric field distribution inside the grating-type trap is shown in Figure 2.6 along the line AB perpendicular to the plane of the grating. The field along AB is shown normalized to the field at A and is plotted against distance in units of the wire separation, s . With a ratio of depth to wire spacing, $\alpha = \text{depth}/s$ of 3.3 the field at one spacing s inside the trap is reduced by three orders of magnitude and has an asymptotic value

Curve 714992-A

Figure 2.5. Maximum normalized field versus s/d for grating particle trap

Curve 714991-A

Figure 2.6.

of about 1.5×10^{-4} at the bottom of the trap (not shown). For traps with a smaller depth-to-spacing ratio, viz., $\alpha = 2.5$ and 1.7 , the fields at the bottom of the trap are reduced to 2×10^{-3} and 2×10^{-2} of the field at A respectively.

2.2 Task 1.2. Adhesive Trap Materials and Concepts

The investigation of the adhesive properties of various coating systems has been initiated with the evaluation of nine organic materials (Tables 2.1 and 2.2). With the exception of the waterborne Hycar 2600 x 205 and the E-5317 materials, all of the other systems are solvent based. Solvent based materials are preferred because waterborne systems contain continuous hydrophilic networks which are conducive to moisture retention or absorption.

Adhesive sensitivity tests were conducted at -40°C , $+25^{\circ}\text{C}$ and $+70^{\circ}\text{C}$. This test involved a 24-hour drying of the coated surface and the placement of five pieces of 13 mil aluminum wire (1/8 in. to 1/4 in. long) on the surface. The panel was inverted, coated side down, and the percent wire pieces remaining on the surface was recorded. A 7/16 in. steel ball (5.6 gms) was then dropped from a height of one inch onto the reverse side of the specimen, followed by another impact from a height of 10 inches. Test results indicate that the two waterborne systems and three of the solvent based systems exhibit excellent adhesive properties. Preliminary tests in a sheath model indicated excellent trapping properties using the Hycar 2600 x 205 adhesive material. Six electrode heads have been covered with six of the systems under consideration for electrical testing.

TABLE 2.1
COATING SYSTEMS EVALUATED

<u>Material</u>	<u>Supplier</u>
Hycar 2600 x 205	B. F. Goodrich Chemical Company
Unbacked Elastomeric Tape	Royston Laboratories
Pliobond 8004	Goodyear Tire & Rubber Company
Pliobond 5001	Goodyear Tire & Rubber Company
Tufmelt 3003	Goodyear Tire & Rubber Company
Tufmelt 3002	Goodyear Tire & Rubber Company
A1450B	B. F. Goodrich Chemical Company
E-5317	Borden, Inc.
38V6 KR/99-T-2	Mobil Chemical Company

TABLE 2.2

ADHESIVE VALUES OF THE COATING SURFACE

Material	Test Condition	Temperature		
		-40°C	+25°C	+70°C
Hycar 2600 x 205	Turn	100	100	100
	1" ball drop	100	100	100
	10" ball drop	80	80	100
Elastomeric Tape	Turn	100	100	100
	1" ball drop	80	100	100
	10" ball drop	80	100	100
Pliobond 8004	Turn	100	100	100
	1" ball drop	100	100	100
	10" ball drop	100	100	100
Pliobond 5001	Turn	100	100	100
	1" ball drop	100	100	100
	10" ball drop	60	100	100
Tufmelt 3003	Turn	100	100	100 ^a
	1" ball drop	100	100	100 ^a
	10" ball drop	40	100	100 ^a
Tufmelt 3002	Turn	---	100	----
	1" ball drop	---	100	----
	10" ball drop	---	40	----
A1450B	Turn	---	100	----
	1" ball drop	---	80	----
	10" ball drop	---	0	----
E-5317	Turn	100	100	100
	1" ball drop	100	100	100
	10" ball drop	40	100	100
38V6 KR/99-T-2	Turn	---	60	----
	1" ball drop	---	0	----
	10" ball drop	---	0	----

^aMaterial flowed at +70°C.

NOTE: All values represent percent of particles remaining on surface.

2.3 Task 1.3. Solid Dielectric Insulation

The support insulators are a critical part of a CGIT design which are particularly vulnerable to contamination. Particles can bond to the insulator surface by Coulomb electrostatic attraction and unless means to discharge the particles are present they can stay on the insulator for long periods of time. This increases the probability of failure across the insulator; in particular for transient overvoltage conditions.

