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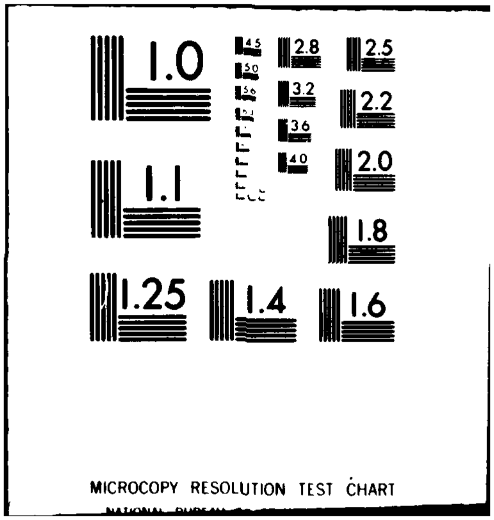
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OPERATIONS RESEARCH REPORT ①

12-ORR-77-1 LEVEL II

UNINTERRUPTIBLE POWER SYSTEMS

OPERATIONAL AND COST CONSIDERATIONS

MARCH 1977

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A study of cost and potential benefits of Unninterruptible Power Systems (UPS) for Air Force communication systems was made, using data from four specific systems. An important conclusion was that UPS justifications should not be based on marginal increased in power availability but upon requirements for "clean" power needed by modern computers and other devices using low-voltage, low-power logic circuits. Such circuits may be particu- over

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) larly susceptible to transients, surges, dropouts, overvoltages and undervoltages (brownouts) which are common anomalies of power furnished by public utility companies. UPS may be needed more to clean up "dirty" power during the 99+% of time it is available, than to furnish power during prime-power outages.

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OPERATIONS RESEARCH REPORT

12-ORR-77

Uninterruptible Power Systems
Operational and Cost Considerations

March 1977

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ABSTRACT

This Operations Research Report, 12-ORR-77, examines the requirements of power reliability and quality used to operate communications and electronic equipment. Specifically, four different systems are studied; namely, the Japan Tropo System (JTS), Automatic Digital Weather Switches (ADWS), Automatic Digital Network (AUTODIN), and Defense Satellite Communications System (DSCS). The intent is to examine the effect of power disturbances with regard to the impact on system operational capabilities and the associated cost implications. In particular, these factors are considered to indicate the applicability of using Uninterruptible Power Systems (UPS) or alternate power strategies or conditioning equipment for the unique requirements of each system examined.

DISCLAIMER

EXECUTIVE SUMMARY

In November 1976, HQ USAF charged AFCS to undertake a cost/benefit study of Uninterruptible Power Supply (UPS) systems, with particular attention to their application in four communications systems: the CONUS and overseas AUTODIN, the Japan Tropospheric System (JTS), the Automatic Digital Weather Switch (ADWS), and the Defense Satellite Communication System (DSCS). Copies of the HQ USAF/KRC message requesting a meeting with AFCS/OA to discuss need for a study, an outline proposed by AFCS/OA, and the KRCXP tasking letter are provided in the Appendix to this report. Although four real-world operating systems were selected as a focus for the study, there was no intent to redefine or justify user requirements for uninterrupted operation or high availability: Availability requirements stated in applicable Air Force Manuals and Regulations, DCA Circulars, and MIL-HDBK-411 were accepted as reflecting the military need.

At the outset of this study, it appeared to cognizant HQ USAF and AFCS personnel that the "benefit" side of the cost/benefit analysis could best be described and quantified in terms of the increase in system availability achievable if power availability were improved from current levels to virtually 100% by addition of UPS. It was well recognized that, within the time constraint, no new measurement program or reporting procedure could bear fruit: Data had to be extracted from existing station logs and reports. Messages were dispatched to field units at stations in each of the four systems of interest, requesting data on station outages and power outages over the past two years, and any additional information pertinent to the study. Because it was anticipated that the data from the field might be incomplete and would probably contain errors and ambiguities, an intensive literature search was undertaken concurrently so that the data obtained from the field could be interpreted in the light of the documented experience of others who had justified the procurement of UPS equipment.

Most of the Japan tropo system stations (six in Japan and one in Korea) operate from commercial power and a rotary UPS, with auto-start/ auto-transfer engine-generators for standby back-up power. The data clearly demonstrate that the UPS successfully protected the JTS stations from commercial power outages and more than satisfied the DCAC 310-130-2 99.9% objective. A two-year total of 226 unscheduled commercial power outages were reported by the seven UPS-equipped stations, comprising a total of more than 212 hours of power outage time, while total station outage time charged to UPS failures was 42 minutes. Because of this successful protection, no data are available by which to estimate what station outage time would have accrued without UPS.

ADWS stations did not have UPS protection, and no clear patterns were discernable from the reported ADWS outage data. This was also confounded by the fact that power arrangements differ widely from site to site. Carswell, the ADWS hub, is powered from a one-of-a-kind Total Energy System which has proven very expensive to operate. Significant operational cost savings could be achieved by a more conventional arrangement using commercial power with military standby. The

Clark ADWS uses Philippine commercial power, and reported 118 station outages due to power problems in 1976, but with a surprisingly low 3-1/2 minutes average station outage. At the other extreme, Fuchu, which is also served by commercial power with military standby, reported only eight power-related station outages in 1976, but the average duration was more than 50 minutes. In both cases, the MIL-HDBK-411 permissible maximum of 53 minutes outage per year was exceeded by more than a factor of 7. A few long outages were reported by Croughton, which has no commercial power, but is served by three diesel generators, any of which can carry the load. At Clark, two drum replacements have been ascribed to drum "head crashes" caused by dirty power, but Carswell, with stable TES power, has had four drum replacements attributed to normal wear and deterioration. With these conflicting indications, any conclusions would be premature without other corroborating data.

At overseas AUTODIN locations where UPS equipment provides protection for all of the critical technical load, a pattern similar to that for the JTS prevails. No station outages due to power problems were reported from Drake or Croughton in 1976, though Drake reported 30 power failures totalling nearly 60 hours. (Croughton had only two power outages.) At Clark, 43 power failures were reported in 1976 totalling more than 52 hours, but DCAC 310-55-1 reports indicate only one station outage was charged to Clark as caused by power problems. Evidently, the UPS equipment is providing excellent protection against the frequent power outages at Drake and Clark AUTODIN locations, and the AFM 88-15, 99.99% criterion is being well satisfied.

Within the CONUS, AUTODIN switches are only partially protected; power for modems, cryptographic equipment and technical control is supplied through a rotary UPS, but the Western Union computer equipment is buffered only by a motor-generator unit with ride-through capability of about 100 milliseconds. Consequently, every power failure at CONUS AUTODIN locations is accompanied by a station outage. Minimum restart time (on standby power) is 15-20 minutes, but often more than an hour elapses before all circuits are restored. This means that three or more commercial power failures per year (including any short interruptions of more than 1/2 second) would be sufficient to cause power availability to CONUS AUTODIN tech loads to be below the AFM 88-15 criterion. By a reconfiguration of the entire AUTODIN critical load, an operational cost saving of more than $100,000 per site annually could be achieved because the expensive leased Western Union motor-generator sets would no longer be required.

The ground entry terminals of the DSCS were powered from military power generation plants, with no UPS. Station outage times are quite long (one to two hours is typical) when they occur. Outage times at three stations (Clark, Shemya, Diyarbakir) were such that the DCAC 310-130-2 99.0% performance objective could not be met for any links involving these sites. Power problems are ascribable more to the age and condition of local generation and distribution equipment than to the need for protection against short outages during switchover from prime to backup sources. Long outages persist even after power restoral, owing to the requirement for elaborate restart procedures and to the characteristics of the equipment. If basic improvements in power generation arrangements are accomplished to guarantee rapid transition from prime to backup power, the addition of UPS could prevent the time extension of system outages incurred by the long start-up sequences. The introduction of the Digital Communication Subsystem (DCSS) digital upgrade equipment could dramatically increase the station's susceptibility to power disturbances. A program of measurement and analysis of the power quality environment should be undertaken, and the DCSS equipment subjected to thorough tests for susceptibility to power disturbances before commissioning.

As these data were assembled and evaluated, it became clear that the intent to describe the potential benefits of UPS in terms of a quantitative marginal increase of system availability could not be fulfilled. In two of the systems (AUTODIN, JTS), it was clear that UPS and other power conditioning equipment were protecting the systems against most of the deleterious effects of power outages, but had unfortunately also precluded the opportunity to obtain data which would quantify station outages without UPS. The ADWS data were inconsistent and confounded by a variety of power arrangements. UPS offers the potential to reduce the characteristic "outage extension factor" incurred by the nature of the DSCS equipment, but only if basic improvements are made to provide adequate prime/standby power arrangements.

More importantly, another significant pattern began to form from the comments which the messages to field units had invited. Those answers mentioned equipment damage due to power surges and transients, and station outages ascribable to, or suspected to be caused by, power fluctuations and disturbances of short duration. About the same time, confirmation of this view emerged from an unexpected source. An Air Staff (KRAD) letter, dated 22 February, subject: Computer Power Enhancements, begins, "When electrical power problems impact a computer. . .", and goes on to suggest that a detailed power analysis should be performed, not to measure the percent availability of power, but to characterize transients, short interruptions, surges, and undervoltage incidents. These concerns were strongly confirmed by the literature survey. From a dozen or more respected technical journals, article after article pointed to the potentially deleterious effects of very short-duration power line disturbances upon the operation of computers and other equipment employing modern solid-state integrated circuitry. Many of these references characterize the problem as a fundamental incompatibility between the "clean" power requirements of solid-state logic circuits and the "dirty" power generally provided by public utilities, and refer to this incompatibility as the "power squeeze". Significantly, the Federal Aviation Administration (FAA), which appears to have the longest experience with UPS systems within the government, refers to such equipment as PCS (for Power Conditioning Systems) to emphasize that their major function (and justification) is to "launder" the "dirty" power; avoidance of outages is viewed only as a small subset of the general problem.

This emphasis on the functions of UPS during the 99+% of the time that power is not "out" suggests that the plan to characterize UPS benefits in terms of outages avoided begs the question whether UPS is needed, since it pre-supposes that UPS would merely fill in the temporal gaps of otherwise "perfect" power. As many of the journal articles assert, and several public utility officials have publicly admitted, this pre-supposition is far from fact. The fact is that public utility companies are installing UPS to assure clean power to their own computer installations which monitor and control power generation and distribution systems.

As the import of this message became evident, the immediate implication was that a cost/benefit analysis based on a marginal increase in availability would be of limited value at best, and possibly misleading at worst, especially since it could only be based on incomplete outage data with no direct before/after comparisons. Consequently, it was decided to concentrate the remaining time and effort available toward a clear and thorough characterization of the real problem, according to the experience of others: how to resolve the basic disparity — i.e., relieve the "power squeeze" — during the 99 percent of the time that commercial (or military) power is supplied. From this viewpoint, the possibility to avoid the 1% or less outage time incurred during transitions from prime to standby power sources can be treated as an incidental, bonus benefit.

The quality of electric power delivered (when there is no "outage") has received little attention. Nearly everyone assumes that 60-cycle power is "pure" and is free from fluctuations and other disturbances. This assumption has no basis in fact. Short-duration interruptions of a few cycles up to several seconds can and do occur at a rate which may be as high as several hundred a year. In addition, overvoltage transients of very short duration (a few hundred microseconds) are frequently superimposed on the nominal supply voltage. These may have peaks as high as five times the nominal crest of the 60-cycle sinusoidal wave. Temporary voltage "sags" greater than 10% are becoming more commonplace. Specifications of the power required for most computers generally ignore the possibility of such power imperfections. However, most computers have built-in provisions to cause orderly power-down and shut-off sequences to be initiated if a significant voltage dip or interruption is sensed having a duration of as little as one cycle or, in some cases, even 1/2 cycle. Consequently, users in government and industry who are dependent upon continuous, on-line computer operation have had to find some resolution of the basic incompatibility of these computers with the quality of power service which can be obtained from public utilities.

The Department of Defense (and Air Force in particular) must consider itself as a member of this community of users who find themselves caught in what is now properly described as "The Power Squeeze". One of the remarkable characteristics of this "squeeze" is that it is poorly documented and generally not well understood. The fundamental reasons for this are that specialized instrumentation is needed and a management commitment is required to expend time, money and personnel resources over a long period of time to establish occurrences of specific computer malfunctions associated with recorded powerline disturbances. In many instances, the cause-and-effect relationship is not immediately evident, and results do not exhibit good repeatability, because the specific effect depends not only upon the type of power line disturbance but also upon which combinations of computer machinery (central memory, input/output, data transfer equipment) are active at the instant the disturbance occurs. In the face of these difficulties, many industrial users have decided not to invest much time and money to prove to themselves that a problem exists and to describe it in detail, but have elected to devote those same resources directly toward obtaining a solution. The same dilemma faces the Air Force in trying to decide which locations and what functions are degraded by power line disturbances to an extent that some type of power conditioning equipment is warranted. Possibly, the management policy adopted by industrial firms merits consideration by the Air Force.

Unlike commercial or industrial organizations, the Air Force is not in business to earn a profit. It is therefore inappropriate to express costs of computer disruption in terms of business lost, spoilage of in-process materials, or loss of customer goodwill. Rather, USAF must find a way to value the quality of the service provided by its communications networks in a wartime or crisis situation. To justify expenditures for power conditioning equipment on economic grounds, the value placed on the quality of this service must be expressed in money. The equation is always difficult to establish, and invariably open to challenge.

Part of the difficulty in deriving such a value is that current guidance expressing the operational requirement for service in terms of availability (typically 99.99% per year) is not readily translatable into equipment specifications in terms of tolerable durations of system outages and permissible frequencies of occurrence of such outages. Taken literally, the 99.99% figure could be interpreted as permitting an outage of 53 minutes provided that no more than one such interruption per year could be guaranteed. At the other extreme, it is also interpretable as permitting several hundred outages per year provided no single interruption had a duration of more than, say, ten seconds. A restatement of MAJCOM's operational availability requirements in such terms would be very useful in translating operational needs into UPS equipment specifications.

Recommendations in all of these problem areas were included in AFCS Operational Analysis Report 3-ORR-67, published almost exactly ten years ago. Though the hindsight of the past decade's experience could suggest modifications to details of some of the specific conclusions and recommendations of that report, their main thrust remains valid. Especially noteworthy are the recommendations to "develop realistic operational effectiveness and reliability criteria for power systems and integrated power/electronics communication systems", and to "develop new design criteria which will minimize the extreme susceptibility . . . (of digital communication equipment) to power . . . discontinuities." The principal changes over the past ten years have been in the widening gap between power quality and the requirements of low power, solid-state electronics, the increasing trend toward digitization of functions previously performed by analog equipment, and the significant improvement in the technology of solid-state UPS (SSUPS). In the same period, many users within industry and government (FAA particularly) have accumulated a wealth of experience and expertise in the procurement, operation, and maintenance of such systems. This experience can be a valuable asset to the Air Force and should be exploited in formulating policies and developing implementation and maintenance procedures for similar systems.

In the near term, there seems to be no reasonable alternative to the "buffer" approach (UPS or other power conditioning equipment) to bridge the power-quality gap for equipment whose undisrupted continuous operation is operationally required. As a long term strategy, it is recommended that Air Force undertake a vigorous program to reduce the susceptibility of new equipment to power disturbances, perhaps even to the extent of incorporating a properly tailored no-break capability as an integral part of C-E equipment design.

Air Force must decide how much time and money should be spent at specific locations to measure and characterize power disturbances, and whether UPS justification should primarily depend upon the user's justification of his requirement for uninterrupted service, or upon how bad the power is, or both. If justification is to depend upon detailed measurement, funds for adequate instrumentation and special teams with appropriate engineering expertise should be authorized, since it is not reasonable to expect that operating units possess the specialized test instruments, knowledge, or experience to obtain meaningful measurements which can quantify, in statistical terms, the quality of electric power available to the site.

Principal conclusions are:

a. Outage data from the field could not be used to describe marginal increases in system availability ascribable to UPS, since no comparable before-and-after data were obtainable.

b. Even if such data were available, UPS justification should not be based on the possibility for slight increases in power availability. UPS is not a substitute for adequate standby power, which is required in any case, but offers the opportunity for smooth transition from prime to standby without interruption.

c. Commercial power quality is already incompatible with the requirements of modern solid-state integrated circuit computers, and the gap is worsening.

d. The power conditioning capability of UPS to bridge this power quality gap is even more important than the capability to ride through complete failures until standby power is brought on-line.

e. Solid-state UPS technology has come of age, and a wealth of experience exists in industry and government (especially FAA) in the specification and justification of UPS as Power Conditioning Systems (PCS), as they are called by FAA.

It is recommended that:

a. Air Force policy for UPS justification should be based upon users' operational requirements and susceptibility to power disturbances of equipment chosen to meet those requirements, but not on detailed and lengthy measurements to prove that power disturbances exist, at a given location.

b. A long-range program be undertaken to reduce susceptibility of current and future C-E equipment to power disturbances.

c. Sample measurements be made by qualified personnel using specially designed instruments to characterize and quantify power disturbances as a basis for tightening UPS and C-E design specifications, and for controlled susceptibility testing.

d. The DCSS digital upgrade equipment for DSCS terminals be subjected to power-disturbance susceptibility tests before deployment.

e. MAJCOMs be invited to restate system availability requirements in terms of tolerable durations and frequencies of service interruptions.

f. CONUS AUTODIN power systems be reconfigured to add the Western Union computer equipment to the technical load served by UPS, permitting a significant cost saving by removing the leased W-U motor-generator sets.

g. The expensive Total Energy System (TES) at the Carswell ADWS be replaced by a more conventional commercial power/military back-up arrangement, with inclusion of UPS, if justified, in accordance with Recommendation a.

TABLE OF CONTENTS

VI. AUTOMATIC DIGITAL NETWORK (AUTODIN)

VII. DEFENSE SATELLITE COMMUNICATIONS SYSTEM (DSCS)

VIII. ALTERNATE STRATEGIES

APPENDICES
TASKING DOCUMENTS

SECTION I

OVERVIEW OF THE PROBLEM

To fulfill its mission in "Providing the Reins of Command" through the operation and maintenance of communications, TRACALS, and other electronic equipment, AFCS must be concerned with fundamental reliability and maintainability aspects of all equipment devoted to such functions. Specifications for communications electronics equipment used by AFCS rightly emphasize reliability and other factors such as training, technical manuals, maintainability and logistic support which directly impact the quality of equipment performance and service which AFCS can provide to the using commands.

The systems which furnish electric power to these same equipments enter somewhat more subtly into the reliability/maintainability arena.

While it is obviously important to consider means to avoid power failures and to provide equipment and procedures to minimize the impairment to vital C-E functions when outages occur, other types of power disturbances can also adversely affect the quality and continuity of service AFCS can provide in less obvious ways, with important implications for planning maintenance resources and estimating reliability of C-E systems. These troublesome aspects of commercial public (and even military standby) power service elicit articles in respected technical journals with titles such as "The Quality of Electric Power"[1] or "Quality of Supply"[2] which the authors use to draw a distinction from narrower, more traditional reliability criteria such as the incident rate of power failures and average duration of outages.

The principal product of AFCS is service. The Command is motivated and structured with the intent to invest that product with the highest possible quality. For this reason, AFCS and other DOD elements with similar missions and motivations must concern themselves with the quality of another service, upon which the quality of their own product depends — the quality of electric power.

It is characteristic of AFCS business that its military communications electronic services are most needed during times of emergency, natural disasters, or attack; i.e., at exactly the times when commercial power utility service is most likely to be disrupted or degraded. In the past, attention in this area has traditionally focused on the requirement for standby power-generation facilities capable of furnishing sufficient power to provide basic services during such emergencies or disasters. Generally speaking, this requirement has been well justified and is satisfied by the installation of suitable diesel-electric generators at most AFCS installations within CONUS and overseas. However, for economic reasons, these generators are operated only when necessary, and the Air Force purchases commercial power from public utility companies to serve both general utility needs and technical loads at virtually all bases at home and overseas. For this reason, AFCS must be concerned with the quality of both commercial and standby power as it affects the economics of normal peacetime operations and the provision of reliable communication services in emergency situations. For example, scenarios in which commercial power may fail throughout a wide region are of particular concern, whether resulting from sabotage or attack, or for such innocent and natural reasons as electro-mechanical failure of components or human error. (These were cited as the "triggering" causes of the massive Northeast blackouts[3, 4] of 1965 and 1967.) Under such circumstances, the transition from commercial power to standby occurs nearly simultaneously at a large number of installations within the affected region. Because of the simultaneous outages, the possibilities for alternate routing are limited, and the backup of communication traffic and the risk of lost messages is more severe. If the outages result from civil disorder, sabotage, or enemy action, they will be concurrent with periods of large-volume military communications traffic and increased rates of high-priority messages.

Despite the fact that military communications must do its job when public power systems may be in chaos, in economic studies there is always the temptation to point to the "wealth of experience" with reliable public power service, all of it during peacetime. However, even peacetime public power is not very "pure", and as communication systems and Air Traffic Control (ATC) services become more sophisticated and more dependent upon modern solid-state computer technology, the sensitivity to other power disturbances such as transients, short dropouts and "brown-outs"* increases, and becomes operationally significant.

It is surprising to many people that electrical power delivered to customers is "dirty" and <u>not</u> free from disturbances and fluctuations. This misconception arises because most household appliances which use electric power for heat, light, or small electric motors are insensitive to power outages or disturbances of a few seconds duration or less. Most of the highly visible public and commercial devices such as elevators, welders, heavy electrical machinery, traffic lights, neon signs, etc., are similarly unaffected by short disruptions. The possibility of massive long-term power failure was completely outside public consciousness until the great Northeast blackout of 9-10 November 1965. Even the recent brown-outs imposed by a number of utility companies during the national energy crisis in the coldest months of the severe 1976-1977 winter escaped widespread public notice, since the impact was more annoyance than inconvenience, as electric clocks ran a little slow and toast took a little longer to brown. However, there is now a growing awareness within the technical community that the long-range energy crisis is very real, that the large interconnected electric power grids are showing signs of stress, and that the situation is likely to worsen before it improves. Nearly two years ago, Mr.

*A brown-out is defined as a deliberate, planned voltage reduction at the generating utility of three, five, or eight percent. The voltage reduction may be accompanied by a frequency drop of a few tenths hertz.

Burkhard Schneider of the Detroit Edison Company was quoted in the IEEE Spectrum[5] as saying "Soon service will begin to deteriorate gradually — frequency and duration of outage will become greater due to the fact that distribution systems will be stretched to the limit". Consequently, it may be inappropriate and even misleading to place much weight on commercial power relability/availability data over the past decade or two as a basis even for peacetime planning or economic justification of power systems for USAF (or any DOD department) over the coming decade. Certainly, such data prior to 1965 was not predictive of the experience since. For overseas installations, commercial power availability (and "purity") data are difficult to obtain, but is a fair judgment that reliability is no better than CONUS power, and every indication in the Pacific theatre suggests it is much worse there.

Moreover, as already suggested, power reliability (i.e., "failure", or "outage", per se) is only a part of the story. Other problems include transients, impulses, surges, and sags of voltage induced by lightning strikes, by sudden load changes by other customers sharing the distribution system or by deliberate shifts of load or generating capacity by power utilities. Normal power switching by local utilities can account for several hundred short interruptions per year with durations ranging from a few cycles to several seconds. Natural phenomena such as lightning, or brief shorting of high voltage transmission lines by birds or small animals or during periods of heavy icing or high winds can also result in power surges or sags of about the same duration, even if complete outage does not occur. This class of power line disturbance can be especially detrimental to computers and other sensitive solid-state electronic equipment. This problem is becoming a matter of rising concern in both government and industry, stemming from the increasing dependence on computers and digital equipment for on-line control of communications, air traffic services, industrial process control, and similar applications. A remarkable characteristic of this problem is that it is not well documented, and therefore, not generally appreciated nor understood. Until recently, instruments for measuring and recording very short power line disturbances have not been generally available. As a consequence, users and designers of computers and other electronic equipment which would be sensitive to power line disturbances have not addressed the problem in their specifications, or, at best, have merely required that circuit breakers or other protection be incorporated to prevent gross damage to equipment without explicitly requiring operation to continue during and following a disturbance.

This situation was noted and well summarized in a 1974 report prepared by the U.S. Department of Commerce entitled "The Effects of Electric Power Variations Upon Computers: An Overview"[6]. This report quotes typical figures (from the very few sources which document such measurements) for the types of transients that have been measured and notes that the effect of such disturbances can only be exacerbated by brown-outs. Typically, computer power specifications cite tolerable variations of plus or minus 10 percent from the nominal 120/208 volt service. Many IBM computers require plus 10 percent, minus eight percent. Thus, during brown-out periods, even very small transients or sags in the supply voltage would exercise built-in voltage regulation devices beyond their design capability.

These facts are being learned and experience accumulated slowly and separately in a number of government and commercial organizations which are dependent upon uninterrupted on-line computer operations to perform their missions and functions. The FAA, for example, has accumulated nearly ten years of experience in the use of solid-state uninterruptible power systems, installed at Air Route Traffic Control Centers. Significantly, FAA chooses to call such systems PCS (for Power Conditioning Systems) to emphasize that the "laundering" of "dirty" power is as important as the avoidance of outages. The diversity of non-government users of similar equipment includes the New York Stock Exchange, air lines, petroleum refineries, chemical plants, textile mills, etc. In companies dependent upon computers for industrial process control, the cost of outages can be expressed in hard dollars in lost business, wastage or spoilage, restart costs, and sometimes in direct damage to equipment. The duration of computer outages and the disruption of the processes which they control typically exceeds (sometimes by hours or even days) the duration of the power failure itself, and computer down-time is often incurred as a result of power disturbances which would not be classed (by public utilities) as outages at all.

In military applications, the direct cost-assignment approach is inappropriate since the Department of Defense is not in business to earn a profit. Disruptions of service and degradation of readiness in emergencies are more pertinent criteria, but unfortunately are not readily comparable to the cost of equipment required to obtain improvements. For example, it is virtually impossible to place a sensible "cost" value on the time required to resynchronize cryptographic equipment following disruption.

As a result, the justification for expenditure of funds to provide reliable and clean power must be a carefully considered mix of direct, hard costs and military operational requirements. It is the intention of this study to present a rounded picture of the various aspects of this problem to help answer the question, "How much money should be spent, and according to what criteria?"

SECTION II

INTRODUCTION/APPROACH

A. BACKGROUND OF THE STUDY.

The origin of current power enhancement efforts recently focused on the program for procurement of a standard familiy of UPS can be traced back to the massive Northeast power failure of 9-10 November 1965. This spawned a study[7,8] which determined that although the power failure resulted in immediate outage of only a small percentage of the total Defense Communication System circuits, the number of affected teletype, AUTODIN, and AUTOVON circuits in the Northeast area was substantial. A significant factor affecting the DCS was the lack of sufficient provisions for auxiliary power at key nodal points operated by Western Union. This lack of back-up power resulted in serious degradation of essential DCS circuitry within the blackout area and overseas circuits in the Atlantic area. The Supplemental Report[8] contained the DOD recommendation that "continuing budget support be provided for achieving and maintaining effective electrical power improvement programs to support DOD communications".

At the same time (almost exactly ten years ago), the Operations Analysis Office of AFCS published Part I of a two-part report[9,10] on AFCS fixed ground power in support of C-E equipment. Among its major conclusions were:

> "The present lack of standardized and high quality power systems in support of communications electronics equipments and facilities has adversely affected the reliable operation of these technical facilities. Power outages and disruptions continue to be one of the major causes of loss in operational effectiveness",
>
> and
>
> "Power systems supporting existing communications-electronics equipment must, due to the critical power requirements and associated power transient susceptibility of this equipment, be of high reliability and of high quality performance."

Among the key recommendations were:

> "As a joint coordinated effort between AFCS, HQ USAF, and DCA, develop realistic operational effectiveness and reliability criteria for power systems and integrated power/electronics communications systems."
>
> "Establish a command position on the design and utilization of

> no-break power systems with increased emphasis on solid-state static floating battery UPS units."
>
> "Establish a program with AFCS to fully analyze the critical input power requirements of digital switching and communications equipment (systems), and to develop new design criteria which will minimize the extreme susceptibility of this equipment to primary power input discontinuities."

A power improvement program was initiated through a DCA/Tri-Service Working Group. This led to the publication, in March 1969, of a Joint DCA Military Department Worldwide Electric Power Improvement Plan, 1971-1975[11], which incorporated existing validated requirements and additional requirements including DSCS Phase II support. The total package included R&D, procurement and contractual funding of approximately $10 million a year for five consecutive years. However, this plan was rejected by DDR&E based on the fact that the system operational availability figures did not justify the cost. Nevertheless, some of the projects were completed through separate O&M actions. One of the products of the working group was MIL-HDBK-411[12] which contained technical guidance for design of power systems in support of the DCS.

An objective of the Working Group was to develop a set of specifications for solid state UPS that would satisfy all current and future DCS power requirements and be satisfactory to all military departments. However, when common agreement could not be reached, DCA asked the Air Force in 1972 to undertake the development of specifications. As a result, AFLC and AFCS were tasked with the development of specifications[13], the programming,[14] procuring, issuing and support of the UPS equipment. This led to the initiation of procurement action, proposal evaluation by Tri-Service/DCA Team, and subsequent selection of a contractor. Following this was a series of contract negotiations. During this period, the Office of Director Telecommunications and Command and Control Systems, Secretary of Defense (DTACCS) requested that AFLC coordinate their program as if it were a DOD standardized program. Also, DTACCS Plans and Ops requested DCA identify a standard family of UPS for all DCS requirements. This was in consonance with their Policy and Operations Objectives Plan for 1976 which included a task to "insure that a standard family of auxiliary power sources and uninterruptible power sources (UPS) are derived for the DCS" and to "determine where UPS are required and where auxiliary power sources can be used in place of the more expensive UPS."[15] DCA responded to the DTACCS request by identifying the Air Force to lead the UPS program.

The UPS contract negotiation period expired before the contract award was approved. In addition, the first procurement of 4.6 million dollars for five UPS to be installed at CONUS AUTODIN sites was suspended based on the lack of adequate justification.[16] Following this, a re-examination of cost-benefit factors began to determine and validate the Air Force requirements for UPS. However, based on requirements of other agencies, efforts to procure a standard family of solid-state UPS were reinstituted with the Air Force, through AFLC, providing contractual coverage and integrated material management support.[17]

B. TASKING.

As a result of the Air Force's desire to re-examine the requirements for UPS, a meeting was held on 20 August 1976 between representatives of AF/KRCX and AFCS to discuss a study to address the basic factors pertinent to potential Air Force needs for UPS. After a general outline for the study was developed and agreed upon, AFCS received a formal task to undertake the study, reference Air Force letter dated 3 November 1976, subject: "Uninterruptible Power Supplies".[18]

C. OBJECTIVES.

The principal objectives of this report are:

1. To identify and describe the problem of power disturbances and outages.

2. To cite sources of experience in documenting and dealing with this problem, and incorporate data drawn from these sources.

3. To examine, in particular, the Japan Tropo System (JTS), the Automatic Digital Weather Switches (ADWS), the Automatic Digital Network (AUTODIN), and the Defense Satellite Communication System (DSCS) as examples of specific systems potentially sensitive to poor quality power.

4. To estimate the impact of power outages and disturbances on the system availability for each of the four systems.

5. To indicate qualitatively the general economic considerations and, in a few cases, present quantitative data.

D. SCOPE.

The impact of power availability on the JTS, ADWS, AUTODIN, and DSCS was examined. In addition, data are incorporated from other sources describing susceptibility to power disruptions of several types of equipment which are integral parts of most C-E systems. Of particular significance are computers, since they are an essential element in two of the systems considered. Cost factors are considered for different possible power configurations which may be employed. Specific recommendations for reconfiguration to achieve cost savings are advanced for CONUS AUTODIN sites and the Carswell ADWS.

E. DATA SOURCES.

Several diverse data sources were used in the preparation of this report, including articles from open technical literature, various one-time and recurring reports and original data. Open literature sources included articles from a wide variety of trade magazines and technical journals, manufacturer's pamphlets and manuals. One-time reports included both military and other Federal Agency reports. Message reports included COMSPOTS, MIREPS and CSV DO(D)7109s; information was also derived from computer printouts as well as from DCAC 310-55-1 and Army SATCOM reports. Original data sources included extracts of power and generator logs as well as station logs. Some strip chart power recordings were also analyzed. There was also a variety of information collected from field unit message responses to queries from this headquarters. Valuable information was also extracted from Air Force Manuals and Regulations, Military Handbooks, DCA Circulars, Military and Federal Specifications, a wide range of military correspondence, other letters and memoranda, miscellaneous messages, and telephone interviews.

F. APPROACH AND REPORT STRUCTURE.

The first efforts in preparing this report were in data collection. Requests were made to the various internal staff elements and to the field for data on system outages and power-related system problems in general. Also, efforts were directed toward drawing on existing experience by gathering pertinent reports found in open literature and through personal telephone interviews. The intention was to pursue a study of system availability improvement and cost analysis with regard to possible SSUPS applications. As the requested information began to flow in and more literature research was accomplished, a different emphasis in the development of the report evolved; though it was clear that small increases in 99.+% availability could be achieved with UPS, it was also evident that its primary benefit lay not in marginal increases in availability but in the benefits derived from the power conditioning effect during the 99.+% of the time prime power is available. As a consequence, the report was reorganized to its present structure. Section I presents a general overview of the problem of power, placing into perspective the overall state of commercial power, the considerations of power failures and power impurities and the difficulties of assigning a dollar value to service disruptions in a military context. Section II contains a brief historical sketch of events related to UPS acquisition leading up to this report and the ingredients used in its development. In Section III, the technical aspects of commercial power reliability and other power characteristics are considered in greater detail. In conjunction, the characterization of the susceptibility of computers and other equipment to power disturbances is examined. The next four sections specifically address each of the four systems of particular interest; namely, the Japan Tropo System, the Automated Digital Weather Switches, Automated Digital Network, and the Defense Satellite Communications System. In each of these, system availability and power-related outages are examined. Where available, cost information is included. Section VIII presents alternate strategies for addressing the problem before it becomes unmanageable. The section includes discussion of opportunities for equipment design to reduce the susceptibility of equipment to power disturbances, and the need for testing equipment and systems to ensure desired performance is maintained under conditions of dirty power. Section IX contains conclusions and recommendations. Attention is directed to the Appendices for detailed summaries of data for the four systems. Appendix E presents cost comparisons for several power system configurations, with and without UPS. Also, Appendix F, a comprehensive reference and bibliography, is included for those having a desire for additional information.

SECTION III

TECHNICAL CONSIDERATIONS

A. RELIABILITY OF COMMERCIAL ELECTRICAL POWER.

Quantitative documentation of public utility power reliability in the United States is surprisingly scarce in the open literature, with a few notable exceptions. The dramatic Northeast blackout of November 9 and 10, 1965, of course, received much attention both in the general press and in technical journals[3] and has been analyzed and reported at length. However, power outages of the same general character (though less widespread and generally for shorter periods) had occurred prior to the 1965 Northeast blackout, and several have occurred since.[4] One of the most recent occurred on July 4, 1976, when about a million people in most of the state of Utah and Southwestern Wyoming were without power for 1½ to six hours. Outside these two states, the incident escaped wide public notice since news coverage of the event was generally eclipsed by the news of the Bicentennial celebration.

A wide area outage of a similar nature occurred in the Pennsylvania/New Jersey/Maryland (PJM) power pool in 1967. Both the 1965 Northeast outage and the PJM 1967 outage were the subject of special investigations and reports by the Manager of the National Communications System[8, 19] on the significant effects of these outages on critical communications and other vital governmental functions and the potential impact of similar outages in the future. The Federal Power Commission also produced a three-volume report.[20]

A small amount of data on less universal outages is available from three surveys conducted by the IEEE. The first of these was in 1959 and the most recent in 1974. The general technique for these surveys was the same in each case. Large industrial power users were asked to respond in a questionnaire indicating the number of occurrences, length of outages, primary causes of outages (when known), and other information. These data were summarized, tabulated, and presented in IEEE publications. The results of these surveys are indicated in Table III-1. The 1959 survey[21] of 54 USA and Canadian industrial plants shows that over an average four year reporting period outages of commercial power occurred at the rate of nearly one per plant per year, with an overall average of two hours downtime per failure. Data from one Latin American petroleum refinery indicated 5½ outages per year, while two Far Eastern petroleum refineries reported an average of six outages per plant per year.

A similar survey was conducted by the Reliability Working Group, of the IEEE, Industrial and Commercial Power Systems Committee during the latter half of 1971 and early 1972[22]. Responses were received from 68 industrial plants in 30 different companies in nine industries. This survey reported only 0.643 failures per plant per year with an overall average downtime of 1-1/3 hours per failure. However, certain data in this survey were subject to possible error due to misinterpretation of the survey form.

In 1974, another survey was conducted in which 87 plants provided usable data.[23] The 1974 survey indicated an average of almost two failures of electric utility services per year per plant for single-circuit (non-redundant) service, but confirmed the average outage period of 1-1/3 hours. As might be expected, outages were significantly more frequent and of longer duration for utility supply circuits operated at distribution voltages (less than 15 kv) than for circuits operated at transmission voltages. Many AFCS communications and TRACALS installations in CONUS and overseas operate from single-circuit service at feeder voltages less than 15 kv. For this class of service, the 1974 survey indicates an average of more than 3.6 interruptions per year, with an average outage time of more than two hours. The latter survey is believed to be more accurate, and since it has a larger data base and is more up to date, the values presented in that survey are to be preferred over those derived from the 1972 survey.

Another source of commercial power service reliability data within the Air Force is a study performed by the Ralph M. Parsons Company[24] in January 1974 for Strategic Air Command. It is an extensive analysis of a typical REA power cooperative which furnishes commercial power to SAC Missile Launch Facilities at Grand Forks, North Dakota. In Section 8 of that study, extensive data are presented on the outages experienced by the SAC Missile Launch Facilities. The frequency of failures generally confirms the frequency reported in the IEEE surveys. As shown in Figure III-1, reproduced from the Parsons study, some launch facilities experienced as many as 45 outages during the seven-year reporting period, and 50 percent of the sites experienced ten or more outages during the same period; i.e., the median was about 1½ outages per site per year, with the average somewhat higher.

The similarity of the data reported in the Parsons study from the rural Grand Forks area to that reported by heavy industrial users is surprising, since the causes for outages are probably quite different. Distribution in rural areas is characterized by very long lines with line exposures as distant as 60 miles or more from the nearest circuit breakers. Most line outages are caused by meteorological influences. In the Great Plains states, lightning strikes are a frequent cause of short interruptions and transients. Thunderstorms are prevalent during the summer months of May through September in the Dakotas, and line outages are common during this period. Breakers and reclosers may operate many times with short duration outages causing power interruptions at the Minuteman sites. In winter, sleet storms cause line damage, resulting in serious interruptions. Storms may continue for many hours and, in such cases, repair crews cannot be dispatched until the storm subsides. Other significant causes include vandalism, shorting by birds or small animals, and falling trees.

TABLE III-1

COMMERCIAL POWER RELIABILITY

RESULTS OF IEEE SURVEYS

SURVEY	NUMBER OF PLANTS REPRESENTED	SAMPLE SIZE, PLANT-YEARS	FAILURE RATE, INCIDENTS PER PLANT PER YEAR	AVERAGE DOWNTIME PER FAILURE, HOURS
1959, US & CANADIAN INDUSTRIES	54	209	0.8373	2
1972, US & CANADIAN INDUSTRIES	68	314.4	0.643	1.33
1974, FOLLOW-UP OF 1972 SURVEY	87	*111.45	1.956	1.32
		**352.00	0.538	0.37
		***27.62	3.621	2.08

* Single Circuit Utility Supplies

** Multiple Circuit Utility Supplies

*** Single Circuit Service at 15KV or less

By contrast, in heavy industrial areas, automobile and airplane accidents and mishaps associated with industry and large construction projects are more frequent causes of power disruptions. Switching surges and undervoltages are correlated with heavy loading and with the greater fluctuation of load which is characteristic of industrial users. A recent radio news report from the Detroit region blamed industrial air pollution; i.e., the deposit of particulate carbons and other conductive material onto high-voltage insulators, as a cause of power failure. While outages apparently occur as often in industrial, heavily populated areas, times to repair and restore services are generally shorter than in rural regions. The exception to this rule is the massive "domino" type of failure, such as the November 1965 Northeast blackout, in which one generating facility after another fell under the load before appropriate disconnections could be activated to save the system, and restoration was a slow and piece-meal process. Other examples of massive, large area outages are presented in Table III-2 below. The pattern of these outages is very similar: a local fault or overload condition caused a generating facility to be taken off-line, and power demands over interconnected grids caused cascading failures before the interconnections could be severed.

TABLE III-2

EXAMPLES OF LARGE AREA, EXTENDED POWER OUTAGES

Date	Area	Time to Restore	Remarks
6 Jun 50	Pacific Northwest (Washington, Oregon, Utah, Montana, British Columbia)	1¼ hours	Damage to motors and other equipment due to low frequency. Industrial losses in aluminum plants and paper mills.
28 Jun 65	Midwest (South Dakota) Iowa, Nebraska, Minnesota, Illinois)	2½ hours	2 million people affected
11 Apr 65	Midwest (South Dakota, Illinois, Missouri, Iowa)	1 hours	Tornado damage
9-10 Nov 65	Northeast (New York Connecticut, Rhode Island, Vermont, New Hampshire, Ontario)	13¼ hours	Worst blackout in US history

2 Dec 65	Southwest (Texas, New Mexico, Mexico)	Up to 2 hours	1 million people affected
11 May 67	Southeast Texas	Up to 7 hours	163,000 customers affected
5 Jun 67	Mideastern Seaboard (New Hersey, Maryland, Delaware, Pennsylvania)	Up to 10 hours	Outage spread within five minutes.
4 Jul 76	Salt Lake Region (Utah, Wyoming)	6 hours	1 million people affected

Following the catastrophic Northeast power failure in November 1965, the Federal Power Commission issued FPC Order #331, dated 20 December 1966, which required all entities engaged in the generation and transmission of electric power to report to the FPC significant interruptions* of bulk power supply. Information from such reports describing 52 failures during the period from 1 January 1967 through 12 June 1967 is included in Reference 20. In addition, limited descriptions are given of 148 power interruptions which were sufficiently important to gain publicity over the period 1954 through 1966. (Presumably, the data were gleaned from newspaper reports.) These data, i.e., 200 power interruptions from 1954 to mid-1967, are summarized and categorized according to cause in Table III-3. By far, the most frequent source of trouble is bad weather, either directly in the form of storms, icing, lightning, etc., or indirectly in flooding or landslides. Equipment failures are the next most frequent cause for failure. Outages due to operating errors, overloads, and intentional curtailment of service are suggestive of stress on public utilities, and the incidence of failures ascribable to sabotage and vandalism is a reminder of the extreme physical vulnerability of public power generation and distribution systems. Also, it must be remembered that the interruptions in Table III-3 are only those considered "significant" by the FPC and do not include "momentary" discontinuties or local outages to small groups of customers caused by failure in small substations, feeder lines, pole transformers, etc. Of the 52 failures reported in the first half of 1967, the average of 51 reported outage durations** was 2 hours 10 minutes — very close to the two hour average reported in the 1959 IEEE survey.

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*A significant interruption was defined as one involving transmission facilities of 69 kilovolts or more and which causes load interruptions of 25,000 kilowatts or more for a period in excess of 15 minutes. In 1970, this definition was modified to exclude load interruptions less than 100,000 kilowatts.

**Reference 20, Vol I, pp 28-29.

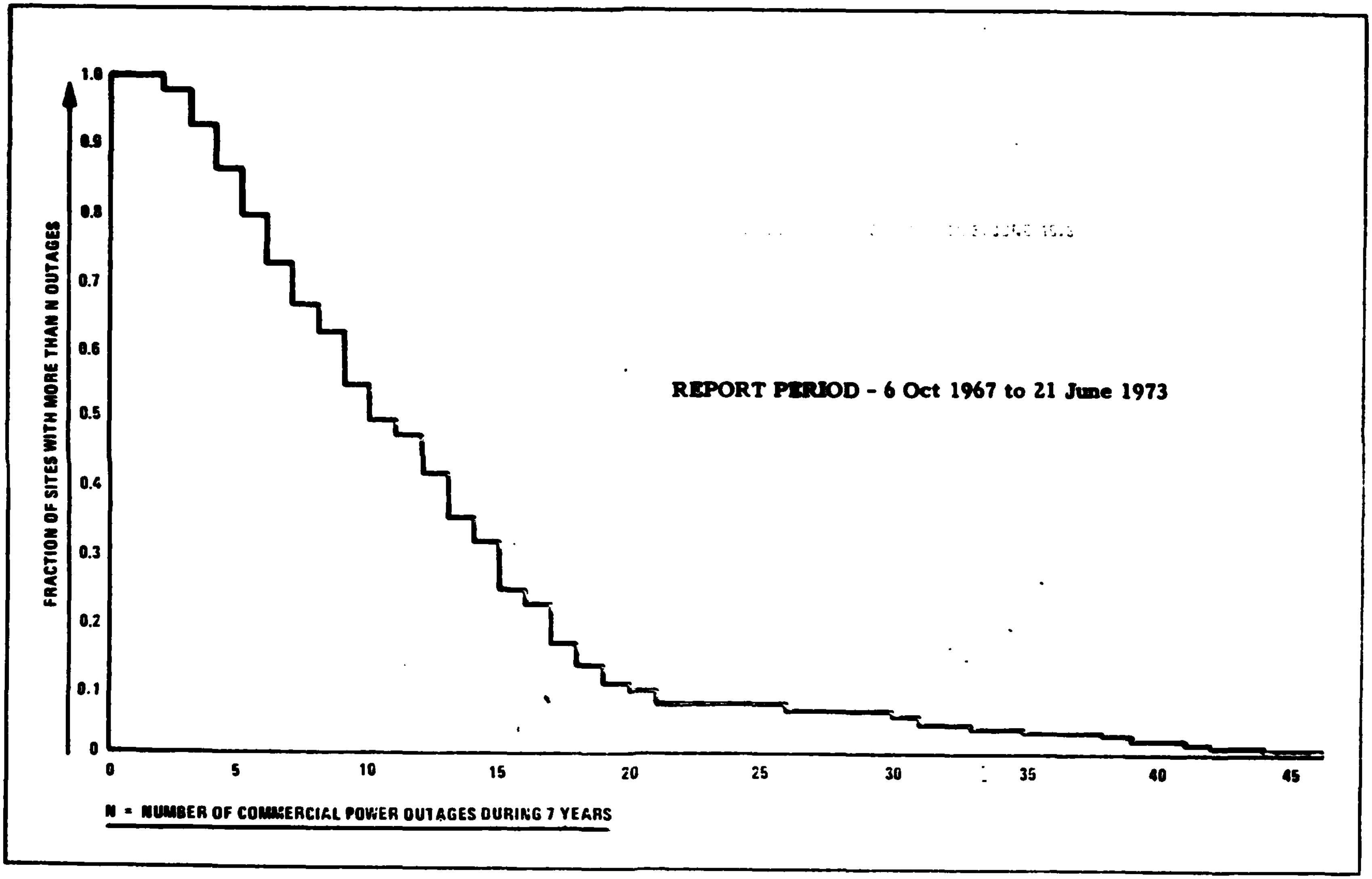


FIGURE III-1 - FREQUENCY OF REPORTED COMMERCIAL POWER OUTAGES AT WING VI

TABLE III-3

CAUSES OF SIGNIFICANT POWER INTERRUPTIONS 1954 - 1967*

CAUSE OF FAILURE OR OUTAGE	NUMBER OF OCCURRENCES
Weather:	
Snow, Ice, Sleet	19
Tornadoes, Hurricanes, Wind	40
Storms, Lightning	14
Flooding, Mudslides, Earthquakes	13
Electrical Equipment Failures	71
Operating Errors, Human Mistakes	10
Overloads & Deliberate Curtailments	6
Sabotage, Vandalism, Pranks	5
Fires	5
Birds, Small Animals	4
Airplane & Vehicle Accidents	3
Other Known Causes	6
Unknown Causes	4
TOTAL	200

* Reference 20, Vol. I, Appendix E.

B. OTHER ASPECTS OF ELECTRICAL POWER.

The data presented in the preceding section deals only with complete power outages, i.e., failures of power which cause shutdown of virtually every piece of equipment or appliance dependent upon electrical power. While the frequency of occurrence of such incidents is one quantitative indicator of the general reliability of the commercial power supply, power availability as reflected in these data is by no means the only measure of commercial power quality nor is it even necessarily indicative of many other important aspects of commercial power service from the customers' standpoint.

Other voltage and frequency defects which deteriorate the quality of electrical power service fall into three general categories.[1] The first of these includes transient under and overvoltages superimposed upon the sinusoidal wave form of normal voltage and frequency. These arise principally from switching surges, lightning strikes, or transients injected by users' equipment or as a result of sudden load switching or power-factor correction by users. They may appear as "spikes", or exhibit a damped-oscillatory characteristic. The second category includes short-term aberrations in voltage and/or frequency which may last for periods of a fraction of a cycle up to several seconds. These may arise from fault-sensing and reclosing of circuit breakers and other protective devices in the power distribution system. These first two categories correspond roughly to the divisions identified in a recent HQ USAF/KRAD letter[25] as "transients" (less than one cycle duration) and "sags and surges" (0.0167 sec to 10 sec duration), respectively. The third category encompasses slowly varying phenomena such as steady state undervoltage or overvoltage and/or frequency variation (outside tolerance limits) from the nominal voltage or frequency level contracted to be supplied by the electric utility company. This category would include, for example, the combined effect of voltage drop in feeder circuits and deliberate brown-outs imposed by public utilities to reduce the demand load in order to conserve fuel or to avoid energizing load-shedding relays under anticipated conditions of heavy demand.

Several sources assert that normal power net switching by local utilities can account for several hundred short outages per year.[24, 26, 27] Duration of these interruptions can range from several cycles to a few seconds. Outages of the same character and duration can be induced during bad weather periods such as high winds, heavy icing, or other circumstances leading to brief shorting of transmission lines causing circuit breakers to open to react to the fault and reclose after the fault is cleared. Several instances of this type of outage were observed during a day of high winds, gusting to more than 40 knots, at Richards-Gebaur AFB on 23 February 1977, as this section of the report was being drafted. These interruptions varied from a few hundred milliseconds (just enough to notice flickering of fluorescent lights) to one which lasted about ten seconds.

Quantitative documentation of the characteristics and frequency of incidence of this type of momentary outage is virtually non-existent and generally unobtainable from utility companies. Mirowsky[28] quotes a leading utility systems representative (not identified) who indicates that within the current state of technology, at any given utility user's location, it is quite probable that there will be voltage disturbances in the feed power with duration from about 30 milliseconds to one minute, having a magnitude up to 100% of the nominal voltage, and with a frequency of occurrence more likely to be several times a day rather than several times a year. At a recent UPS Seminar at the University of Wisconsin, Mr. W. P. Rades of the Wisconsin Electric Power Company stated that power interruptions of five minutes or less are considered "momentary" interruptions rather than outages by his company, and that no records are kept of such short-duration power breaks. The disinclination on the part of public power suppliers to furnish data descriptive of short interruptions is understandable, since a considerable economic investment in instrumentation would be required, plus manpower to assemble and interpret the data; and, in the end, the basic causes of power faults (weather, switching, sudden changes in user loads, etc.) are such that there is probably little that a public utility can do to improve the situation. Nevertheless, this type of information is of considerable value to users in installations which must plan and justify methods to insure uninterrupted, "clean" power to critical loads. An interesting (but not widely publicized) fact is that public power utilities themselves are installing UPS[29] in order to maintain continuity of computer control, especially during emergencies which stress the power generation capability and which could result in the power company being unable to power its own monitoring and control equipment.

Such data as are available have been collected mostly by users faced with the problem. One table of test data, presented by two suppliers of UPS equipment,[30, 31] shows averages ranging from 4 to 12 power line fluctuations per day recorded at a mixture of computer installations including a bank, an insurance company, a research organization, a government agency, a manufacturer, and an auto leasing firm. "Fluctuation" was defined as a voltage variation higher than 10% or lower than -8% of the nominal 208 voltage supply, lasting from 2 to 100 milliseconds.

A report of similar recordings at the Naval Supply Center in Charlottesville, South Carolina,[32] showed a considerably lower frequency of occurrences, as presented in Table III-4. In this table, the nominal supply voltage was 120 volts. An overvoltage incident was defined as exceeding 130 volts and an undervoltage as less than 110 volts, with the disruption enduring more than one cycle. Recorded occurrences of transient disturbances greater than +40 volts (high transient) or -40 volts (low transient) having durations from ½ to 200 microseconds are also presented.

TABLE III-4

RECORDED VOLTAGE FLUCTUATIONS BY TYPE AND MONTH

	FREQ ERROR	UNDER VOLTAGE	OVER VOLTAGE	LOW TRANSIENT	HIGH TRANSIENT	TOTAL
DEC 1975	0	0	0	3	0	3
JAN 1976	0	0	0	3	5	8
FEB	0	3	0	3	6	12
MAR	0	0	0	2	6	8
APR	0	4	0	5	0	9
MAY	0	0	0	2	2	4
JUN	0	12	0	0	6	18
TOTAL	0	19	0	18	25	62

Information on transients and surges is somewhat more accessible,[33] possibly because voltage surges are of interest to the utilities themselves in specifying insulators, surge suppressors, and lightning arrestors for high voltage transmission lines. A 1961 committee report by the AIEE Transmission and Distribution Committee[34] indicates that the peak value of transients resulting from switching surges can reach values typically 2½ to 3 times the nominal phase-to-neutral crest voltage. Characteristically, such transients are oscillatory, with a duration which normally does not exceed a few hundred microseconds. In 1970, another report on the same subject by the same committee[35] confirmed the findings of the earlier report by stating that the majority of peak values of switching surges was less than 2.5 times the normal line voltage; but under some circumstances, peaks as high as five times the nominal voltage are possible. Transients associated with deenergizing a line are typically more severe than those which occur when energizing.

Martzloff and Hahn[36] reported measurements of surge voltages in residential and industrial locations collected over a two year period in the late 1960's. The reporting technique involved film exposures of a modified Tektronix oscilloscope activated by a threshold circuit set to be sensitive to high-level, short duration transients. Another technique employed a specially built surge counter package which was simpler and more easily employed to count the number of occurrences of high voltage surges, without attempting to measure the peak voltage accurately. The results of these measurements showed that peak voltages up to 1500 volts on nominal 60 cycle, 120 volt residential power service were not uncommon, and that such peaks were often associated with sudden changes in load current from appliances or other residential electrical equipment (e.g., oil burner, fluorescent lamp, pump motor, etc). The same article reports one instance of a transient surge of 5600 volts appearing on 120 volt residential service, concurrent with a lightning stroke in the general area. Several other instances of lightning strikes were correlated with surge peaks well above 1000 volts on normal 120 volt power service.

In 1971, the Navy performed a special evaluation at NAVRADSTA(T), Isabela and Aguada, Puerto Rico, to characterize the transients on the power distribution system which could be induced by lightning.[37] The recorded disturbances were categorized into three major types: oscillatory transients, spike voltages and voltage dips as shown in Tables III-5 and III-6. The first type, oscillatory transients, were by far the most common disturbances. They are characterized by an exponentially damped oscillation which usually lasts less than one quarter cycle of the power frequency. The frequency of the oscillations, however, was higher than expected, ranging from 1 kHz to 10 kHz. The transients were usually predominant on one phase of the three-phase system with smaller traces showing up on the other two phases.

The values presented in Tables III-5 and III-6 respresent the most predominant transients regardless of which phase they occurred on. The voltage dips and outages were usually preceded by an oscillatory transient. At NRS(T), Isabela, 26 of the 27 recorded voltage dips were preceded by an oscillatory transient. The voltage dips also occurred on all three phases at once, with varying degrees. There did not seem to be a preferred phase; however, the particular phase which demonstrated the largest transient usually demonstrated the severest dip also. At NRS(T) Aguada, the total number of disturbances was considerably less (56 as compared to 182). However, the data is very similar and proportionally the same.

TABLE III-5

Summation of Monitoring Data from NRS(T), Isabela
23 August - 9 September 1971

DESCRIPTION	NUMBER
Lightning Storms Experienced	11
Lightning Related Disturbances	182
Non-Lightning Related Disturbances	2
Observed Lightning Events	107
Oscillatory Transients	150
Average Value of Voltage Peaks	54.8V
Average Duration of Oscillation	2.9 ms
Average Frequency of Oscillation	4678 Hz
Spike Voltages	31
Average Level of Positive Peaks	51.8V
Average Level of Negative Peaks	154V
Average Pulse Width at Base	.27 ms
Voltage Dips	27
Average Voltage Dip, Phase A	89V
Average Voltage Dip, Phase B	85.3V
Average Voltage Dip, Phase C	81.9V
Average Duration of Cycles of 60 Hz	57 cycles
Number of Complete Outages	4

TABLE III-6

Summation of Monitoring Data from NRS(T), Aguada
18 September - 26 September 1971

DESCRIPTION	NUMBER
Lightning Storms Experienced	8
Lightning Related Disturbance	56
Non-Lightning Related Disturbances	2
Observed Lightning Events	156
Oscillatory Transients	44
Average Value of Voltage Peaks	43V
Average Duration of Oscillation	2.14 ms
Average Frequency of Oscillation	4470 Hz
Spike Voltages	5
Average Level of Positive Voltage Peaks	33V
Average Level of Negative Voltage Peaks	25V
Average Pulse Width at Base	.3 ms
Voltage Dips	9
Average Voltage Dip, Phase A	96.3V
Average Voltage Dip, Phase B	102V
Average Voltage Dip, Phase C	107V
Average Duration in Cycles of 60 Hz	16.1
Number of Complete Outages, All Phases	0

The spike voltages seemed to have a much higher peak than the oscillatory transients, but were fewer in number and were seldom accompanied by voltage dips. Both positive and negative spikes were recorded; however, the limitations of the recording equipment prevented a thorough analysis of this type of disturbance. Some were so fast that the recording equipment could not respond quickly enough to prevent some distortion. Table III-7 presents results of similar tests at Griffiss AFB in June and July 1971,[36] and confirms the pattern of voltage dips associated with lightning disturbances.

Early in 1974, Allen and Segall[39] reported measurements of power line disturbances also using specially constructed instrumentation. Several monitoring locations were used in two phases of data collection. The first phase data base consisted of about 38 monitor-months collected over a 16-month period. Results indicated an incident rate of power line disturbances higher than the authors had expected. Undervoltages (below 90% of nominal level) averaged 5.66 per month per monitoring site and oscillatory transients occurred at an average rate of 42.2 per month per site. A second phase of recording from mid-1970 to mid-1972 accumulated a data sample of 109 monitor-months. In this phase, an attempt was made to sample a representative cross-section of climatic and geographical regions of the US, as well as a representative cross-section of major types of utility loads and utility transmission and distribution networks. The results showed high number of power line disturbances: a total of 6244 disturbances of all classes, or an average of more than 60 per month per monitoring location. Oscillatory switching disturbances (2831), spikes larger than 25% of nominal peak voltages (1676), and short-duration undervoltages (1569) were the most common. Sixty-five (65) complete outages are also included in the grand total. A large number of the undervoltage situations (666) were identified as a line drop to the region between 80% and 90% nominal line voltage for a duration of only one cycle or less. However, there was also a significant number (465) of instances of the same level of voltage drop which persisted for more than 900 cycles (15 seconds). Overvoltages (103) larger than 110% of nominal also were almost completely contained in two duration classes: one cycle or less (34), or persisting for more than 15 seconds (66).

The authors also summarized the statistics of duration of complete outages (zero voltage on all three line phases) in the second stage of their investigation (65 outages from 29 locations). The cumulative distribution of outages is shown in Figure III-2. Nearly 30 percent were shorter than .01 minutes (36 cycles) with the median outage time about six seconds, and the average about 11 minutes, owing to a couple of long outages of an hour or more. Of particular interest for specification of power buffering equipment is the observation that 90% of the outages could have been handled by a 20 minute UPS without resorting to additional backup generators.

In a later paper,[40] the same authors showed that the rate of occurrence of power line disturbances is related to the type of distribution system, with the highest rates associated with single feeder, overhead systems, as might be expected.

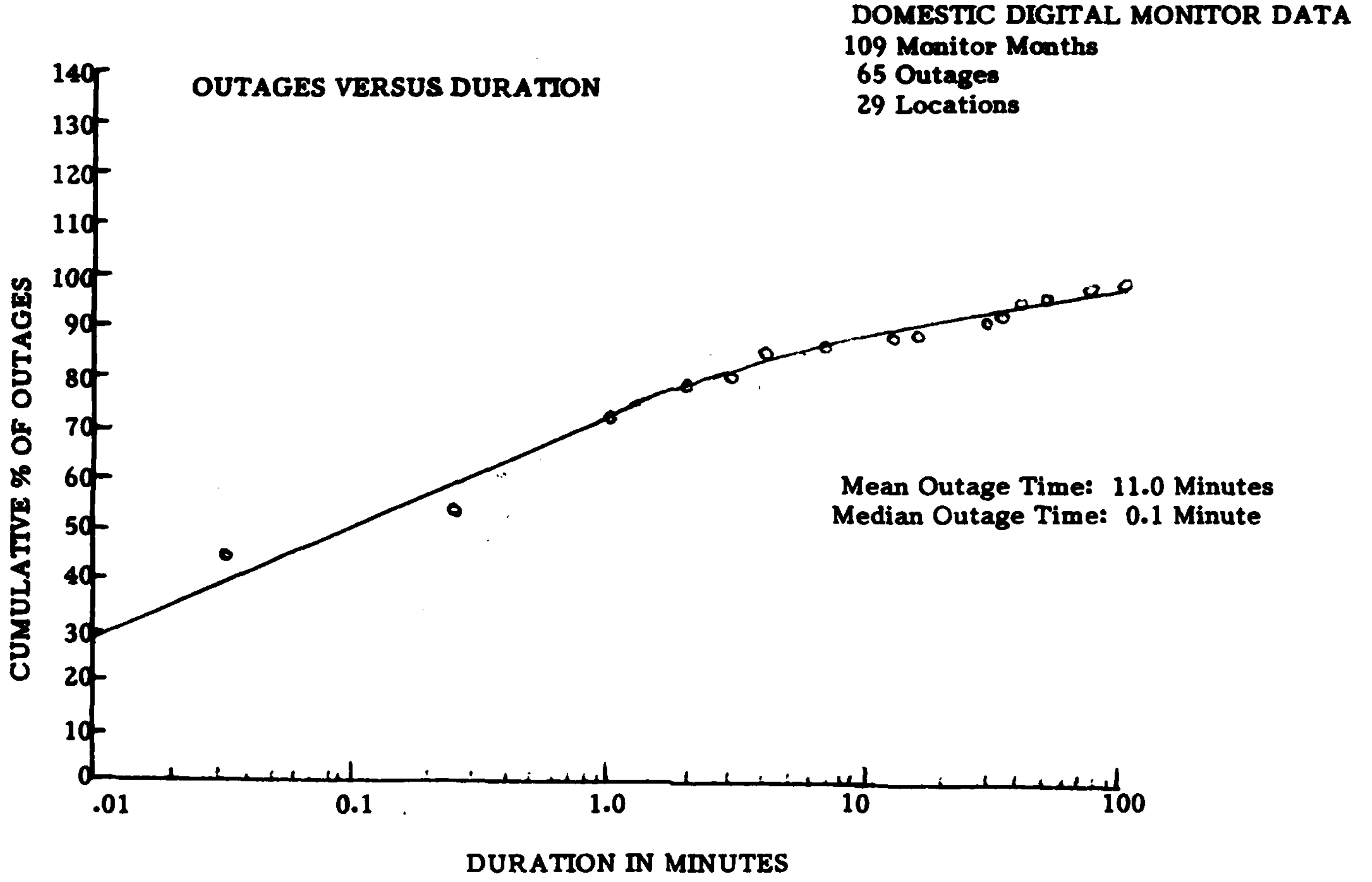


FIGURE III-2. CUMULATIVE PERCENT OF OUTAGES VERSUS DURATION IN MINUTES

TABLE III-7

Lightning-Caused Voltage Disturbances

	Three-Phase Line-to-Neutral Voltage at Maximum Dip (RMS Volts)			
Time (Day:Hour:Min:Sec)	Phase A	Phase B	Phase C	Duration of Voltage Dip (Cycles)
176:15:41:28	0	0	0	150
176:15:44:33	46	46	46	25
182:11:13:02	94	105	92	10
182:11:26:03	100	103	83	12
184:12:30:50	75	74	82	4
184:12:39:12	105	63	97	5
193:15:37:17	105	95	110	4
195:92:37:15	102	99	98	6
195:17:58:13	100	75	68	8
205:01:42:15	110	90	105	5
205:02:33:50	90	90	86	4
205:13:35:08	72	102	63	8
205:13:48:22	0	0	0	116

C. IMPACT OF POWER LINE DISTURBANCES ON COMPUTER OPERATIONS.

Much material has been published both in open technical literature and in publications of the Department of Defense and other government agencies on the effects of electric power variations on computers.[42-54, 28, 55-59, 6]. However, most articles in the open literature present very little solid data to relate specific effects to measured power disturbances. This fact is symptomatic of an important characteristic of the problem: cause-and-effect relationships are extremely difficult to pinpoint, and require a sizeable investment by the user in instrumentation, time and patience to develop, summarize, and interpret such data. Also, most power-line disturbances (other than complete outages) are by nature very rapid, transitory and relatively infrequent, and therefore present special problems for instrumentation. Their impact on computer operations is characterized by poor repeatability, since the specific effect of any particular type of power disturbance will depend greatly upon what peripheral equipment may have been activated, what types of input/output transfers are in progress, and what type of processing is occurring at the instant that a disturbance occurs. In some cases, there may be no evident, immediate malfunction of equipment. If the disturbance causes incorrect operation of logical circuits which results in destruction or alteration of data, the manifestation of the effects may escape notice for several minutes or even several hours.

Many of the available sources[1, 46, 50, 51, 58] which discuss this problem describe the susceptibility of computers to power disturbances by means of a two-dimensional graph (time versus magnitude) such as Figure III-3a which shows a power specification boundary between the tolerable disturbances and those which can be expected to cause trouble. Figures III-3b-3d suggest that there is probably a fuzzy "gray" area between the two regions. At one extreme, very large disturbances of very short duration (such as spikes or oscillatory transients) can destroy or alter data if such pulses are coupled through power supplies into logical circuits. Slightly longer disturbances, such as a complete loss of supply voltage for about 15 milliseconds, or dips and surges of 20% or more for longer than 30 milliseconds may cause trouble with peripherals or input/output equipment, and may even trigger an automatic shut-down sequence. At the long-term end of the chart, the tolerance borders are determined primarily by the steady-state voltage regulation range of built-in power supplies. A typical specification is ±10%, though IBM normally specifies +10% and -8%. Table 8 in the IEEE "Orange Book"[60] lists typical computer power specifications. If the supply voltage is operating near the low boundary of this steady-state specification, sensitivity to short term transients is increased, not only because power supply regulators have less margin within which to absorb further variations, but also because a low line voltage may induce other problems such as less effective air conditioning, and/or lower speed of operation of built-in air circulation fans. Resultant hot-spots, in turn,

TABLE III-8

Summary of Recordings of Impulses from Dranetz Power-Line Disturbance Analyzers

ORGANIZATION	FAA	SAC
APPLICATION	ARTS-3 Terminal Area Air Traffic Control	Minuteman Launch Facility LF K-07
LOCATION	Detroit, Michigan	Grand Forks AFB, North Dakota
RECORDING PERIOD	22 days 28 Dec 76-18 Jan 77	40 days 9 Sep-8 Nov 76
NOMINAL POWER	120V (120/208V, 3 phase)	480V, 3 phase
NO OF INPULSES RECORDED (Total)		
ØA	188	422
ØB	503	115
ØC	261	337
HIGHEST IMPULSE (any phase, any day)	296V (1.75 times nominal AC peak)	1504V (2.22 times nominal AC peak)
ZERO-VOLTAGE Incidents (No/duration)	None	One/1 sec

WHAT ARE THE TYPICAL COMPUTER POWER TOLERANCES?

The typical tolerances specified by most computer manufacturers are as follows:

STEADY STATE VOLTAGE CONDITION: ± 10%. For IBM main frames + 10%, -8% is specified.

VOLTAGE CONTINUITY: Zero volt for no longer than 4 to 15 milliseconds.

VOLTAGE DIPS AND TRANSIENTS: Dip or surge no greater than 20% for periods no longer than 30 milliseconds.

FREQUENCY VARIATION: ± ½ Hz to ± 3 Hz with a maximum rate of change of 1½ Hz per second together with a wave distortion less than 5%.

The computer power requirements are graphically shown in Figure 3a. **Excursions outside the envelope could result in computer errors.**

WHICH POWER PROBLEMS CAUSE COMPUTER PROBLEMS?

While it is impossible to say exactly which power irregularities cause computer problems, some generalizations can be made. Figures 3b-d are graphic representations of all the possible power irregularities that could occur together with indications as to which ones should, probably will not, or possibly could cause errors in the operation of a modern high speed computer.

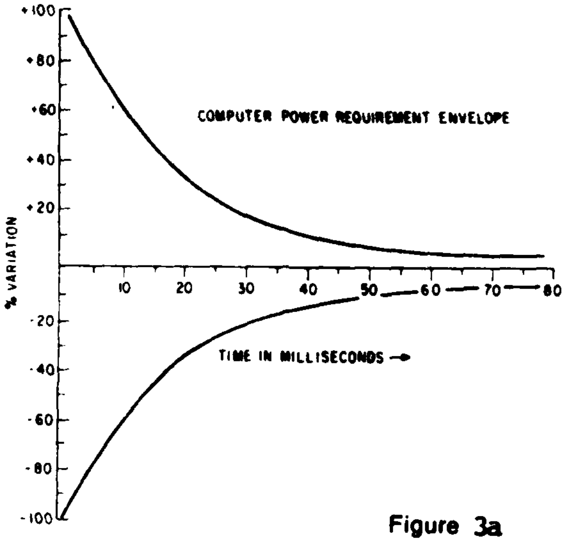


Figure 3a

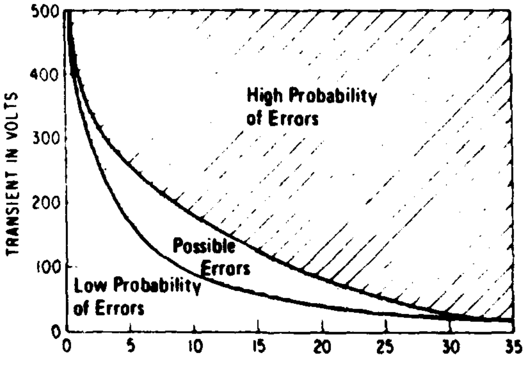


Figure 3b PROBABILITY OF ERRORS RESULTING FROM TRANSIENTS OF VARIOUS AMPLITUDE AND DURATION

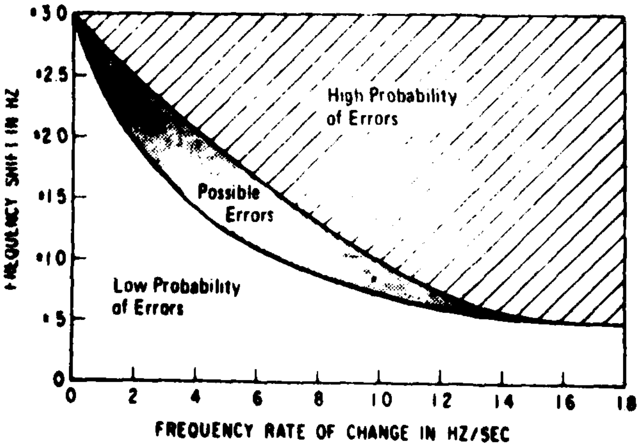


Figure 3c PROBABILITY OF ERRORS RESULTING FROM FREQUENCY SHIFT

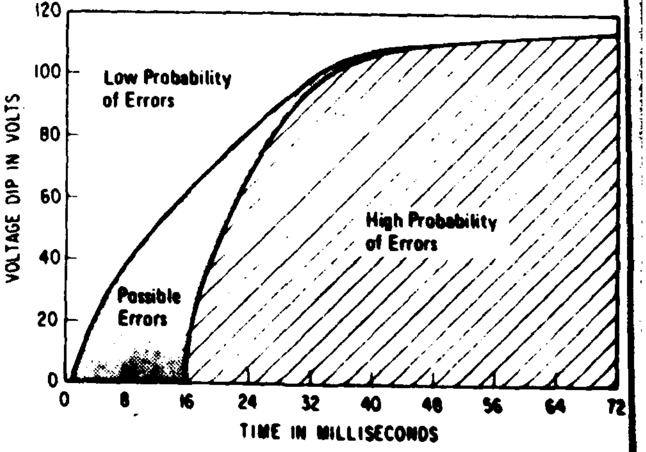


Figure 3d PROBABILITY OF ERRORS RESULTING FROM DIPS AND OUTAGES OF VARIOUS DURATION

Figure III-3

(Used by permission from Randolph Engineering, Inc., Austin, Texas) offer increased susceptibility to error from transients in solid-state logic components, and to failure by momentary out-of-spec operating conditions.

A small amount of data was obtained from Dranetz* power line disturbance analyzers[41] installed at two locations representing widely differing applications, geographical/cultural environment and type of public utility. Strategic Air Command furnished a summary of 40 days of recordings at a Minuteman Launch Facility in North Dakota, and a similar summary was obtained from FAA of recordings taken over a 22-day period at the Detroit ARTS-3 Terminal ATC Facility. Table III-8 presents the essential interesting elements of these data. Considering the difference between the rural, long-line distribution system at Grand Forks and the highly industrialized environment of the Detroit metropolitan area, the figures for the incidence of short inpulse transients are surprisingly similar. Also, it is noteworthy that the average daily impulse rates per phase, 14 per day at Detroit, 7 per day at Grand Forks) are much higher than the average of one or two per day (depending on threshold setting) reported by Allen and Segal,[39] but the peak inpulses are consistent with the findings of the IEEE Committee Reports. The single case of a short outage at Grand Forks (one second, at 11:06:23 on 8 October 1976) would not be classed as an outage by a public utility, and might even escape general public notice, but would be long enough to initiate a power-down sequence in most computers.

Two similar but independent verbal categorization and descriptions of possible deleterious effects are presented in Tables III-9, and III-10 below. The first is from a 1973 Department of Commerce report[6] which developed an overview of the problem and attempted to indicate the potential economic effects of computer outages in industry and in government. The second is an attachment to a recent HQ USAF/KRAD letter[25] which promulgated a new section entitled "Power Enhancements" to be incorporated as paragraph 3-25 in AFR 300-12. It is of some significance to note that from 1973 (Table III-9) to 1977 (Table III-10), no real progress can be noticed in the description of cause-and-effect relationships. Both tables use essentially the same type of "may cause", "may occur", "possible results" language. This vagueness doubtless stems not from a desire by either author to deliberately be evasive, but from lack of any authoritative data-base of quantitative evidence. Such lack does not support a conclusion that no real problem exists, but it does attest to the difficulty and expense of collecting concrete, documented facts. Only within the past year or two have recording instruments designed for this type of service been generally available to users desirous of compiling the necessary measurements. As late as 1972, researchers in this field were using specially constructed instrumentation of their own design.[39] Meanwhile, the sizeable investments in power-conditioning equipment by many industrial and commercial companies such as airlines,[61] textile mills,[62] manufacturing plants, banks,[63] New York Stock Exchange, insurance companies, petroleum chemical plants, rubber and plastics industries,[48] whose operations (and profits) depend upon

*Dranetz Engineering Laboratories, Inc., South Plainfield NJ

TABLE III-9

Typical Computer Requirements, Power Disturbances and Results

	I	II	III	IV
	Typical Computer Requirements (at equipment connections	Typical utility power (delivered at service entrance)	Possible power received (at equipment connections)	Possible results of power problem in column III
Steady State Voltage	120/208 volts ± 10 percent, (+10 percent, -8 percent for IBM mainframes)	120/208 volts ± 5 percent	120/208 volts + 1 percent, -9 percent, due to drops between service and equipment	output errors, unscheduled shutdown, loss of information, costs of downtime, recovery, reruns
Transient Voltage	no dips or surges greater than 20 percent for longer than 30 milliseconds	large loads coming on-line in vicinity can exceed limits in vicinity can exceed limits in column I	with possible lower steady state voltage above, transients could drop voltage beyond limits	errors, shutdown, possible equipment damage, loss of information, costs of downtime, recovery, reruns
Voltage Continuity	most compueters will not tolerate a loss of voltage for longer than 15 milliseconds	complete outages exceeding 15 millisseconds can occur from power net switching lightning	power discontinuities for longer than 15 millisseconds	errors, shutdown, pasible equipment damage, loss of information, costs of downtime, reruns, recovery
Frequency	60 Herts ± 1/2 Hz*	Sudden heavy loads can cause a change of 5 Hz or more, but usually frequency is satisfactory	adequate frequency received at computer	no effects

** Compiled from discussions with numerous authorities in both the computer and utilities fields.

* Some mainframes require 415 Herts power.

TABLE III-10

Summary of Computer Power Disturbances

Type of Voltage Disturbance	Voltage Specificaion of Disturbance	Duration of Disturbance	Typical Effects on Computer Equipment	Typical Power Enhancement Projects
Outage	85% VRMS or less	More than	Built-in voltage sensrs will power down computer equipment in an uncontrolled manner. Processing is interrupted usually resulting in excessive restart/rerun time, possible loss of data, or damage to hardware.	Uninterruptible power supply system, standby diesel generators, dual power feeders, general improvements to base power distribution system.
Momentary Over or Under Voltage (sags and Surges)	Below 85% VRMS and between 105% and 115% VRMS	From 16.7 ms (1 cycle) to 10 seconds	Equipment may power down depending on duration and magnitude of disturbance. If so, processing is interrupted usually resulting in excessive restart/rerun time and in severe cases loss of data and damage to hardware may occur.	Motor generator sets, line voltage regulators, balance computer load on three phase power, imporve computer equipment grounding, general impvorment to base power distribution system.
Transients (Measured above of below instantaneous line voltage of 208/120 VRMS)	100-350% VRMS or higher	Less than 16.7 ms (1 cycle)	No direct effects on systems may be detected. Data disruptions leading to errors, unready indications, etc., may cause individual equipment to stop processing. Rarely, a severe transient may cause equipment to power down. Damage to electronic components may also occur if the equipment is not properly grounded.	Fast response line voltage regulators, isolation transformers, transient suppressors, power line filters, primary and secondary lightning arresters, balance computer load, improve computer equipment grounding.

uninterrupted computer operations, added to the large investment by FAA,[59] represents powerful de facto evidence that the problem is not a mere phantom. Apparently, many managers have decided not to spend much time and money to prove to themselves that they have a problem and to describe it in detail, but have elected to invest those resources directly in a solution.

Some fragmentary documentation does exist. The IEEE Orange Book[60] includes a few case histories, one of which relates computer malfunction to spikes and transients of more than 10% and in excess of 8 milliseconds duration. However, the types of malfunctions are not identified, nor is the type of computer on which they occurred. Amos[30] includes a small table (Table III-11) of results of power interruptions on computer installations at several locations and indicates impact in terms of recovery time. In an excellent 1966 article[28] which has been quoted extensively[26, 31, 60] over the past decade, Mirowsky reported the results of carefully controlled experiments in which power to individual units of a large electronics/computer complex was interrupted for known durations ranging from a fraction of a cycle to several cycles. All interruptions were less than ½ second, which is about the duration of power loss necessary for an incandescent light bulb to produce a noticeable flicker. The results are presented in Table III-12, which indicates that a number of input/output and display devices were adversely affected by interruptions of less than one cycle in duration, and vital central computing and memory modules were disturbed by interruptions of two or more cycles. In the same article, Mirowsky notes that "It is now clear that the two systems — the electronic system and the power distribution system — are not compatible in their present configuration or in their specifications (or legal regulations)". More than ten years later, many users in both government and industry are still "discovering" the validity of that observation.

Within the Department of Defense, the US Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California deserves special praise for its singular contributions in this field over the past dozen years or more, beginning at a time when the problem of power disturbance effects on computers and C-E equipment was not generally recognized. Mirowsky's article,[28] published in early 1966, references NCEL Technical Note N-621, "Power System Transients and a Power Transient Simulator", describing results of work already accomplished by NCEL in the early 1960's to construct special equipment both for power line monitoring and recording and for power disturbance simulators useful for controlled tests of the susceptibility of C-E equipment. In the years since, NCEL has published a number of reports describing the results of power system monitoring and equipment susceptibility tests at C-E installations of all three services.[55-58, 64-75] These reports are characterized by thoroughness and professionalism. As a general rule, the susceptibility test reports establish and document specific effects of oscillatory transients, spikes, and/or short-duration interruptions on individual units or sub-elements of C-E and computer installations.

TABLE III-11

DOCUMENTED UTILITY POWER FAILURES
Class II and Class III

Type Use	Months	Number of Interruptions Momentary	Long	Total Power Off-Time	Recovery Time
Chemical	38	26	2	55 mins.	156 hours
Tobacco	36	29	4	12 hrs.	141 hours
Financial	26	32	3	5 hrs.	128 hours

Line Frequency 60 Hz (cycles)	Time (milliseconds)	Unit	Performance Interrupted	Data Altered	Other Units Affected
Less than 1 cycle	**1.5**	**Decommutator**	×	×	
	1.5	**Tape recorder**			**Decommutator**
	1.5	**Alphanumeric symbol generator**	×		**Computer**
	4.0	**Computer external memory**	×		**Computer**
	5.0	**Computer typewriter**	×	×	**Computer**
	5.0	**Alphanumeric display unit**	×		
	5.75	**Computer control console**	×	×	
	7.0	Card reader	×		Computer
	10.0	Tape search unit	×	×	Computer
	10.0	Card reader	×	×	Computer
	12.0	Computer input–output module	×		Computer
	15.5	Tape controller	×		Computer
Less than 2 cycles	16.5	Compute module	×		
	20.5	Compute module	×	×	
	23.0	External memory	×	×	Computer
	25.0	Receiver decoder		×	Alphanumeric displays
Less than 3 cycles	40.0	Data converter and transmitter	×		Computer
	44.0	Magnetic tape recorder	×		Decommutator
	50.0	Command controllers		×	Control system
Less than 4 cycles	60.0	Scanner		×	
Less than 5 cycles	70.0	Receiver decoder	×		Alphanumeric system
Less than 6 cycles	100.0	Wall clock	×		
Less than 7 cycles	115.0	Magnetic tape recorder	×	×	
	125.0	Magnetic tape recorder	×		Computer
18.5 cycles	200.0	Recorder, chart	×		
18.6 cycles	310.0	Count-down time generator	×		Computers
19.6 cycles	325.0	Count-down time generator	×	×	Computers
24 cycles	400.0	Count-down time generator	×	×	Computers and tape search
27 cycles	450.0	Computer complex console	×		Oscillograph

From Mirowsky (28).

TABLE III-12 - Schedule of Short Duration Power Interruptions versus Start of Equipment Effects

Of general interest is a 1970 NCEL report[55] of results of transient susceptibility tests of Digital Subscriber Terminal Equipment (DSTE), which may be considered typically representative of a wide family of standard computer peripherals such as card and paper tape readers and punches, page printers, and associated control units. Figure III-4 is a block diagram of the DSTE System, and Table III-13 summarizes the results of the tests on individual DSTE equipment items. It shows very high susceptibility of most units to pulse voltage transients and to momentary power interruptions within the range of one-half cycle to nine cycles. Steady state undervoltages of 105 to 100 volts caused the Common Control Unit (CCU) to power down. A momentary power interruption of 1½ cycles caused the Paper Tape Punch, High Speed (PTPHS) to lose the ready signal and go to the stop mode. Pulse voltages as low as 20V p-p, both negative and positive, caused various units of the system to revert to a non-operational mode. On individual tests, the PTPHS, Card Punch, High Speed (CPHS), and Paper Tape Punch, Low Speed (PTPLS) experienced various degrees of susceptibility to transient high frequency voltages superimposed on the input sinusoidal voltage depending on the actual frequency and duration. The different effects of this were parity errors, out of sync, loss of read signal, and stop mode conditions. A particular problem was documented with the page printer (PP). During the startup sequence, the initial input surge current to the electric motor drops the line voltage to approximately 87 volts for about 1.2 seconds. The threshold for the PP to revert to a power down mode is 85 volts, steady rate. Hence, there is only a two volt margin if input line voltage is at its nominal value; if line voltage is more than two volts low, the initial surge can cause the voltage sensing element in the PP to invoke the power-down mode.

For insight of the susceptibility to power disturbances, it is of some interest and importance to understand how the "Power Squeeze" has come about. What has happened in the past several years to suddenly thrust this problem upon the community of computer users? Has commercial power become "dirtier" than it used to be, or are the designers of computers now taking shortcuts which were formerly unconscionable in order to maintain a price edge in extremely competitive market? The truth is closer to the situation implied by the second question, though the susceptibility of modern computers to power disturbances is more incidental than intentional.

In a well-written article on this situation, Renfrew[27] presents three significant points. First, in the so-called "third generation" design of computers which use integrated circuits extensively to achieve small size, greater component reliability and lower cost, the improvements are realized by reducing the operating power levels. This means both reduced signal levels and reduced power dissipation. Reduced signal power implies reduced signal-to-noise ratio, also, if the noise is generated externally to the system. Pragmatically, the result is a higher error rate in the computer. As indicated in preceding sections, noise on power circuits has doubtless always existed, but has only been made manifest by the sensitivity of modern low-signal computing circuits to such disturbances.

TABLE III-13. Summary of Digital Subscriber Terminal Equipment Transient Susceptibility Tests

Item	Load Current (AMPS)	Steady State Overvoltage (volts)	Steady State Undervoltage (volts)	Momentary Outage (cycles)	Momentary Undervoltage (volts-cycles)	Momentary Overvoltage (volts-cycles)	Negative Polarity Pulse voltage (volts)	Positive Polarity Pulse voltage (volts)	Frequency Over (hertz)	Frequency Under (hertz)	Square Wave	High Freque (K hertz)
Common Control Unit (CCU) C-8120(P)/G	5	150-W	90-F	2-3/4-F	90-5.5:F	160-20:W	30-F	110-F	66-W	54-W	W	W
Card Punch, High Speed (CPHS) RO-312/G	14	150-W	90-F	5-F	90-6:F	160-20:W	20-F	30-F	66-W	54-W	W	2,5,10:F
Card Punch, Low Speed (CPLS) RO-313/G	8	150-W	90-F	3/4-F	60-2:F	160-20:W	290-F	170-F	64-F	54-W	W	W
Reader, Punched Card (RPC) RP-152/G	8.2	150-W	85-F	8-3/4-F	72-10:F	160-20:W	25-F	30-F	66-W	54-W	W	W
Reader, Punched Tape (RPT) RP-154 (P)/G	4.3	150-W	85-F	1/2-F	85-20:W	160-20:W	30-F	25-F	66-W	54-W	W	W
Paper Tape Punch, High Speed (PTPHS) RO-314/G	15	150-W	85-F	3/4-F	80-4:F	160-20:W	30-F	30-F	64-F	54-F	W	0.5, 0.75, 1.5,2,5,10:
Paper Tape Punch, Low Speed (PTPLS) RO-315/G	8.5	150-W	70-F	1/2-F	60-20:W	160-20:W	30-F	30-F	66-W	54-W	W	2,5,:F
Page Printer (PP) RP-157/G	11	150-W	85-F	3-1/2-F	75-7:F	160-20:W	30-F	30-F	66-W	54-W	Could not start	W
TOTAL DSTE SYSTEM	74	150-W	100-105-F	1-1/2-F	*	*	20-F	20-F	66-W	54-F	------	---------

NOTE: W Denotes that system functions
F Denotes that system malfunctions

* Not performed, starting currents too high for synthesizer

(Reproduced from Reference #55)

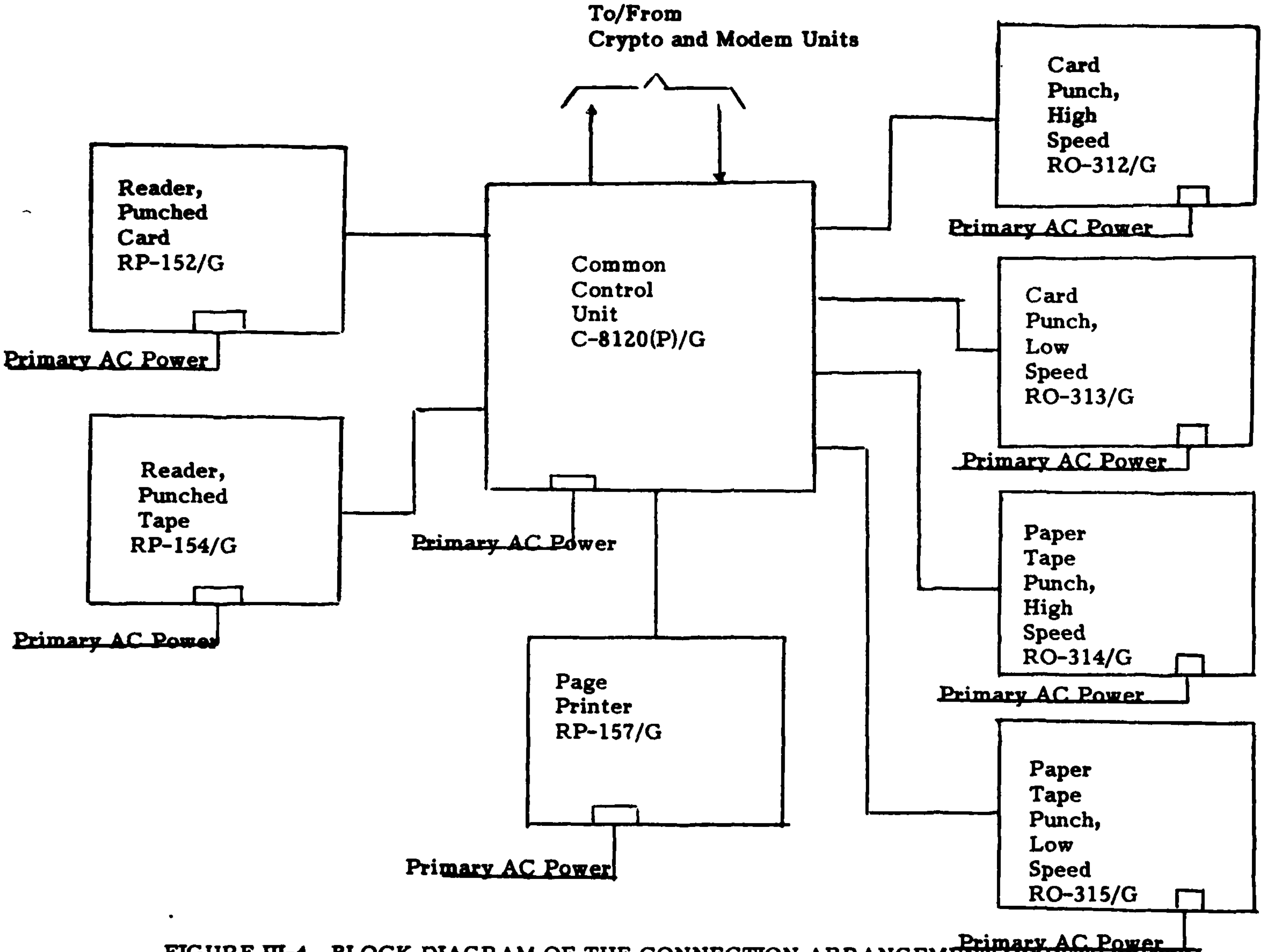


FIGURE III-4. BLOCK DIAGRAM OF THE CONNECTION ARRANGEMENT OF DSTE SYSTEM

Renfew's second point is similar to the first, but relates to spurious signals which may enter into circuits through common grounding. Again, because modern integrated circuits operate at low signal level and have high gain parameters, low noise levels in grounding systems can be amplified and cause trouble. For this reason, he suggests that the computer should have its own low-impedance "private" ground and a fully isolated neutral.

The third point is somewhat subtler. The criteria of noise and low power dissipation rate dictate that the internal power regulation systems of a computer must have very fast response times. Fast response, drawing upon energy stored at low voltage in local power supplies dictates very large capacitors whose bulk tends to nullify the miniaturization gains in digital logic circuits, and increases cost considerably in an area that contributes little to the operational utility of the computer, i.e., it is not a strong "selling point". Consequently, internal power supplies are designed with just enough stored energy to provide an orderly shut-down of the computer whenever power failure is detected, but not enough to be considered a running reserve of power. Renfrew notes that most computers have very fast-acting alarm circuits which shut the unit down within one to five milliseconds of the first indication of a power fluctuation. These figures are supported by many other sources[42, 44, 46]. Effectively, this means that an undervoltage or dropout of even ½ cycle of line power would be sufficient to trigger such a shut-down. The essential point is that computers are not designed to solve the problems of the power systems on which they depend.