Efforts will be directed towards obtaining insulator materials and methods of surface treatment to reduce the particle attraction and adherence to the surface. Materials which are being considered for use in the 1200 kV semiflexible cable project (DOE Contract ET-78-C-01-2870) are also scheduled for tests to determine the electrostatic properties.

Methods are presently being evaluated which will provide reliable quantitative measurements of attraction forces between particles and insulation and of particle adherence forces. These include ways of mechanically pulling particles off the surface and the use of variable oscillating diaphragms where the acceleration forces on the particles cause them to detach from the surface.

The elimination of electrostatic bonding forces on particles requires that the charge on the particle be removed. Partially conducting coatings applied to the conductor surface can be used to discharge attached particles. Such coatings are now being evaluated in terms of conductivity and adherence properties. It is obvious that the coatings and other surface treatments

must be compatible as insulator materials and must have good arc resistance properties.

2.4 Task 1.4. Manufacture and Field Control Methods

The techniques used during manufacture and field installation to eliminate particle effects are divided into four areas as follows:

- a) Mechanical Vibration
- b) Cleaning
- c) Field Jointing
- d) Field Conditioning

In the first area of mechanical vibration, we will be using results now being obtained as part of the DOE 1200 kV Semi-Flexible CGIT development program. In that effort excitation at selected frequencies will be investigated as a means of more efficiently moving particles out. The present technique relies on vibrating the assembly using a powerful air driven vibrator which is extremely noisy. The technique is effective but also produces wear on parts which are not specifically designed to tolerate such vibration. More gentle vibrators at lower frequencies have been tried. These are not objectionable from a noise viewpoint but have the disadvantage of only moving the larger particles.

During the next quarters cleaning, field jointing and field conditioning will be evaluated based on actual experience with routine production over the last eight years. Results of field testing will be collected and analyzed for information related to particle elimination.

SECTION 3

TASK 2. MAJOR EXPERIMENTAL SYSTEMS AND VERIFICATION STUDIES

3.1 145 kV System Experimental Test Chamber

Figure 3.1 shows a convenient and versatile test chamber for realistic study of particle effect elimination techniques. The test region is a 9 m (30 foot) length of 145 kV bus which will initially contain standard Tri-Post and conical insulators. The bus is provided with several particle injection bosses. The conductor has a hemispherical cap so that end viewports have an unrestricted view of the coaxial interior. Viewports are also provided in the side of the bus near the conical insulator.

For studying effects of slope, the test bus can be inclined at any desired angle up to 20° by pivoting at a hinged bellows at the bushing end.

The bushing and tee (which includes a gas stop insulator) are available Westinghouse owned equipment. They are capable of approximately 500 kV 60 Hz RMS L-G and 1100 kV BIL. This is in excess of requirements for studies to breakdown at up to 50 psig SF₆ in the coaxial bus fitted with insulators.

The bus enclosure is 226 mm (8.9 inches) inner diameter with a 7.6 mm (.3 inch) wall of 6063-T6 aluminum. The bus conductor is 88.9 mm (3.5

inches) outer diameter with a 15.24 mm (.6 inch) wall of 6101-T64 aluminum. These items will be made using normal factory production techniques so they will be representative of actual installed equipment.

The insulators are welded to or cast on the bus conductor as is standard practice. To make disassembly easy both insulators are provided with wheel assemblies. The conductor is jointed on both sides of the conical insulator so it can be reversed or modified easily.

Since all parts are essentially standard, the time required for production is minimized.

SECTION 4

PROGRAM FOR NEXT QUARTER

Work will continue on conductor and sheath concepts.

Solid insulation materials and coatings will be evaluated.

Computer calculation of particle traps will be continued for optimized concepts and experimental evaluation will commence.

Adhesive materials will be tested in electric fields and in actual particle traps. Aging tests will continue.

Manufacture and field control methods will continue to be evaluated.

Production will start on 145 kV system test section.

SECTION 5

LIST OF CONTRIBUTORS

Electrostatic Particle Elimination Concepts

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Adhesive Trap Materials and Concepts

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Manufacture and Field Control Methods

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Major Experimental Systems and Verification Studies

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