D. SUSCEPTIBILITY OF OTHER C-E EQUIPMENT TO POWER DISTURBANCES.

The information in this section is derived or extracted from reports prepared by the Naval Civil Engineering Laboratory (NCEL). These may be referred to for more detailed information. As noted above, NCEL has developed unique test equipment configurations which permit controlled, quantitative, power transient susceptibility testing. These include the Power Transient Data Acquisition Monitor which can automatically record up to 12 power waveforms and the Power Transient Synthesizer which can provide AC with controlled power fluctuations transients and other disturbances.

Transmitters and receivers of the TSEC/KG-13 communications equipment were found to be susceptible to momentary power interruptions lasting 3/4 cycle and longer. They both operated satisfactorily with a ½ cycle interruption. The steady state undervoltage and overvoltage limits were determined to be 80V and 140V, respectfully. See Table III-14 for additional parameters.

Similarly, transmitters and receivers of the TSEC/KW-26B failed at 2½ and 3 cycles of momentary power interruption, respectively. The steady state undervoltage and overvoltage limits were determined to be 100V and 140V, respectively, for the transmitter and 95V and 140V, respectively, for the receiver. See Table III-14 for additional details.

TABLE III-14. THRESHOLDS OF ACCEPTABLE POWER-PARAMETER DEVIATIONS

Test Item	Steady-State Undervoltage (rms volts)	Steady-State Overvoltage (rms volts)	Momentary Undervoltage for 20 Cycles (rms volts)	Momentary Overvoltage for 20 Cycles (rms volts)	Momentary Power Interruption (msec)	Momentary Frequency Deviation (Hz)	Superimposed Sinusoidal High-Frequency Voltage (peak volts)	Sine-Wave Trace Discontinuity (peak volts)	Positive Pulse Voltage (peak volts)	Square Wave
TSEC/KG-13 *transmitter 1*	80	140	80	140	8.3	±6	150	170	150	operated
TSEC/KG-13 *receiver 1*	80	140	80	140	8.3	±6	125	170	150	operated
SN-394(V)/G *synchronizer*	80	140	80	140	2	±6	5	75	75	did not operate
TSEC/KW-26B *transmitter 1*	100	140	90	140	33.3	±6	150	170	200	did not operate
TSEC/KW-26B *receiver 1*	95	140	90	140	42	±6	150	170	200	did not operate
TT45 Teletype	not run	not run	not run	not run	16.7	±3	not run	not run	not run	not run

Reproduced from Reference 56

The SN-394(V)/G Electrical Synchronizer unit provides automatic resychronization for crypto equipments and is commonly used with the KG-13. The synchronizer did not function with a 1/8 cycle momentary power interruption without loss of synchronization of the KG-13s. Table III-14 shows additional parameter limits.

The CODEX AE96 Modem 35a operated satisfactorily up to the maximum steady state test voltage of 135 Vrms and would lose sync at a steady state undervoltage of 90 Vrms. It would also lose sync with a ½ cycle Hz momentary power interruption. No effect on operation was noted with frequency variations from 54 to 66 Hz and a maximum superimposed pulse voltage of 350 peak volts, 10 and 100 microsecond pulse widths applied.

The WECO 207 Modem also operated satisfactorily up to 135 Vrms and would lose sync at 90 Vrms steady state undervoltage. Of two modems tested, one lost sync at 3/8 cycle momentary power interruption and other other at ½ cycle. No effect on operation was noted with frequency variations from 54 to 66 Hz. For the two modems, one lost sync with a superimposed pulse voltage of 75 peak volts at 10 microseconds pulse width and 100 peak volts at 100 microseconds. The other modem lost sync at 125 peak volts at 10 microseconds pulse width and 150 volts at 100 microseconds.

The limited examples cited above are merely indicative that the general problem of susceptibility to power disturbances is not limited to computer installations. As communications systems and subsystems are modernized to take advantage of modern digital processing techniques, other manifestations of the power squeeze can be expected to become increasingly common. In addition to requirements for remedial measures which can bridge the power gap, a need for standard methodology of susceptibility testing for new equipments is obvious.

SECTION IV

JAPAN TROPO SYSTEM

A. GENERAL.

System Description - The Japan Tropo System (JTS) runs from Hakone to Sofu, with a passive repeater at Rokko. From Sofu, a microwave link extends to Seburiyama. From Seburiyama, a tropo system extends to Yaetake, Okinawa, via a relay station at Chiran. Also from Seburiyama, two systems extend to Changsan, Korea. The first is a microwave system, with a passive repeater at Tsushima. The second microwave system is between Seburiyama and Itazuke, which is extended to Changsan via a tropo system. Sofu and Iwakuni are connected via microwave. The JTS essentially ties together two clusters of stations. One cluster is in the Tokyo area, and the other in Kyushu, except for Iwakuni, a U.S. Marine Air Station. On the northern end of the JTS, Camp Zama is the major nodal station into which AUTODIN circuits from the Camp Drake switching center, and AUTOVON circuits from the Fuchu switching center are distributed or consolidated and introduced into the JTS from the Kanto Plains Communications System. To best understand the complexities of the interconnections with Camp Zama, see the Kanto Plains Communications System diagram, Figure IV-1. On the southern end of the JTS, Seburiyama is the major nodal point, but is limited in break-out capability. The greater part of the facilities transiting Seburiyama are through grouped. Itazuke is the point at which the greater part of the systems breakout to channel level. The systems under consideration are a mix of tropo, microwave and broadband lease, which are connected in a network. The entire trunking plan is illustrated in Figure IV-2. The JTS supports the DCS switched networks, common user, PACAF, MAC, SAC aeronautical air defense networks, CRITICOM and Security Service, and a high percentage of Army and Navy communications. To attempt to rank the various stations in order of importance is problematical. With the exception of the Kanto Plains, the systems are configured in a single line chain without grid interconnectivity. The systems are equipped with NEC equipment, and are under contract for all operations and maintenance.

Distribution of Restoration Priorities - A sampling of restoration priorities reflects that there are relatively few priority one circuits, the highest concentration being priority 3 and 00.

Impact Statement - Loss of power at Camp Zama, or any one of the repeater stations between Camp Zama and Seburiyama (Hakone, Rokko and Sofu), would impair the DCS AUTODIN and AUTOVON interswitch trunking systems. Also affected would be PACAF *Command and Control (C^2), SAC, MAC, the air defense networks and Army and Navy C^2. Seburiyama is another major point which would be of significant impact in case of power loss because of the high concentration of backbone trunking. Seburiyama is the key focal

KANTO PLAINS COMMUNICATIONS SYSTEM

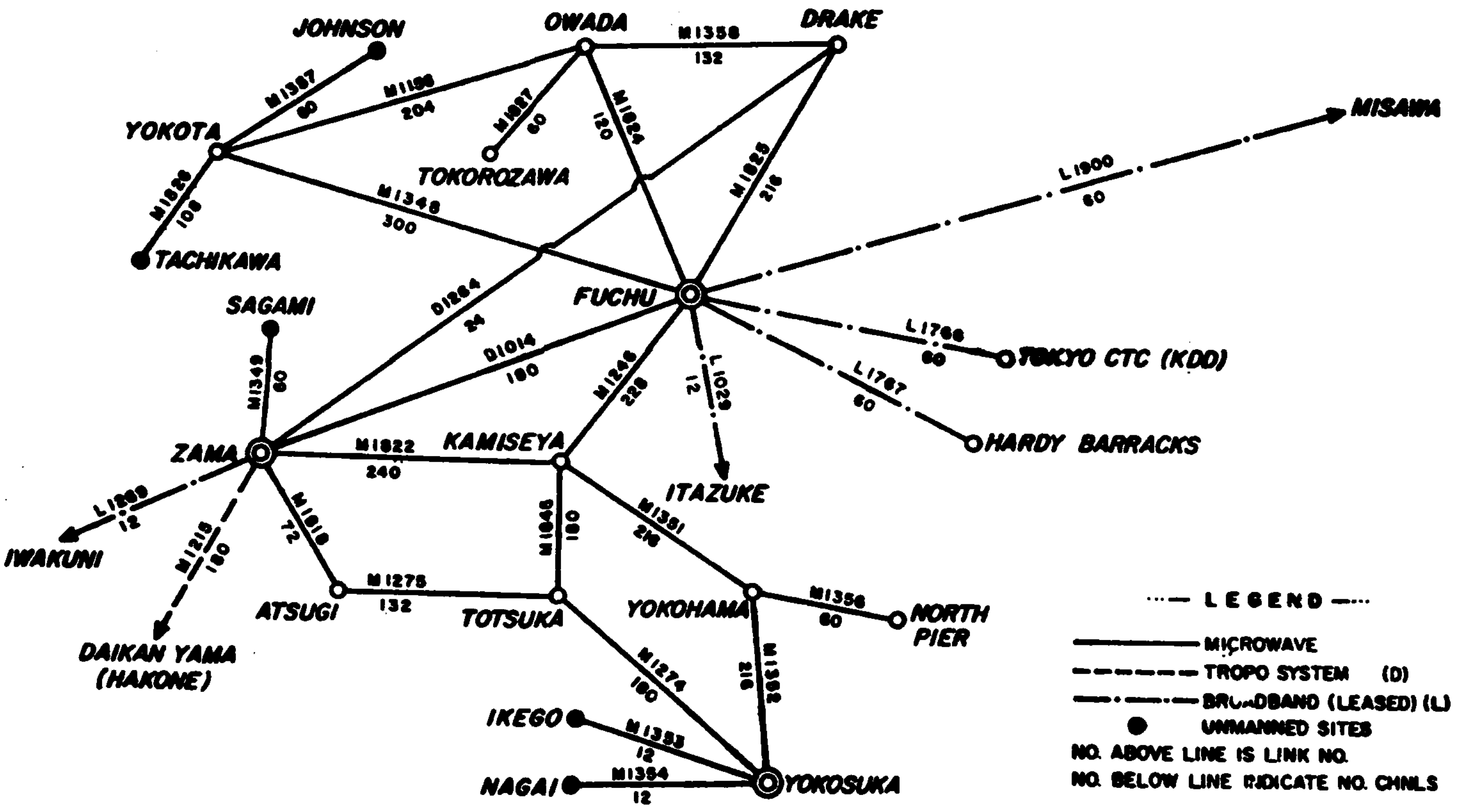


FIGURE IV-1

JAPAN REGION COMMUNICATIONS INTER-CONNECTIVITY

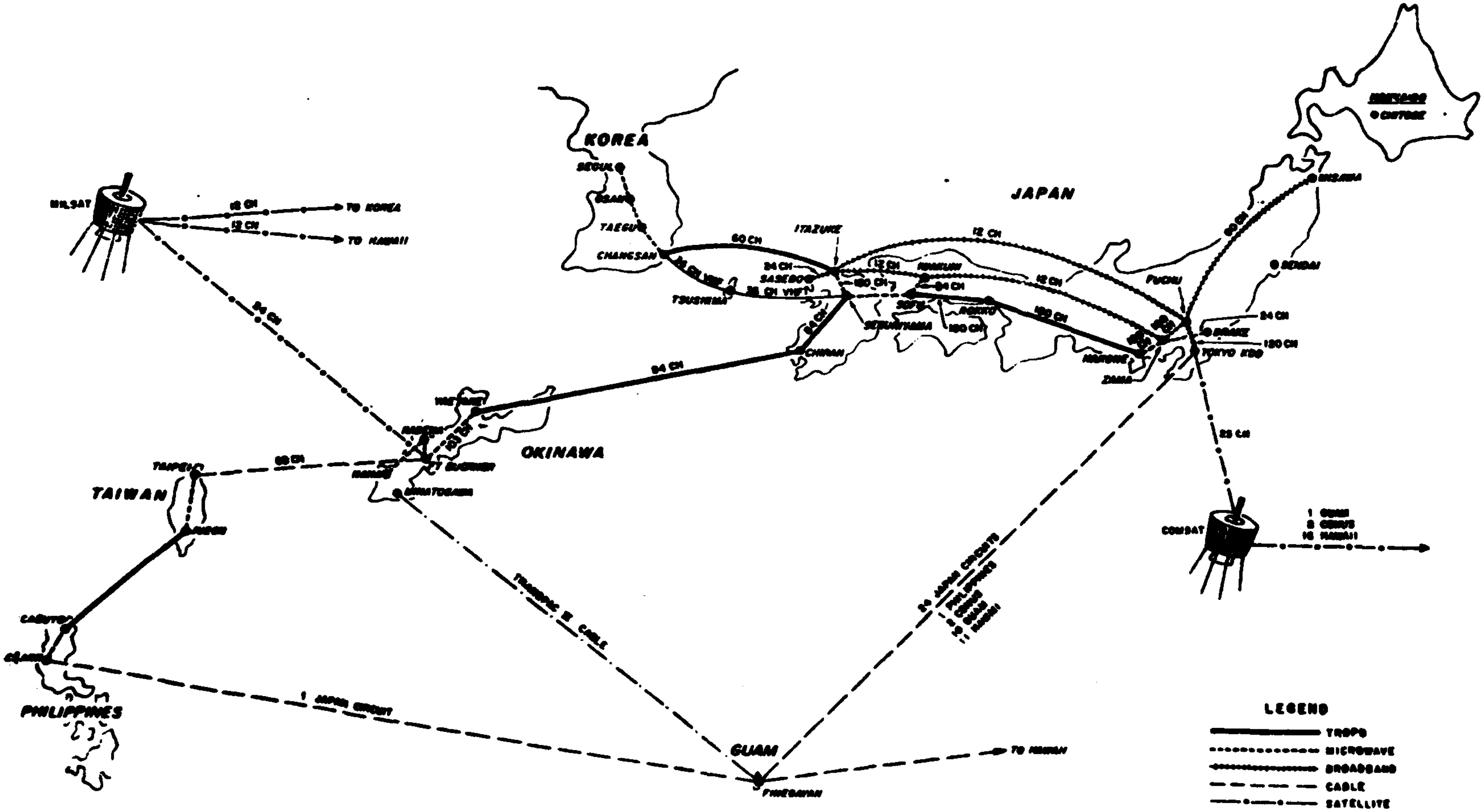


FIGURE IV-2

point for interconnectivity between Japan/Korea and Japan/Okinawa. Loss of power at Itazuke would impair Japan/Korea communications to a degree, but alternate routing is available for high priority services via Seburiyama. Loss of power at Chiran or Yaetake would impair Japan/Okinawa services, but some alternate routing is available via the TRANSPAC cable and satellite facilities. Loss of power at Changsan would limit access between Korea and Okinawa and disrupt Japan for the switched networks, air defense communications and some C^2, but a measure of alternate routing capability is available via MILSAT facilities between Korea and Okinawa. Iwakuni has a relatively small communications capability and loss of power at this location would only affect their primary mission, unless simultaneous outage occurred on the backbone tropo system and some services were restored via the leased broadband facilities at the time of power loss.

B. DOD POLICIES AND DIRECTIVES ON SYSTEM AVAILABILITIES:

DCA Circular 310-130-2[76] - Disseminates Defense Communications System (DCS) management thresholds and is applicable to activities of the Department of Defense responsible for operations and maintenance of, or deriving service from, elements of the DCS. The following management thresholds and performance objectives have been established:

DCS Links	Management Thresholds	Performance Objectives
Microwave	99.0	99.5
Tropo	99.0	99.9
DCS Trunks		
Microwave	99.0	99.5
Tropo	99.0	99.5

DCA Circular 350-195-2[77] - Establishes operational responsibilities for periodic exercising of DCS station auxiliary electric power systems.

AF Regulation 91-4[78] - Outlines the policy, responsibility and technical standards for the maintenance and operation of electric power systems in the Air Force.

MIL-HDBK-411[79] - This handbook was developed by the Defense Communication Agency in accordance with the Defense Standardization Program. It provides consideration for use in the design, installation and acceptance of power and air conditioning subsystems for Department of Defense Long Haul DCS Communication Facilities. Paragraph 4.2.2.2.d states that, "The primary power supply, auxiliary power supply, and distribution system shall be engineered to provide 99.99% availability (exclusive of scheduled outages) to the technical load bus and not in excess of 53 minutes total outage during any one year".

C. JAPAN TROPO SYSTEM POWER SYSTEMS.

Power System Descriptions - There are three basic power system configurations used within the Japan Tropo System.

1. Commercial power used as the primary power source with auto-start/auto-transfer diesel engine driven generator sets as the back-up power source. Should commercial power fail, there will be an interruption experienced and the back-up unit will auto-start and auto-transfer onto the line.

2. Commercial power as the primary source, with a rotary type (engine-motor-generator) uninterrupted power system (UPS) serving the communications equipment load and an auto-start/auto-transfer diesel engine driven generator set as the back-up source. In case of a total UPS failure, the communications equipment load can be manually transferred to either commercial power or the back-up generator. Also, manual synchronization capability is provided for performing an uninterrupted transfer of load between these power sources.

3. Diesel engine driven generator sets, "Class A" as the only source of power. Should the unit on the line fail, there will be an interruption experienced and the back-up unit will auto-start and auto-transfer on to the line.

4. Type of Power System by Location:

Camp Zama - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Changsan - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Hakone - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Itasuke - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Iwakuni - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Rokko - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Seburiyama - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Sofu - Commercial Power-Prime, UPS-Tech Load, Diesel Generator-Back-Up
Yaetake - Commercial Power-Prime, Diesel Generators Back-Up
Chiran - Diesel Generator Sets Prime.

D. UPS OPERATIONAL AND OUTAGE INFORMATION.

The mainland Japan Tropo system contains seven locations having a rotary uninterruptible power supply (UPS) providing the power for the technical C-E equipment load. At the remaining locations, all of the station load is supplied by generator sets on a continuous basis. The other JTS stations are at Changsan, Korea for which only incomplete data could be obtained, and Yaetake, Okinawa which is presently operated by the Army but will become the responsibility of the USAF in March 1978. During CY 75, 113 unscheduled commercial power outages, covering all mainland Japan locations with UPS, were experienced causing a total of 117.9 hours of engine driven operating time. (See Appendix A-1 and A-2 for a breakdown of events and durations by location.) Also noted were 33 scheduled power interruptions for the same operating locations which created another 92.8 hours of engine driven operating time for a CY 75 total of 146 scheduled/unscheduled power interruptions and 210.7 hours of engine driven running time. For CY 76, 113 unscheduled commercial power outages were experienced at all mainland Japan locations with UPS causing a total of 98.4 hours of engine driven operating time. (See Appendix A-4 and A-5 for a breakdown of events and durations by location.) Also experienced were 30 scheduled power interruptions for 84.4 hours of engine driven operating time for a total of 143 scheduled/unscheduled power interruptions and 182.8 hours of engine driven running time. Examination of the data indicates that for 1975 and 1976 there were roughly 16 events per station, per year. However, Itazuke had significantly more outages. These outages (59 events in 1975 and 49 events in 1976) accounted for about one half of the total number of outages for all UPS equipped mainland Japan stations. Excluding Itazuke, the other stations averaged about 10 events per year per station. Appendix A-3 depicts the UPS operational events by time increments caused by unscheduled commercial power interruptions at each mainland location using UPS. It should be noted that the unscheduled outage times are not station operational outages or the actual duration of the commercial power outage but represent the amount of time the generators were run because of the onset of the commercial power loss. Therefore, the duration of the commercial power outage is for an unknown duration but no longer than the time the generators were operated. For 1975 and 1976, the distribution of outage data was very similar. There was a yearly average of 41 outages between 1 and 10 minutes long, 25 outages between 11 and 30 minutes, and 46 outages which were longer. In other words, for 113 outages per year, 67 (on the average) were 30 minutes or less. Except for Itazuke, the majority of outages were between 1 and 10 minutes. Itazuke not only had more outages, but they were longer in duration. Examination of the unscheduled outages for 1975 and 1976 by month (Appendix A-2 and A-5) show the events fairly randomly scattered with a hint that the spring months of February and March and the late summer months of July through September are effected more than others. In CY 76, only two power outages, for three and two minutes respectively, could be established for Chiran which operates on generator sets as the only source of power. Project YOK 73-024-R5 is to provide commercial power as the primary source reverting the generator sets to back-up power. This project has been approved. Because there is no provision in this project to provide an UPS, all unscheduled interruptions of the commercial input power will result in a communication outage. The back-up generator sets will be provided auto-start and auto-transfer capabilities which will function (upon noting a failure) to place the unit on the line. Noting the documented power interruption data at other locations being served by commercial power as the primary power source, this station can be expected to be affected approximately the same. It must also be noted that this configuration is also the mode of operation at Yaetake, Okinawa. Yaetake power outage data for CY 75/76 is contained in Appendix A-6 and A-7. Since Yaetake has commercial power as prime and diesel generators with auto-start and auto-transfer, an estimated two to three minute operational outage will be incurred for each power outage until the back-up power is available. There were 16 events in 1975 and five events in 1976. Therefore, using the number of events and estimated operational outage per event, Yaetake would have exceeded an operational availability of 99.99% each year. The data for Yaetake in Appendix A-6 and A-7 reflects the actual duration of the commercial outages. Data was not obtained on the actual operational outages or how long the generators were operated.

If the seven sites with UPS had not been UPS equipped, and based on three minutes operational outage until the station was restored on back-up power (based on 1975/1976 operational outages: 14 events and 42 minutes), 17 is the maximum number of outages that could be experienced and still achieve an availability of 99.99%. Considering this, even without UPS, nearly all stations would have provided 99.99% availability in 1975 and 1976. The exceptions are Itazuke with 59 and 49 events in 1975 and 1976, respectively, and Sofu with 19 outages in 1976.

The result of this extrapolation for the mainland Japan UPS equipped stations must be carefully placed in perspective, however. There is no way of knowing, based on available data, how many transients and momentary outages less than the threshold to activate the UPS diesel engine may have occurred but were hidden by the buffering of the UPS. Conversely, there is no data to support that there would be an adverse effect on present equipment without UPS.

Data available on all circuit interruptions due to power associated causes was very limited and could not be cross referenced. However, from a 1976 UPS study, DCS outage summary report and material provided by the 1956 CG, there was a total of five events for 12 minutes either from the rotary UPS failing to start when an outage occurred or because it was inoperable due to PMI or maintenance actions, in which case the generators would have been manually started.

TABLE IV-1

MAINLAND JAPAN JTS UPS SUMMARY

This data provides the UPS availability, utilization figures and the time lost due to maintenance downtime and UPS failure/unavailibility for CY 75 and CY 76.

CY 75

Location	Hr Avail Per Yr	Maint Downtime (Hr)	UPS Avail for OPR (Hr)	UPS Eng Driven Time	UPS Reported Outage Time (Min)
Camp Zama	8760	141	8619	20:01	
Hakone	8760	618	8142	29:0	2
Itasuke	8760	447	8313	64:03	3
Iwakuni	8760	128	8632	10:25	
Rokko	8760	408	8352	22:02	6
Seburiyama	8760	608	8152	54:10	
Sofu	8760	208	8552	11:02	1

CY 76

Location	Hr Avail Per Yr	Maint Downtime (Hr)	UPS Avail for OPR (Hr)	UPS Eng Driven Time	UPS Reported Outage Time (Min)
Camp Zama	8760	350	8410	17:22	
Hakone	8760	91	8619	33:49	3
Itazuke	8760	425	8335	49:56	2
Iwakuni	8760	239	8521	18:18	
Rokko	8760	1123	7637	15:39	9
Seburiyama	8760	2759	6001	27:43	10
Sofu	8760	128	8632	21:12	6

E. OTHER CONSIDERATIONS.

Planned network reconfigurations will have a definite effect on the JTS and must be considered in any planning. In the near future, an AN/MSC-46 satellite terminal will be installed at Camp Zama. This will provide circuit connectivity to Hawaii, Philippine Islands and Korea in addition to other locations. The significance of these may be better appreciated by examining Figure VI-2. It may readily be seen this will provide a significantly improved altroute capability in the event of failures within the JTS. It is planned that eventually the satellite link at Camp Zama will be digitized, which may possibly occur before the projected replacement of the AN/MSC-46 by an AN/MSC-61 in the early 1980's.

The present power production equipment was installed at most sites in 1962. Seburiyama and Itazuke were completed in 1972 with used equipment relocated from Fuchu and Tachikawa. All UPS generators which support the JTS are high speed (above 1000 RPM) and have a life expectancy of approximately 20 years. These generators have required an increasing amount of maintenance as reflected in Table IV-1 which shows that it nearly doubled from 1975 to 1976 (2633 hours versus 5,191 hours downtime).

The real estate ownership at Yaetake will change from Army to Air Force in March 1978 and the Base Civil Engineer at Kadena Air Base will assume depot level responsibilities. The existing generators are old and the automatic switch gear is unreliable. The Nippon Electric Company, by Army request, investigated the deficiencies in November 1976, and estimated it would cost in excess of $100,000 to rehabilitate the existing switch gear. Also in November, the Army began an architect-engineer study to determine the feasibility of relocating two relatively new 500 KW generators from Tengan to Yaetake[80]. Although not yet completed, the results from this study may enter into the transfer agreement.

Another consideration is the approved and planned 96 channel digital system between Seburiyama and Changsan with a baseband relay at Tsushima. This will be installed, operated and maintained by the Japanese Government and will replace existing tropo and VHF links between these sites. When this is completed, the Itazuke site will be closed. It is anticipated that this may occur about September/October 1978. Plans are to then move the Itazuke tech-control and baseband repeater to Seburiyama, increasing its significance as a communications nodal point.

Also, the Nippon Electric Company (NEC) has submitted an unsolicited proposal to the Air Force for converting the JTS from an analog to a digital system. One part of this proposal deals with the installation of SSUPS at each location. Since the unsolicited proposal was not available for examination for this report, its costs and rationale could not be evaluated.

F. SUMMARY.

The Japan Tropo System (JTS) includes seven mainland Japan stations operating on commercial power with rotary UPS and auto-start/auto-transfer backup generators, one mainland Japan station with diesel primary power; one station at Changsan, Korea operating on commercial power with rotary UPS, and one station at Yaetake, Okinawa operating on commercial power with auto-start/auto-transfer back-up generators.

Current altroute capability for the JTS is limited but will significantly improve when the Camp Zama satellite terminal becomes operational. This improved capability is also significant because after the Seburiyama to Changsan digital link becomes operational and the Itazuke links rehomed, Seburiyama will become a major communications mode between Korea, Okinawa, and Japan. Another important node in the JTS is Camp Zama, because it provides major connectivity to the Fuchu AUTOVON switch and the Camp Drake switch.

The outage data for the seven UPS equipped mainland Japan stations reveals that they met the DCS management thresholds and performance objectives in both 1975 and 1976. These stations experienced a total of five events and 12 minutes station operational outage in 1975 and nine events and 30 minutes in 1976. Significantly, there was a total of 226 unscheduled commercial power outages in 1975 and 1976 which caused no operational outage because of the UPS. However, Itazuke experienced about one half of the total for each year (59 in 1975 and 49 in 1976). This problem will resolve itself since the Itazuke site will close in the fall of 1978.

Because the UPS masks the operational impact of power outages and because there is no before UPS and after UPS comparative data, the actual impact of UPS can only be estimated. In addition, the impact of outages on operational availability requirements of users being provided communications by the JTS is unknown because the requirements are not stated in terms of minimum tolerable number of events, durations and frequency of occurrence.

The rotary UPS are nearing the end of their life cycle and are becoming increasingly difficult to maintain. This is reflected in the hours of downtime for UPS maintenance which nearly doubled from 1975 to 1976.

Finally, any future consideration for digitization of the JTS must address the need for UPS.

SECTION V

AUTOMATIC DIGITAL WEATHER SWITCHES (ADWS)

A. DESCRIPTION OF THE ADWS (BASED ON AFCSR 105-2).[81]

General - The computerized Automatic Digital Weather Switches (ADWS) are the nucleus of the global Automated Weather Network (AWN). Other elements in the AWN are the Manual Weather Relay Centers (MWRC), their associated tributaries, and other various weather teletype circuits used in the collection and dissemination of environmental and meteorological weather data to support the Air Weather Service (AWS) mission. This network is also the prime system for the collection and dissemination of Notice to Airmen (NOTAM) messages pertinent to navigational facility status as set forth in AFR 55-16, the Air Force Notice to Airmen (NOTAM) system.

Mission of the AWN - The mission of the AWN is to provide efficient, reliable, and timely communications support to AWS. This includes delivery of all data including foreign intercepted weather data to the Air Force Global Weather Central (AFGWC); transmission of AFGWC generated products to AWS and other Air Force and Department of Defense (DOD) user activities, the collection and dissemination of weather data to support Base Weather Station observing and forecasting, and NOTAM collection and dissemination. The AWN also directly supports the U.S. Army and Navy, including the dissemination of weather data to terminal activities and keying of weather broadcasts to the Navy fleets.

ADWS Mission - Within the AWN, each ADWS has a two-fold mission. First, all input data is processed by the Automatic Digital Weather Edit Program (ADWEP). Then, after processing by the ADWEP, data is switched by the Automatic Digital Weather Communications Program (ADWCP) to circuits and users as designated by AWS. An extension to the ADWS is the MWRCs which perform a similar mission.

The AWN Structure. (See Figure V-1.) The AWN is interconnected with high speed digital data circuits, interswitch trunks (see Figure V-2), with low and medium speed circuits used for collection and dissemination of data. Teletype networks supporting the AWN include the CONUS Meteorological Data System (COMEDS) networks, the Astrogeophysical Teletype Network (ATN), overseas theater teletype networks, terminal extensions off civil (U.S. and foreign) meteorological networks, and weather intercept circuitry.

Although the AFGWC is the primary meteorological processing center served by the AWN, other interfaces exist with the Navy Fleet Numerical Weather Central (FNWC), the National Meteorological Center (NMC) operated by the National Weather Service (NWS), the Federal Aviation Administration

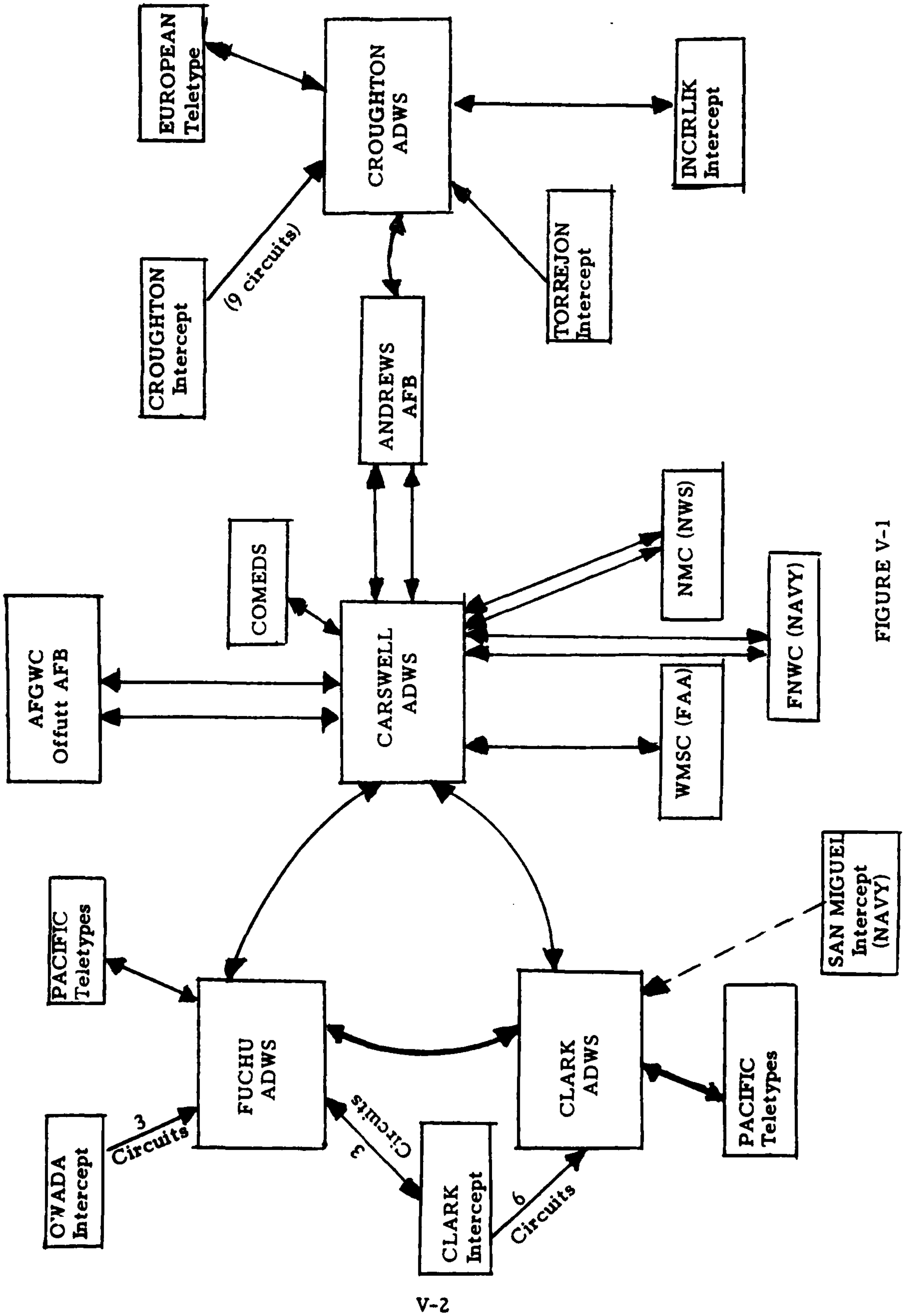

EUROPEAN Teletype
CROUGHTON ADWS
INCIRLIK Intercept
CROUGHTON Intercept
(9 circuits)
TORREJON Intercept
ANDREWS AFB
AFGWC Offutt AFB
COMEDS
CARSWELL ADWS
NMC (NWS)
FNWC (NAVY)
WMSC (FAA)
PACIFIC Teletypes
SAN MIGUEL Intercept (NAVY)
FUCHU ADWS
CLARK ADWS
PACIFIC Teletypes
O'WADA Intercept
3 Circuits
3 Circuits
CLARK Intercept
6 Circuits

FIGURE V-1

AUTOMATED WEATHER NETWORK (AWN)

INTERSWITCH TRUNKS (IST)

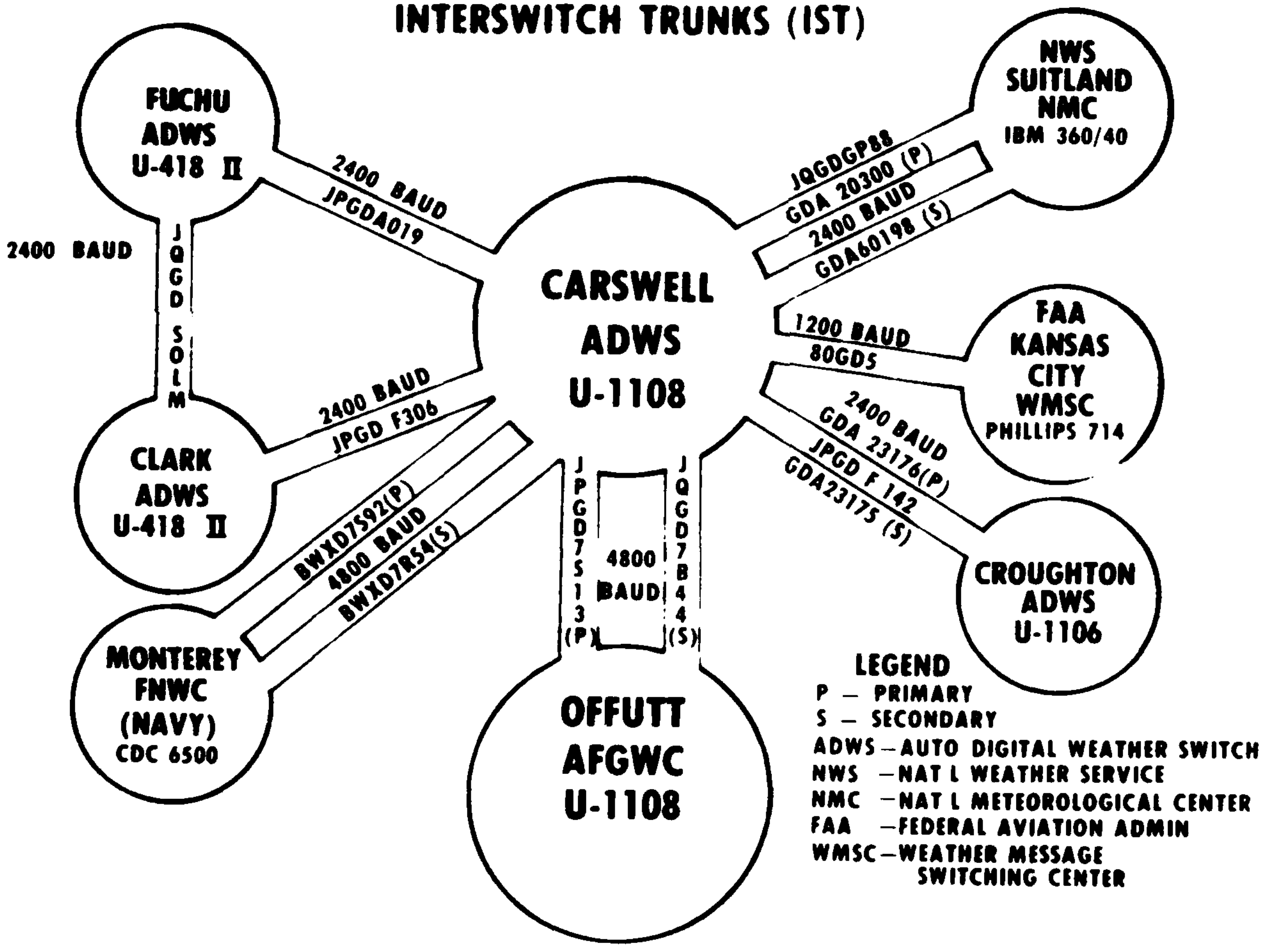


FIGURE V-2

(FAA), Weather Message Switching Center (WMSC), the Japanese Meteorological Agency (JMA), the British Meteorological Office (BMO), and the German Weather Service (DWD) Meteorological Center at Offenbach.

The weather intercept facilities, configured with antennas, radio receivers, and connected to designated ADWS with low speed teletype circuits, obtain data by monitoring scheduled Radio Teletypewriter (RATT) and Continuous Wave (CW) broadcasts emanating from foreign countries. Intercepted data is edited by the connected ADWS and then switched via the AWN to the AFGWC. The timely and efficient accomplishment of this task is the primary function of the AWN. See AFCSR 105-1 for further details.

B. ADWS POWER CONFIGURATIONS.

There is no standard power configuration for the ADWS. Each ADWS power configuration is described separately in the following paragraphs.

Fuchu ADWS - Commercial power serves as prime power to this facility. The commercial power is 50 Hz and is converted to 60 Hz for the ADWS by a 150 KW converter. The converters also provide a voltage buffering effect. Back-up power is provided by two 150 KW emergency generators on a two-bus arrangement. The generators are automatic start/transfer and can be switched from one bus to the other. Power panels serving the ADWS are connected to one of the buses. Power distribution to the ADWS is by a 75-foot underground cable. There is a dedicated feeder from the converter to the ADWS.

Clark ADWS - The prime power is commercial and is supplied by the National Power Company (NPC). The technical load and utility load each have a separate receiving transformer rated at 150 KVA. Back-up power is provided by a 150 KW emergency generator with a manual control unit for the utility load and a 175 KW emergency generator with automatic start/transfer for the technical load. These two services are tied via a normally open circuit breaker. The technical load and utility load have their own distribution power panel. The technical load has 200 percent back-up power available. Power distribution to the ADWS is by feeder 1309. Other major consumers on this feeder include base data automation, base photo lab and 13th AF complex. The automatic transfer panel is becoming difficult to support and is programmed for replacement. A significant deficiency is the primary distribution system because of its age. This will be addressed by a contracted project to establish a critical feeder (No. 1315). Work is scheduled to be completed in June 1977. However, the project will be accomplished with major sections of two existing feeder systems which are old and in slightly less than fair condition. Power for the critical feeder will be base generated. However, the base power plant is presently insufficient to carry all base loads during commercial power outages and contains several old and difficult to support prime movers. The situation will be further compounded as base power will be called upon more and more to make up the difference between the required base loads and the maximum power which can be supplied by the NPC.

Historically, this has been the case and it is expected to get worse based on indications by NPC officials.

Croughton ADWS - Primary power is provided by 350 KW, 480 VAC, White Superior diesel generators. One generator provides the prime power while a second is a "hot-running" back-up (sharing the load) and a third is in PMI status. There is approximately 35 yards distance from the power plant to the transformer vault underground to substation distribution panels. Other major power users on the feeder are the crypto room, tech control, airways, and receiver site. It is programmed to change to commercial power as prime power. Project Croughton 14-2 will provide redundant switchgear and Project Croughton 77-0022 will provide frequency converters that will be prime with existing base power used for emergency back-up.

Carswell ADWS - The Carswell ADWS has three power sources available, depending on whether it is for the tech-load or utility load.

Tech-Load - The Carswell ADWS electronic communication equipment is supplied primary electrical power by a Total Energy System (TES) consisting of two (2) natural/propane gas turbine generator sets. These generators are rated at 250 KW, 277/480 V, 60 cycles. TES power is fed from the TES power plant underground, 64 feet through 500 MCM conductors to a 225 KVA transformer (used to step down voltage to 120/208V). Power is then routed 66 feet overhead to a 1000 amp General Electric transfer and distribution panel. TES power is controlled by an 800 amp circuit breaker located on this panel. There are no other consumers on this feeder.

Utility-Load - The Carswell ADWS air conditioning system is supplied primary electrical power by commercial power. Commercial power at 7200 volts is delivered to the ADWS through an overhead 3.0 copper conductor approximately one mile in length from the main substation. Nominal regulation of commercial power is attained at the taps of three each 250 KVA and one each 225 KVA transformers located behind the ADWS power plant. At this point, commercial power is split. Commercial power is then delivered overhead approximately 15 feet to a 1500 amp circuit breaker, continuing on to power a 1600 amp Federal Pacific Electric transfer and distribution panel. Commercial power is also supplied to a 1000 amp circuit breaker where it is used as standby power for the ADWS tech load. Major consumers on the commercial feeder are (1) base supply, and (2) base exchange.

Stand-by Power - The present standby power plant configuration consists of two 250 KW White Superior diesel generator sets. These generators are manually air started. Generator No 1 is connected directly to "B" buss. Generator No 2 is connected directly to "A" buss. Both "A" and "B" buss can be tied together through an 800 amp breaker. In the event of a commercial power failure to "B" buss, Generator No 1 is started and placed on the line for "B" buss load (air conditioning). In the event of a TES and commercial power failure to "A" buss, Generator No 2 is started and placed on the line for "A" buss (computer). In the event of TES, commercial and failure of either generator, the 80 ton air conditioning unit will be placed on the line of the remaining generator with the tech (computer) load.

Upgrade Action - No modifications or upgrading has occurred within the past two to three years which contributed to system operational efficiency. Modifications planned in the future which will contribute to system operational efficiency are: (1) installing a larger natural gas boost compressor which will eliminate continuous need for propane gas; (2) utilizing TES chilled water for facility air conditioning, thus eliminating 100 and 80 ton air conditioning units.

C. POLICIES AND DIRECTIVES.

General - The AWN is operated and maintained by AFCS. Real time management is accomplished by the Automated Weather Network Management Center (AWNMC) at Carswell AFB, Texas. The policies and procedural guidance necessary for AFCS/AWS activities to operate the USAF Automated Weather Network and its supporting systems are contained in AFCSR 105-2, Automated Weather Network (AWN) Operations and Management.

Manuals and Regulations.

AFM 88-15,[82] Air Force Design Manual Criteria and Standards for Air Force Construction, Chapter 23, Section A.

Paragraph 23-7a states "The system shall be designed and configured to provide a reliability of 99.99%. Reference MIL-HDBK-411, paragraph 4.2.2.2-d."

Paragraph 23-1 states "Justification for facility modification or upgrading will be based on operational requirements and will be determined on a case-by-case basis."

AFR 91-4, Maintenance and Operation of Electric Power Systems, AFCS Sup 1,[83] Attachment 1. Additional Operating Requirements for Operation of Emergency Power Systems Supporting Long Haul Communications, paragraph 1, states in part, that "if the primary power source is placed in jeopardy due to thunderstorm activity in the immediate vicinity or other hazardous circumstances, the emergency power system will be placed on line to support the power load and provide maximum assurance of a continuous source of suitable power."

AFR 85-17/AFCS Sup 1,[84] paragraph A1.01.

This requirement states that for long-haul power production facilities for which AFCS has operational responsibilities, including ADWS, unique mission requirements dictate a departure from normal maintenance standards and procedures for certain items of equipment different from that required by

AFM 85-17. This is to meet the requirements of MIL-HDBK-411 and AFM 88-17 which require the primary power supply, auxiliary power supply, and distribution system to be engineered and maintained to provide 99.99 percent reliability.

D. OPERATIONAL IMPACT OF POWER OUTAGES.

Background - Although neither AFCS nor AWS retain documentation establishing the original required operational effectiveness, it is currently contained in AFR 85-17/AFCS Sup 1, paragraph A1.01. The requirement is for the ADWSs to operate with an in-operation effectiveness of 99.99% and the overall AWN System standard to be 99.0%.[85, 86]

The AWN was approved and implemented in 1965. The need for improved operational capability for providing weather support was recognized in AFCS ROC 7-69, Automated Terminal Weather Dissemination/Display System (ATWDDS); TAF ROC 321-73, Automated Tactical Environmental Sensor System (ATESS); and TAF ROC 725-73, Tactical Environmental Dissemination and Display System (TEDDS). These requirements were consolidated and replaced by a single document, AFCS ROC 601-77, Automated Weather Distribution System (AWDS). This ROC also includes AWS required operational capabilities expressed in Mission Analysis on Air Force Weather Mission - 1985(U), January 1973, SECRET.[87]

All too often, requirements are obscured through generalization or through the process of consolidation as they move up higher in the management hierarchy. What is needed, in order to perform a meaningful UPS study, is to be provided availability requirement stated in other, more meaningful terms. Namely, what is the user operational impact of being denied service for 5 minutes, 15 minutes, or 30 minutes - once per day, twice a day, or more. The answers to this question have special significance in terms of short power outages. Previously, the perishability of weather data has been examined and usually identified it in terms of hours since the weather observation, and not in terms of minutes.[87] Hence, it appears that the aggregate operational availability requirement has never been substantiated in terms of short duration, loss of service periods. The following paragraphs will address this issue.

Data Delay Versus Loss - When a power outage occurs, some data will be delayed until power returns and communications are restored. Other data will be permanently lost. Between the ADWSs, data is transferred on an acknowledgement basis so that if receipt is not confirmed, the sending switch will retain the data until it is successfully transferred. Weather data inputs to the ADWSs by low speed teletype circuits are by simplex circuits. As a consequence, if an ADWS is down, the data sender may not know his transmission was not received and the ADWS may not realize that it had missed a data input transmission.

Operational Impact of a 15-30 Minute Outage - Fuchu. It is the consensus of chief weather forecasters at Yokota, Kadena, and Osan Air Bases that a 15-

30 minute loss of weather data would have a minimal impact on operations in any other than extremely adverse weather conditions. Each forecaster feels that valid operational forecasts could be developed from previously received information and local observations.[88] However, during a Fuchu ADWS outage, intercepted radioteletype weather data from Tiksi, Irkutsk, etc., would be unrecoverable; major bases and command facilities such as Kunsan, Osan, Tango, etc., would be isolated from weather teletype; weather data distribution to Northern Pacific locations would be delayed; and the primary altroute for Clark ADWS would be lost.

Operational Impact of a 15-30 Minute Outage - Clark. During an outage of this length, major bases and command facilities, such as the Joint Typhoon Warning Center, Clark AB, Nicoles AB (PAF), and the Naval Weather Service Environmental Detachments at Cubi Point and Midway Island would be isolated from weather teletype.

Intercept radioteletype data from Kuala Lumpur, Hankow, Saigon, Djakarta, New Delhi Hemispheric, New Delhi Subregional, Karachi, Hanoi, Canberra, Wellington, Nairobi, Bangkok, Tashkent, Irkutsk, Tananarive, St. Denis, Macadan, Sverdlovsk, and Khabasovsk broadcast would be unrecoverable.

All weather data in the system at the time of outage is delayed approximately 80 minutes since a reload from tape is normally required after an outage of this nature.

If the outage is shorter and does not require a reload, messages will be delayed for a lesser time. For example:

1. Four minutes commercial power outage. Facility came up on auto restart back-up generators. A total of 37 messages were delayed.[89]

2. Commercial underfrequency which lasted 10 seconds resulted in 2 minutes outage until back-up generators were operating. A total of 23 messages were delayed for 2 minutes.[90]

3. Commercial outage caused 3 minutes outage time until back-up generators were operating. There were 53 messages delayed. About an hour later, 1 minute of outage was incurred while switching from generators back to commercial power. There were 32 messages delayed.[91]

Weather data copied via CW broadcast from Nairobi, Taipei, Hanlow, Hofei, Chengtu I and Chengtu II would be delayed, depending on the length of the outage, until the single 75 baud transmitter available could transmit the delayed tapes. Important weather data for Micronesia would be delayed or possibly lost to the Joint Typhoon Weather Center.

Input only circuits must be informed of the outage through the technical control facility thus increasing the time in which data would be retransmitted from input circuits by approximately 30 minutes.

Back up support to the PMHH broadcast at Fleweacen, Guam, would be non-existent. Weather observations and forecasts for the central and south Pacific would be delayed or lost in some cases and distribution throughout the entire Pacific area for this data would be delayed. The primary altroute for Fuchu and Carswell ADWS would be lost for the entire period.

In response to a query by the Clark ADWS, the following units indicated that a 15 to 30 minute outage would have a minimal impact on their operational mission: Det 5, 1st Weather Wing CAB PI, Fleet Weather Central Pearl Harbor, NWSED Cubi PT PI, NWSED Diego Garcia and Fleet Weather Central, Guam. Those queried but not responding included: Det 2 1st Weather Wing, Andersen AFB Guam; 901 Weather Squadron, Nichols AB PI; NWSED Agana NAS Guam, and 1st Weather Wing, Nimitz Hill.[92]

Operational Impact of a 15-30 Minute Outage - Croughton. The following statement of impact will be the case after the closure of the MWRC facilities which are scheduled for the summer of 1977.

During a scheduled power outage/swap or interruption, all data intercepted from Leningrad, Moscow, Novosibirsk, Archangel, Stockholm, Alma Ata, Potsdam, Sverolovsk, Kiev Catro, Sofia, Nairobi, Tashkent, Tbilisi, Dakar, Kano, Algiers, Pretoria, and Brazzaville would be permanently lost during the period approximately ten minutes prior to the outage through approximately ten minutes following the outage. In addition, data received from uncontrolled civil broadcasts and non-Air Force loop would also be permanently lost.

Data in the system prior to the outage would be recovered but delayed accordingly. If this outage were unscheduled, the impact could be greater in that (1) not all out stations could be advised to hold data; (2) recovery of data received prior to the failure would be delayed even further due to off-line recovery techniques; and (3) the ARQ data base would be lost if the power failure caused any errors in data written to the drums or in program steps held on the drum.

All US and NATO customers in Europe, the MED, the Far East, and North Atlantic, including Lajes would be deprived of inter-intra theatre data during the outage.

At Mildenhall, there would be a serious effect on airborne aircrew service by affecting flight safety during emergencies, especially during marginal weather; also, it would create a backlog of pilots waiting to be briefed. At Alconbury, there would be a severe effect on aircraft recovery and flight safety, both here and at alternate bases, if the outage occurred during marginal weather. At Lakenheath, the most severe impact would be the loss or delay of recoverable forecasts, amendments, hourlies, and specialized products used during alerts. A missing amendment could be especially disastrous creating unhappy customers, degraded quality support and possible flight safety problems. There would be a minimal impact at Bentwaters, but numerous short outages or a prolonged outage will severely impair the ability to safely support the 81 TFW. At Pedelli, solar events requires immediate notification.[93] Any response with a time delay of five minutes is considered excessive.

Operational Impact of a 15-30 Minute Outage - Europe. The following information was provided by the 2d Weather Wing.[94] During routine operations, a 15-30 minute outage would have minimal impact at most units. The actual seriousness of the outage would be dependent on the weather conditions, frequency and time of occurrence, the unit's mission, theater situation and the availability of weather data from other sources. In some cases, units have access to data from indigenous sources. Units which would be more seriously effected are the two solar observing units which have a requirement to report solar flare data within five minutes of observation to AFGWC. This data is used to support DOD communication, surveillance and space system operations. The actual impact of the delay of this data would have to be obtained from the end product users who are supplied this information from the AWN. Delay of weather support provided to the US Army to support border surveillance could have a significant impact. These units require timely data to assist in preventing a boarder overfly during marginal weather conditions.

Operational Impact of a 15-30 Minute Outage - Carswell. During the period of the outage, AFGWC will be denied all weather data. This is an especially severe impact since intercept data cannot be relayed from overseas ADWSs. The overseas ADWSs, AFGWC and the Monterey FNWC will hold data during a Carswell outage because of the ACK-NAK interface. Recoverability of data from other sources can be summarized as follows (listed in order of importance):

(1) Suitland National Meteorological Center will hold data for up to eight hours automatically.

(2) Braniff (South American Data) will begin holding data after telephone notification.

(3) FAA Kansas City WMSC will hold data until 58 minutes past each hour if a telephone call to FAA can be completed.

(4) AUTODIN traffic from the Tinker ASC can be held indefinitely after completion of a telephone call.

Controlled circuits (Carswell polled - COMEDS, Alaska, North Atlantic, etc.) will not receive any data during a Carswell ADWS outage. This would impact the flying mission at every AF base in the Western Hemisphere and have a similar impact on other military and civilian installations. Additionally, they cannot transmit during an outage. Their data must be manually held until polling resumes. Uncontrolled input circuits (Argentina FAA Diamondhead, Rewarc, Miami Hurricane, Pacific NOTAM, Cape Canaveral, Abino, Great Lakes) would continue transmitting during an outage and their data lost. A verbal request for retransmission could recover this data but with additional delay. All Alaskan intercept data (copied from Khabarovsk, a DOD priority 1-1 target) is lost and unrecoverable. The following other mission support customers would be denied service during a Carswell ADWS outage: Navy fleet broadcasts, AFTAC, Army Atmospheric Science Laboratory, Cheyenne Mountain Weather Support Unit (WSU), TAC WSU, Chanute Tech Training Center, AFCNF, Olathe Kansas ARTCC, the Holloman and Falehla Solar Observatories and any exercises in progress. It should be highlighted that the AF world-wide collection and dissemination of NOTAMS would cease during a Carswell ADWS outage. Output data to all Carswell ADWS customers is delayed at least twice the computer outage time. This may be longer if severe weather is experienced concurrently. A nine hour delay in weather data removes its operational value and it becomes only historical.

Operational Impact of Outages - AFGWC. The capability of the AFGWC to meet users' time requirements for information is directly related to the processing time, i.e., the period from the time AFGWC receives a request until it is transmitted to the customer. Also, it is dependent on the allowable time between observation and when it is entered into the data base. The apparent impact of a 15-30 minute outage can be misleading because the effect of a computer disruption is "snowballed" up and down the line. Thus, a 30 minute power outage at the Carswell ADWS could cause the AFGWC applications programs to be up to two hours and twenty minutes late and cause the cancellation of low priority products. Some of the requirements are as follows: MAC needs computer flight plans within one hour of the time ordered; SAC requires the command post displays in near real time; SESS data (solar information) is required within two minutes; there are Special Strategic Program (SSP) requirements; and the following required WWMCCS response times.[95]

1. Query/response for observations, terminal forecasts, point warnings, and selected products in the WWMCCS data base - 30 seconds.

2. Criteria checked observations and forecasts - 5 minutes.

3. Dynamic criteria update - 1 hour.

4. Routine routing of observations and forecasts - 5 minutes.

5. Routing of selected routine products - 5 minutes.

6. Request for displays not available in the WWMCCS data base - 30 minutes.

E. POWER OUTAGES.

General - The power outage data was taken from the CSV DO(D)7109 Daily

AWN Operator Summary; CSV DO(M)7109, Monthly AWN Monthly Operations Summary; and extracts from station logs. The difference in power configurations between stations and the various methods of recording information in stations logs has necessitated summarizing station outage data in different formats. In addition, there are some apparent inconsistencies between the 7109 reports and the information supplied by the logs because of the differences in reporting criteria. Therefore, the precise numbers are not as important as the relative magnitudes and distributions of the outages.

Fuchu - The Fuchu ADWS experienced six power outages in 1975 (Appendix B-1) of which five were due to a loss of commercial power and one was a faulty circuit breaker in tech-control. These outages resulted in 11 minutes loss of operational time. Although there was only a total time of about 11 minutes when the commercial power was not available, the generators were run longer (14 hours 34 minutes) to insure that the commercial power had stabilized. The generators were also used twice, for a total of 41 hours 45 minutes, as a precaution against a possible outage due to a typhoon. In 1976, there was a total of eight outages which resulted in a total loss of ADWS operational time of 6 hours 46 minutes (Appendix B-4). In comparison to operational outages due to other reasons, power accounted for 2.9% of the total number of outages which resulted in 38.5% of the loss of operational time (Table V-1).

Clark - For a 12½ month period (Appendix B-2), Clark experienced a total of 157 power outages and fluctuations. This resulted in the backup generators being used 47 times. Not readily apparent in these numbers is another 47 times an outage occurred while switching back to commercial power from the generators. A total of 8 hours 14 minutes ADWS operational outages were incurred and the generators were operated for 204 hours 07 minutes. During CY 76, 111 of the 118 power outages were due to a commercial power outage (as shown by 7109 reports summarized in Appendix B-4). Power outages accounted for 26% of the total number of outages for all reasons and 35% of the ADWS operational outage times for all reasons (Table V-1).

Croughton - For CY 76, six power outages were experienced which resulted in a cumulative operational outage of 4 hours 26 minutes (Appendix B-6). Power outages accounted for 2.4% of the total number of outages for all reasons and 37.8% of the operational outage time (Table V-1).

Carswell - For CY 76, two power outages to the tech-load were experienced which resulted in a cumulative operational outage of 32 minutes. For these instances, generators provided power for a total of 24 hours 20 minutes (Appendix B-3). It should be noted that normally two TES turbines are operating in parallel so that if one fails, there is no outage. The non-tech load, normally on commercial power, was switched to generator back-up power 23 times. This resulted in 29 hours 40 minutes of generator operating time because of the commercial power outages, and 62 hours and 43 minutes as a precaution against thunderstorm activity. All categories of power outages accounted for 1.2% of the total number of outages and 33.3% of the operation outage times (Table V-1).

TABLE V-I

ADWS

SUMMARY: STATION OUTAGES 1976
(# Outages/Minutes)

	CARSWELL	CLARK	CROUGHTON	FUCHU
Environment (Not Power)	4/291	5/276	6/41	0/0
Power	10/284	118/385	6/266	8/406
Equipment	296/196	34/133	22/83	54/149
Other	356/54	247/252	128/147	149/410
Program	196/27	49/53	90/166	66/90
Total	862/854	453/1099	252/703	277/1055
% Due to Power $\left(\frac{\text{Power}}{\text{Total}} \times 100\right)$	1.2/33.3	26.0/35.0	2.4/37.8	2.9/38.5

F. EFFECTS OF POWER OUTAGES/QUALITY.

Each ADWS is comprised of a computer, its peripherals and communication interfaces. A sudden power loss, reapplication or other power aberrations may cause interruptions to system operation, data to be lost or even equipment damage under certain situations. Hence, not only is equipment performance affected, but cost of maintenance for the equipment in terms of manpower and parts. The following paragraphs concern these problems as experienced at some of the ADWS. They are examples of what is typically encountered.

Fuchu - In February 1975, a 29 minute commercial power failure due to unknown trouble at Kitatama substation occurred. Although 60 Hz power was restored on back-up generators, the 50 Hz generator was not immediately started. Later, a problem was experienced with a circuit breaker in attempting to switch back to commercial power. As a result, the temperature to the computer drums cooled and was out of tolerance. Although the computer was reading into the FH 880 drums, it was not into the 330A and B drums. Repeated efforts to bring up the 330 drums failed. A UNIVAC maintenance man was called. He noted that the UNIVAC Manual states that if a 330 drum has a complete stoppage, it takes approximately two hours to power up and bring the temperature up to operational capabilities and bring the revolutions up to operational limits. It was 6 hours 7 minutes after the initial power outage occurred before the system was operational and another 43 minutes before maintenance could restore operation on the one 330 drum which had remained inoperative. (See Appendix B-6 and B-7 for additional details.)

On 1 Jan 77, a one minute commercial power outage resulted in a 37 minute switch outage. After power was restored, the operators powered up all the equipment which was on line at the time of the failure. However, the FH 880 drum remained in fault condition due to out of tolerance drum temperature and speed. (See Appendix B-8 for details.) On 10 Jan 77, a "one-second" power fluctuation was experienced which resulted in the U413 CPU halting after a series of attempts to read program to core from drum, a power up procedure restored the drum. Total switch downtime due to the power fluctuation was 10 minutes. (See Appendix B-9.)

Clark - A power outage requires that all equipment be reset. If it is very long, the 880 drums loses speed and the temperature drops, the amount depending on the length of outage. Temperature and speed must be restored to normal before it can resume operation. It takes approximately 30 minutes to bring a drum to normal operating temperature after a 30 minute outage.

Normally, power fluctuations or outages do not cause damage to drums. However, it does increase the likelihood, because each occurrence makes it necessary to raise the heads and not lower them until the power has been restored and stabilized. Under certain conditions, this process results in a head crash which causes damage to drum tracks, which means that other undamaged tracks must then be used. For example, currently the "A" 880 drum has no tracks available out of an original 80 spare tracks. The loss of spare tracks were caused by power disruptions related head crashes. As a result, the Clark ADWS is obtaining a replacement drum from the Croughton ADWS. Although protective fuses minimize damage to the equipment, it still occurs. It is estimated that drum life has been decreased by one-half due to power problems at this ADWS.[96] More recently, an example of the power problem occurred on 2 Mar 77 at 0826Z, when a base-wide power fluctuation occurred which caused the ADWS auto-start generator to come on line. Everything worked and at 1120Z, the ADWS tried to manual switch back to the commercial power. This procedure requires a manual restart of the systems and a resultant two minute operational outage. At 1139Z, it was determined that the drum could not be cleared. The other system could not be used because the "A" drum had been previously logged red. As a result, UNIVAC maintenance was notified and, after lengthy and complete troubleshooting, the drum writer boards were found bad and replaced at 1655Z to restore operations. Operational outage duration was 5 hours 30 minutes.[97]

Carswell - The UNIVAC Computer Systems Handbook, MA 1380, emphasizes that the computer power source must be void of variable loads from other sources. It also states that the computer DC power supplies cannot tolerate any break in power. But if a motor-generator is used, providing protection for approximately 200 millisecond, power breaks can be tolerated.

Testing and experience has shown that the drums are most sensitive to frequency variations which should be kept within ±0.25 Hz of the 60 Hz nominal. The rest of the system can withstand ±0.5 Hz variations.[98]

The UNIVAC FH1782 and FH432 drums spin at high speed during normal operation. The longer the power outage, the more the drums will slow down and a corresponding longer time will be required to bring them up to speed. If they come to a complete stop and cool to room temperature (40 minutes), the UNIVAC maintenance handbook for FH1782 and FH432 drum subsystems (HB 1680 and HB 1679) states that an hour is required to restore them to operation. The remainder of the installed UNIVAC 1108 computer system is less sensitive and is operational several minutes after power is returned.

Local procedures require UNIVAC maintenance to restore the system from a power outage. The maintenance contract provides for on-call response of one hour during the principal period of maintenance (0800-1700L Monday-Friday) and "best effort" any other time. This means that powering up the system cannot begin until UNIVAC is on site.

G. SYSTEM PERFORMANCE.

Carswell is the communications hub of the AWN, feeding all input data to Offutt AFGWC where it is processed. The information products are then distributed back through Carswell to the users. Thus, system outages may affect the time flow of information in either direction. One indicator that can be used to gauge system performance is the average daily percent availability between Clark, Fuchu, Croughton and Offutt. This is depicted in Figure V-3 which shows availability for Clark-Offutt as 99.01%, Fuchu-Offutt as 99.02%, and Croughton-Offutt as 98.17%. Also shown are the average daily outages for each switch (power shown separately) and the communications between the switches. Several conclusions can be drawn from this information. In every case, the communications outages between switches exceed that of any of the switches. In particular, the Croughton-Carswell link had an average daily outage of 16.37 minutes compared to the others which were 3.15 minutes, 3.14 minutes, and 5.73 minutes. Clark had the highest average outage time. This was 3.01 minutes of which 1.05 minutes was due to power outages for all reasons. It should be noted that these power outages are defined as operational outages due to power problems and does not reflect the duration of prime power outage because backup generators are placed on-line to end the power outage when prime power is lost.

The impact on availability by adding UPS would be minimal. For instance, based on the information in Figure V-3, and using Clark to Offutt as an example, adding the Clark and Carswell station outages and the Clark-Carswell and Carswell-Offutt IST average daily outages, the total is 14.22 minutes average daily outage or an average daily availability of 99.01% (close approximation owing to the use of averages). If we assume perfect power (no outages), the total average daily outage becomes 12.39 minutes and the availability improves to 99.14%. In other words, it increases 0.13%. UPS provides clean power and, because the ADWS is computer based, it is possible that there might be a reduction of station outages due to "other" reasons. However, this cannot be substantiated by hard data.

The impact on end-to-end performance, as shown in Figure V-3, if the Carswell TES is replaced with commercial power without UPS, may be significant. For instance, the TES provided reliable, stable power and was credited with only one total failure in 1976, which accounted for 32 minutes outage. As an indication of commercial power reliability, the Carswell non-tech load had to rely on back-up generated power five times in 1976 because of commercial power failures. Assuming 30 minutes of switch outage for each commercial failure (minimum estimated time required to restore system operations), the systems best case performance (no power outage) for each end-to-end link would decrease by 0.23%. As a result, each of the end-to-end percent availability figures shown in Figure V-3 would be below 99.0% availability.

H. ECONOMIC CONSIDERATIONS.

Carswell TES Costs - The TES is maintained by contract with the Air Research Manufacturing Company of Arizona, a division of the Garrett Corporation at a cost of $114,000 annually. In addition, the TES (gas turbine) uses natural gas, but propane gas must be used to supplement the natural gas

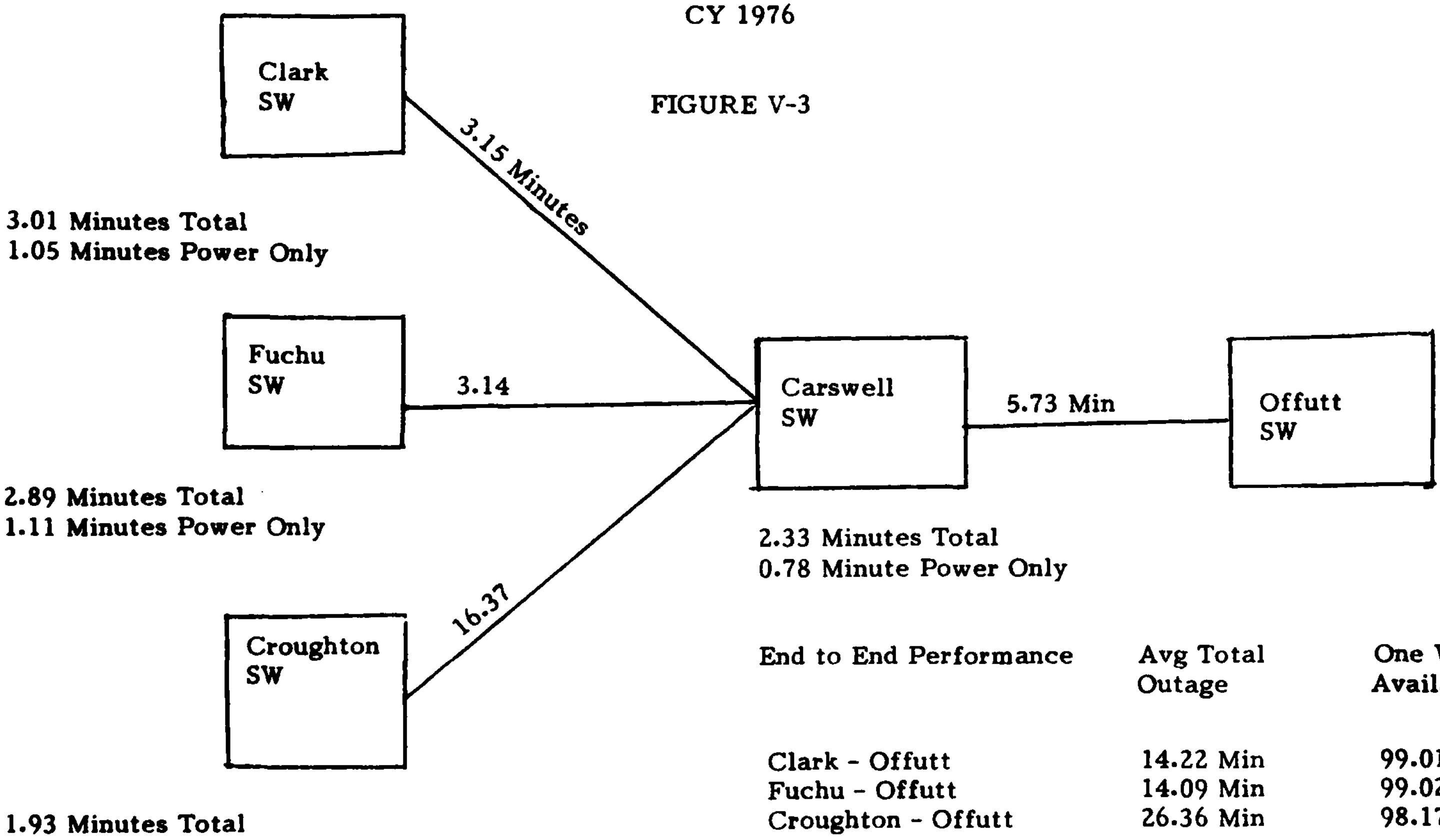
ADWS

OUTAGE SUMMARY

DAILY AVERAGE

CY 1976

FIGURE V-3



End to End Performance	Avg Total Outage	One Way % Availability
Clark - Offutt	14.22 Min	99.01%
Fuchu - Offutt	14.09 Min	99.02%
Croughton - Offutt	26.36 Min	98.17%

pressure. The pressure must be maintained from 17 PSI to 22 PSI for the operation of the natural gas booster pump which must boost the operating pressure to approximately 120 PSI. This consumes approximately 140 gallons of propane daily at a cost of $0.30 per gallon.[99] Currently, the cost of propane is $0.31 per gallon and is expected to increase because of the "energy crisis". Unofficially, it has been reported that the pressure of natural gas is expected to reach new lows this summer which means that the consumption of propane would correspondingly increase. During FY76, the TES used $70,000 in natural gas and $25,000 in propane for a total of $95,000 in TES fuel costs. Therefore, the annual cost of the maintenance contract and fuel for the TES is $209,000.

Commercial Power Cost - The metered technical load of the TES is 130 KW.[100] In addition, the ADWS must have air conditioning which is supplied by a 100 ton air conditioner. As a part of this unit, there are four compressors. Depending on the outside/inside temperature differential, these will be cycling at a different rate, hence drawing different amounts of power. However, on the average, they require about 105 KW. (The actual range based on a May 76 survey was 50 to 200 KW.) Therefore, at a commercial power cost of 1.76 cents per KWH, the cost for the technical load is $20,043 annually. The total power cost for both the technical load and utility load is $36,230 annually. If SSUPS were installed, there would be a somewhat greater power requirement due to the heat from the SSUPS which should be removed by air conditioning. Based on 130 KW technical load, an additional $5,319 annually is required for air conditioning.

Manpower - The ADWS power production function is authorized ten 543X0 manpower spaces. This provides a manning of two persons at a time on a 24 hour per day, 7 days a week basis to provide the maintenance and response to bring up the back-up manual start generators as required. There is a range of power configurations which might be applied to the ADWS, each affecting the manning. There are also other possible manpower arrangements, but all are contingent on factors such as the operational requirement and the maintenance concept for UPS. Currently for the authorized manning levels, the ten positions cost is $98,750 per year.

Cost Differential - The cost differential between TES power and commercial power (per previous paragraphs) is $172,770 annually excluding potential manpower savings.

Other Factors - There are other factors and considerations which would have varying effects on the overall cost differential.

The ADWS computer maintenance contract with UNIVAC falls under the purview of items 132-1 and 132-11 of GSA Contract No GS-00C-00932. This stipulates the prime period of maintenance as 0800-1700L, Monday through Friday, for which no additional charges are incurred. (Maintenance FY 77 will be $266,000 excluding overtime.) However, if the UNIVAC maintenance man is called in to bring up the system after an outage, the overtime maintenance charge is $55.00 per hour with a minimum of $55.00 charge per occurrence. The maximum charge is $275.00 per occurrence, and even though the TES power is very reliable and stable, there still have been outages. Although the breakout by reason is not available, there has been $49,188 expended on overtime from when the TES was installed in 1 Jun 70 through FY 76.[101]

It is possible to modify the TES to reduce its cost of operation. This could be accomplished by modification to the TES natural gas booster compressor so it could operate with lower natural gas pressures (10 PSI has been suggested as the lower limit as opposed to the present 17 PSI). This would eliminate the necessity of using propane as a supplemental fuel, but would correspondingly increase natural gas consumption. However, due to the price differential in the fuel costs, a net savings would result.

Before all UPS procurement was suspended, approximately $49,000 was spent on an UPS room and $165,000 on a new air conditioning system. These are sunk costs which will not have to be incurred again if UPS is to be installed. In general, then, getting rid of the TES and placing the technical load on commercial power would save about $189,000 annually. If an UPS were installed, depending on its efficiency, the savings would reduce to about $183,000 annually. Although there are no cost considerations which are enough to amortize the initial cost, there are potential savings due to the power conditioning benefits of UPS.

Clark - Commercial power is being used for the Clark ADWS technical and utility loads. If a SSUPS were to be installed with an efficiency of 88% and a technical load of 130 KW is considered, then 148 KW must be supplied. This is 18 KW more which must be purchased. However, the 18 KW inefficiency results in heat which, although not essential, should be removed. Considering air conditioning inefficiency, this will require about an additional 27 KW of electricity. Therefore, the total increase in required electricity is about 45 KW.

It should be noted that the cost of a new 880 drum is $85,165 and the cost of a rebuilt drum with exchange is $19,000. There have been two drums replaced at Clark. It cannot be definitely proven that power problems caused the drum damage, but Clark personnel are highly suspicious that they did.

Under a previous UPS scheme which was cancelled, a special room was built and another back-up generator was installed. This was a new 160 KW Wakashaw equipped with manual start and transfer. Therefore, the physical facilities do exist if a SSUPS were to be installed. Accordingly, this is not a cost which would have to be included.

It is anticipated that manning levels would probably remain the same.

Fuchu - Commercial power at Fuchu is 50 Hz. This supplies the air conditioning power directly and is converted to 60 Hz for the 80 KW technical load by a 150 KW converter. If a SSUPS were installed, the converter would not be needed. The efficiency of converter is comparable to the SSUPS. Therefore, the SSUPS would result in a higher annual cost only because of the air conditioning requirement. Based on an UPS efficiency of 88% and a technical load of 80 KW, 11 KW in heat would be generated. Based on air conditioning efficiency, about 16 KW additional electric load would result which would cost an additional $6,300 annually.

Croughton - It is already planned to change to commercial power. Included will be the cost of a frequency converter for the ADWS. If SSUPS were installed, the frequency converter would be unnecessary.

Other Factors - There are other factors which affect cost of the various power configurations which might be applied at each site. For example, some sites have existing physical space for UPS and others do not. In addition, the manning criteria for UPS plus back-up generators has not been decided and, even so, is subject to operational requirements.

I. SUMMARY.

The computerized Automatic Digital Weather Switches (ADWS) form the backbone of the Automated Weather Network (AWN). The system availability objective is 99.0% and the station power objective is 99.99%. Of particular significance in system engineering is the number of outage occurrences and duration of each which can be tolerated before the mission is adversely impacted. Based on the information received, it appears that an occasional 15-30 minute outage can be tolerated at Clark and Fuchu and less than five minutes at Croughton. Because Carswell is the hub, its requirement is greater than any single other switch.

None of the four ADWS stations met the objective power availability of no more than 53 minutes outage (99.99%) per year. Carswell, Clark, Croughton, and Fuchu each had respectively 284, 385, 266 and 406 minutes of operational outage due to loss of power. In each case, this accounted for about one third of the total station outage time. The site experiencing the greatest number of power outages was Clark, in 1976, when it had 118 outages. The effect of power outages on the system performance are greater than may be apparent from examining only their duration. This is because power outages often cause a memory loss which means that additional time is required for a memory reload and verification. Also, if the outage was long enough, it can take up to two hours to bring the drum temperature and speed up to operational specifications. Power outages have also been credited with equipment damage in some cases. Outages also affect the operational traffic. Traffic can be delayed depending on the outage length, time to reload the memory, if necessary, and backlog. Low speed traffic can be lost but is normally recoverable by requesting a retransmission of all traffic which may have occurred during the outage, except that data intercepted from foreign sources is normally totally lost.

SECTION VI

AUTOMATIC DIGITAL NETWORK (AUTODIN)

A. SYSTEM DESCRIPTION.

The Automatic Digital Network (AUTODIN) is a switched network of the Defense Communications System (DCS). The AUTODIN functions as a single, integrated, world-wide, high speed, computer-controlled, general-purpose communications network, providing record communications service to the Department of Defense (DOD) and other Federal Government agencies. The AUTODIN consists of all AUTODIN Switching Centers (ASC's) and all terminal stations connected thereto. This secure, fully automatic switching network is designed, and programmed to provide continuous operation, minimal loss of service and no loss of traffic. There are 17 ASC's in the AUTODIN; nine in the CONUS and Hawaii and eight overseas. The eight Air Force centers operated by AFCS are located at Norton and McClellan AFBs in California; Tinker AFB, Oklahoma; Gentile AFS, Ohio; Andrews AFB, Maryland; Clark AB, Philippines; RAF Croughton, United Kingdom; and Camp Drake, Japan. The U.S. Army centers include Ft Detrick, Maryland; Hancock, New York; Pirmasens, Germany; Coltano, Italy; Ft Buckner, Okinawa; and Taegu, Korea. The U.S. Navy operates the Albany, Georgia; Wahiawa, Hawaii; and Finegayan, Guam ASCs. Figure VI-1 depicts the ASC locations.

B. POLICIES AND DIRECTIVES.

Allied Communications Publication (ACP) 121/US Sup-1(E) was developed under the direction of the US Joint Chiefs of Staff and is promulgated for guidance and information of the Armed Forces of the United States and other users of U.S. military communications facilities. Paragraph 331b depicts the Speed-of-Service (SOS) objectives that apply to the total elapsed communications handling time from the time of file at the message originator's telecommunications center/communications terminal (TCC/CT) to the time available for delivery at the addressee's TCC/CT.

Precedence	SOS Objective
Flash	As fast as possible with an objective of less than 10 min.
Immediate	30 Minutes
Priority	180 Minutes
Routine	360 Minutes

While message Speed-of-Service does not directly equate to system availability thresholds, it is a major factor in the final determination of system and facility performance indicators.

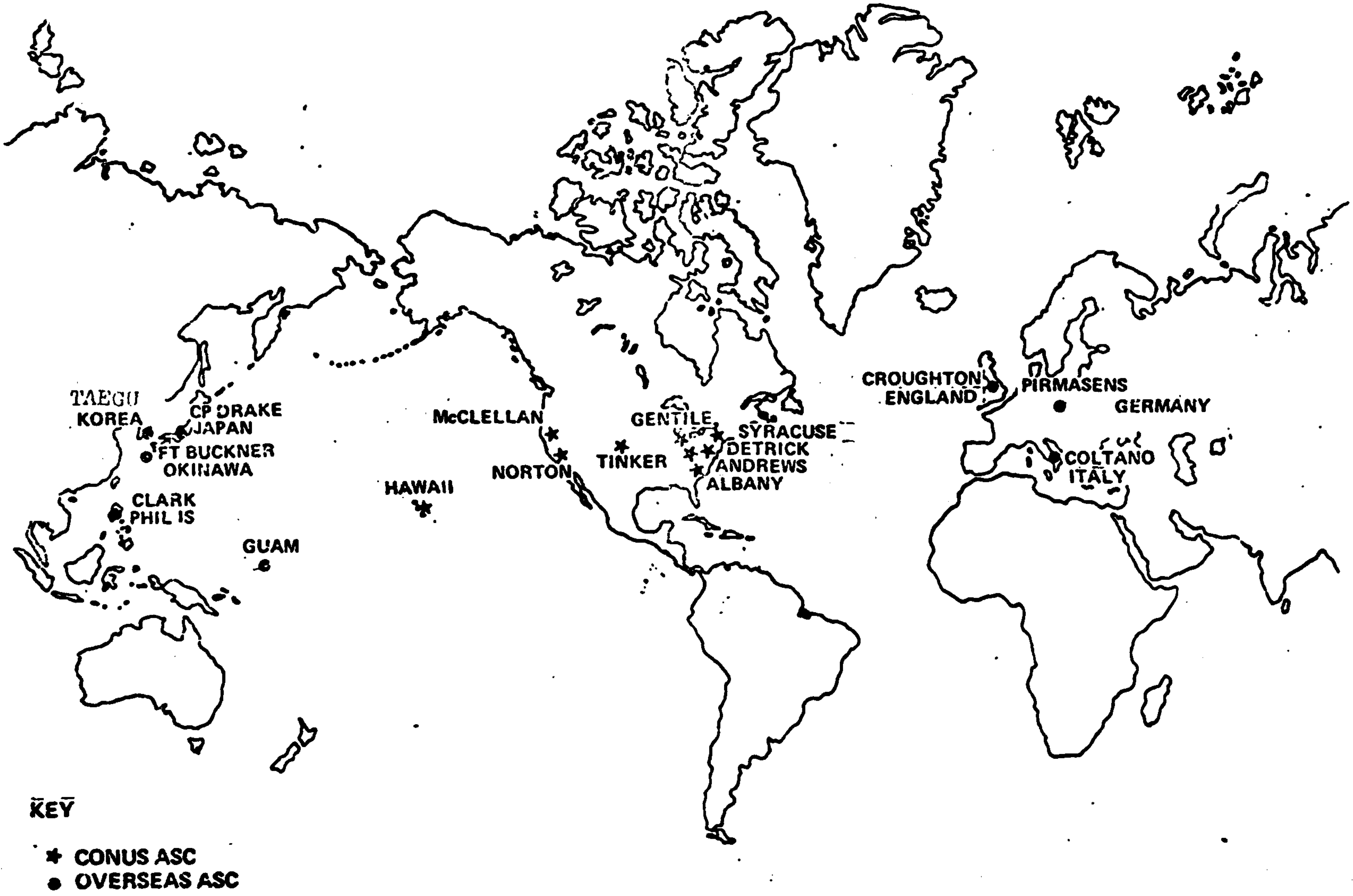


FIGURE VI-1. AUTODIN SWITCHING CENTER LOCATIONS

DCA Circular 310-130-2[76] disseminates Defense Communications System (DCS) management thresholds and is applicable to activities of the Department of Defense responsible for the operation and maintenance of or deriving service from elements of the DCS. The following management thresholds have been established:

(1) AUTODIN System Efficiency: 99.5%

(2) AUTODIN Switching Center Efficiency: 99.5%

(3) AUTODIN Tributary Efficiency: 95.0%

MIL-HDBK-411[79] was developed by the Defense Communication Agency in accordance with the Defense Standardization Program. It provides consideration for use in the design, installation and acceptance of power and air conditioning subsystems for Department of Defense long haul DCS communication facilities. Paragraph 4.2.2.2.d. states that the primary power supply, auxiliary power supply and distribution system shall be engineered to provide 99.99% availability (exclusive of scheduled outages) to the technical load bus and not in excess of 53 minutes total outage during any one year.

AFR 91-4[78] outlines the policy, responsibility and technical standards for the maintenance and operation of electric power systems in the Air Force.

DCA Circular 600-60-1[102] provides a guide for preparing and reviewing cost estimates and economic analysis of DCA-managed systems, programs and projects. It presents DCA cost data, planning factors, estimating procedures, methods and formats related to communication systems planning, programming, budgeting and program evaluation.

DCA Circular 350-195-2[77] establishes operational responsibilities for periodic exercising of DCS station auxiliary electric power systems.

C. POWER CONFIGURATION DESCRIPTION.

The AUTODIN Switching Centers (ASCs) have two distinct configurations: CONUS and overseas. Correspondingly, the power requirements are distinct and two different power generation and control configurations exist. Within these two configurations, minor local variations may occur.

CONUS ASCs - The primary power source is commercial power with diesel engine-driven generators providing a secondary/back-up source. A typical secondary power source consists of three 440 KW diesel engine-driven generators. Two are required for on-line support with the third one in standby should one of the two on-line generators fail. In addition to the back-up generators, two 220 KW Uninterruptible Power Supplies (rotary flywheel) are provided at each ASC. (See Figure VI-2.) These units support only the modem, tech control and cryptographic equipment. A typical UPS (rotary flywheel)

CURRENT
CONUS ASC POWER CONFIGURATION

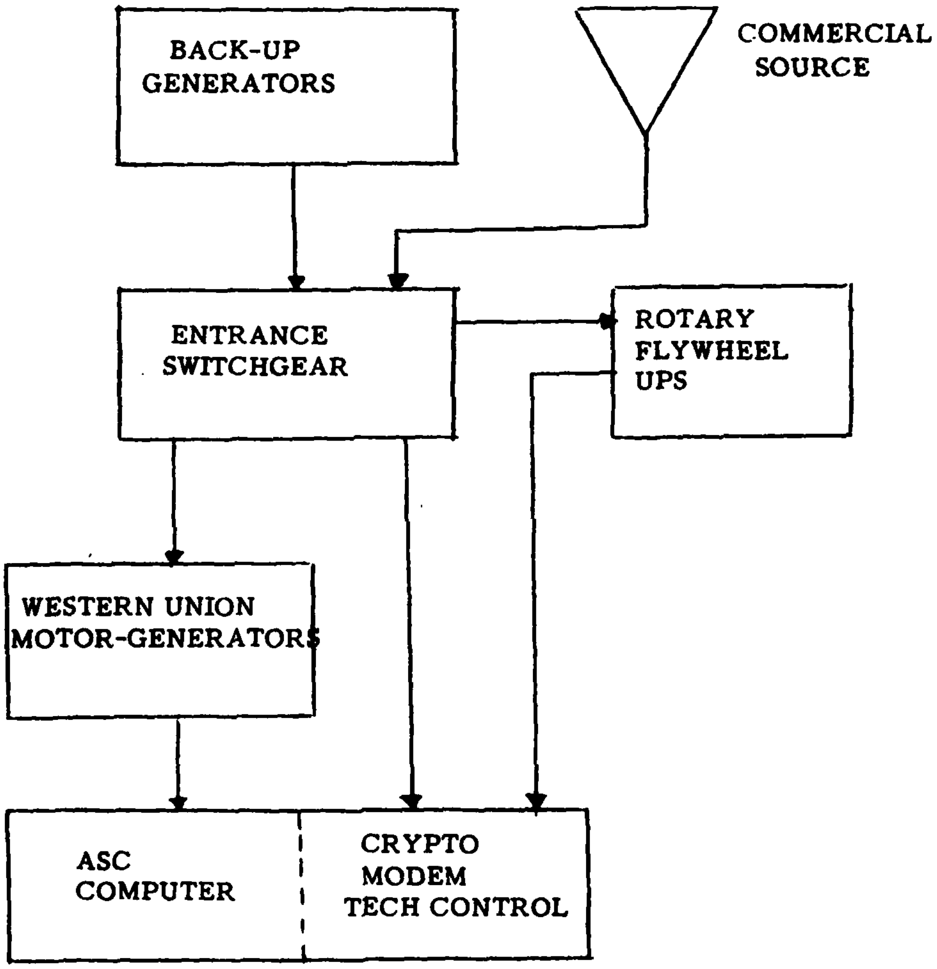


FIGURE VI-2

consists basically of an AC motor, generator and flywheel, on a common rotating shaft, coupled to a diesel engine through an automatic clutch. This type of UPS provides prime power/load isolation with transient protection on a continuous basis and maintains the continuity of power to the technical load upon short interruptions/fluctuations of the prime power source. However, the computers in the CONUS ASCs are not supported by the UPS. At each facility, the computers are supplied power from five motor-generator units (leased from Western Union) and are used only as buffers to provide prime power/load isolation with transient protection. (Note: These units serve no other purpose and could be deleted upon installation of a UPS sized for the station technical load.)

Overseas ASCs - Overseas, commercial power is the primary source with diesel engine-driven generators providing a secondary power source. The primary or secondary sources provide power to the UPS subsystem consisting of five DC motor-driven AC generators (rotary UPS) and a solid state UPS. (See Figure VI-3.) The rotary UPS consists of two DC power supplies (rectifiers), a battery facility, five DC motor driven AC generators and associated controls and switch gear. Each DC power supply is able to provide power for the motor-generators and simultaneously charge the battery facility. The battery facility consists of 120 2.2 volt cells connected in series and is capable of providing power to the motor-generating units for 15 minutes in the event of a primary or secondary power source failure. Each motor-generator is capable of providing 50 KW of AC power. Three units are operated in parallel to provide power for the average ASC load. The other two units are maintained in a standby status to assume a load upon failure of any of the on-line units. The solid state UPS (commonly referred to as the UPS bypass) consists of a solid-state rectifier/charger and a static frequency inverter with controls and switch gear. The rectifier/charger converts the three-phase AC primary or secondary input power to DC voltage and the inverter converts the DC voltage into a three-phase AC output. Upon a primary or secondary power failure, the inverter is powered from the battery facility.

Since the supportive power requirements for the CONUS and overseas ASCs differ, the power techniques for each will be addressed separately.

CONUS ASCs

Known/Anticipated Primary Power (Commercial) Outages/Fluctuations: Upon any known/anticipated primary power outage, the station resorts to backup power until the primary power source stabilizes. Experience has shown that commercial power is adversely affected during periods of severe weather turbulence. In such situations, it is standard operating procedure (SOP) to go to backup power before the severe weather results and to continue on backup power until the weather conditions improve (AFR 91-4/AFCS Sup 1).[83] Normal procedure is for the base weather station to alert the NCMO of all severe weather warnings. The NCMO then relays the information to all concerned. This procedure also applies when commercial power interruptions are scheduled.

OVERSEAS ASC POWER CONFIGURATION

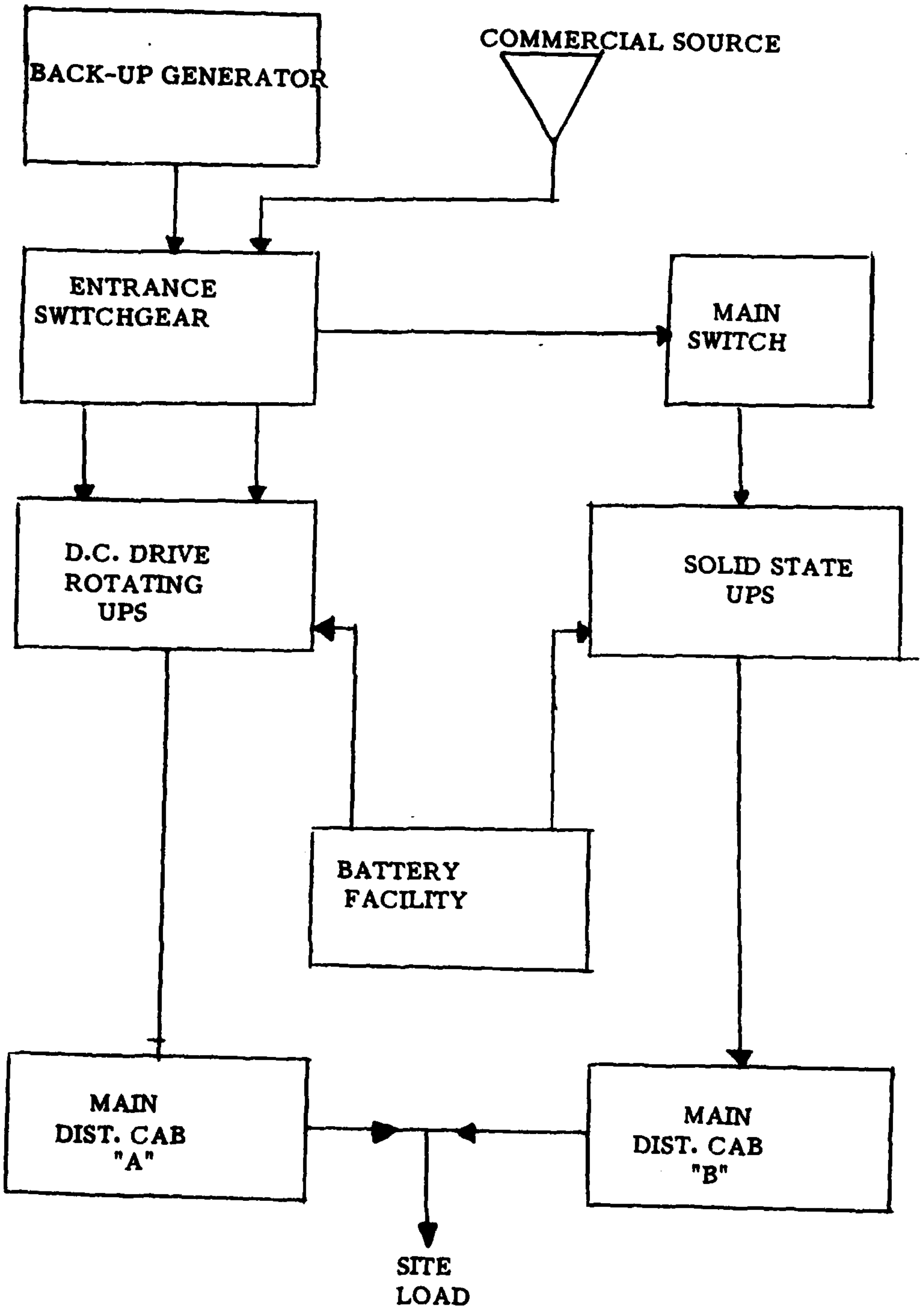


FIGURE VI-3

Figure VI-4 lists the events and time the back-up power source was utilized because of inclement weather. For 1976, the back-up generators were used a total of 257 times for 1,976.2 hours of operation, i.e., 7.7 hours/turn-on. Figure VI-4 graphically portrays the increased usage with the onset of the rainy spring and summer seasons. It should be noted Gentile contributed over half (151 compared to 257 total) of the number of turn-ons, possibily indicating an extra cautious concern over power fluctuation effects or higher incidence of inclement weather conditions.

Unscheduled Primary Power (Commercial) Outages/Fluctuations: Unscheduled power outages/fluctuations of 41 milliseconds (2.5 cycles) or greater will result in a facility outage since power for the computer and computer-associated devices does not come through the rotary UPS. Normal procedure is to restore the facility on back-up power until the primary power source stabilizes. Since modem, technical control and crypto are supported by the rotary UPS, all circuitry remains up and is restored to service as soon as the computer is made available for on-line operation. The minimum restart time for the computer without reloading is 15-20 minutes and 30-50 minutes should the computer require reloading. Figures VI-5 and 6 list CONUS ASCs power outages for the year 1976 by system and by site. On the average, each power outage lasted about one hour. There were about six outages per year per site. Except for an anomaly in December, the number of outages seem to follow the inclement weather pattern. Most outages were less than 30 minutes long; the distribution generally followed that experienced by industry and as reflected in the open literature.

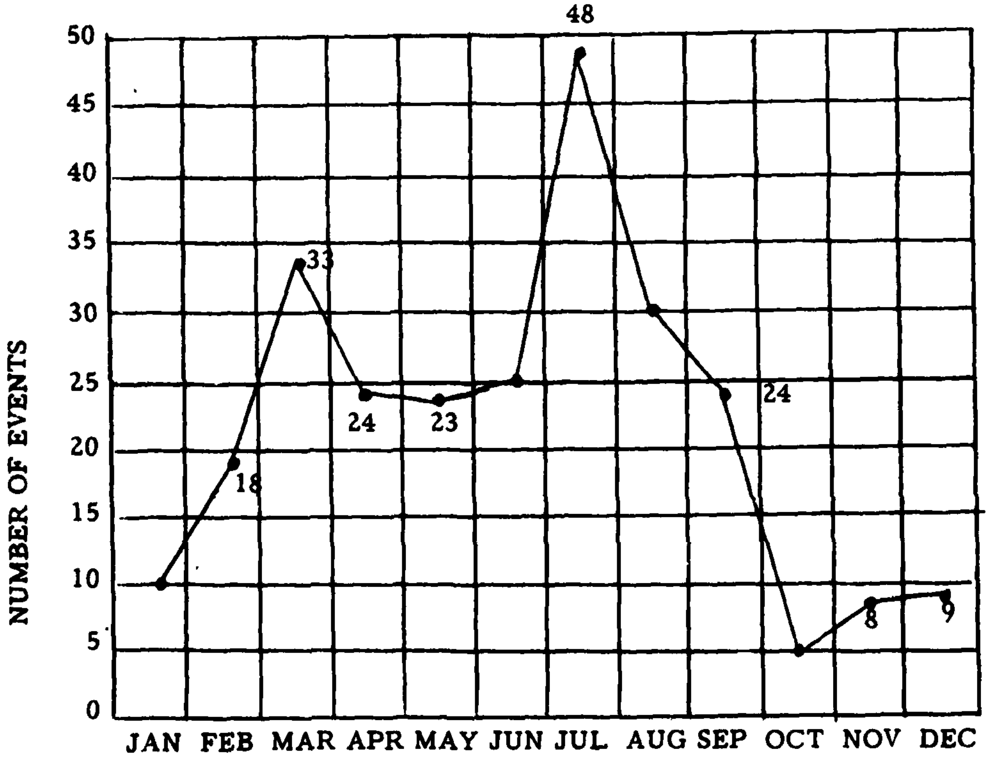
Loss of UPS: If accompanied by the above, extended circuit outage can result beyond the facility outage. Once the computer is restored to on-line operation and the first subscriber is restored to service, all subsequent outage is reflected as being individual circuit outage vice facility outage. For Mode II and V circuits, restoration is extended due to coordination requirements with the individual subscribers.

Loss of Environmental Subsystems (Air Conditioning): All off-line equipment is powered down. Only the minimum equipment required for operation without subscriber degradation is left operational. When established thresholds for temperature/humidity are exceeded (extended AC outage), all equipment is powered down; i.e., facility outage results.

Preventive Maintenance: In accordance with DCA directives, semiannual preventive maintenance (PM) on certain equipment (AC Distribution Rack and the Bit Buffer Units) requires facility shutdown. Accompanying instructions state that these preventive maintenance actions will be scheduled to coincide with other planned ASC shutdowns. It is commonplace for a planned ASC shutdown for other reasons not to be scheduled for periods of time exceeding the interval of the PM. In these instances, either a specific PM downtime must be scheduled or the PM must be delayed. In most cases, the latter is done.

CONUS AUTODIN DIESEL ENGINE DRIVEN GENERATORS OPERATING TIME DUE TO WEATHER CONDITIONS (AFR 91-4/AFCS Sup 1) BY SYSTEM AND BY SITE

1976	TOTAL EVENTS	TOTAL TIME, MIN	
BY SYSTEM	257	118573 (1,976.216 Hrs) (≈.7 Hrs/Event)	
BY SITE			% OF TIME
ANDREWS	32	7283	1.4
GENTILE	151	35122	6.68
McCLELLAN	5	1416	.27
NORTON	44	62035	11.8
TINKER	25	12727	2.52



MONTHLY DISTRIBUTION OF TOTAL EVENTS
CONUS AUTODIN (AIR FORCE) SYSTEM

FIGURE VI-4

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UNINTERRUPTIBLE POWER SYSTEMS: OPERATIONAL AND COST CONSIDERATI--ETC(U)
MAR 77 M MILAKOVICH, C E JACOBS
UNCLASSIFIED 12-ORR-77 NL

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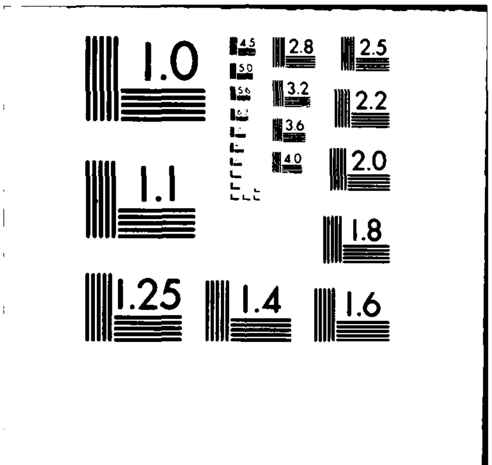
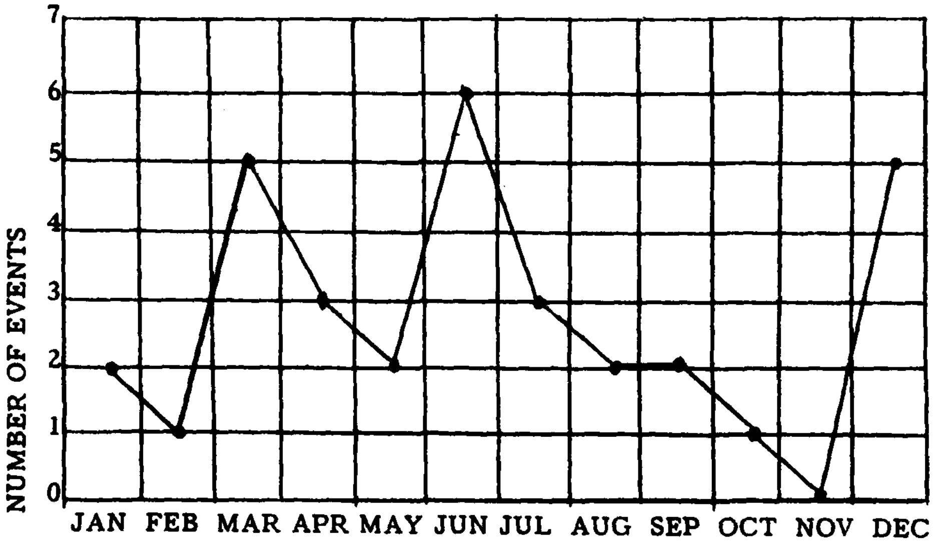


MICROCOPY RESOLUTION TEST CHART

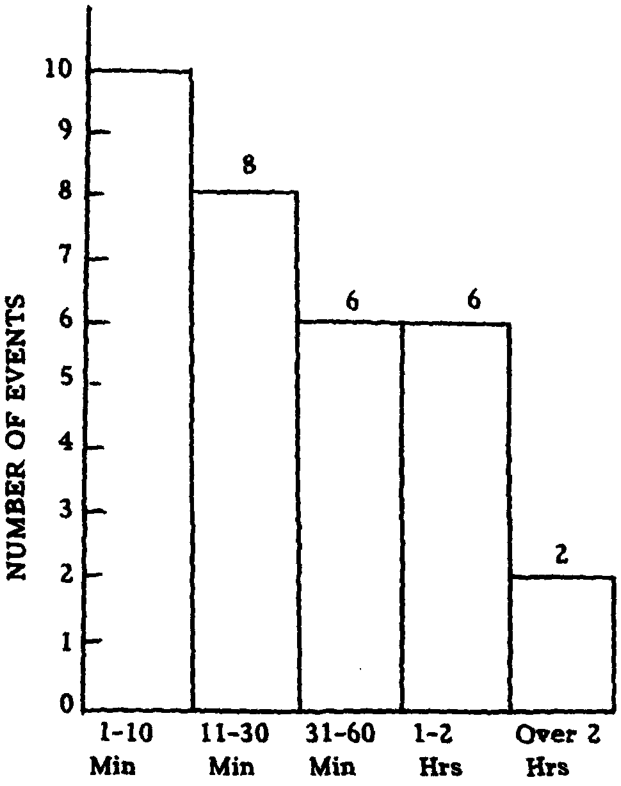
CONUS AUTODIN (AIR FORCE) POWER OUTAGES, 1976
BY SYSTEM AND BY SITE

	TOTAL EVENTS	TOTAL TIME, MIN
BY SYSTEM	32	1869 (58.4 Min/Event)
BY SITE		
ANDREWS	5	188
GENTILE	6	404
McCLELLAN	9	411
NORTON	5	606
TINKER	7	260



MONTHLY DISTRIBUTION OF TOTAL EVENTS
CONUS AUTODIN (AIR FORCE) SYSTEM

FIGURE VI-5



CONUS AUTODIN POWER OUTAGES
TOTAL EVENTS
DISTRIBUTION BY TIME
1976

FIGURE VI-6

Overseas ASC's

Known/Anticipated Primary Power Outages/Fluctuations: Same as that for CONUS. Figure VI-7 lists overseas AUTODIN (Air Force) power outages for 1976 by site. Although there are fewer sites, compared to CONUS installations, they had over twice the number of outages. On the average, their outage time per event was over half again as much. Moreover, Croughton's performance was significantly better than Camp Drake or Clark.

Unscheduled Primary Power Outages/Fluctuations: When power is lost to the rotary or solid state UPS subsystems, the ASC continues operation on the battery power source. As previously explained in the rotary UPS paragraph, the battery facility can provide sustained power to the rotary or solid state UPS subsystems for approximately 15 minutes after which the primary or secondary power source must be restored. If an extended loss of the primary and secondary power sources is anticipated during the first few minutes of power outage, all spare equipment is immediately powered down; i.e., each ASC has an emergency load shedding plan. It has been demonstrated that an overseas ASC operating on the battery facility with minimum equipment load can sustain operation for a period of hours. (This is not recommended except under emergency conditions.)

Loss of Rotary or Solid State UPS: If a rotary or solid state UPS subsystem failure occurs, a facility failure results until a manual switchover to the other UPS subsystem is performed. In addition to restoration of the computer, circuit outage over and above the facility outage can occur since circuit resets are required. Because of problems with the solid state unit, extended periods of unavailability of this unit are common.

Loss of Environmental Subsystems (Air Conditioning): Same as that for CONUS ASC's.

Maintenance: The rotary UPS (DC drive motors) has proven to be generally quite reliable when operated under a well planned PM program. However, the controls of the DC drive motors are sensitive to environmental changes. As three units are required on-line in parallel, any unit out of sync will trip off-line and cause a power outage.

The solid state UPS purchased through Philco-Ford from AVETEL (now bankrupt) have never performed satisfactorily. There have been a deluge of failures, such as blown fuses, burned contacts and control boards, and shorted filter capacitors. Though the prime contractor, Philco-Ford, still provides some maintenance support, the units cause more operating problems and power outages than the operating personnel can cope with.

D. OPERATIONAL IMPACT OF POWER OUTAGES.

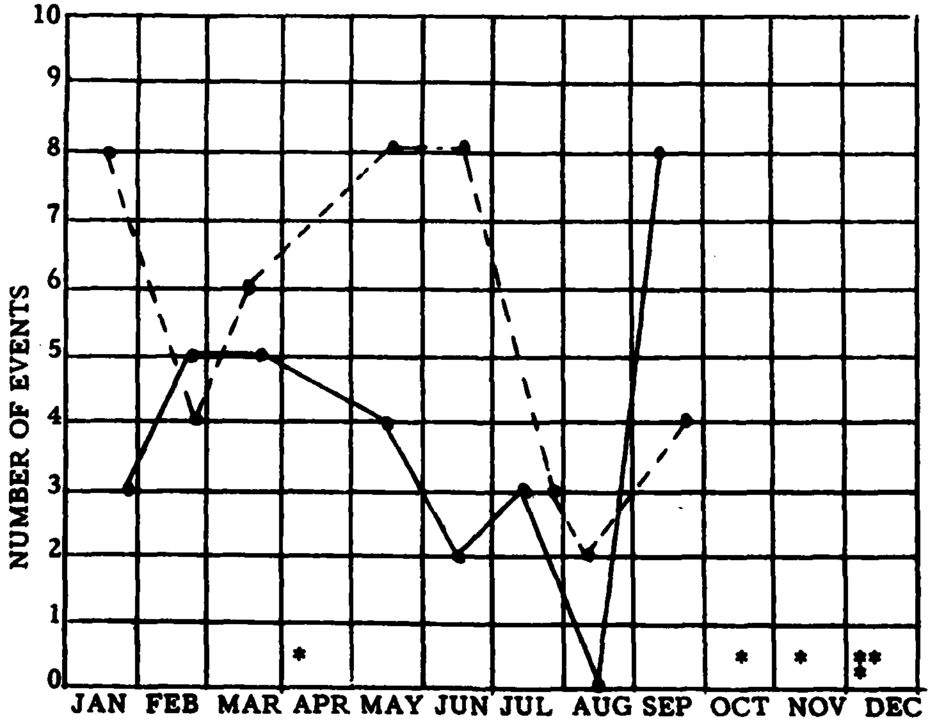
The operational impact of any ASC outage must be measured against the customers' requirement for AUTODIN service during the outage period.

CONUS AUTODIN (AIR FORCE) POWER OUTAGES, 1976
BY SYSTEM AND BY SITE

	TOTAL EVENTS	TOTAL TIME, MIN
BY SYSTEM	75	6739 (112.316 Hrs) (≈1.5 Hrs/Event)
BY SITE		
CAMP DRAKE	30	3554
CLARK	43	3154
CROUGHTON	2	31

* Data not available on Cp Drake and Clark for months of April, October, November, and December.

** Croughton had only two power outages during 1976, both in December for total time of 31 minutes.



MONTHLY DISTRIBUTION OF TOTAL EVENTS
OVERSEAS AUTODIN SITES

————————— Camp Drake
- - - - - - - - - Clark

FIGURE VI-7

Because the AUTODIN is a common-user system serving many different types of networks, it was considered unfeasible and beyond the scope of this study to determine customer requirements in order to assess the overall impact of each outage. However, the impact of a power outage on traffic flow extends beyond the actual duration of the outage because of the time required to restore the equipment to an operational status and the time necessary to coordinate and establish communications. Under the reporting guidance of DCAC 310-55-1,[103] the station outage is considered terminated when the first circuit is restored. The time required to restore all circuits may be significantly greater. Appendix C-1 shows that the average station outage at the eight Air Force ASCs due to power problems as reported under DCAC-310-55-1, was 53 minutes in 1976. This compares with the 32.5 minute average outage reported by the Norton ASC (Appendix C-3) where outage was defined as from the start of the power outage to when the station equipment was restored to operational status but communications not necessarily restored yet. The McClellan ASC reported that service denied or delayed to all connected subscribers as a result of power fluctuations/failures was a total of 411 minutes in 1976 (Appendix C-3) for an average of 45.6 minutes per event. These figures may be misleading unless the reporting criteria is clear. A more detailed examination of one single outage at McClellan presents a different picture; as an example, the 17 Jun 76 outage is described in detail in Appendix C-4, paragraph c. Briefly, power failed and was not restored until 61 minutes later. However, the ADUs were not up and it wasn't until 92 minutes after the power was restored that all circuits had been returned to service. This outage was considered typical by the McClellan ASC of the restoration time necessary when power is interrupted.

E. EFFECTS OF POWER DISTURBANCES ON EQUIPMENT.

It is seldom possible to directly attribute electronic equipment damage to power disturbances. However, as indicated in Section III of this report, studies have shown that maintenance actions on computers have been significantly decreased when supplied with UPS conditioned power. Appendix C-4 contains limited data which tends to support the findings of these studies. Research of station logs at the McClellan ASC has shown that typically the station equipment experiences about three failures per month when there are no power problems and that the number of unscheduled maintenance actions increases significantly after a power outage. After the 17 Jun 76 power outage there were six power supplies that failed within the following 24 hours. In the subsequent 30 day period, there were 15 unscheduled maintenance actions. In another case, nine maintenance actions were performed within the two weeks following the power outage on 30 Sep 76. There are also other effects on the equipment which can not yet be substantiated. As an example, COMSPOT reports occasionally make mention of excessive computer errors for no explainable reason. Unless a special evaluation is performed to obtain substantiating data, there is only conjecture that the errors may be caused by power disturbances.

F. ECONOMIC CONSIDERATIONS.

Figure VI-8 presents an annual average electrical power cost for a CONUS AUTODIN facility with an existing rotary UPS. The data was obtained from each station and is presented as an average for the five Air Force operated facilities. The average annual cost for power per station including the annual recurring rental fee of $107,160 for the Western Union motor-generator units is $252,316. This equates to $.05216 per kilowatt hour.

Figure VI-9 presents the annual estimated electrical power cost for a CONUS AUTODIN facility. If reconfigured for SSUPS, as shown in Figure 10, and the present rotary UPS replaced with a SSUPS with sufficient capacity to carry the entire station technical critical load, the total facility load is estimated at 510 KW of which 240 KW is the load to be served by the SSUPS. The number of operating hours on the back-up generators (due to inclement weather) is not included because with the use of an SSUPS, inclement weather should not affect the technical power system. The major difference in cost is the deletion of the rental fee for the Western Union motor generator units. These units will not be required with the use of a SSUPS sized for the total technical load. The estimated annual power cost is $133,992 for the SSUPS system versus $251,316 for the existing system. This represents an annual estimated savings in electrical power cost of $10,164 plus $107,160 (M.G. Rental Fee) which equates to $117,324 per facility.

Eventual replacement of the CONUS rotary UPS installations (most of which are now approaching their tenth year since installation as rebuilt equipment) by solid state UPS is recommended on the basis of operational cost savings due to the high efficiency achievable with the solid state systems. An example calculation showing that such savings can overcome the initial cost differential of solid state UPS within about five years is presented in Section VIII of this report. It remains to be seen whether there might be additional savings as a result of reduced manning because the "ride through" capability (15 minutes UPS battery) may permit better pooling of power operating personnel resources.

G. SUMMARY.

The Automatic Digital Network (AUTODIN) is a secure switched network providing a single, integrated high speed, computer-controlled record communications service. There are seventeen AUTODIN Switching Centers (ASCs) of which eight are Air Force operated. Of these, five are located in the CONUS and three are overseas. Since the CONUS and overseas ASCs each have two distinct configurations, they will be addressed separately.

For the CONUS ASCs, the primary power is commercial with back-up diesel-engine driven generators providing a secondary source. In addition, each station has a rotary (flywheel type) UPS which provides primary power/load isolation only to the modem, tech control and crypto equipment. This provides

ANNUAL AVERAGE ELECTRICAL POWER COST
CONUS AUTODIN WITH EXISTING ROTARY UPS

Facility Load	550 KW
Number of hrs on Commercial Power	8,344 Hrs (Note 1)
Number of hrs on back-gen	
(1) Due to inclement weather (AFR91-4, AFCS Sup 1, Atch 1)[83]	395
(2) Unscheduled Cml Power Outages	6
(3) Scheduled Outages (Per DCAC 350-195-2)[77]	15
	416 Hrs
Cost:	
Commercial Pwr 8344 X 550 X $.03 (Note 2)	$137,676
Operating Back-up Gen = 416 X 550 X .0833 X $.34 (Notes 3 & 4)	6,480
	$144,156
Rental Fee, Western Union Motor-Gen Sets ($8,930 - per month for 5 units, per DECO Pricing)	$107,160
TOTAL	$251,316

NOTES:

(1) Number of hours per year = 8,760

(2) Commercial power per kilowatt hour = $.03 (DCA Circular 600-60-1, Table 24-13)[102]

(3) Fuel Consumption per kilowatt hour - .0833 gal (DCA Circular 600-60-1, Table 24-13)

(4) Diesel Fuel cost per gallon = $.34 (DCA Circular 600-60-1, Table 24-13)

Figure VI-8

ANNUAL ESTIMATED ELECTRICAL POWER COST, CONUS AUTODIN FACILITY WITH SSUPS

Facility Load with existing power system		550 KW
(a) Less Motor Loads of		
(1) Rotary UPS	240 KW	
(2) Western Union Motor - Gen Sets	60 KW	300 KW
		250 KW
(b) Plus loads of		
(1) 300 KVA @ .8P.F. SSUPS for Tech Load (Note 5)		240 KW
(2) 12.8 Tons of Air Cond for SSUPS (Note 6)		20 KW
TOTAL LOAD:		510 KW

Number of Hrs on Commercial Pwr - 8,718 (Note 1)	
Number of Hrs on Back-Up Gen Per DCAC 350-195-2[77]	36 Hrs.
Number of Hrs on Back-Up Gen, Cml Pwr Outage	6 Hrs.
	42

Cost: Commercial Pwr	
8,718 X 510 X $.03 (Note 2)	$133,385
Cost of Operating Back-Up Generator	
42 X 510 X .0833 X $.34 (Notes 3 and 4)	607
TOTAL:	$133,992

NOTES:

(1) Number of hours per year = 8,760

(2) Commercial power per kilowatt hour = $.03(DCAC 600-60-1)[102]

(3) Fuel consumption per kilowatt hour = .0833 gal (DCAC 600-60-1)

(4) Diesel Fuel Cost Per Gallon $.34 (DCAC 600-60-1)

(5) Efficiency of 85%.

(6) Energy Loss of SSUPS only. Does not include area solar, sensible and latent heat gains.

FIGURE VI-9

transient protection on a continuous basis and maintains the continuity of power during short interruptions (line fluctuations) until the back-up generators are put on line. There is no UPS support to the ASCs data processing equipment; however, Western Union provides five motor-generator units as buffers to provide power/load isolation with transient protection. These units serve no other purpose and could be removed upon the installation of UPS sized for the total station technical load. Since the rotary UPS does not support the computers in the ASCs, a primary power outage of 41 milliseconds or greater will result in a facility outage of 15-50 minutes. However, even though the station outage ends when the first circuit becomes operational, it can take a significant amount of additional time until the last circuit becomes operational. This can take up to 60-90 minutes additional time. In 1976, the five CONUS (Air Force operated) ASCs experienced a total of 32 unscheduled primary power outages for a total time of 31 hours and 9 minutes. The major causes for the reported outages were due to the prime sources voltage and frequency fluctuation. The back-up generators were operated for a total time of 1,976 hours and 13 minutes due to inclement weather, for an average of 7.7 hours per turn-on. Distribution of the events shows increased usage with on-set of spring and summer seasons. The Gentile ASC contributed over half the total number of turn-ons.

The annual cost for electrical power per site for the CONUS ASCs is $251,316. This includes an annual recurring rental fee of $107,160 for the Western Union motor-generator units. The estimated annual cost per site upon deletion of the Western Union units and replacement of the rotary (flywheel) UPS is $133,992. This represents a savings in electrical power cost of $117,324 per site.

If the CONUS ASC power arrangement were reconfigured for SSUPS, the rotary (flywheel) UPS and the Western Union motor-generator units presently used are not required, if the SSUPS is sized for the total station tech-load and provided with a 15 minute battery facility. The SSUPS configuration recommended is the redundant type with static and manual bypass capabilities. The efficiency of rotary UPS is about 70% compared to a conservative figure of 88% for SSUPS. Based on this difference, the cost for SSUPS would be amortized in about five years.

The primary power source at the overseas ASCs is commercial with back-up diesel-engine driven generators providing a secondary source. These sources provide power to the UPS subsystem which is a rotary UPS (motor-generator) and a solid state UPS. Also, a DC power supply (batteries) sized for 15 minutes operating time is provided to power the UPS subsystems upon a prime/back-up power outage.

In 1976, for a reporting period of eight months, the three overseas ASCs (Air Force operated) experienced a total of 75 power outages for a total time of 112 hours and 19 minutes. Camp Drake facility experienced 30 outages for a total time of 3554 minutes (59 hours 14 minutes) and the Clark ASC experienced 43 power outages for a total time of 3154 minutes (52 hours 34 minutes). The Croughton facility experienced only two outages for a total time of 31 minutes. These were caused by fuse failure during transfer from the rotary UPS to the static UPS. The cause of the power failures at Drake and Clark were varied, such as feeder and circuit breaker malfunction, regulator malfunction, motor-generators tripping off-line, defective control boards, etc. However, because the ASC were protected by UPS, there was only one operational outage attributed to an unscheduled loss of power.

The data presented in this section of necessity describes only power outages which are gross in nature, i.e., which arise from major disruptions because of mechanical failure of portions of the power generation or distribution systems provoked by adverse weather or other outside influences over which neither the Air Force or commercial power companies have any control. These data cannot show what the effect would be of transients, momentary outages or other short time disturbances on the AUTODIN switches since current UPS and Western Union rotating machinery protect the system against such disruptions. Because these equipments are in place, they also effectively "protect" AFCS from the opportunity to collect quantitative data on the effects of such disturbances without UPS protection for comparision with the outage frequencies experienced with protection.

PROPOSED NEW
CONUS ASC POWER CONFIGURATION
WITH SOLID STATE UPS

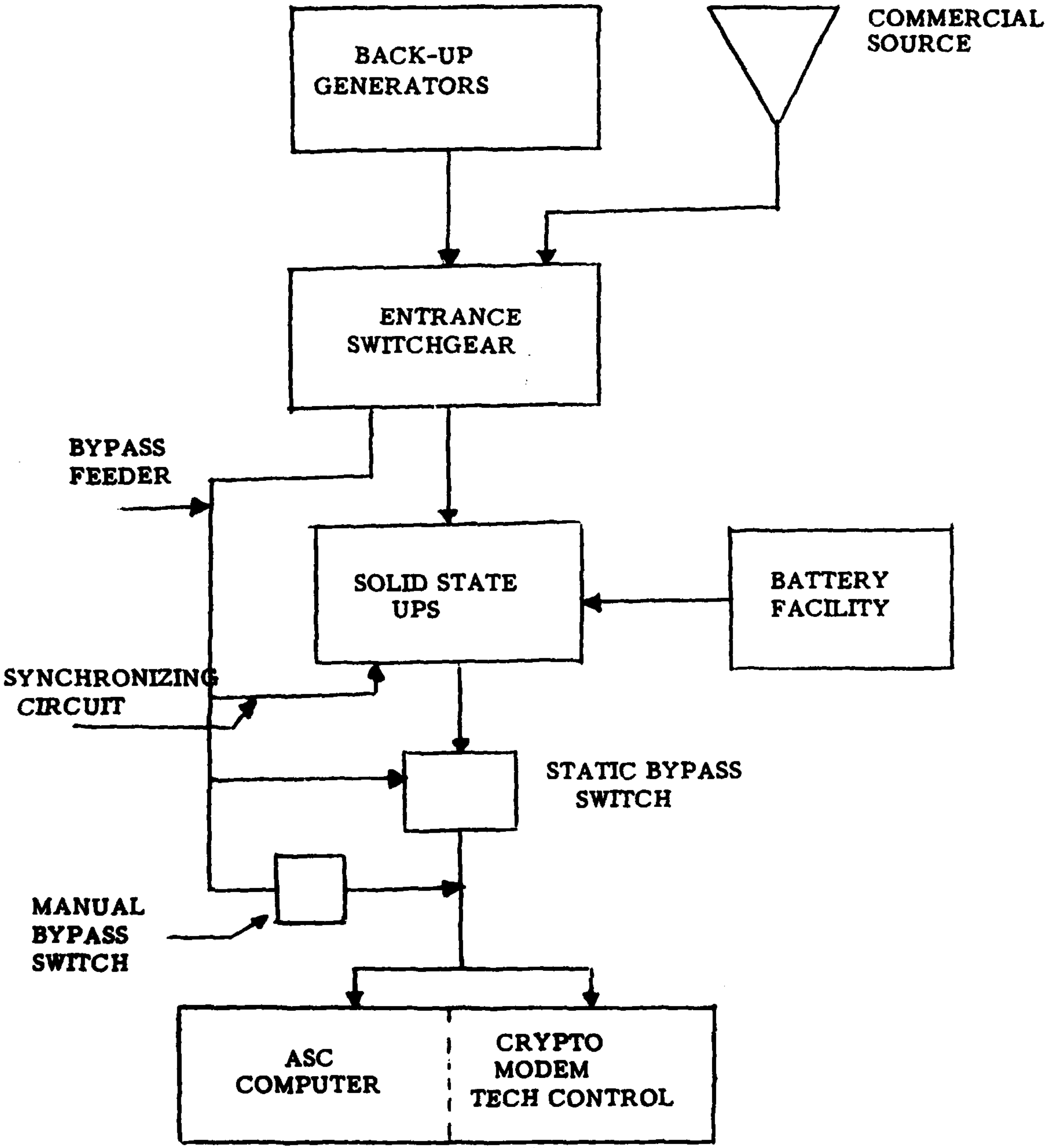


FIGURE VI-10

SECTION VII

DEFENSE SATELLITE COMMUNICATIONS SYSTEM (DSCS)

A. DESCRIPTION OF THE DSCS.

General - The DSCS is the satellite portion of the Defense Communication System (DCS). It is made up of various ground entry communication terminals called Earth Terminal Complexes (ETC) operating through geosynchronous satellites, orbited about the equator. The system provides high quality and reliable communications for distances of 6,000 miles or more. The satellite employs several transponders beamed at the earth through high path-gain narrow beam and earth coverage antennas. The satellite provides a multiple access capability that can be made highly versatile by employing sharing techniques. Some of these are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and sharing of VF groups. The ETC can employ unprotected digital communications techniques, highly reliable analog techniques, protected Spread Spectrum Multiple Access (SSMA) techniques or combinations of these techniques. The ETCs are capable of automatically tracking the satellites and are made up of various SHF radio equipments, components, a multiple carrier frequency conversion subsystem and analog or digital modem/ multiplexers.

ETC's in use or programmed are the new AN/FSC-78 fixed heavy terminal complex (HT), programmed medium terminals AN/MSC-61 (MT), and existing heavy transportable (AN/MSC-46) and medium transportable terminals (AN/TSC-54). Each can employ a Digital Communication Satellite Subsystem (DCSS) later in Stage 1C. Because of differences in configurations, each system will be treated separately in this section.

The following existing AF locations are represented in this section:

LOCATION	TERMINAL	NO.	PRIMARY USER(S)
Woomera AS	AN/MSC-46	1	ADCOM
Clark PI	AN/MSC-46	2	AFSC, CINPAC, 13AF
Sunnyvale CA	AN/FSC-78	2	AFSC (Future various)
Elmendorf AK	AN/MSC-46	1	AAC
Shemya AK	AN/TSC-54	1	ADCOM
Lajes AZ	AN/TSC-54	1	Various
Diyarbakir TU	AN/MSC-46	1	ADCOM

Phase II DSCS is planned for implementation in incremental stages to progressively achieve the capability to meet DOD stated requirements to augment the DCS by using the capabilities of communications satellites. Stage 1C of Phase II will introduce new Phase II DSCS earth terminals, and digital modulation and multiplex equipment to convert the system from a primarily analog capability to a primarily digital transmission capability, providing multiple access on the satellite by employing Frequency Division Multiple Access (FDMA) techniques. Present plans call for providing a full digital communications capability under Phase II Stage 1C by employing the DCSS. The DCSS will normally be integrated into the ETC, but in some unique situations, may be split between the ETC and its Technical Control Facility (TCF). Reference Figure VII-1.

Power subsystems for the terminals are normally engineered as part of the site construction design, and quality, quantity and types of power subsystems will vary. Present power subsystems consist of use of commercial or military furnished prime power with an appropriate number of manually switched backup power generators provided for use during loss of prime power.

Mission

The primary mission of the DSCS is to provide communications service in support of the critical World Wide Military Command and Control System (WWMCCS) and other requirements as approved by the JCS. These include[104]

Wideband channels.

Extension of DCS in Support of Contingency Operations.

Navy Ship-Shore.

Diplomatic Telecommunications Service.

Advanced Airborne Command Post.

Ground Mobile Forces (GMF) Communications.

White House Communications Agency.

Intra-Area Trunking in both Europe and the Pacific.

AUTOVON and AUTODIN Trunking.

NATO and Allied use of DSCS.

Earth Terminal Complex Systems. The following are technical descriptions of each existing or programmed ETC complete with power requirements.

AN/FSC-78 Fixed Heavy Terminal[105] - The AN/FSC-78 employs a 60 foot parabolic, steerable antenna, the associated antenna drive/tracking equipment, heating and cooling equipment, waveguide/feed assembly and electronics equipment to perform various functions including redundant cryogenically cooled-parametric amplifiers. The bulk of the electronics

Earth Station Configuration - Stage 1C

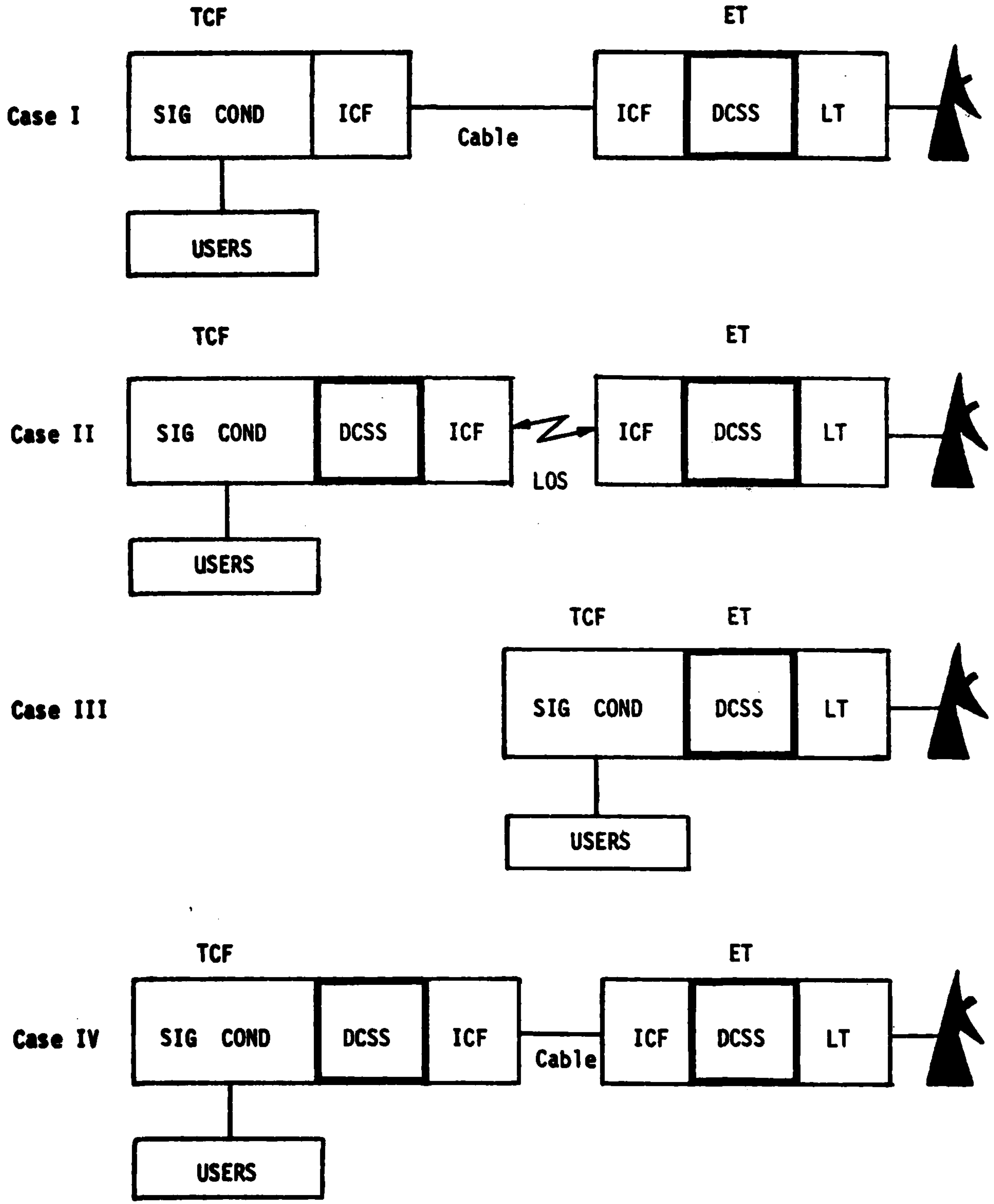


FIGURE VII-1

equipment is housed in a pre-engineered building. This equipment and the associated power switching system consists of redundant transmit power amplifiers with an associated heat exchanger equipment located outside the building, providing 3.5 KW of RF output power to the antenna feed. A frequency conversion subsystem is capable of providing nine up-link (TX) and 15 down-link (RX) carriers, and a control and monitor group provides subsystem status and control, manual and automatic tracking information to the antenna drive system, intermediate amplifiers and various built-in test facilities. (See Figure VII-2).

The power subsystem is engineered as part of the building design and conforms to the specifications outlined in Ford Aerospace and Communications Corporation WDL Technical Report 5068A, 28 June 1974. Figure VII-3 is a single line drawing of this recommended power configuration. The following power specifications apply:

1. Critical Power: 130 KVA w/o DCSS
155 KVA with DCSS

2. Non-Critical Power: 100 KVA w/o DCSS
130 KVA w/DCSS

3. Protection: (Provisions are made to automatically disconnect prime power when following limits are exceeded. Restoration is done manually).

Voltage: 120/208V ±10% for more than one minute.

Frequency: 50/60 Hz ±5% for more than one minute.

Voltage: 120/208V ±20% any period.

Frequency: 50/60 Hz ±10% any period.

4. Technical Equipment:

Voltage: 120/208V ±10% 3 phase, 4 wire.

Frequency: 50/60 Hz ±5%.

Voltage Balance: ±2% Balanced load.
±5% Unbalanced load.

Harmonic Distortion: ±5%

Phase Displacement: ±1 degrees balanced
±5 degrees unbalanced

Recovery from a power outage of less than ten minutes duration could require ten to twenty minutes for the HT transmitter equipment time delay

AN/FSC-78 FUNCTIONAL BLOCK DIAGRAM

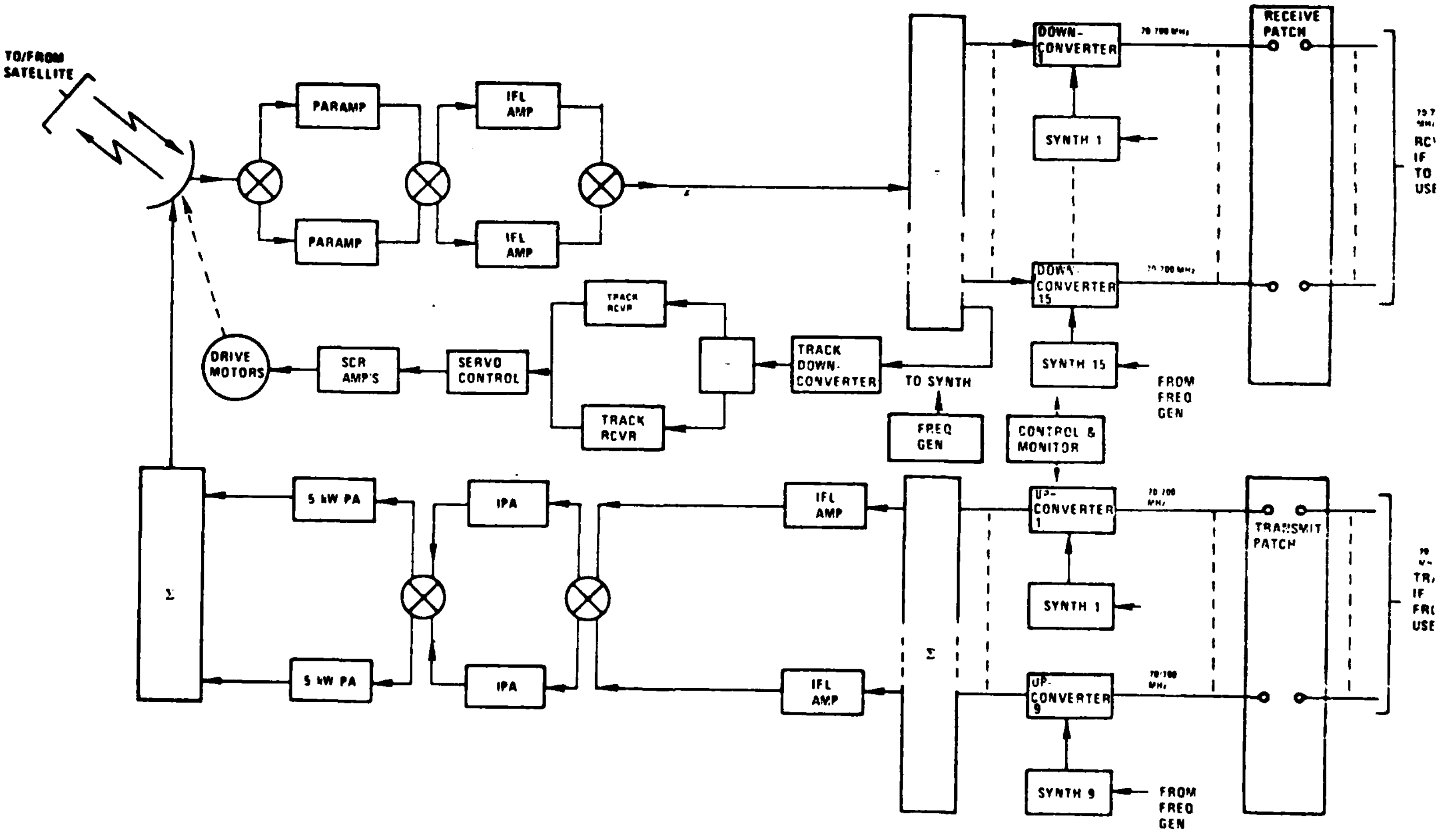


FIGURE VII-2

[illegible]

1. ITEMS SHOWN IN DOTTED LINES ARE FURNISHED AND INSTALLED BY PHILCO-FORD.
2. JB-1 SHALL BE A [illegible] NEMA 1 ENCLOSURE ([illegible] OR EQUAL). JB-2 SHALL BE A [illegible] NEMA 1 ENCLOSURE ([illegible] OR EQUAL).
3. [illegible] POWER REQUIREMENTS.
4. [illegible] (1 NO AND 1 NC CONTACT) WILL TRIP C.B.1 AND C.B.3 SIMULTANEOUSLY.

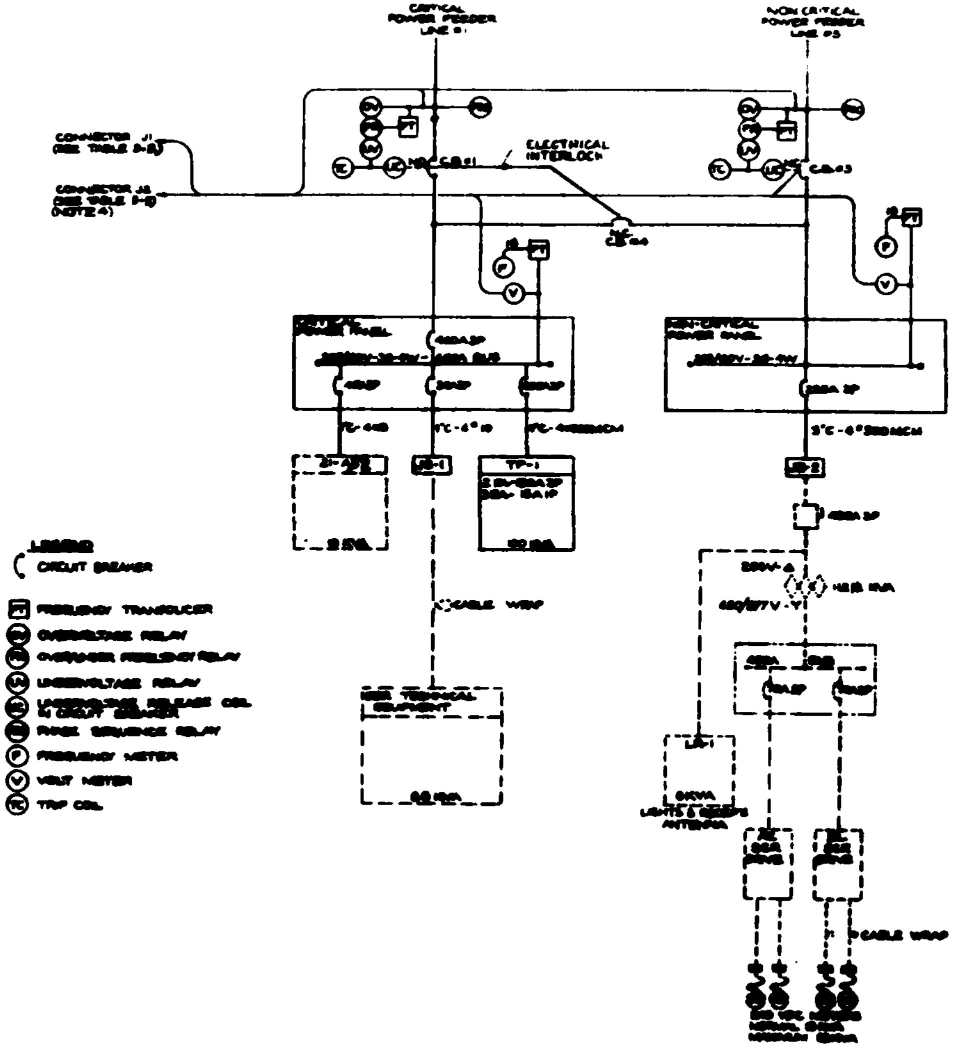


FIGURE VII-3. ONE LINE POWER SYSTEM DIAGRAM - DSCS circuit to reset. Recovery from a power outage of ten minutes or longer may require as much as 1.5 hours to cool down cryogenic system in the parametric amplifiers. These amplifiers are cooled to temperatures of 12 to 25 degrees Kelvin.

AN/MSC-61 Medium Terminal[106] - The AN/MSC-61 consists of the same electronics subsystems as employed in the FSC-78, except that a smaller (38 ft) parabolic reflector is used. The bulk of the electronics equipment is housed in three vans. The technical description is the same.

Ford Aerospace and Communications Corporation WDL Technical Report 5068A, 28 June 1974, recommends that the electrical power to operate the technical equipment be obtained from a non-critical power feeder supplied at each site. The feeder will supply power for all site equipment including critical technical equipment, non-critical technical equipment and utility equipment. A critical power feeder may be supplied at the discretion of an individual site to supply power to the critical technical equipment. The critical technical equipment consists of the equipment that is necessary to maintain transmit/receive capability with a synchronous satellite. The antenna drive system is connected to the non-critical feeder because of the small angular rate of travel of a synchronous satellite. Interruptions in power on the non-critical feeder to the antenna and air conditioning equipment in excess of 10 minutes may result in the loss of communications. (See Figures VII-4 and VII-5.)

The power requirements are:

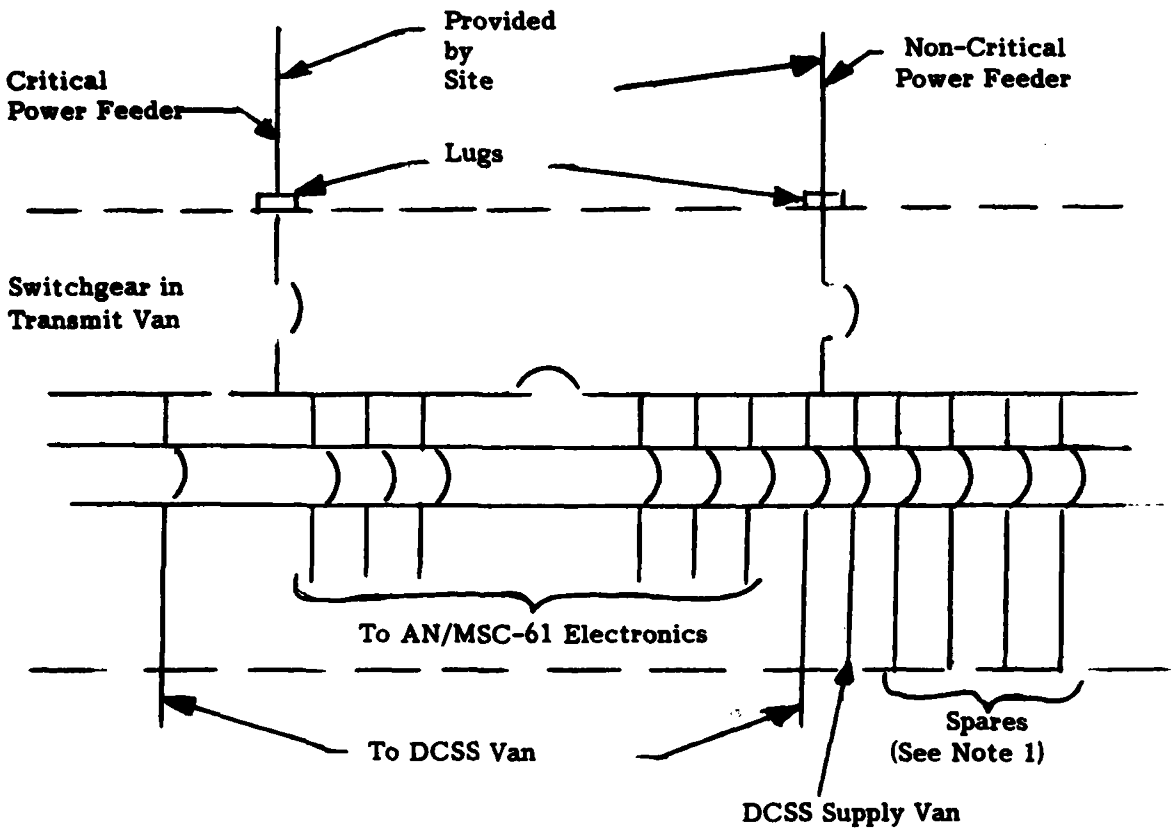
Voltage: 120/208VAC ±10% 3 phase, 4 wire.

Frequency: 50/60 Hz ±5%.

Load: Critical - 160 KVA w/DCSS
Non-Critical - 205 KVA w/DCSS
Critical - 130 KVA w/o DCSS
Non-Critical - 145 KVA w/o DCSS

NOTE: Power requirements listed do not include utility power for external facilities such as security lights.

AN/TSC-54, Medium Transportable Earth Terminal[107] - The AN/TSC-54 (Figures VII-6 and VII-7) employs four 10-foot parabolic reflectors integrally assembled as a steerable cloverleaf reflector as part of the antenna-receiver-transmitter group. The group contains the antenna, redundant uncooled parametric amplifiers, a single Klystron type transmit power amplifier capable of 5 KW RF power output to the antenna, its associated power supplies, controls and heat exchanger equipment, antenna drive/tracking equipment, subsystem control assembly and waveguide/feed assembly. The remaining electronic equipment is housed in vans consisting of:



NOTES

1. Each spare has 25 KVA capacity. Two spares are included at 20 KVA each for the Maintenance and Supply Vans. Additional load connected to the spare connectors should be added to the primary power requirements.

2. The non-critical power feeder is supplied by the site and should be sized for the full critical and non-critical load.

3. The critical power feeder is only required if an UPS is used. The feeder is supplied by the site and should be sized for the critical load.

4. Inter-van cables will be provided as part of the equipment.

5. Neutral shall be grounded at the power source only.

Figure VII-4. One Line Power System Diagram - AN/MSC-61

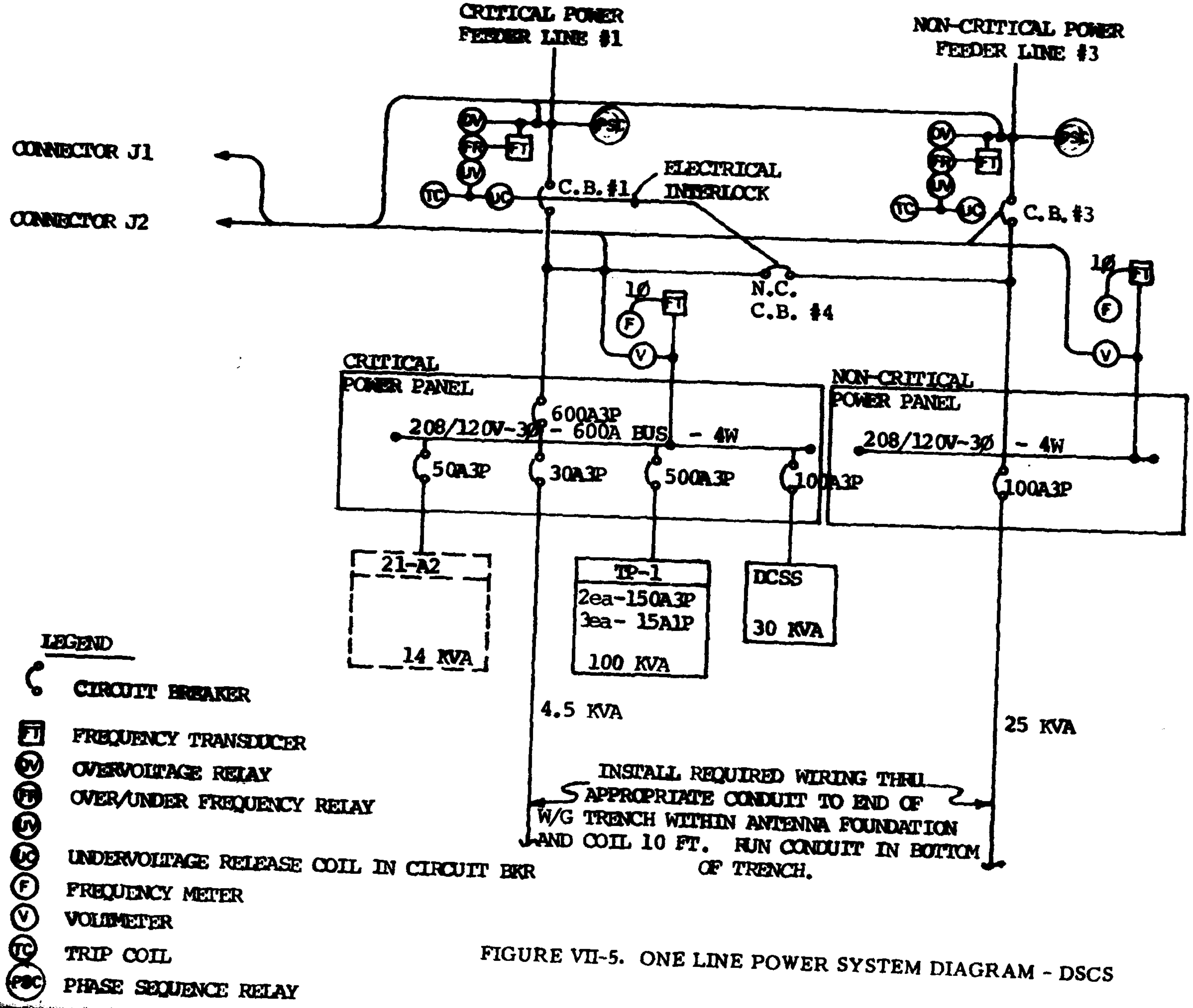


FIGURE VII-5. ONE LINE POWER SYSTEM DIAGRAM - DSCS

AN/TSC-54
SIMPLIFIED BLOCK DIAGRAM

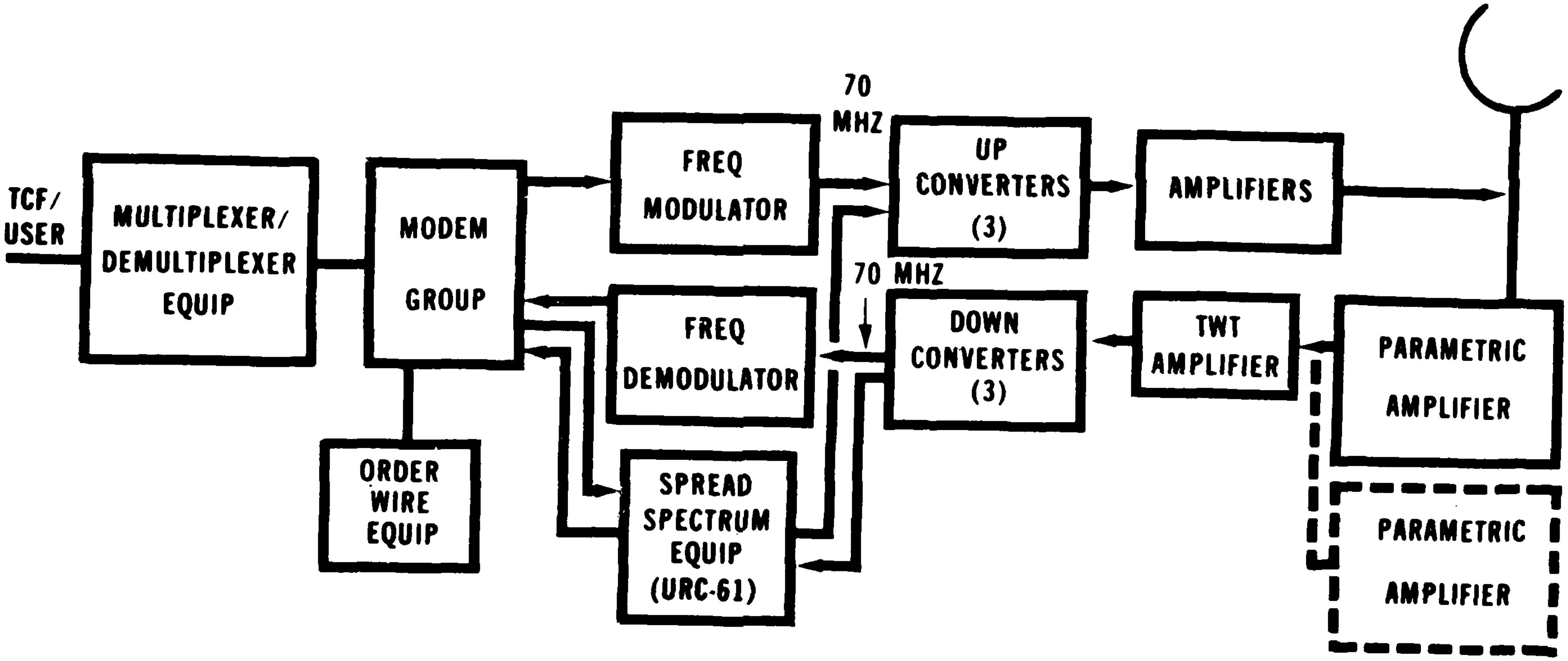


FIGURE VII-6

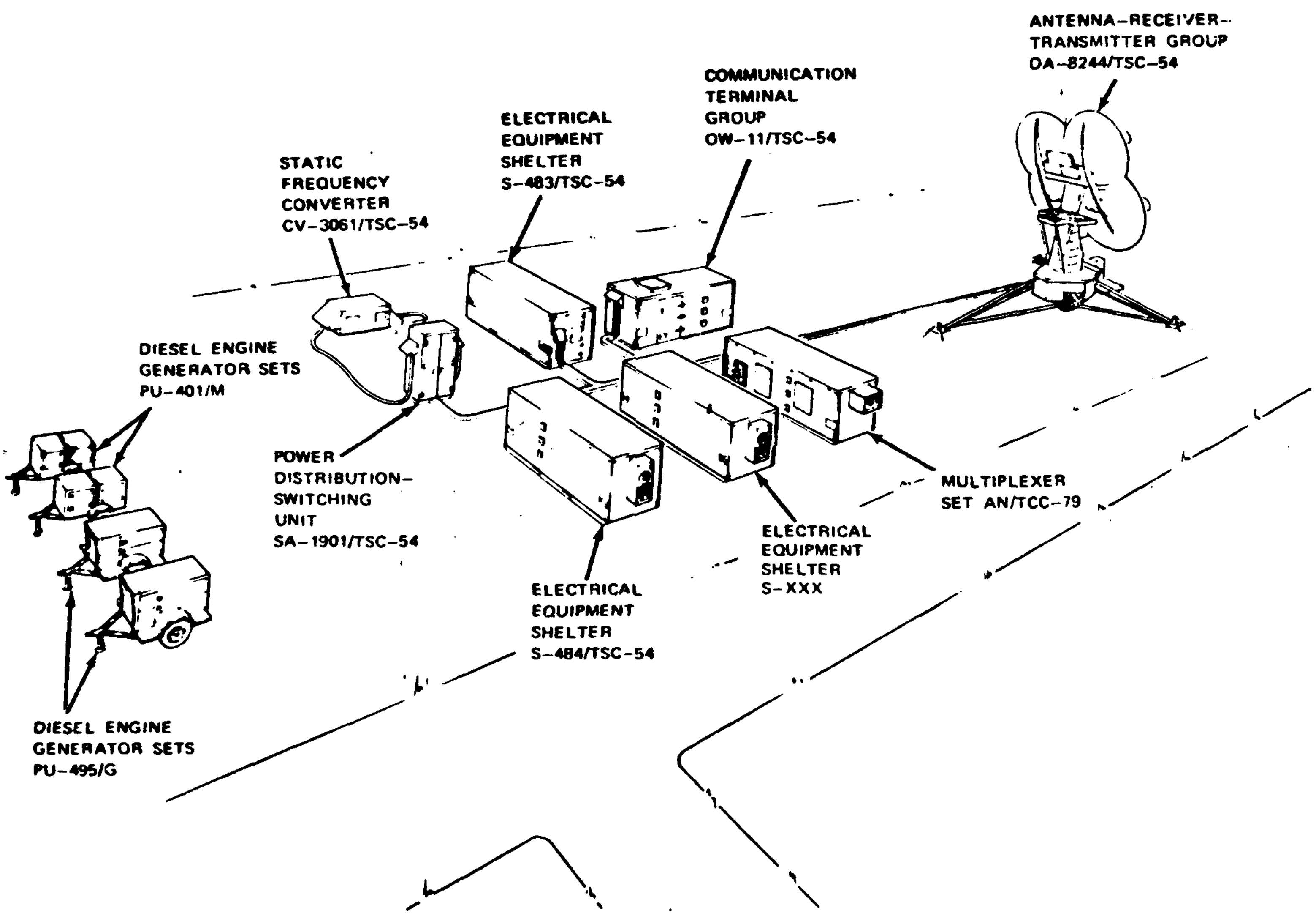


FIGURE VII-7. TYPICAL ETC USING THE SATELLITE COMMUNICATIONS TERMINAL AN/TSC-54

1. The communications terminal group (also called Operation Control Van (OCV)) housing the frequency conversion subsystem capable of providing three up-link and three down-link carriers, control and monitor assemblies providing subsystem status and control, automatic and manual tracking information, tracking demodulators, the Radio Communications Subsystem, AN/URC-61 (Spread Spectrum), intermediate amplifiers, limited built-in test facilities and heating and cooling equipment.

2. The maintenance van housing various tools, test equipment, technical data, limited parts storage bins, workbench and heating and cooling equipment.

3. The storage shelter van, housing authorized on-site spare parts and the shelter heating and cooling equipment.

NOTE: The terminal is presently equipped with the multiplexer set, AN/TCC-79, consisting of multiplex equipment and modems to provide 12 VF user channels and 15 TTY channels. (See Figure VII-7.)

The power subsystem is separated from the vans and antenna and consists of:

1. A power distribution-switching unit providing selection control and monitoring of primary AC power from the 400 Hz frequency converter or the PU-401 400 Hz power generator.

2. A static frequency converter or a rotary type frequency converter that provides conversion of 60 Hz AC commercial or PU-495 60 Hz power generator to 400 Hz and supplies it to the power distribution switching unit.

3. Two 400 Hz power generators PU-401 and two 60 Hz PU-495 units for either primary or back-up power.

The power requirements for the AN/TSC-54 are:

1. Voltage:

(a) 120VAC, 50/60 Hz, 3 phase (commercial or generator) or 120VAC, 400 Hz, 3 phase (generator).

(b) 24 VDC (generator).

2. Frequency: 50/60 Hz or 400 Hz.

3. Load:

(1) 100 KW at 50/60 Hz.

(2) 45 KW at 400 Hz.

Recovery from a power outage of any length requires a minimum of 10 minutes for the transmit power amplifier time delay circuit to reset.

AN/MSC-46, Heavy Transportable Earth Terminal[108] - The AN/MSC-46 (Figures VII-8 and VII-9) employs a 45-foot transportable parabolic, steerable antenna, its associated antenna drive/tracking equipment, heating and cooling equipment, waveguide/feed assembly, and electronics equipment to perform various functions including redundant cryogenically cooled parametric amplifiers. The bulk of the electronics equipment is housed in vans consisting of:

1. Communications-Antenna Control Van (Operations Control Van (OCV)) housing the frequency conversion subsystem capable of providing six uplink and 15 downlink carriers, control and monitor assemblies providing subsystem status and control, automatic and manual tracking information, tracking demodulators, remote power control system, the Radio Communications Subsystem, AN/URC-55 (Spread Spectrum), intermediate amplifiers, built-in test facilities and heating and cooling equipment.

2. Power Distribution Group (Transmit Van) - housing the high power amplifier (HPA) capable of 10 KW RF power output to the antenna, the low power amplifier capable of 5 KW RF power output to the antenna, associated control and power supply subsystems, redundant intermediate power amplifiers, power distribution equipment (providing subsystem power control and control of commercial/base prime power or back-up generators), and heating and cooling equipment.

3. Electronic Equipment Maintenance Van - housing tools, workbenches, storage bins for storing various tools and test equipments and heating and cooling equipment.

4. Cargo Container Assembly (Cargo Van) - for storing authorized, on-site spare parts.

The power subsystem is housed in the power distribution group van and is capable of control and monitoring prime power, isolating prime power from back-up power system through a 1,000 amp circuit breaker, subsystem control and providing automatic phasing of back-up generators and remote start circuitry. The monitors and controls for remote start of the back-up generators is contained in the OCV. This panel contains various switches and monitoring devices to enable remote starting, connecting, disconnecting and parallel connecting back-up generators. The back-up generators (PU-495) are supplied as part of the ETC. The power requirements are:

1. Voltage: 120/208V ±10%, 3 phase, 4 wire.

AN/MSC—46
SIMPLIFIED BLOCK DIAGRAM

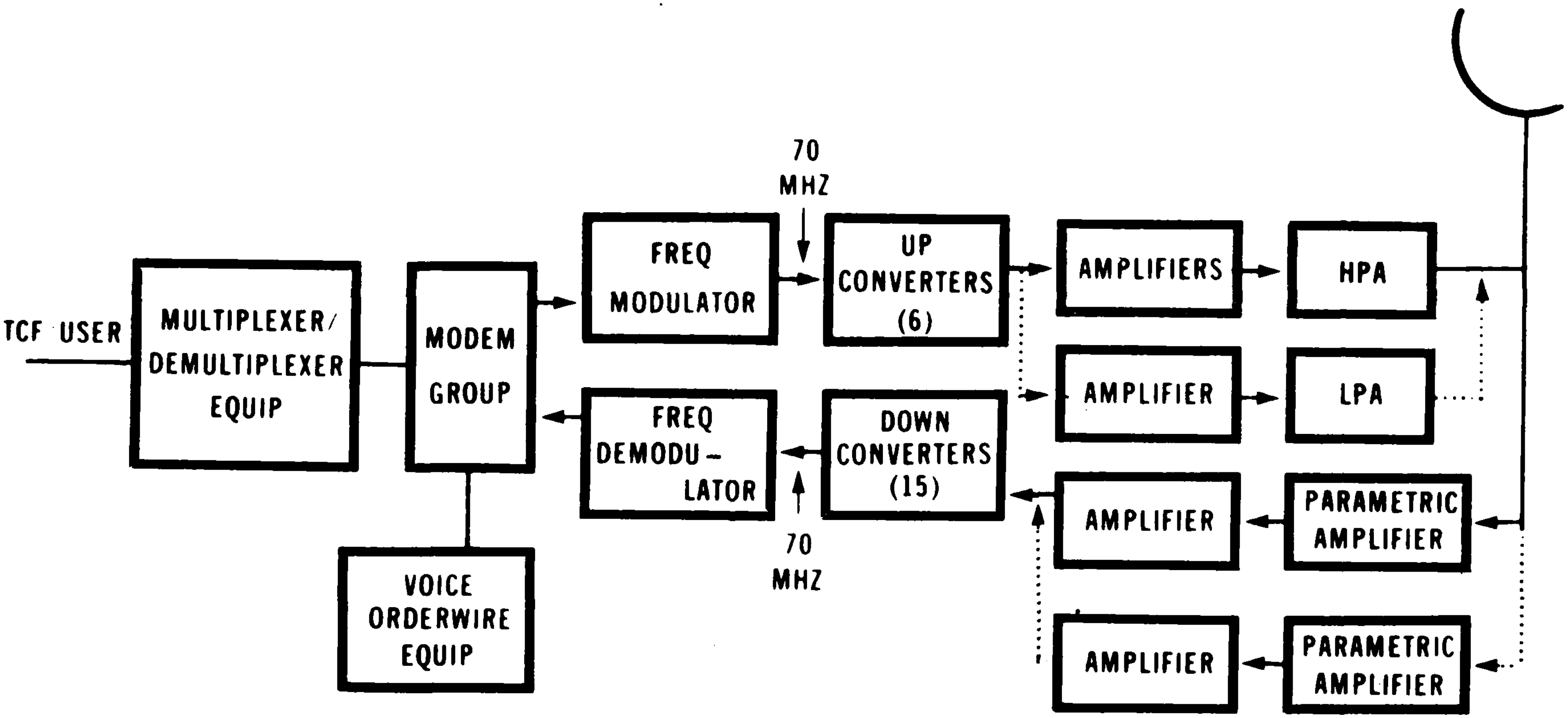


FIGURE VII-8

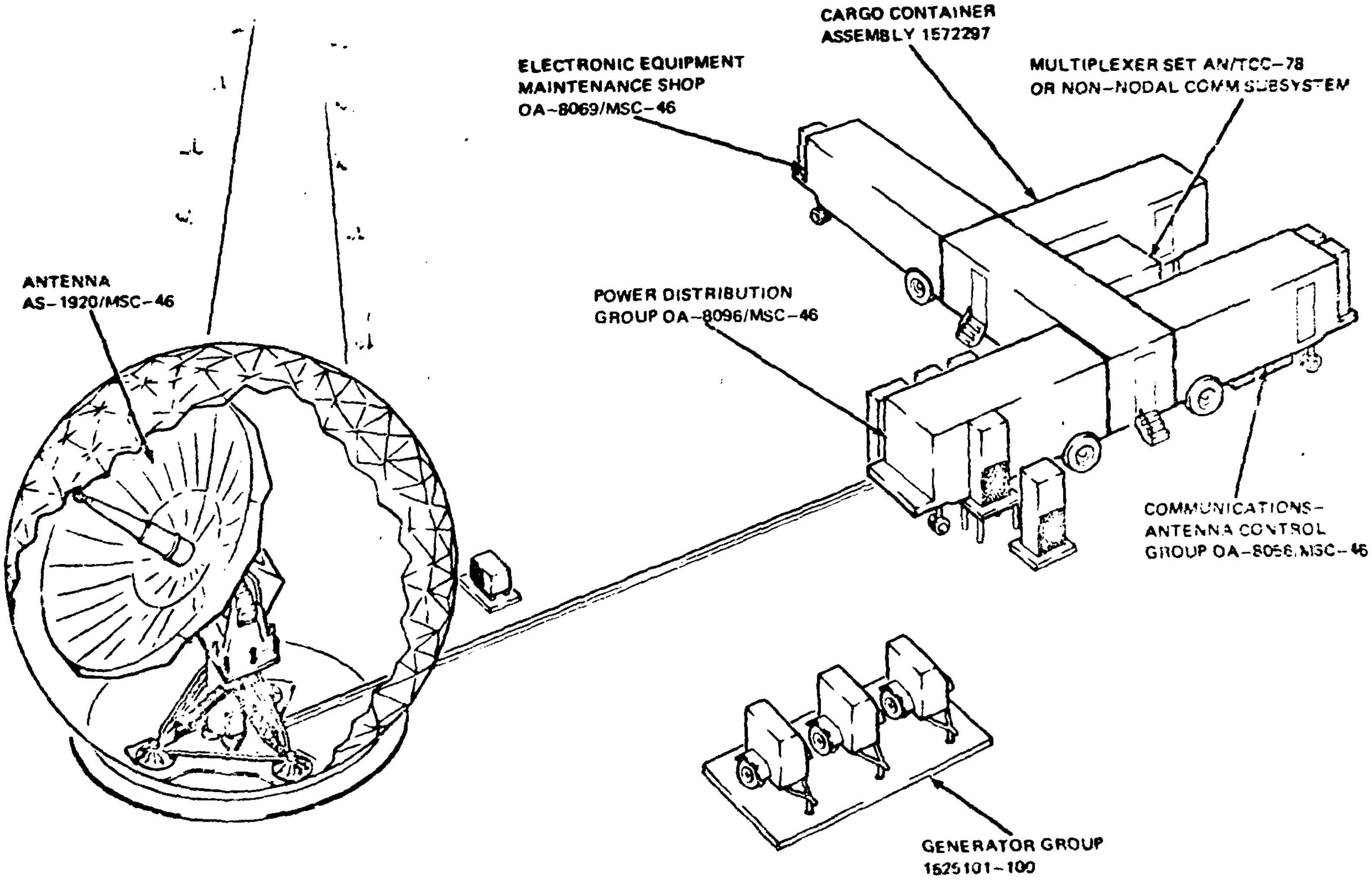


FIGURE VII-9. TYPICAL ETC USING THE SATELLITE COMMUNICATIONS TEMRINAL AN/MSC-46 (Nodal and Non-Nodal)

2. Frequency: 50/60 Hz ±5%.

3. Load:

(a) 178 KW with Nodal Communication Subsystem, AN/TCC-78 (analog).

(b) 167 KW with Non-Nodal Communications Subsystem, AN/FCC-55, or interim contingency communications subsystem (ICCSS).

(c) 187 KW (critical) and 30 KW (non-critical) with DCSS van.

Recovery from a power outage of less than ten minutes could require ten to twenty minutes for the transmit power amplifiers time delay circuit to reset. Recovery from a power outage of ten minutes or longer could require as much as 1.5 hours to cool down cryogenic system in the parametric amplifiers.

Description of DCSS[109] - The DCSS is comprised of modulation, multiplex, coding and processing equipment necessary for assembling various types of user data into a digital form suitable for transmission over a DSCS link. It will employ Binary Phase Shift Keying (BPSK) modulation initially in the unprotected mode. Access through the satellite will be accomplished by employing a Frequency Divison Multiple Access (FDMA) technique. Later in Stage 1C of the program, Quaternary Phase Shift Keying (QPSK) modulation will be used to provide greater spectrum economy. The protected mode will employ the QPSK method and access through the satellite will be accomplished by a Code Divison Multiple Access (CDMA) method. Each DCSS will be housed in either a building or a van depending on the type of associated ETC. Each van will also house its own heating and cooling equipment. (See Figure VII-10.)

The power subsystem (Figure VII-11) is designed into the DCSS and requirements are:

1. DCSS Van Configurations:

(a) Voltage: 120/208VAC ±10% for a period greater than 3.5 seconds, 3 phase, 4 wire.

(b) Frequency: 50/60 Hz ±5% for a period greater than 3.5 seconds.

(c) Load: 25 KW critical, 30 KW non-critical.

2. DCSS Building Configurations: 21 KW critical.

Recovery of the DCSS from a power outage would depend upon mode of operations employed. For example, the worst case occurs with use of the QPSK mode. Acquisition time could be as high as 1,000 seconds (16 minutes, 40 seconds) with the modem operating in its full wideband configuration.

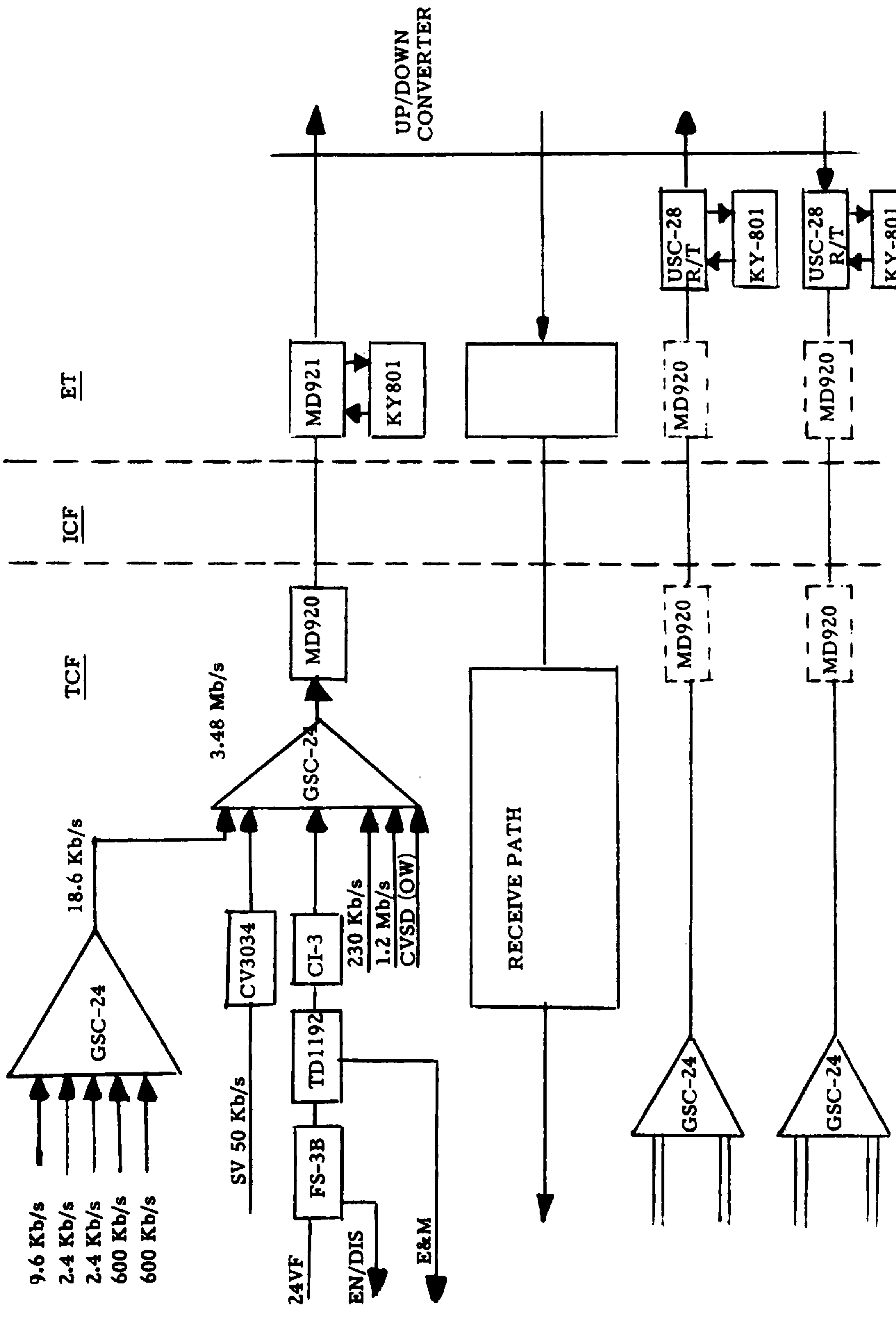


FIGURE VII-10. TYPICAL DCSS BUILDING BLOCK

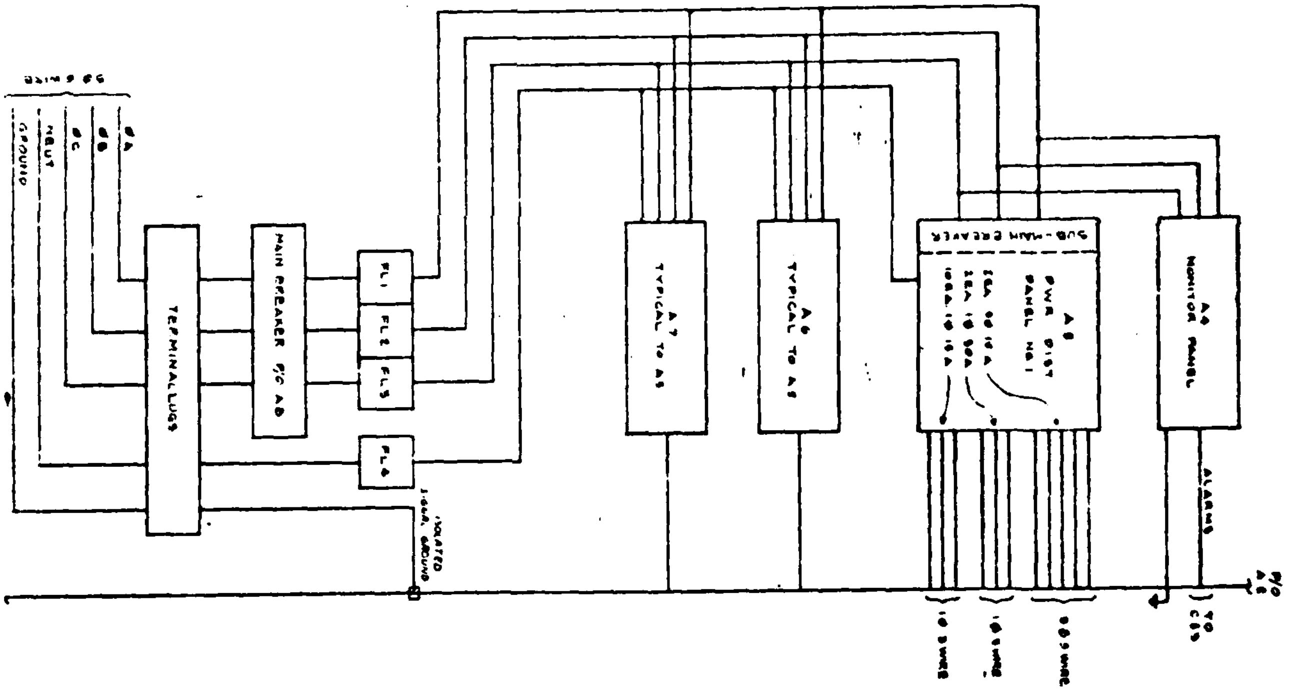


FIGURE VII-11. TYPE 1 RACK POWER BLOCK DIAGRAM

Considering the effects on user acquisition times, i.e., crypto key change takes 1,621 seconds or 27 minutes (worst case), the impact of even a short power outage can be quite significant. Backlogging of user message traffic would be the direct result.

B. DSCS SITE DESCRIPTIONS/POWER CONFIGURATIONS.

General - Existing power configurations of each site vary greatly, affected by mission, locality, and availability of spare back-up power generation equipment. The following is a discussion of such configurations that presently exist at each site.

Shemya AK AN/TSC-54 - The ETC at Shemya, Alaska is an AN/TSC 54, and requires 400 Hz power for operation. It is provided by converted 60 Hz power or standby 400 HZ generators.

Primary Power Source. The prime power sources for the terminal are two 2400 volt, 3-phase power plants, routed through Feeder No. 25. The power production facilities consist of an old Alco-Worthington plant with three 1300 KW units and six 1250 KW units and a new Cooper-Bessemer plant with four 3000 KW units. One plant cannot normally supply power to the entire island and some load shedding is necessary when one plant is down. Feeder No. 25 is one of the most heavily loaded distribution lines on the island. Three cables extend 1200 feet underground from the power complex to the main base. From that point, three overhead lines extend 800 feet to a point where it branches to feed all the loads on the west end of the island and overhead lines to the AN/TSC-54 terminal 1700 feet to the south. Since this is a heavily loaded feeder, it is generally the first choice for load shedding when problems occur at the power plants. Being exposed to the weather, it suffers from corrosion problems and has a bad record of power outages and power fluctuations due to high winds. This 60 Hz prime power is then routed to a 400 Hz converter, and then to the terminal. There is no redundant converter.

Back-Up Power - Backup power is provided by two sources. First, there are two 60 Hz PU-495 generators, each capable of holding the site load. The output is again fed into the same 400 Hz converter as used with primary power. Second, there are two 400 Hz PU-401 generators, each again capable of holding the terminal technical load.

The back-up facilities for the AN/TSC-54 are adjacent to the terminal. Equipment for paralleling with island power is installed on-site.

A new permanent AN/MSC-61 and DCSS will replace the AN/TSC-54 in 1979, increasing the load on the feeder. The existing power requirements will be upgraded to accommodate this increased load.

Lajes AZ AN/TSC-54 - The ETC configuration at Lajes, like Shemya AK, requires 400 Hz power for operation.

Primary Power Source - Prime power for this terminal is provided by the Lajes base power plant. Distance from the power plant to the terminal is less than 1000 feet.

Backup Power Backup power is the standard backup system normally provided with the AN/TSC-54 and is identical in operation as the backup power at Shemya AK.

Diyarbakir TU AN/MSC-46 - This ETC is a standard AN/MSC-46 configuration requiring 60 Hz power.

Primary Power Source - Base prime power source is a contractor operated and maintained power plant. There are eight 1000 KW generators in the plant supplying power to the entire base. The feeder to the AN/MSC-46 terminal is 3300 feet underground. No other major consumers share this feeder. The feeder is connected to a substation at the terminal.

Backup Power - The backup power system consists of three remote start/manual connect PU-495 generators. The generators cannot be paralleled with prime power as configured. A commercial power lock-out breaker is provided in the terminal to insure this condition does not occur. The three PU-495 generators can be paralleled with each other in any combination. Phase sequencing is automatic through circuitry built into the terminal enabling operator to bring on-line any generator combinations, remotely from the terminal. This configuration is standard on the AN/MSC-46 satellite terminal. Two of these units are required to handle the terminal load.

Elmendorf AK AN/MSC-46

Primary Power Source - Prime power is supplied by the U.S. Army Ft Richardson power plant via Feeder No 4. The plant has a capacity of 18,000 KW generated by gas-fired steam-turbine generators. Feeder No 4 is a 200 amp line running both overhead and underground to the terminal. It extends from the plant via three underground 4/0 copper lines, 6500 feet to a switching center. This point serves no base loads. From the switching center, the line extends 5000 feet by three overhead 1/0 copper lines to a point where it branches off to feed the northern part of Ft Richardson. The northern run extends 21,000 feet overhead via three No 6 copper lines to the terminal on Elmendorf AFB. This line shares loads to four other minor consumers. The total demand on this feeder is 70 amps.

Backup Power - The backup power is the standard AN/MSC-46 power subsystem, consisting of three PU-495 generators. Operation of terminal power subsystem is the same as that explained in the Diyarbakir section. This terminal will be replaced by an AN/FSC-78 in late 1977.

Woomera AS AN/MSC-46

Primary Power Source - The prime power source for the terminal is provided by a Class A base plant operated and maintained by a mixture of Air

Force and contract personnel. The plant contains three on-line generators with two standby units and is located approximately 150 feet from the terminal.

Backup Power - No backup power is available at Woomera AS because of the proximity of the prime power plant.

Clark AB PI AN/MSC-46 - The situation stated below is temporary as the site will obtain a system supported by four 400 KW White Superior generators under the existing FY 76 MCP SATCOM allied support program. The site critical load consists of two AN/MSC-46 ETCs and a patch and test facility. In addition, it should be noted that the primary system carries numerous heavy non-technical loads and consists of mostly 20 year old equipment. A project is underway to establish a critical feeder to provide load shedding of non-technical loads.

Primary Power Source - Prime power is generated by the base power plant and is fed via a 16,600 foot overhead/underground line. This same line feeds a multiple family housing area, base water plant, and water pump houses.

Backup Power - Backup power consists of two EMU-18 generators for each terminal (four total) and one PU-495 generator for the patch and test facility. This configuration does not meet DCA criteria for a Class B power system. In addition, commercial power is available but has been unreliable.

Sunnyvale CA AN/FSC-78

Primary Power Source - The prime power source for both AN/FSC-78 terminals is a Class A plant located less than 500 feet from the ETC. This plant also provides power to the satellite control facility.

Backup Power - No backup power is available due to the proximity of the primary power source.

C. POWER OUTAGES AND EFFECTS.

General - Power-related failure rates of each DSCS terminal is dependent largely on its power configuration, both prime and back-up. Less evident is the extent of actions required by the terminal operator following a power outage. For example, in the AN/FSC-78, there are 126 component controls and indicators that must be checked or activated during the initial system turn-on procedure. This does not include approximately 266 fault and monitor indicators located throughout the terminal, nor does it include the analog or digital communications subsystem equipment. These indicators are only checked when alarms or faults are activated as a result of power-up procedure. During turn-on resulting from a short term power outage, a minimum of 33 controls and indicators must be checked or activated. The AN/FSC-78 is the most complex of the three represented DSCS terminals. The AN/MSC-46 and AN/TSC-54, although not as complex, are housed in vans. Therefore, more time is required for restoration because of the physical separation of some of the electronics subsystems. Trunk precedence/restoral priority is the same as that of the highest priority circuit carried on that trunk.

A short statement of power outage events and adverse results of such outages is presented below for each DSCS location. This is based, in part, on the summary of outages shown in Table VII-1. (A more detailed analysis of total events and times for each site can be found in Appendix D-5. Further, it should be noted that the outages are power outages only and not communication outages.)

Shemya AK - There was a significant increase in outages from 1975 to 1976; 15 outages averaging 2 hours 32 minutes each compared to 66 outages at an average of 2 hours 14 minutes each. A significant cause of outages was power fluctuations,[110] In 1976, there were 13 instances in which a power fluctuation caused an outage. In each case, equipment was recycled and service restored. In three other incidents, the ETC suffered outages caused by feeder failure with one case causing damage to a 6 volt power supply and FM demodulator.

Lajes AZ - This site experienced only two outages in 1975 for a total outage time of 3 hours and 43 minutes. The outages increased significantly in 1976 to 18 outages with a 1 hour 29 minute average per event. No specific information of cause or results of outages are available.

Diyarbakir TU - In 1975, there were seven outages for a total of 19 hours 46 minutes compared to 10 outages for a total duration of 106 hours 8 minutes in 1976. Two of the 1976 outages resulted in subsequent equipment failures.[111] In the first case, a 34 minute power outage caused a 1 hour 45 minute outage of parametric amplifiers. In the second case, site servo systems were inoperational for over 53 hours because of damage from a power fluctuation.

Elmendorf AK - This site experienced few power outages. There were three outages for a total duration of 43 minutes in 1975 compared to five outages for a total duration of 12 hours 6 minutes (2 hours 25 minutes average) in 1976. Four of the 1976 outages were due to feeder problems from such diverse causes as high winds, a blown line fuse, and in two cases, automobiles hitting power poles.[110] No communications equipment damage resulted from these interruptions.

Woomera AS - Power at this site is extremely reliable with no power outages in 1975 and two in 1976 (7 hours 43 minutes total duration). No specific information of causes or results of outages are available, but a notable problem is frequent local power fluctuations. (See Appendix D-6.)

Clark AB PI - This location had a total of 43 outages for a duration of 65 hours and 35 minutes in 1975, more than any other station. In 1976, the more

TABLE VII-I

SUMMARY DSCS POWER OUTAGES FOR 1975/1976

	1975			1976		
STATION	TOTAL EVENTS (NO)	TOTAL TIME MIN/HR, MIN	AVERAGE TIME HR, MIN/EVENT	TOTAL EVENTS	TOTAL TIME	AVERAGE TIME/EVEN
SHEMYA	15	2886/48 hr 6 min	3 hr 12 min	66	8816/146 hr 56 min	2 hr 14 min
LAJES	2	223/3 hr 43 min	1 hr 52 min	18	1601/26 hr 41 min	1 hr 29 min
DIYARBAKIR	7	1181/19 hr 14 min	1 hr 49 min	10	6338/105 hr 38 min	10 hr 34 min
ELMENDORF	3	43/0 hr 43 min	0 hr 14 min	5	726/12 hr 6 min	2 hr 25 min
WOOMERA	0	0	0	2	463/7 hr 43 min	3 hr 51 min
CLARK	43	3935/65 hr 35 min	1 hr 32 min	63	11,133/185 hr 33 min	2 hr 57 min
SUNNYVALE	0	0	0	1	131/2 hr 11 min	2 hr 11 min
TOTAL	70	8268/137 hr 48 min	1 hr 58 min	165	29208/486 hr 48 min	2 hr 57 min

severe year, there were 63 outages for a total duration of 185 hours 33 minutes (2 hours 57 minutes average). Numerous power outages and fluctuations resulted in equipment damage. In 1976, there were two cases of parametric amplifier failures due to power outages. Other equipment failures due to power outages and fluctuations were on the AN/URC-61, the servo system, and in three instances, a transmitter.[111]

Sunnyvale CA - The location had only one power outage in 1975/76. This was 2 hours 11 minutes in duration. After restoral, twenty minutes were required to sufficiently cool parametric amplifiers to restore communications.[112]

Overall, Shemya, Diyarbakir, and Clark had significantly more power outages than the other stations. Each of the stations experienced more outages in 1976 than in the previous year. In 1975, for all stations, there was a total of 70 outages for a total duration of 137 hours 48 minutes, 1 hour 58 minutes average). This compares to 165 outages in 1976 which had a total outage duration of 486 hours 48 minutes (2 hours 57 minutes). For the two years, the average outage duration was 2 hours 39 minutes.

Again, it is necessary to state that the above outages are prime power outages and not terminal communication outages. Shown in Table VII-2 are some examples of communications outages extracted from recent COMSPOT messages. Shown are a total of 30 comm outages and each outage duration in minutes. Also shown are the duration of the prime outage, if known, how long it took before back-up generators were started and supplying power to the terminal, and information on the nature of the power problem, or any resulting equipment damage. In two cases, there were outages caused by failure of power components affecting both prime and back-up power. In four cases, there was damage or equipment problems resulting from the power outage which influenced the duration of the comm outage. There were 18 cases where data was provided to determine the time duration between a power failure and when back-up generators were brought on-line. This was found to be 7.16 minutes. Excluding the two power equipment and four comm equipment influenced outage durations, the average comm outage was 21.6 minutes. If the five cases of power/comm equipment influenced outages (referred to previously) are included, the average comm outage is 30 minutes. DCAC 310-130-276 states that the performance object for DSCS terminals is 99.0% and the management threshold is 95.0%. Based on the performance objective, 5256 minutes (or 87 hours 36 minutes) is the maximum allowable cumulative outage per year.

In general, Clark, Shemya and Diyarbakir failed to meet DCA performance objectives. Because of the long outages involved, installation of UPS is not warranted (based on availability criteria) until the base power generator/distribution systems are upgraded.

D. OPERATIONAL IMPACT OF POWER OUTAGES.

General - Because of the nature of customer circuits and their sensitivity (see Mission of the DSCS, paragraph A), the operational impact of each ETC

TABLE VII-2

EXAMPLES OF TERMINAL COMMUNICATION OUTAGES (COMSPOT REPORTS)

LINK OUTAGE	PRIME POWER OUTAGE	COMMENTS
42 min	?	Restored on B.U.
27 min	?	Restored on B.U.
15 min	?	Restored on B.U.
1 hr 44 min	0	400 Hz converter problem caused loss of auto track and manual capability of antenna servo system
25 min	?	Restored on B.U.
26 min	?	Restored on B.U.
24 min	?	Took 13 min to bring up B.U. because of sync problem
1 hr 17 min	24	Restored on B.U.; antenna pedestal corrected and filters were changed in the heat exchanger purity loop
15 min	?	B.U. on line 1 min
18 min	31 hr Est	B.U. on line 8 min, base feeder problem
16 min	1 hr 32 min	B.U. on line 8 min
15 min	11 hr 58 min	B.U. on line 3 min, outage due to high winds
17 min 15 min	57 min	1st B.U. on line 5 min and later failed; 2nd B.U. on line 3 min. Base main circuit breaker defective
24 min	?	B.U. on line 8 min
17 min	Flux	-
26 min	?	B.U. on line 15 min delay due to problem with generator switch

22 min	0	Tripped circuit breaker during planned power changeover. B.U. on line 12 min.
1 hr 18 min	57 min	B.U. on line 18 min, delay due to base power personnel not on hand. Transmitter was in continuous interlock fault.
18 min	1 hr 9 min	B.U. on line 3 min
22 min	?	No notice PMI by base power
1 hr 5 min	?	B.U. would not assume load and had to be manually placed on line.
26 min	?	B.U. on line 11 min.
18 min	?	B.U. on line 6 min.
34 min	?	B.U. on line 11 min.
19 min	?	B.U. on line 6 min.
20 min	?	B.U. on line 10 min.
42 min	Flux	Blew servo fuses and drove antenna to stop limits.
21 min	?	B.U. on line 3 min, blew fuses in terminal.

will not be described separately. However, across the entire spectrum of equipment, the recovery capability of the ETC equipment is limited by present design. Power outages of ten minutes or less require substantial time for circuit restoral. The following are examples of delays:

(1) The transmitters employ a ten minute time delay circuit that inhibits activation immediately after power restoral. Reference Appendix D-1.

(2) In those systems employing cryogenically cooled parametric amplifiers, failure of 20 minutes or longer requires evacuation of the vacuum vessel, recooling and restablization of the amplifier before reliable operations can be resumed. These procedures require up to 1.5 hours to complete. Reference Appendix D-2.

(3) All of the systems contain numerous, highly stablized, phase locked oscillators, over-stabilized crystal oscillators and sensitive DC amplifiers used in its tracking circuits. They are affected by temperature and all must be restabilized and/or realigned when power is removed for even short periods. Restabilization and alignment requires a minimum of 20 minutes to complete. Reference Appendix D-3.

(4) The tracking control circuits, when subjected to conditions outlined in Appendix D-3, have caused large transients that blow fuses in the servo drive circuits after restoral, and has caused complete loss of antenna drive in the AN/MSC-46 terminals. Replacement of 30 fuses and realignment requires a minimum of 20 minutes. Reference Appendix D-4.

Another factor encountered following a power outage and after the terminal equipment time delays are completed is that the satellite must be relocated. Depending on the stability of the orbit and the duration, this may be accomplished quickly or could require up to 15-20 minutes. After the satellite has been relocated, permission must be obtained via orderwire to transmit to the satellite before the link is re-established. Next, the transmit and receive radio and voice channel levels must be checked. The the circuits are passed to the local technical control facility where they are checked before they are released for operational use. If the outage was fairly brief, the whole procedure takes only a short time. But if altroutes have been established because of the outage, longer time is required.

The operational impact of outages for each terminal varies, depending on the number and priority of the circuits it carries as well as its relationship to other DCS paths. If there are sufficient altroutes, the operational impact of a brief outage is not severe. But if the terminal is a key nodal point, several trunks are lost at one time.

However, it should be noted that ETC's set up for digital operation (DCSS) will be much more dependent on stable, uninterrupted power. Studies have been performed on the impact of power interruptions and their effects on DSCS/DCSS terminals, with results indicating that even outages of extremely short duration will have adverse effects on customer service.[113] For example in one study, a MD-1002 QPSK modem (set on wide) had a mean time of 792 seconds (13 minutes, 12 seconds) for reacquisition of signal.[114] This time is in addition to any ETC recovery time (normally ten minutes minimum) and will still require resynchronization of crypto equipment. Thus, even for a small power outage, customer service was found to be interrupted for an estimated duration of 27 minutes. Also, a brief power interruption or sag caused the transmitted output level to vary, thus varying receive levels at the distant end. This may cause a higher bit error rate depending on the magnitude and duration of the reduced fade margin. Only a small decrease can be significant because margins are relatively small, varying between 1.5 and 8 dB depending on the system. In addition, these variations also cause intermodulation products which can degrade the communications of all customers using that satellite.

E. OPERATIONAL IMPACT OF POWER QUALITY.

Definition - The quality of power is basically determined by its smoothness; this means a lack of voltage sags, surges, and transient impulses as well as frequency variations. These variations are caused by numerous items in ETCs such as turning on of radio components (most notable being power amplifiers), continuous activation of air conditioning units, and externally caused fluctuations.

Cause and Effect - The effects of AC line fluctuations can best be seen by resultant equipment outputs as shown in Appendix D-7. Thus, it has been found that certain power amplifiers have power outputs directly related to power fluctuations of a short term (see Appendix D-7a) and of a longer term (see Appendix D-7b) nature. This can then be noted as an actual fluctuation of power output. This, in turn, will cause a resulting fluctuation in power output demand from a customer sharing satellite (as used in DSCS) which will vary the output of each carrier in relation to its input signal strength received. However, the total power out of a customer sharing satellite is a constant, and when one carrier increases in strength, the satellite will correspond by increasing its power output for that carrier. This will cause a resultant decrease in power output of other carriers, causing other customers to have weaker signals, more noise, and increased intermodulation products.

This resultant effect is considerably more critical for DCSS. In this case, when the strength of a particular receive signal is decreased even by small amounts, the signal-to-noise ratio of the digital signal will correspondingly decrease. Thus, a higher number of errors are caused with a resulting degradation of system efficiency. Therefore, with narrow receive fade margins, even small power fluctuations can cause loss of data.

F. SUMMARY.

There are seven Air Force terminals in the Defense Satellite Communications System (DSCS) which employ three different types of ground entry terminals. Although each is now analog, they will all become digital carriers with the programmed addition of the Digital Communications Satellite Subsystem (DCSS). The terminals provide both common user dedicated circuits to support a variety of missions and is an important element in the Defense Communications System (DCS).

The satellite earth terminals are more vulnerable to power outages than other types of equipment because of their design. When operating in the present analog environment, recovery from a power failure is governed by built-in communications equipment time delays which require 10 to 15 minutes before they are reset and equipment stabilization time. In this latter case, it may require up to 1½ hours for the recooling and restabilization of cryogenically cooled parametric amplifiers, depending on the length of the power outage. Even a brief power transient can cause a 20 minute outage in newer systems like the AN/FSC-78 because it can blow fuses. This would necessitate replacing the fuses and accomplishing the power turn on procedures during which a minimum of 33 controls and indicators must be checked or activated.

All seven terminals are provided prime power from base generators and have a varied assortment of power distribution systems. Woomera and Sunnyvale have feeders 150 feet and 500 feet long, respectively, and therefore have no back-up generators. Lajes is less than 1000 feet, Diyarbakir is 3,300 feet underground, and Shemya is a heavily loaded feeder 6,200 feet underground/2,700 feet overhead.

Shemya, Diyarbakir and Clark had significantly more power outages than the other stations - 15 events/2886 minutes, 7 events/1181 minutes and 43 events/3935 minutes in 1975, respectively; and 66 events/8816 minutes, 10 events/6338 minutes and 63 events/11,133 minutes in 1976. This compares to a combined yearly average for the other four stations of four events and 413 minutes. Each of these stations experienced more outages in 1976 than in the previous year. Woomera and Sunnyvale had no outages in 1975 and only two and one, respectively in 1976. The average power outage duration experienced for the satellite terminals were all long indicating a high occurrence of problems which are more than transient in nature. In 1975, the average power outage was 1 hour 58 minutes compared to 2 hours 57 minutes in 1976.

The length of time to restore communications after a power outage is a function of equipment design and the amount of time required to restore power with either the back-up generators or prime power. A brief outage or even a fluctuation may be sufficient to cause the terminal to "power down". Typically, it takes about seven minutes to bring a back-up generator on line and equipment time delay circuits require another 10 minutes. The cryogenically cooled parametric amplifier requires from a few minutes up to 1.5 hours to cool down depending on the outage length. If fuses were blown, they would have to be replaced. Overall, if there was no equipment damage, it would require about 22 minutes to restore communications from when prime power was first lost. However, equipment damage or degradation can be caused by a power outage which will lengthen the time to restore communications. In addition to possibly blowing fuses, circuits may require realignment or even replacement, the antenna servo system may not respond properly or there may be other indicators which must be checked if not in the proper state.

There will be a significant difference in the impact of power on communications after the installation of the digital subsystem. The modems and crypto equipment may require 10 to 15 minutes for signal acquisition and resynchronization. In addition, since the output power is a function if AC power level, momentary voltage interruptions or sags can lower the transmitter output power. In turn, this will cause the receive signal at the distant terminal to have a lower signal-to-noise ratio which may cause data errors, depending on the magnitude and duration of the "fade". This may be significant since satellite fade margins may be as low as 1.5 dB.

Only Clark, Shemya, and Diyarbakir failed to achieve the performance objective of 99.0% in 1976. For these cases, the application of SSUPS could only help in one way. Because of the long power outages which are typically experienced, SSUPS would be able to provide 15 minutes time in which the backup generators can be brought up, synchronized and switched. Hence, this would provide uninterrupted communications. The application of UPS is not a panacea for power problems. For a balanced solution, the first concern should be improving the base power generation/distribution systems at Clark, Shemya, and Diyarbakir. A big unknown which may have a significant impact on the decision to install UPS is the potential susceptibility of the digital subsystem in the field environment. Because of the digital, solid-state circuitry and its synchronization requirements, there is a potentially significant problem. Considering this, the power conditioning characteristic of SSUPS may be required. However, there is currently little reliable data available to make a prognosis.

SECTION VIII

ALTERNATE STRATEGIES

A. GENERAL.

Section III of this report identified and described the widening technological gap between the power requirements of miniaturized integrated circuit digital electronic equipment and the quality of electric power generally obtainable from public utility companies. In particular, this disparity is describable in the time domain as a susceptibility of high-speed, low-power logical circuits to noise impulses with durations measured in microseconds, and in terms of shortened time-constants of internal computer power supplies to the extent that their "ride-through" capability to bridge power interruptions has been reduced to a single cycle or even 1/2 cycle of the 60 Hz supply. Though the availability of quantitative measurements of power disturbances is limited, all such data consistently confirm that occurrences of both impulsive noise and power interruptions lasting for a full cycle or more can be expected on commercial power service lines several times per day. This section examines several strategies and options to bridge this gap and relieve the pressure of the "Power Squeeze".

B. BASIC ALTERNATIVE STRATEGIES.

The problem can be tackled by attempting improvements on either side of the incompatibility separately, on both sides simultaneously, or by adding equipment which "absorbs" or resolves the differences without fundamental change on either side. The basic alternative strategies are:[28]

1. Modify the design of the power generation and distribution system to be compatible with the electronic systems they serve.

2. Modify the design of the electronic equipment so that its operation is not disrupted by power disturbances which are known to be characteristic of the power service on which it depends.

3. Modify both systems to meet a criterion that is realistic for both.

4. Interpose a "buffer" which can accept a wide class of power disturbances and interruptions at its input, but which provides "clean" power at its output, meeting the requirements of the electronic systems.

The first strategy is not a realistic one for the Air Force. Although USAF is an important member of a large community of users interested in bringing pressure on public power companies to "clean up their lines", only marginal improvements can be expected, since the fundamental causes of power line disturbances are such that there is little utility companies can do to avoid them without prohibitive cost. (Ref. Section III) The possibility of complete independence from public power is open to USAF, but power generation in military-owned plants cannot be expected to be economically competitive with commercial power (with isolated exceptions) and many of the problems and costs associated with commercial generation and distribution of high quality power would also plague military plants.

The second possibility -- modifying the electronic systems to be impervious to power disruptions -- is worthy of consideration as a long-term Air Force strategy. Steps in this direction were recommended by the AFCS/OA report of 1967.[9] A wide spectrum of possible options exist within this general strategy. Among the more superficial (but inexpensive) possibilities are simple schemes to reduce the susceptibility of computers and other electronic equipment to the most bothersome types of disturbances and interruptions. Examples of such measures are increasing the "ride-through" time constants of internal supplies by adding capacitance to the filtering circuits,[68] increasing the interruption time tolerance of sensing circuits which initiate power shut-off sequences, load balancing (in three-phase systems) and exercising special care in grounding arrangements. Other possibilities doubtless could be discovered for particular systems by engineers intimately familiar with the equipment. However, the "easy fix" class of options cannot be expected to handle power outages or sags of more than about one second, at best; beyond this, the components required for electrostatic or electromagnetic energy storage become impracticable in both size and cost.

At the other extreme of the spectrum, but still within the "fix the electronics" strategy, is the possibility for an UPS capability built in as an integral part of the electronic system (or computer) power supply equipment. The ultimate requirement in many cases is for a clean, uninterrupted, low voltage DC power source. It is ironic that the current power squeeze has fostered arrays of equipment in which raw AC power is subjected to three successive conversions to produce usable DC voltages for computer logic circuits. Incoming power is first rectified to produce high-voltage DC which is used to charge large banks of two-volt batteries connected in series. The DC voltage is then converted to "clean" high-voltage AC (with special pains taken to minimize harmonic content) which is then supplied to a computer or electronic system power supply rack where it is transformed to low-voltage AC and then rectified and smoothed to supply low-voltage DC. This is ridiculous from a system-engineering viewpoint, and makes sense only because a well-defined power interface specification exists (60-cycle power) toward which UPS manufacturers can design and build, and which computer/electronics manufacturers can expect. The price of this convenient interface is most of the cost of the equipment to perform the three conversions identified above (when one is theoretically sufficient) and the attendant operational costs ascribable to the inefficiencies incurred in these conversions.

In addition to the reduction of these inefficiencies, an advantage of this approach is that the application of conditioned power could be made more selective, i.e., furnished only to those computer/digital functions which demand high quality. Power requirements for blower fans, lights, drive motors, electromechanical clutches, solenoids, etc., are much less restrictive than for computing, logic, memory and control units. This opportunity for greater selectivity offers potential for significant savings, since the separation of loads restricts the influence of load-induced transients, and the units most demanding of high power quality are generally not the highest consumers of power.

The major disadvantage of such an approach is that a very firm resolve and commitment would be required by USAF to buck the trend which both government and industry have established over the past ten years to buy "off-the-shelf" equipment and worry about how to make it work with "dirty" power afterward. In addition, some new type of DC power interface specification (standard family of DC voltages?) would probably be necessary to make the concept economically attractive to both UPS and electronic system manufacturers, and this new interface standard would be resisted by all who have a vested interest in the status quo. It is also true that any DC-UPS engineered to generate the "standard" voltage family would probably be over-designed for any particular application. However, it is hard to imagine how the cost penalty for this solution could be worse than that associated with the current situation.

The third strategy (fix both sides) is not viable as a general solution for the same reasons which eliminate the first strategy. However, on a case-by-case basis, such a strategy may be considered, at least as an interim solution. Particularly where the prime power plant is a military facility, there may be opportunities to "clean up the lines" and prevent momentary interruptions to the extent that these measures, in combination with reductions in equipment susceptibility, would offer a workable solution. A disadvantage of this approach is that it requires some semblance of overall system engineering which encompasses the power generation and distribution system. This places an additional burden on the System Project Office (SPO) responsible for equipment development and procurement, since it may be impossible to "contract-out" this overall system engineering responsibility because of different "colors" of money involved.

The fourth strategy (buy a buffer) is where the action is, and a dozen or more companies are vying for a piece of that action; in fact, nearly that many firms offer SSUPS and other power conditioning equipment on a GSA schedule. A large number of options and configurations of rotary and solid state equipment are available[60, 115, 116] and many have been used successfully for a number of years.

Historically, the rotary type of "ride through" system, as shown in Figure VIII-1, was the first to see wide usage. In its simplest form, it employs an induction motor with low-slip characteristics to drive an alternator and a large flywheel, which stores a reserve of energy in the form of rotational inertia. Under load, the output frequency is typically 59.8 Hz. When input power is lost, the energy stored in the flywheel maintains output frequency above 59.5 Hz for intervals of 1/2 second to perhaps four or five seconds depending upon the size of the flywheel and the electrical load. While such a system provides good buffering against transients and short interruptions or sags, to extend its no-break coverage beyond a few seconds becomes difficult because of the impractically large mass required in the flywheel. To keep the weight down, high speed is desirable, but to minimize noise and reduce maintenance on bearings, low speed is desirable. A common operating speed is 1800 RPM. The principal advantage is its conceptual simplicity and familiarity to people trained in the operation and maintenance of rotating electric power machinery; its disadvantages are the limited no-break coverage duration, and lack of protection against low frequency, since the output frequency must always be lower than the input by about 0.2 Hz. During brownouts, when both voltage and frequency may be reduced, it is conceivable that raw power might support the load, while the "clean" power provided by the system would not.

A straightforward improvement to the arrangement in Figure VIII-1 is the addition of a diesel engine unit aligned on the same rotating axis, as shown in Figure VIII-2, with a clutch which is engaged when failure of the prime power source is sensed. The stored inertia may then be used to start the engine in addition to providing the "ride through" required until mechanical power can be furnished by the engine. Alternatively, a separate starter motor may be used and mechanical coupling delayed until the engine is up to speed. Units of this type are currently in service at CONUS AUTODIN locations and at Japan tropo sites. The system has many of the same advantages and disadvantages of the simple system shown in Figure VIII-1, except that the rapid pickup of the load by the engine provides protection against outages longer than can be handled by the flywheel alone. However, there is only one chance to start the diesel, and during the 10 seconds or so start-up time required before it can supply rotational power, the frequency may drop 2 or 3 Hz. Also, the diesel engine must be dedicated to the critical load supported by the rotary UPS and cannot be used to supply other standby power.

To overcome some of the objections of the system diagrammed in Figure VIII-2, the arrangement shown in Figure VIII-3 has been used. Rotating machinery still provides the principal buffering and isolation, but the reserve of energy is stored in a battery bank, which is charged from a rectifier which also furnishes power to a DC motor. The amount of stored energy depends on battery size; a 5 to 10 minute capacity provides several chances to get standby generators running and power re-established to other loads (if required) before it becomes necessary to furnish power to the rectifier again. This type of rotary UPS is used in overseas AUTODIN locations, and has exhibited fairly good reliability. Because the large rotating mass is replaced by the battery as a means of energy storage, problems of alignment and bearing maintenance are greatly reduced, but maintenance of DC motor brushes and commutator has been introduced. Output frequency need not be less than input frequency and can be held to 60 Hz ±0.25 Hz. However, speed control of the DC motor is sometimes a problem and the job of synchronizing and paralleling several units

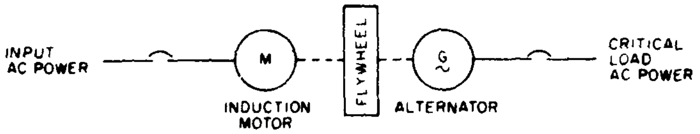


Figure VIII-1
Simple Inertia-Driven "Ride-Through" System

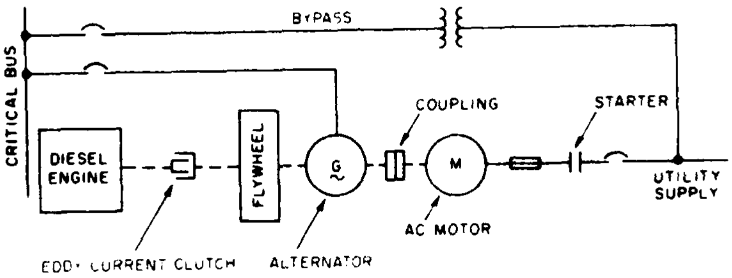


Figure VIII-2
Rotating Flywheel No-Break System

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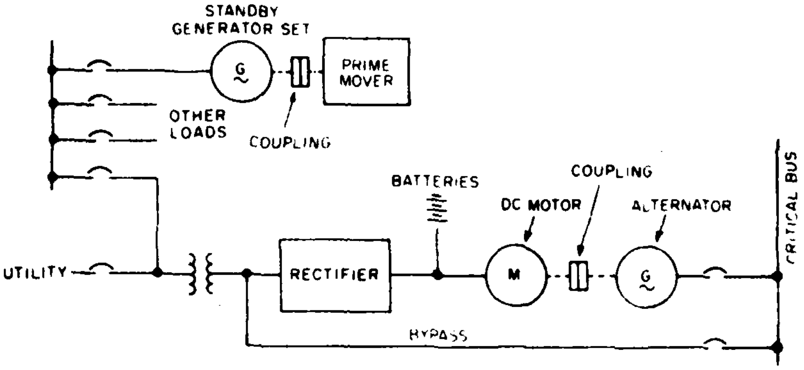
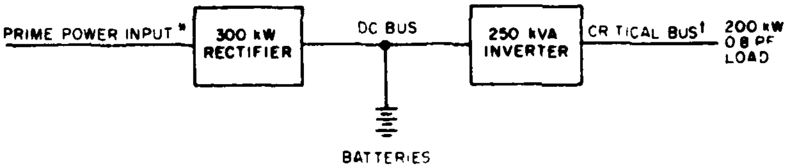


Figure VIII-3
Engine-Generator Supported Battery Inertia System



*May be subject to items (1) (5):
†Is essentially free from items (1) (5):

(1) Voltage dips
(2) Frequency variations
(3) Momentary interruptions
(4) Transient disturbances
(5) Power interruptions

Figure VIII-4
Nonredundant Uninterruptible Power Supply System

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can be a ticklish chore. Acquisition cost is 10% to 20% higher than the system of Figure VIII-2, owing to the addition of a third electromechanical rotating unit and the battery banks, but the arrangement permits the standby engine-generator facility to serve other loads in addition to the UPS-protected critical bus.

Figure VIII-4 shows the elements of a simple Solid-State Uninterruptible Power Supply (SSUPS) system. Basically, the DC motor and AC alternator in Figure VIII-3 have been replaced by a non-rotating inverter; the input switchgear and standby generator arrangment could be used with the SSUPS in Figure VIII-4 also. The principal advantages are precise, clean, uninterrupted power with excellent frequency control, voltage regulation, and fast transient response. Mechanical maintenance problems of rotating machinery are obviated and no special foundations or precise mechanical alignments are necessary. Efficiency is significantly higher than for rotating systems; typical figures for static systems range from 75% to 90%, as compared to a 60% to 80% range for rotary UPS. Though the initial cost of a static system may be as much as 40% higher than a rotary system with equivalent reliability and rating, the higher efficiency affords the opportunity to recover this price differential within a few years in reduced costs of wasted power.[117] A sample calculation is presented in Table VIII-1, page VIII-14.

If a failure occurs in the rectifier, the load is still supported from battery power, permitting several minutes to perform emergency maintenance or replace the faulty component, but the arrangement of the SSUPS shown in Figure VIII-4 suffers the weakness that any failure in the inverter results in an immediate interruption of power to the load. This weakness is not negligible, since solid-state inverter elements do not yet have the reliability of a rotating alternator. The situation can be greatly improved by the addition of a bypass switch, which is also a fast-acting, automatic, solid-state device. Two such switches are shown in Figure VIII-5, although they would normally be supplied in a single unit. The pair is functionally equivalent to an electronically operated double-pole, double-throw switch with higher power-handling capacity.

Two modes of operation of such a switch are possible.[43] In the forward transfer mode, the switch normally connects the load directly to the AC line, bypassing the SSUPS. When an interruption or sag is sensed, the load is switched to draw power from the static inverter. This scheme has the advantage that the power loss due to SSUPS inefficiency is not incurred until the prime power source fails; however, it also offers little protection against transients and surges present in the raw power, which is a principal motivation for installing the UPS in the first place. In the more common reverse transfer mode, power normally flows through the SSUPS to the load (with losses due to inefficiency) and the switch reverts to the raw power position only upon a failure in the inverter. This arrangement assures that the load is never exposed to raw power except during (emergency) inverter maintenance and has the additional advantage that the large current in-rush capacity of the prime source can be called upon automatically to rapidly clear faults in the load. As a rule of thumb, the static bypass switch adds about 20% to the cost of a non-redundant SSUPS, but increases reliability by about a factor of 10.

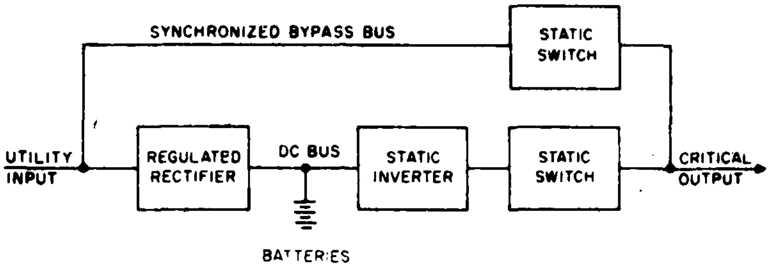

Figure VIII-5
Uninterruptible Power Supply System with Static Bypass

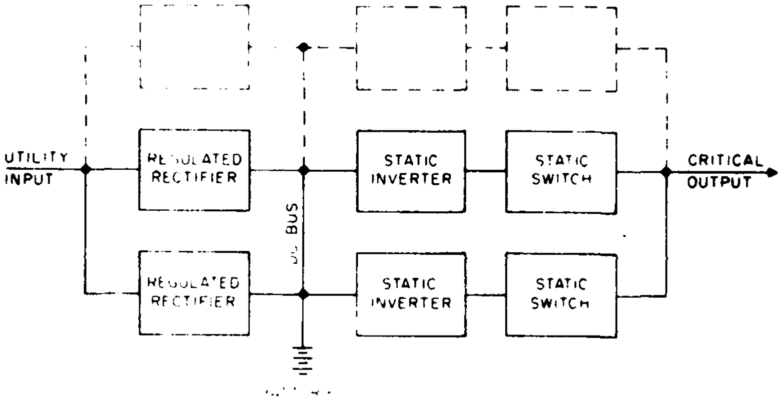

Figure VIII-6
Redundant Uninterruptible Power Supply System

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To obtain the reliability advantages of redundancy, a number of arrangements are possible as suggested by Figure VIII-6. Batteries are not normally duplicated, since their inherent reliability is very high. Use of redundant inverters without redundancy in the rectifier section is also reasonable, since a rectifier failure does not cause an immediate interruption to the load. Partial redundancy schemes are common; e.g., a 200 KW critical buss might be served by three paralleled 125 KVA inverters, any two of which are sufficient to carry the load. Static bypass switches operated in the reverse transfer mode may also be incorporated, of course, as an addition to the layout depicted in Figure VIII-6.

A hybrid arrangement which retains several of the advantages of both rotary and solid-state systems (Figure VIII-7) has been used successfully and has demonstrated good reliability.[30] During normal operation, power flows from the prime source through the rectifier to power the inverter and also maintain the batteries at the proper charge level. The inverter and control circuitry can be much simpler than those normally used in solid-state UPS, since their sole function is to power a synchronous motor which, in turn, drives the alternator to furnish clean AC power to the critical technical load. The solid-state frequency control can regulate the frequency within ±0.1% of the required standard during the time that the battery maintains power to the system and, under normal operation, the control may be locked to the frequency of the incoming power. The rotating machinery provides excellent isolation for the technical load and the system exhibits good voltage and frequency stability under changing load conditions. Since no flywheel is used and no DC motor is involved, maintenance of mechanical components is minimized. The system has the advantage that its simplicity permits routine servicing by plant electricians experienced in conventional power control systems and basic electronics. Cost is comparable to that of a non-redundant SSUPS.

If system outages can be tolerated when power fails, but load isolation is still necessary to protect equipment from overvoltage transients and other short power disruptions, motor-generator sets without means for mechanical or electrical energy storage may be satisfactory. The inherent mechanical inertia of a motor-generator combination can provide a ride-through period of a few hundred milliseconds, which is sufficient for protection against fast disturbances, but would not prevent power loss as major circuit breakers open and reclose in reaction to major faults or lightning strokes. Many other types of equipment and techniques are available to furnish partial answers to some classes of "dirty" power - lightning arrestors, transient suppressors, voltage regulators, isolation transformers, etc. If uninterrupted system operation is not required, a full UPS capability may be unnecessary, and an engineering analysis of the type of power disturbances encountered and their impact on specific equipment items can indicate which types of buffering equipment will be adequate. Implicit in a decision to pursue this course of action is the risk that the time and expense required to perform such an engineering analysis, plus the procurement cost of the "partial" solution chosen might equal or exceed the cost of an UPS solution.

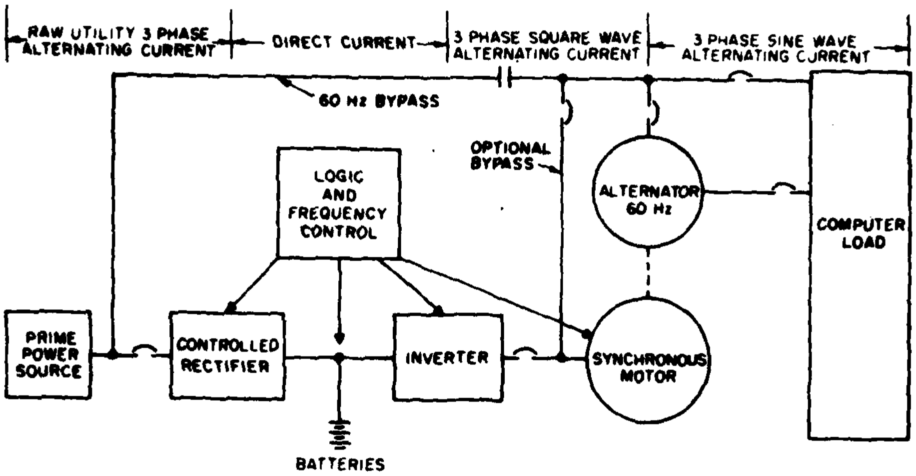

Figure VIII-7
Combination Static, Battery, and Rotating Uninterruptible Power Supply System

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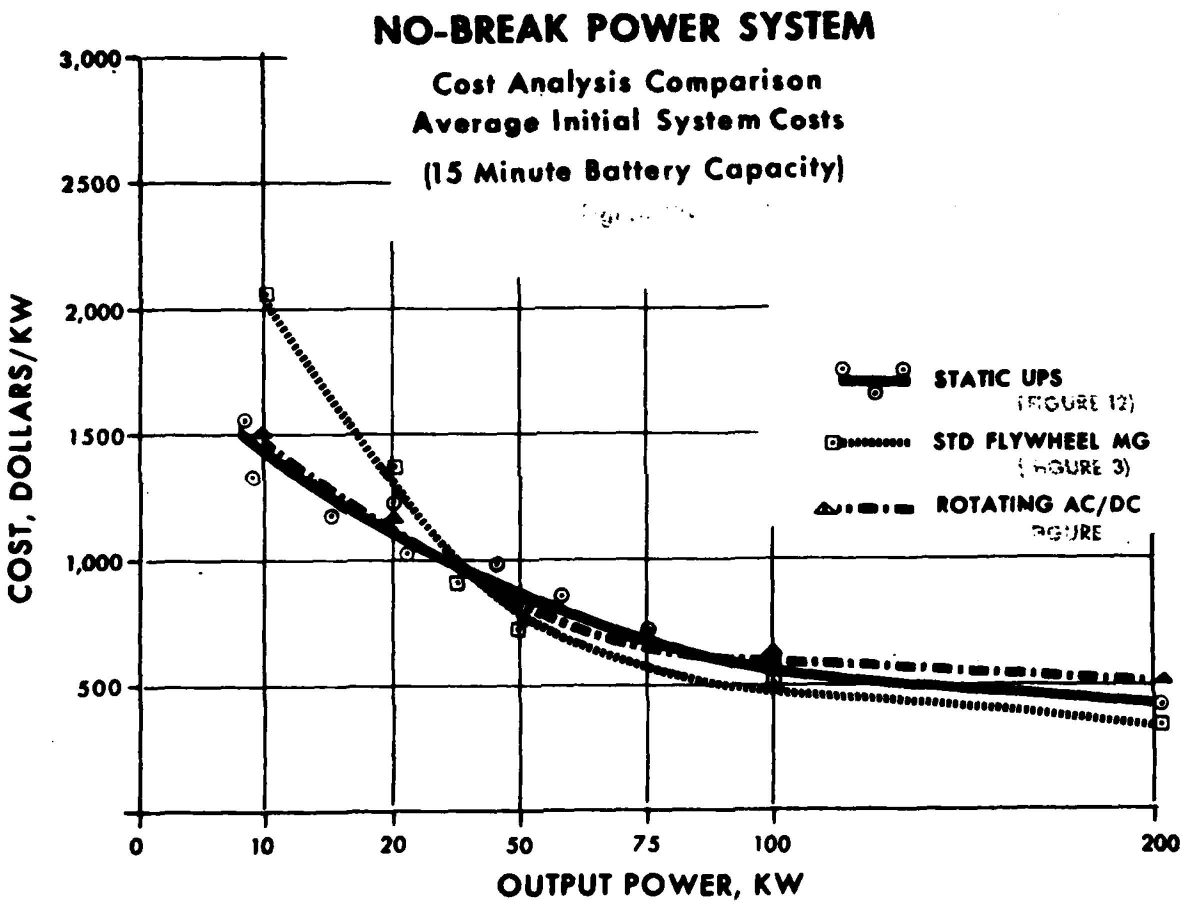
C. SOLID STATE UPS COST AND RELIABILITY.

Procurement costs for solid state UPS have not changed appreciably in the past 10 years. The cost chart of Operations Analysis Report 3-ORR-67, Part II,[10] reproduced here as Figure VIII-8, is still valid as rule-of-thumb guidance. Inflationary pressures of the past decade, which otherwise would have more than doubled the 1967 costs, have been offset by economies achieved by higher production volume for this class of equipment. The significant change since 1967 is the improvement in reliability, as solid-state UPS technology has come of age. In contrast to the dismal experience with the AVTEL equipment procured and pressed into service during the time this technology was still in its infancy, recent applications of both large and small capacity units in government and industry have demonstrated that the theoretical reliability predictions can be achieved in practice. To quote a few examples, FAA is generally very pleased with the history of performance and reliability of the units serving the large computer complexes at the Air Route Traffic Control Centers, and has recently obtained smaller SSUPS units for terminal area installations by off-the-shelf procurement through the General Services Administration. Trans World Airlines reports that no interruptions of power to their large multi-computer complex in Kansas City have been experienced in the year and a half since they installed a SSUPS facility through which more than 2 megawatts of power flows.[119] A Bell Labs special study examined a single family of minicomputers operating throughout the US and concluded that 40% to 60% fewer maintenance actions were required on UPS-protected minicomputers.[120] Continental Telephone has a computer installation near St Louis which was plagued almost daily with computer outages and damage from power line transients before their 125 KVA SSUPS system was installed three and one half years ago, and they report only one failure since.[121] Other users report similar experiences. Unfortunately, none have been able to offer records or reports of SSUPS maintenance costs nor of before-and-after comparisons of computer maintenance which would document quantitatively the value of the SSUPS installations in these terms. However, some equipment suppliers now offer maintenance contracts at surprisingly low rates; $400 to $600 per month, including replacement spares, may be considered typical for installations in the 100-500 KVA range.

Appendix E presents an economic comparison of acquisition and operational costs of several power plant configurations, with and without UPS. The configurations chosen and the example load selected are illustrative only; no recommendation is implied that a power configuration for the sites of the DSCS (or any other of the four systems considered) should be selected from these examples.

D. SUMMARY.

In summary, of the several strategies available to the Air Force to resolve the "power squeeze", the "buffer" or "power-conditioner" approach is probably the only viable alternative as a general, near-term approach, and would put the



NO-BREAK POWER SYSTEM

Cost Analysis Comparison
Average Initial System Costs
(15 Minute Battery Capacity)

Figure VIII-8

Air Force "in step" with other users facing the problem. Within this strategy, a number of equipment options and configurations are possible. Over the past decade, solid-state UPS technology has advanced significantly, and most new installations are of this basic type. Costs of SSUPS have generally "held the line" since 1967 as inflation has escalated. Higher efficiencies of SSUPS systems also offer significant operational cost savings over rotary types.

As a long term strategy, there is merit in instituting an organized effort to reduce the susceptibility of C-E equipments to power disturbances, and to consider built-in power conditioning *alternatives to the "external buffer"* approach.

TABLE VIII-1

ROTARY/SOLID STATE UPS COST COMPARISON
Basis: Now-year dollars, discount rate 8%

Example: load, 150 KW @ 0.9 power factor.

Efficiencies reported from field measurements of rotary systems at CONUS AUTODIN sites range from 41.9% to 89.9% with most in the 65-75% range. Seventy percent used in cost comparison below.

Efficiency claimed by Teledyne/INET proposal[118] for 250 KVA unit from standard family solid-state UPS is 90% @ full load, 88% @ half load. A conservative value of 88% was used for 250 KVA unit delivering 150 KW to load. In addition, a penalty of 50% of the power lost due to inefficiency was added for operating cost of air-conditioning equipment to remove heat from wasted power.

Total power consumption, rotary system @ 70% = 150 KW/.7 = 214 KW

Power consumption, solid-state system @ 88% - 150/.88	170 KW
Power consumption of A/C to remove 20 KW in heat:	10 KW
Total power consumption, solid-state system	180 KW
Annual cost of power @ $0.03/KWH*, rotary system	56,239
Annual cost of power, solid-state system	47,304

COST COMPARISON	ROTARY	SOLID STATE
Acquistion cost, 200 KVA unit*	88,000	120,000
Cost of Power, 1st year	56,239	47,304
Cost of Power, 2nd year	52,073	43,800
Cost of Power, 3rd year	48,216	40,555
Cost of Power, 4th year	44,644	37,550
Cost of Power, 5th year	41,337	34,769
5 year cost**	330,509	323,978
Cost savings per year, in favor of SSUPS, from higher efficiency		
(Then-year dollars)		$8935.00

* Source: DCA Cost and Planning Factors Manual, Amended December, 1973.[102]

** Excluding spare parts and cost of manpower for operation and maintenance.

SECTION IX

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS.

1. Justification for UPS equipment should not be based upon the possibility for marginal increases in availability of power to C-E systems. Power availability near 100% can be achieved with adequate standby power generation capacity (which is needed in any case) and facilities for rapid start and switchover in the event of failure of the prime source.

2. Applicability of UPS equipment should be judged on an evaluation of users' needs for continuous uninterrupted operation, and the technical characteristics of C-E systems whose function is to fulfill those needs, and in particular, upon the capability of the equipment to function properly during and following power line disturbances including, but not restricted to, complete loss of power for short periods up to a few minutes. An opportunity exists for a cost-optimal tradeoff between the time required to switch to standby power and the ride-through capability needed.

3. Data descriptive of the types and frequencies of power line disturbances (other than complete failures) at worldwide operating locations and their effects on specific elements of C-E equipment used by AFCS do not exist, nor can they reasonably be expected to be obtained from current maintenance organizations. Special test equipment, special expertise, time and patience are required to develop such data.

4. A fundamental incompatibility exists between the quality of power required by low signal-level, integrated circuit, solid-state devices and the quality of power generally available from commercial power companies. This disparity was articulated more than ten years ago, has been experienced by hundreds of computer users in government and industry since, and is acknowledged by both computer manufacturers and public utility companies.

5. Nothing in the history of the service of public power in the United States prior to 1965 was predictive of the massive Northeast blackout and similar cascading failures over the past twelve years. Similarly, it cannot be anticipated that current power availability figures will prevail in the coming decade. On the contrary, public utility spokesmen predict a gradual deterioration in the quality of public electric power — increasing frequency and duration of outages, smaller margins of reserve, and necessity for brownouts and/or curtailment during periods of high demand.

6. Of the alternative strategies conceptually plausible for resolving this power disparity, the only realistic near-term approach is to insert buffering equipment which is able to absorb the most common types of power disturbances and furnish high-quality power to the critical load. A number of

equipment configurations and options are available. Motor generator sets, with and without means for energy storage, and solid-state UPS (SSUPS) systems are the most common systems in use. The trend is toward SSUPS, and away from rotating machinery.

7. Because the problem has already existed for a number of years, a wealth of experience in the specification and use of UPS is available from industry and government (especially FAA). Several lines of SSUPS equipment are available on a GSA schedule.

8. Restatement of operational requirements in terms of the rates and durations of interruptions considered tolerable (in wartime or crisis situations) would be helpful in translating such requirements into equipment specifications.

9. Treated on a case-by-case basis, it is entirely possible in some instances that power-buffering equipment less costly than a full UPS would be adequate. However, a commitment of time and money for special instruments and expertise is required to make this determination.

10. Significant operational cost savings can be achieved by:

a. Reconfiguring the power system for CONUS AUTODIN sites to support the entire technical load by UPS, removing the expensive leased Western Union motor-generator sets.

b. Reconfiguring the Carswell ADWS facility by replacing the current Total Energy System (TES) with a more conventional arrangement of commercial power with suitable military standby backup, whether or not UPS is included.

B. RECOMMENDATIONS.

1. It is recommended that basic Air Force policy on power-conditioning equipment, including UPS be in consonance with the precedent already established in Military Specification MIL-E-4158E (USAF),[122] paragraph 3.2.30.3.2.2, i.e., ". . . if uninterrupted operation is a requirement, the devices for accomplishing the improvements in the tolerance limits of the primary power, or for attaining uninterrupted operation, shall be considered part of the equipment group and shall be provided therewith . . ." In particular, this would mean that the decision whether buffering equipment is necessary would not be dependent upon detailed measurements of power disturbances at locations where the equipment is to be deployed: it would be accepted that power is "dirty" in the U.S., and not likely to be cleaner elsewhere in the world.

2. It is recommended that action be taken to initiate a long-range program to reduce the susceptibility of computers and digital subsystems of C-E equipment to power line disturbances. An important aspect of such a program

should be the investigation of the technical, organizational, and fiscal feasibility of designing and building UPS ride-through capability as an integral part of C-E systems and/or subsystems.

3. Whether or not Recommendation No. 1 is accepted, it is recommended that a program of measurement and data compilation of power line disturbances be undertaken at representative worldwide locations, to establish a quantitative data base against which UPS specifications can be written and both UPS and C-E systems without UPS can be tested. Equipment for measurement and recording of power disturbances is now available commercially. It is recommended that teams of qualified people be formed to perform this function to design test procedures, install equipment, assemble measurements, interpret data, and prepare written summary documentation.

4. Using the data so generated, it is recommended that tests of susceptibility to power line disturbances be devised and incorporated as a portion of standard acceptance testing for at least the digital portions of all new C-E equipment procurements.

5. If Recommendation No. 1 is not accepted and procurement of UPS or other power-conditioning equipment is to be dependent on characterization of power problems on a site-by-site basis, it is recommended that specific uniform guidance be established with respect to procedures to be used, instrumentation characteristics required, specific measurements necessary, quantity of data or monitoring duration required, etc., and resources provided (e.g. the special team of Recommendation 3) to field units charged with developing such characterizations.

6. It is recommended that MAJCOMs and other users of Air Force communications facilities be invited to restate availability requirements in terms of tolerable frequencies and durations of service interruptions.

7. It is recommended that the reconfigurations described in Conclusion 10 be implemented.

APPENDICES

T- Tasking Documents

A. JTS Related Information

B. ADWS Related Information

C. AUTODIN Related Information

D. DSCS Related Information

E. Economic Comparison of Power Supply Systems

F. References/Bibliography

TASKING DOCUMENTS

HQ USAF/KRC 061615Z Aug 76, Uninterruptible Power Supplies (UPS) Contract Negotiations.

Outline (Table of Contents) Uninterruptible Power Supplies (UPS): Cost-Benefit Analysis

HQ USAF/KRCXP Ltr, 3 November 1976, Uninterruptible Power Supplies (UPS)

061615Z AUG 76
FM HQ USAF WASH DC/KRC
TO HQ AFLC WPAFB OH/LO
HQ AFCS RICHARDS-GEBAUR AFB MO/CE/OA/EP/DE
INFO HQ AFCS SCOTT AFB IL/SY
HQ PACAF HICKAM AFB HI/DC
DCA WASH DC/530

UNCLAS
SUBJ: UNINTERRUPTIBLE POWER SUPPLIES (UPS CONTRACT NEGOTIATIONS)
REF: HQ USAF/KRC 191230Z JUL 76

1. WE HAVE EVALUATED REPLACING THE EXISTING AIR FORCE CONUS AUTODIN ELECTRO-MECHANICAL UPS WITH SOLID STATE UPS AND HAVE DETERMINED THAT IT IS NOT JUSTIFIED AT THIS TIME. THEREFORE, REQUEST AFLC TERMINATE PRESENT SOLID STATE UPS CONTRACT NEGOTIATIONS.

2. THE NEED FOR SOLID STATE UPS OR REPLACEMENT OF ELECTRO-MECHANICAL UPS AT AUTOMATIC DIGITAL WEATHER SWITCHES, JAPAN TROPO SYSTEM SITES OR THE PENTAGON, AIR FORCE DATA SERVICES CENTER AND/OR PROPOSED ALTERNATIVE SITE MUST BE FULLY JUSTIFIED BEFORE WE CAN SUPPORT ANY NEW UPS PROCUREMENT.

3. REQUEST A REPRESENTATIVE OF AFCS/OA MEET WITH AIR STAFF PERSONNEL DURING THE WEEK OF 16 AUG 76 TO DISCUSS STUDIES AND ANALYSIS THAT MAY BE REQUIRED TO FURTHER ADDRESS THIS SUBJECT.

OUTLINE
(Table of Contents)

Uninterruptible Power Supplies (UPS): Cost-Benefit Analysis

I. Introduction.

II. Description of UPS. A low cost-of-ownership UPS will be described.

III. Systems Performance Analysis.
A. Parameters to be considered.
B. Systems to be analyzed.
1. Japan Tropo System (JTS).
2. Automatic Digital Weather Switches (ADWS).
3. CONUS AUTODIN.
4. Defense Satellite Communication Systems (DSCS).
C. Data to be used.
1. Message distribution for peacetime and during crisis/exercise.
2. Power-related unscheduled outages and distribution.
3. Total unscheduled outages.
4. Total scheduled outages.

IV. Cost-Benefit Analysis. Factors to be considered.
A. System performance.
B. UPS cost.
C. Reliability of commercial power.
D. Operational impact.
E. DOD policies and directives on availability requirements.

V. Summary of Results.

APPENDIX. Economic Analysis of UPS Systems.
1. Alternative UPS systems.
a. Nonredundant SSUPS. Static switch/no static switch.
b. 50% redundant SSUPS (no static switch).
c. Rotating diesel UPS. Maintenance spare/no maintenance spare.
2. Economic analysis of alternatives.
a. Factors to be considered.
(1) Initial acquisition cost.
(2) Operation/maintenance cost.
(3) Installation cost.
(4) Power cost.
(5) Logistic support
(6) Reliability.
b. Cost breakout.
(1) Nonrecurring cost.
(2) Recurring cost.
3. Recommendation.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C.

3 NOV 1976

REPLY TO ATTN OF: **KRCXP**

SUBJECT: Uninterruptible Power Supplies (UPS) (Your Ltr, 20 Sep 76)

TO: AFCS/OA

1. We have reviewed the outline for the subject study. Under paragraph III 2, systems to be analyzed, we request all Air Force AUTODIN Automatic Switching Centers (ASC) be included in the study.

2. Another factor brought to our attention as a result of our own CONUS AUTODIN ASC power study is the significant reliability contribution of standby generators. Allegations have been made that ASC standby power generators operate approximately 20 percent of the total time. It appears the threat of electrical storms and other adverse weather reports are enough to sustain this dependency on standby power generators. In assessing system performance, request you consider several strategies of using UPS to maximize reliability and minimize total input power operating and/or maintenance costs; e.g., switch to standby generators only after a prime source interruption, or continue on prime power until adverse weather is actually experienced then switch to standby for the duration of the storm, etc.

3. At a recent reliability seminar on electrical power equipment it was acknowledged that most industrial users consider their standby generators more reliable than commercial power. For your information, the failure rate per year of CONUS electric utilities is 1.956 and the associated switch gear is 0.0336. This data and other information from the reliability seminar is attached.

4. Request you provide a progress report on 15 January 1977 and complete the study by 31 March 1977. Arrangements to brief the Air Staff on the study will be made later.

FOR THE CHIEF OF STAFF

William J. Vipraio

WILLIAM J. VIPRAIO, Colonel, USAF
Chief, Plans and Programs Division
Directorate of Command Control
and Communications

3 Atch
1. Reliable Evaluation
2. Survey
3. Cost of Elec Interrupt

APPENDIX A

JAPAN TROPO SYSTEM DATA

JAPAN TROPO SYSTEM
APPENDIX A-1

CY 75 UPS total scheduled/unscheduled operational events and running time caused by unscheduled commercial power interruptions and scheduled outages for test runs distribution system repair and maintenance causes.

	Unscheduled		Scheduled	
Location	Events	Duration	Events	Duration
Camp Zama	7	3:37	6	16:24
Hakone	10	14:07	5	14:55
Itazuke	59	54:04	7	9:59
Iwakuni	6	3:25	2	7:00
Rokko	8	10:02	4	12:00
Seburiyama	12	27:21	5	26:49
Sofu	11	5:19	4	5:43
Subtotal	113	117:55	33	92:50
+ Sched	33	92:50		
TOTAL	146	210:45		

NOTE: Chart information provided by data submitted by the 1956 Comm Gp.

JAPAN TROPO SYSTEM
APPENDIX A-2

CY 75 UPS Operational Events by Month Caused by Unscheduled Commercial Power Interruptions At Each Mainland Location

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Camp Zama				3	3		1					
Hakone			1			2		1	2	3	1	
Itazuke	1	1	4	8	9	8	6	1	6	7	6	2
Iwakuni			2				3	1				
Rokko			2		2		2		1		1	
Seburiyama	1		1				2	2	2	3		1
Sofu			1	1		5	1		1	1		1

CY 75 UPS running time by month caused by unscheduled Commercial Power Interruptions at each Mainland Location

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Camp Zama				:37	2:11		:49					
Hakone			4:15			4:35		:10	1:07	3:50	:10	
Itazuke	:29	2:55	7:25	4:20	14:12	11:38	3:52	:20	1:29	2:10	4:47	:36
Iwakuni			:34				2:46	:05				
Rokko			2:37		1:51		1:21		2:30			1:43
Seburiyama	:29		:18				:42	24:04	1:10	:35		:03
Sofu			:16	:10		4:22	:07		:10	:08		:06
TOTAL	:49	2:55	15:25	5:07	18:14	20:35	9:37	24:39	6:26	6:43	4:57	2:28

NOTE: Chart information provided by data submitted by the 1956 Comm Group.

JAPAN TROPO SYSTEM
APPENDIX A-3

CY 75 UPS Operational Events by Time Increments Caused by Unscheduled Commercial Power Interruptions At Each Mainland Location

Location	1-10 Min	11-30 Min	31-60 Min	1-2 Hours	Over 2 Hours
Camp Zama	4	1	1	1	
Hakone	5	1		1	3
Itazuke	15	13	9	16	6
Iwakuni	3	1	1	1	
Rokko	2	1		3	2
Seburiyama	6	3	1	1	1
Sofu	7	1	1	2	
TOTAL	42	21	13	25	

CY 76 UPS Operational Events by Time Increments Caused by Unscheduled Commercial Power Interruptions At Each Mainland Location

Location	1-10 Min	11-30 Min	31-60 Min	1-2 Hours	Over 2 Hours
Camp Zama	3				2
Hakone	4		1	2	3
Itazuke	14	19	7	3	6
Iwakuni	3	2	1	3	
Rokko	3		2	1	1
Seburiyama	5	5	1	1	2
Sofu	9	4	2	3	1
TOTAL	41	30	14	13	15

JAPAN TROPO SYSTEM
APPENDIX A-4

CY 76 UPS total scheduled/unscheduled operational events and running time caused by unscheduled commercial power interruptions and scheduled outage for test runs and distribution repair and maintenance causes.

	Unscheduled		Scheduled	
Location	Events	Duration	Events	Duration
Camp Zama	5	11:22	2	6:00
Hakone	10	12:54	8	20:55
Itazuke	49	37:55	4	12:01
Iwakuni	9	5:32	6	12:46
Rokko	7	5:54	3	9:45
Seburiyama	14	10:54	5	16:49
Sofu	19	15:07	2	6:05
Subtotal	113	98:28	30	84:21
+Sched	30	84:21		
TOTAL	143	182:49		

JAPAN TROPO SYSTEM
APPENDIX A-5

CY 76 UPS Operational Events by Month Caused by Unscheduled Commercial Power Interruptions At Each Mainland Location

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Camp Zama		1					2	1	1			
Hakone		4			2	1			1		1	1
Itazuke	3	4	3	1		2	6	1	1	2	25	1
Iwakuni		1						3	5			
Rokko		1	1		4				1			
Seburiyama					2		1	1	5	2	1	2
Sofu	1	1				1	3	3	5	2	2	1
TOTAL	4	12	4	1	8	4	12	9	19	6	29	5

CY 76 UPS Running Time by Month Caused by Unscheduled Commercial Power Interruptions At Each Mainland Location

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Camp Zama		7:04					4:05	:10	:03			
Hakone		2:15			3:02	:59			1:03		4:15	1:23
Itazuke	4:48	3:33	1:15	3:00		:25	3:47	:10	:07	4:40	12:25	3:35
Iwakuni		:13						1:28	3:51			
Rokko		2:10	:55		2:54				:05			
Seburiyama					4:07		:06	:05	2:14	3:32	:09	:41
Sofu	7:00	1:35				:05	:28	:45	2:39	:59	:10	1:26
TOTAL	11:48	16:50	2:10	3:00	10:03	1:29	8:26	2:28	9:59	9:11	16:59	6:05

JAPAN TROPO SYSTEM
APPENDIX A-6

LOCATION: Yaetake Power Outages

1975 Total Events: (T.E.) 16 Total Time: (T.T.) 20:30

T.E. Dist by Time	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	2	1	4	5	4

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	1	1	1	4	0	1	4	1	2	1	0	0

T.E. Monthly Average: 1.3

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	:57	1:09	1:55	10:50	0	:40	2:52	2:07	7:31	1:30	0	0

T.T. Monthly Average: 2.27 Hrs

JAPAN TROPO SYSTEM
APPENDIX A-7

LOCATION: Yaetake Power Outages

1976 — **Total Events:** (T.E.) 5 — **Total Time:** (T.T.) 15:21

T.E. Dist by Time:	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	0	2	1	0	2

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	1	0	1	0	0	1	0	2	0	0	0

T.E. Monthly Average: .4

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	:12	0	11:10	0	0	:30	0	3:29	0	0	0

T.T. Monthly Average: 1:17 Hrs.

APPENDIX B

ADWS DATA

APPENDIX B-1

FUCHU ADWS OUTAGES
(Hr:Min)
(Station Logs)

1975 Month	# of Out-Outages	# of CML Power Outages	# of Other Power Outages	ADWS Operational Outage Time	Time On Generator Due to CML Outages	Time On Generator Due to Weather	Time On Generators Due to Other
FEB	1	1	0	0:01	2:37	0	0
MAR	1	1	0	0:07	1:53	0	0
AUG	0	0	0	0	0	36:45	0
SEP	3	3	0	0:03	10:04	0	0
OCT	1	0	1	0	0	5:00	3:26
Summary	6	5	1	0:11	14:34	41:45	3:26

APPENDIX B-2

(CLARK ADWS Outages (hr:mn)
(Station Logs)

	# of Outages/Pow-Flux	# of Times Switched to Back-Up	Operational Outage loss of Coml Pwr	Operational Outage Switching Back to CML Pwr	Time Spent on Generators
Dec 75	22	5	1:02	0:35	21:12
Jan 76	12	5	0:26	0:23	13:15
Feb 76	7	2	0:22	0:06	3:32
Mar 76	7	2	0:19	0:13	16:23
Apr 76	9	1	0:26	0:04	8:53
May 76	19	4	0:35	0:14	15:59
Jun 76*	12	6	0:27	0:20	18.48
Jul 76	11	4	0:28	0:15	28.17
Aug 76	10	4	0:21	0:20	13.34
Sep 76	5	1	0:08	0:02	2:58
Oct 76	21	6	0:38	0:20	21:17
Nov 76	15	5	0:19	0:18	16:42
Dec 76	7	2	0:23	0:10	23:27
TOTAL	157	47	4.54	3:20	204:07
30 da Av =	12.53	3.75	0:23	0:16	16:17

*Data for 11-30 Jun unavailable

APPENDIX B-3

Carswell ADWS Outages (Hr:Min)
(Station Logs)

Month Year	# of Outages Switched From TES to CML Back-Up	Time on Coml Power (Tech-Load)	Time For Loss Of Tech Pwr when TES was Operational	ADWS Operational Outage	# of Times Switched Non-Tech Load from CML to Gen	on Gen	Time Non Tech Load on Gen due to Weather	Time Scheduled Outage due to Cml Outage
1975								
Feb	1	1:31	+	+	0	0	0	=
Mar	1	4:38	+	+	0	0	0	+
May	1	3:32	+	+	0	0	0	+
Jun	1	7:20	+	+	0	0	0	+
1976								
Feb	0	0	0.06	0:32(1)	0	0	0	0
Apr	0	0	0	0(2)	0	0	0	0
May	0	0	0	0	9	34:26	19:45	0
Jun	0	0	0	0	3	9:45	0:02	4:28
Jul	0	0	0	0(2)	5	9:04	4:40	0
Aug	0	0	0	0	3	7:13	0	0
Sep	1	11:50	0	0	0	0	0	0
Oct	0	0	0	0	1	2:15	0	0
Nov	1	12:30	0	0	2	0	5:13	4:03
Total CY 76	2	24:20	0.06	0:32	23	62:43	29:40	8:31
Monthly Av CY 76	0.16	2:00	0	0:026	1.9	5:09	2:26	9:39

+No Data available.

(1) Does not reflect 2 momentary power flux which caused equip to recycle.

(2) Does not reflect 1 momentary power flux which caused equip to recycle.

APPENDIX B-4

ADWS POWER OUTAGES

A recap of Jan-Dec 76 power outages (scheduled and unscheduled) which caused the ADWS to be non-operational. (# of Outages/Minutes). Data from 7109 reports.

	Carswell	Clark	Croughton	Fuchu
JAN:				
Pwr - Backup				
Pwr - Coml		7/26		1/24
Pwr - Mil				
Pwr - Otr				
FEB:				
Pwr - Backup		1/3		
Pwr - Coml		5/22		
Pwr - Mil				
Pwr - Otr	1/34			
MAR:				
Pwr - Backup				
Pwr - Coml		5/19		
Pwr - Mil				
Pwr - Otr		1/3		2/55
APR:				
Pwr - Backup				
Pwr - Coml		9/26		1/4
Pwr - Mil	2/0			
Pwr - Otr				
MAY:				
Pwr - Backup				1/106
Pwr - Coml		6/36		
Pwr - Mil				
Pwr - Otr				
JUN:				
Pwr - Backup		1/0		
Pwr - Coml		16/62	1/0	
Pwr - Mil				
Pwr - Otr				
JUL:				
Pwr - Backup		1/8		
Pwr - Coml		9/35		
Pwr - Mil	1/7			
Pwr - Otr			1/4	

	Carswell	Clark	Croughton	Fuchu
AUG:				
Pwr - Backup		1/0		
Pwr - Coml		6/25		
Pwr - Mil				
Pwr - Otr				
SEP:				
Pwr - Backup				
Pwr - Coml		5/9		1/40
Pwr - Mil	1/0			
Pwr - Otr				
OCT:				
Pwr - Backup		1/3		
Pwr - Coml		16/39		
Pwr - Mil			2/259	
Pwr - Otr				1/167
NOV:				
Pwr - Backup		1/10		
Pwr - Coml	2/0	10/21		
Pwr - Mil	1/0			1/10
Pwr - Otr	2/243		1/2	
DEC:				
Pwr - Backup				
Pwr - Coml		7/38		
Pwr - Mil			1/1	
Pwr - Otr				
SUB-TOTAL:				
Pwr - Backup	0/0	6/24	0.0	1/106
Pwr - Coml	2/0	111/358	1/0	3/68
Pwr - Mil	5/7	0/0	3/260	1/10
Pwr - Otr	3/277	1/3	2/6	3/222
Power Total	10/284	118/385	6/266	8/406

APPENDIX B-5

ADWS OUTAGES BY CATEGORY FOR 1976
OUTAGES/MINUTES
DATA FROM 7109 REPORTS

	CARSWELL	CLARK	CROUGHTON	FUCHU
JAN				
ENVIRONMENT	2/23	7/26	2/0	1/24
EQUIPMENT	16/18	0/0	3/7	7/14
OTHER	35/4	20/36	21/9	14/48
PROGRAM	8/0	4/1	2/6	8/9
FEB				
ENVIRONMENT	1/34	6/25	0/0	0/0
EQUIPMENT	18/3	2/4	5/9	9/25
OTHER	29/3	9/12	7/12	12/48
PROGRAM	6/0	2/1	4/21	7/16
MAR				
ENVIRONMENT	0.0	6/22	0/0	2/55
EQUIPMENT	15/4	4/4	0/0	7/15
OTHER	18/0	16/17	23/38	16/8
PROGRAM	2/0	4/4	2/2	5/6
APR				
ENVIRONMENT	2/0	9/26	0/0	1/4
EQUIPMENT	19/0	10/29	0/0	1/0
OTHER	23/3	24/12	10/5	15/7
PROGRAM	5/0	14/13	17/46	1/1
MAY				
ENVIRONMENT	0/0	16/36	0/0	1/106
EQUIPMENT	14/0	3/10	1/0	6/13
OTHER	22/0	17/14	10/20	10/227
PROGRAM	26/2	3/2	13/19	3/4
JUN				
ENVIRONMENT	2/268	17/62	5/41	0/0
EQUIPMENT	17/7	2/1	1/1	3/12
OTHER	28/4	29/37	11/7	15/30
PROGRAM	15/0	7/10	8/4	4/15

	CARSWELL	CLARK	CROUGHTON	FUCHU
JUL				
ENVIRONMENT	1/7	10/43	1/4	0/0
EQUIPMENT	68/17	1/0	1/0	3/12
OTHER	61/16	18/10	6/1	10/6
PROGRAM	14/0	3/4	8/5	14/8
AUG				
ENVIRONMENT	0/0	8/294	0/0	0/0
EQUIPMENT	45/2	3/0	1/0	8/26
OTHER	45/9	24/24	10/6	12/2
PROGRAM	35/14	0/0	3/11	10/15
SEP				
ENVIRONMENT	1/0	5/9	0/0	1/40
EQUIPMENT	24/12	0/0	0/0	1/3
OTHER	25/5	18/5	11/5	12/1
PROGRAM	30/8	3/5	12/23	1/7
OCT				
ENVIRONMENT	0/0	21/49	2/259	1/167
EQUIPMENT	37/104	0/0	8/62	4/4
OTHER	32/5	26/44	2/2	11/14
PROGRAM	24/0	2/6	4/7	3/0
NOV				
ENVIRONMENT	5/243	11/31	1/2	1/10
EQUIPMENT	14/21	8/23	2/4	4/20
OTHER	18/5	28/41	9/14	9/8
PROGRAM	4/0	4/3	4/5	2/0
DEC				
ENVIRONMENT	0/0	7/38	1/1	0/0
EQUIPMENT	9/8	1/62	0/0	1/5
OTHER	20/0	18/0	8/28	13/12
PROGRAM	27/3	3/4	13/17	8/9

OUTAGES/MINUTES

TOTAL	CARSWELL	CLARK	CROUGHTON	FUCHU
ENVIRONMENT	14/575	123/661	12/307	8/406
EQUIPMENT	296/196	34/133	22/83	54/149
OTHER	356/54	247/252	128/147	149/410
PROGRAM	196/27	49/53	90/166	66/90
TOTAL	862/852	453/1099	252/703	277/1055

APPENDIX B-6

Part of Msg from 1956 Comm Gp 151400Z Feb 75 RCSCSVDEAR7101.

2. FUCHU STC, DTC, ADWS AND AERO STATION
3. BOLG 690 and 163 FUCHU AS JAPAN
4. 150220Z FEB 75 150241Z FEB 75
COMML POWER FAILED AT 150220Z AND WAS RESTORED AT 150249Z.
5. 150222Z FEB 75 2 MINUTES 150250Z FEB 75 9 MINUTES
6. FUCHU STC AND DTC NONE, FUCHU AERO STATION 9 MINUTES FUCHU ADWS 367 MINUTES NOT ALL POWER TROUBLES.
7. COMML POWER FAILURE, OPERATOR ERROR AND CIRCUIT BREAKER. FUCHU TROPO SITE AND BLDG 175 NO INDICATED PROBLEMS BLDG 690 B&U GENERATOR PLACED ON LINE MANUALLY.
8. COMML POWER FAILED AT KITA TAMA SUBSTATION, REASON UNKNOWN. BLDG 161 AUTOSTART 60 HZ GENERATOR STARTED AND ASSUMED LOAD AS REQUIRED. OPERATOR RCVD CALL FROM SOMEONE WHO SAID THEY DID NOT HAVE ANY POWER. HE ASSUMED THAT THEY WERE TALKING ABOUT 60 HZ. OPERATOR TRIPPED BREAKER AND SHUT DOWN FLANT BACK UP MANUAL. OPERATOR STATED HE HAD NO KNOWLEDGE THAT HE WAS SUPPOSED TO START THE 50 HZ GENERATOR AND PLACE ON/LINE. ONCE INFORMED BY D.E. STAFF DUTY NCO, APPROX 0300Z, HE STARTED 50 HZ GENERATOR AND PLACED ON/LINE. ONCE COMML POWER WAS RETURNED, OPERATOR TRIED TO RETURN TO COMML POWER, BUT COULD NOT DUE TO A FAULTY 50 HZ CKT BREAKER. MAINT MAN ARRIVED AND FOUND CKT BREAKER G/1 WOULD NOT GO PAST MID POSITION INTO COMML RESET. MAINT MAN WORKED ON CKT BREAKER AND WAS FINALLY ABLE TO REPOSITION CKT BREAKER INTO THE NORMAL COMML POWER POSITION. AIR CONDITIONER POWER WAS INTERRUPTED ON 5 OCCASIONS WHEN OPERATION WAS ATTEMPTING TO RETURN TO COMML POWER. THIS CAUSED OUT OF TOLERANCE TEMPERATURES IN THE FUCHU ADWS, 50 HZ IS FOR A&C ONLY.

APPENDIX B-7

Part of Msg from 1956 Comm Gp - 151400Z Feb 75 MIREP 5623 & IOR/RR

CONCERNING THE FHU ADWS.....BETWEEN 0353Z AND 0435Z, THE ADWS ATTEMPTED RESTORAL. THE AIR CONDITIONER HAD COOLED SYSTEM SUFFICIENTLY BY 0419Z AND OPERATIONS ATTEMPTED TO BRING UP SYSTEM. ALTHOUGH COMPUTER WAS READING PROGRAM INTO THE F880 DRUMS, IT WAS NOT READING INTO THE 330 A-B DRUMS. OPERATIONS TRIED VARIOUS CONFIGURATIONS USING BOTH THE 330A AND 330B DRUMS. THEY WERE STILL UNABLE TO BRING SYSTEM UP. OPERATIONS PLACED A CALL TO UNIVAC MAINT AT 0430Z REQUESTING A MAINT MAN TO CHECK OUT SUSPECTED EQUIPMENT TROUBLE AT FHU. MAINT CALLED BACK AT 0450Z AND CONFIRMED THAT HE WAS ON HIS WAY. AT C435Z, THE GENERATOR MAINT MAN HAD TAKEN THE 50 CYCLE POWER OFF/LINE TO WORK ON THE CIRCUIT BREAKER. THE AIR CONDITIONER WAS RESTORED AT 0520Z. THE UNIVAC MAINT MAN ARRIVED AT 0610Z AND WAS BRIEFED ON 330 DRUM TROUBLE. 330A DRUM HAD AN UNDERTEMPERATURE LIGHT AND A WRITE FAULT INDICATION. 330B DRUM ONLY HAD A WRITE FAULT INDICATION. UNIVAC ADVISED THAT AFTER COMPUTER HAD POWERED UP, THE DRUM WOULD INTERMITTANTLY POWER ITSELF DOWN. THE UNIVAC MANUAL STATES THAT IF A 330 DRUM HAS A COMPLETE STOPPAGE, IT TAKES APPROXIMATELY 2 HRS TO POWER UP & BRING TEMPERATURE UP TO OPERATIONAL CAPABILITIES AND BRING REVOLUTIONS UP TO OPERATIONAL LIMITATIONS. MAINT BELIEVES THIS WAS COMPLICATED BY THE INTERMITTANT AIR CONDITIONER INTERRUPTIONS AND THE 0435/0520 AIR CONDITIONER OUTAGE. AT 0824Z THE UNDERTEMPERATURE LAMP INDICATION WENT OUT ON DRUM 330A. OPERATIONS RELOADED AND RECYCLED DRUM TO RESTORE THE ADWS AT 0827Z. AT THIS TIME, THE ADWS ENTERED INTO HAZARDOUS CONDITION DUE TO ONE OR TWO 330 DRUMS BEING INOP. MAINT STARTED TO TROUBLESHOOT 330B DRUM, AND AT APPROXIMATELY 0840Z THE MAINT MAN POWERED DOWN THE DRUM, RECYCLED AND WHEN THE DRUM WAS POWERED BACK UP THE WRITE FAULT INDICATOR ON 330B DRUM CLEARED. MAINT KEPT DRUM UNDER OBSERVATION UNTIL 0910Z WHEN HE THEN DECLARED IT USABLE AND ADWS WAS BROUGHT OUT OF HAZCON AT 0910Z.

COMMANDERS ASSESSMENT.

NO WEATHER DATA WAS PASSED THROUGH THE FHU ADWS DURING DURATION OF OUTAGE. A SYSTEMS RECOVERY WAS NOT PERFORMED DUE TO A RAPPED TAPE CAUSED BY A POWER SURGE DURING REWIND.

APPENDIX B-8

Part of Msg From 1956 Comm Gp - 0110430Z Jan 77 RCS CSVDOAR 7153/MIREP/5613/FER

5. ANALYSIS OF OUTAGE.
A. OUTAGE OCCURRED 0100305-0100343
B. NUMBER AND AFCS OF PERSONNEL

AFSC	RANK	NBR ON DUTY
29570	E6	1
29530	E5	1
29530	E4	1

C. RESULTS OF FAILURE
AT 0306Z POWER FAILED, OPERATOR RAISED HEADS ON FH880 DRUMS. THIS IS NORMAL PREVENTIVE MEASURE TO ELIMINATE POSSIBLE DRUM DAMAGE. POWER REMAINED OUT FOR APPROX 1 MINUTE. THE POWER FAILURE CAUSED FOLLOWING EQUIPMENT SPEAKERS TO TRIP.
A & B FH880 DRUMS
A & B GH330 DRUMS
A-B-C-D TAPE SERVOS
A & B SCS CABINETS
A & B 1004's
EQUIP TRANSFER CABINET
TAPE TRANSFER CABINET
AFTER POWER WAS RESTORED, THE OPERATORS POWERED UP ALL THE ABOVE EQUIP ON "A" SYS, WHICH WAS ON LINE AT TIME OF FAILURE. HOWEVER, THE FJ330 DRUM REMAINED A FAULT CONDITION.
OPERATOR AGAIN ATTEMPTED TO POWER UP "A" FH880, WHEN THIS FAILED AGAIN, A CHECK OF TEMPS INDICATED A BELOW NORMAL 90 DEGREES TEMP/NORMAL 98-102.
0315Z POWERED UP EQUIPMENT ON "B" SYSTEM.
HOWEVER HEADS DID NOT LOWER ON "B" FH380 UNTIL 0325 WHEN DRUM ACHIEVED APPROPRIATE TEMPS AND SPEED. 0325. AT THIS TIME OPERATOR ATTEMPTED TO READ PROGRAM TAPE INTO "8" SYS CORE AND ONTO "8" SYSTEM FH380 AND 330 DRUMS. IT REQUIRED ATTEMPTS ON THREE SEPARATE TAPE SERVOIS BEFORE A SUCCESSFUL READ WAS ACCOMPLISHED.
0343Z. SUCCESSFUL READ AND SYSTEM OPERATING.
D. PAST EXPERIENCE INDICATES POWER FAILURES VERY SELDOM CAUSE ALL EQUIPMENT TO FAULT, GENERALLY CAUSING ONLY THE FH880 TO FAULT. THE ADDITIONAL POWER-UP REQUIREMENTS INCREASES RECOVERY TIME APPROX 5 MIN PER SYS.

APPENDIX B-9

Part of Msg from 1956 Comm Gp - 110431Z Jan 77 RCS CSVDOAR 7153/MIREP/5614/FER

5. ANALYSIS OF OUTAGE.

A. OUTAGE OCCURRED 0100423-0100433

B. NUMBER AND AFCS OF PERSONNEL

AFSC	RANK	NBR ON DUTY
29570	E6	1
29530	E5	1
29530	E4	1

C. RESULTS OF FAILURE

AT 0423Z ADWS EXPERIENCE MOMENTARY/1 SEC/POWER FLUX. INITIAL INDICATION BEING THAT THE 0413 CPU CAME TO A STOP. OPERATOR MADE 2 ATTEMPTS TO READ PROGRAM TO CORE FROM DRUM.

WHEN THIS FAILED, AN ATTEMPT WAS MADE TO READ FROM PROGRAM TAPE TO CORE AND DRUM. WHILE OBSERVING THE CPU OPERATIONS/ MAINTENANCE PANEL DURING TAPE READ OPERATOR NOTED THAT THE READ FUNCTION STOPPED WHEN ATTEMPTING TO WRITE TO THE FH330 DRUM. A CHECK OF THE FH330 INDICATED IT HAD FAULTED. POWER UP PROCEDURES RESTORED DRUM. PROGRAM TAPE WAS THEN READ IN AND SYSTEM OPERATING AT 0433Z.

D. FAULT INDICATORS ON FH330 ARE INTERNAL AND FOR OBSERVATION REQUIRE OPENING OF FH330 CABINET.

APPENDIX C

AUTODIN DATA

APPENDIX C-1
AUTODIN UNSCHEDULED OUTAGES DUE TO POWER - 1976
(DCAC 310-55-1)

STATION		DATE	OUT	IN	DURA	RFO	REASON FOR OUTAGE
ANDREWS	ADR	760402			0043	YRK	DIN SW U/S PWR OTG CMML&MIL
		760404			0014	YRK	DIN SW U/S POWER SURGE
		760536			0038	YRG	DIN SW U/S PWR OTG MIL/TOTAL
		760715			0022	YRK	DIN SW U/S PWR OTG CMML&MIL
	*** TOTAL OUTAGE TIME - 117						
CAMP DRAKE		NO OUTAGE TIME					
CLARK	CKD	760830			0030	YHS	DIN SW U/S PWR CKT BKR MALFN
	*** TOTAL OUTAGE TIME - 030						
CROUGHTON		NO OUTAGE TIME					
MCCLELLAN	MCL	760325			0004	YRK	DIN SW U/S PWR RELAY HALFCN
		760408			0012	YRH	DIN SW U/S PWR OTG CMML/PRI
		760531			0085	YRJ	DIN SW U/S PWR OTG CMML/TOT
		760601			0022	YRU	DIN SW U/S PWR OTG CMML/TOT
		760601			0005	YRK	DIN SW U/S PWR OTG CMML&MIL
		760617			0061	YRU	DIN SW U/S PWR OTG CMML/PRI
	*** TOTAL OUTAGE TIME - 189						

GENTILE	GNT	760311	0004	YRH	DIN SW U/S PWR OTG CMML/PRI
		760619	0054	YHX	DIN SW U/S PWR OTHER
		760623	0023	YRH	DIN SW U/S PWR OTG CMML/PRI
		760630	0009	YHS	DIN SW U/S PWR CKT BKR MALFN
		760726	0005	YHX	DIN SW U/S PWR OTHER
		761005	0000	YRQ	DIN SW U/S AC PWR SUPPLY EO

*** TOTAL OUTAGE TIME - 95

NORTON	NTN	760183	0020	YRH	DIN SW U/S PWR OTG CMML/PRI
		760133	0040	YRH	DIN SW U/S PWR OTG CMML/PRI
		760319	0025	YRG	DIN SW U/S PWR OTG MIL/TOTAL
		760415	0000	YRD	DIN SW U/S PWR OUT OF FUEL
		760505	0007	YRH	DIN SW U/S PWR OTG CMML/PRI

*** TOTAL OUTAGE TIME - 092

TINKER	TKR	760230	0068	YRG	DIN SW U/S PWR OTG MIL/TOTAL
		760418	0076	YRK	DIN SW U/S PWR OTG CMML&MIL
		760428	0009	YRG	DIN SW U/S PWR OTG MIL/TOTAL
		760428	0029	YRG	DIN SW U/S PWR OTG MIL/TOTAL
		760615	0966	YRK	DIN SW U/S PWR OTG CMML&MIL
		760618	0006	YHS	DIN SW U/S PWR CKT BKR MALFN
		760831	0040	YRK	DIN SW U/S PWR OTG CMML&MIL
		760903	0026	YRK	DIN SW U/S POWER DIP
		760915	0002	YHS	DIN SW U/S PWR CKT BKR MALFN
		760910	0006	YHS	DIN SW U/S PWR CKT BKR MALFN

*** TOTAL OUTAGE TIME - 1160

ALL STATIONS	TOTAL OUTAGES	32
	TOTAL OUTAGE TIME	1683 Minutes
	AVERAGE TIME/OUTAGE	52.6 Minutes

APPENDIX C-2
NORTON ASC POWER OUTAGES 1976

RADAY	TIME POWER FAILED	TIME CENTER CYCLING	EQUIP TYPE	DESCRIPTION
051	2143Z	2251Z	All equipment	A buss feeder breaker tripped; power restored at 2213Z.
109	0730Z	0845Z	All equipment	Lost all power trying to bypass UPS - lost all power to ASC. Modem up at 0751Z
119	1338Z	1407Z	All equipment	Suspect bad circuit breaker.
167	0754Z	0845Z	All equipment	Lost all power; Modem/Tech Control up at 0758Z.
216	1631	1640Z	All equipment	CDP-2 was down from 1631Z-1739Z due to bad board as result of power failure.
238	0250Z	No lost time	ADP, MMU-2, SCMP	Suspect power hit; equip errors and lights blink simultaneously.
244	0918Z	0920Z	MOD/TC/CRYPTO	UPS-1 failed on line.
247	0140Z	0206Z	All equipment	Power restored at 0151Z; output breaker tripped; voltage flux while trying to run up UPS-1.

TOTAL TIME (Start of power failure to when center was cycling) : 260 minutes.

AVERAGE TIME PER EVENT: 32.5 minutes.

APPENDIX C-3

Part of 2049 CG/LGMS msg 212205Z Jan 77, Subj: Equip problems resulting from power fluctuations/failures.

1. DOCUMENTAITON HELD ON FILE IN THE MCCLELLAN AUTODIN SWITCHING CENTER DOES NOT EXCEED ONE CALENDAR YEAR, I.E., FROM JAN 1, 1976 TO PRESENT.

2. THE FOLLOWING INFORMATION IS SUBMITTED: EQUIPMENT TYPE: AUTODIN SWITCHING CENTER EQUIPMENT AND ALL PERIPHERAL DEVICES.

PROBLEMS CAUSED BY PWR FLUX/FAILURE: SERVICE DENIED OR DELAYED TO ALL CONNECTED SUBSCRIBERS.

DATE/TIME (LOCAL)	DURATION	DESCRIPTION OF INCIDENT
7MAR76 0800-0829	9 MINS	COML PWR FLUX
25MAR76 0820-0825	5 MINS	COML PWR FLUX
8APR76 1228-1240	12 MINS	COML PWR FLUX
31MAY76 1435-1628	113 MINS	COML PWR FAILURE
17JUN76 1217-1333	76 MINS	COML PWR FAILURE
01OCT76 1759-1955	116 MINS	COML PWR FAILURE
06DEC76 0702-0744	42 MINS	COML PWR FLUX
18DEC76 0117-0126	9 MINS	COML PWR FLUX
27DEC76 1034-1103	29 MINS	COML PWR FAILURE

3. DOCUMENTATION FOR THIS ASC IS RECORDED ON DD FORM 1753 (MASTER STATION LOG).

APPENDIX C-4

A. NCA/DE Msg 091300Z Sep 76, Subj: Standard family of solid state uninterrupted power, was sent the ASCs in NCA requesting the following information:

1. LIST ALL COMPUTER MALFUNCTIONS, EQUIPMENT OR COMPONENT WEAKING DETERIORATION OR FAILURE AND ANY LONG RANGE DISRUPTION WHICH COULD BE ATTRIBUTED IN ANY WAY TO POWER FLUCTUATIONS OR EVEN SUSPECT VARIATION IN VOLTAGE OR FREQUENCY.
2. LIST ALL COMPUTER COMPONENTS WHICH FAILED DUE TO SUSPECTED POWER VARIATION AND THE COST OF EACH.
3. LIST ALL TRAFFIC DELAYS BY PRECEDENT WHICH WERE CAUSED BY POWER DISRUPTIONS, VARIATIONS OR OUTAGES.

B. 2104 CS/ASC Msg 171330Z Sep 76, Sub: Standard Family of Solid State Uninterrupted Power Systems, submitted the following information, covering the six month period from 1 Mar 76 to 1 Sep 76:

1. A. ICCDP-1 (INTEGRATED CIRCUIT COMMUNICATIONS DATA PROCESSOR POWER SUPPLY FAILURE
RADAY 202 0707Z - 2038Z
RADAY 207 0552Z - 0802Z
B. SDU-1 (ACCUMULATION AND DISTRIBUTION UNIT) BLOWN CAP ON THE LOGIC BOARD
RADAY 104 0909Z - 1553Z
2. COMPONENT COSTS INVOLVED IN EACH REPAIR WERE MINIMAL (LESS THAN ONE DOLLAR).
3. THIS UNIT CANNOT PROVIDE THIS INFORMATION. THE INFORMATION ON MESSAGE DELAY BY PRECEDENCE CAN ONLY BE SUPPLIED WHEN AN ON-LINE RECOVERY IS ACCOMPLISHED. THIS ASC HAS NOT HAD TO DO ANY ON-LINE RECOVERIES DURING 1976 AS ALL POWER OUTAGES RESULTED IN SYSTEM RESTARTS RATHER THAN SYSTEM RELOADS WHICH GENERATE ON-LINE RECOVERIES:
THIS IS AN LGM/ASC/WESTERN UNION COORDINATED MESSAGE.

C. 2049 CG/ASC Msg 211950Z Sep 76, Subj: Standard Family of Solid State Uninterrupted Power System, provided the following response:

1. THE ASSESSMENT REQUESTED IS IMPOSSIBLE TO PERFORM IN THE ALLOTTED TIME FRAME AND EXACT COSTS WOULD REQUIRE EXTENSIVE, EXPENSIVE, TIME CONSUMING ANALYSIS IF AT ALL POSSIBLE TO OBTAIN. EVERY EQUIPMENT REPAIR ACTION PERFORMED WOULD NEED TO BE ANALYZED, AND IN MOST INSTANCES, REPAIRS COULD NOT BE DIRECTLY CONNECTED TO A POWER FAILURE. HOWEVER, AN INFERENCE CONNECTING MOST EQUIPMENT FAILURES TO POWER

PROBLEMS CAN BE MADE BASED ON THE FACT THAT THE NUMBER OF UNSCHEDULED MAINTENANCE ACTIONS INCREASES BY50 PERCENT OR MORE AFTER AN OUTAGE. THE FOLLOWING INFORMATION WAS TAKEN FROM MASTER STATION LOGS TO GIVE AN EXAMPLE OF ACTIONS REQUIRED BY THIS SECTION WHEN A POWER PROBLEM DEVELOPS.

2. ON 17 JUN 76 AT 0417Z, A POWER FAILURE DEVELOPED WITHOUT UPS HOLDING THE CRYPTO SYSTEMS IN OPERATION, AT 0518Z POWER WAS RESTORED; HOWEVER, THE ADU'S WERE NOT UP AND THE NUMBER OF CIRCUITS REQUIRING RESET WAS UNKNOWN AT 0545Z. IT WAS UNTIL 0650Z BEFORE ALL CIRCUITS HAD BEEN RETURNED TO SERVICE. THIS OUTAGE IS TYPICAL OF THE RESTORATION TIME NECESSARY WHEN POWER IS INTERRUPTED AT THIS CENTER. IN ADDITION TO CRYPTO OPERATION TIME, IT WAS NOTED THAT DURING THE FOLLOWING 24 HOUR PERIOD, SIX POWER SUPPLIES FAILED. ALSO, IN THE SUBSEQUENT 30 DAY PERIOD, 15 UNSCHEDULED REPAIR ACTIONS WERE MADE WHICH MAY HAVE RESULTED DUE TO THIS POWER FAILURE. THE CRYPTO EQUIPMENT HERE WHEN POWERED DOWN. AS WITH ANY NORMALLY POWERED ELECTRONIC EQUIPMENT WHICH HAS BEEN IN SERVICE SEVERAL YEARS, HAS A TENDENCY TO HAVE POWER SUPPLY AND REGUAR FAILURES WHEN VOLTAGE FLUCTUATES OR IS SHUT OFF AND TURNED BACK ON WITH THE RESULTANT CURRENT SURGES.

3. TO EVALUATE COMPUTER DETERIORATION OR FAILURE AND ANY LONG RANGE ASC EQUIPMENT FAILURES WOULD REQUIRE RESEARCHING WESTERN UNION FILES ON EACH PIECE OF EQUIPMENT AND IN THIS CASE THE REASONS FOR FAILURE OR DETERIORATION WOULD NOT BE ATTRIBUTED TO POWER FAILURES.

D. 2049 CG/DO Msg 142145Z Oct 76, Subj: Standard Family of Solid State UPS provided the following update to their msg "C" above.

1. ON 30 SEP THE ASC HAD A COMMERCIAL POWER FLUCTUATION. THE ASC DOWNTIME RAN FROM 1902 TO 2006. AS IN OTHER FAILURES NO DIRECT ELECTRONIC DAMAGES COULD BE ATTRIBUTED TO THE LOSS OS POWER, BUT IN THE TWO WEEKS FOLLOWING WE HAVE EXPERIENCED A DRAMATIC INCREASE IN ASC EQUIPMENT FAILURES. RESEARCH OF RECORDS INDICATES THAT 3 FAILURES PER MONTH IS TYPICAL WHEN WE DO NOT HAVE POWER PROBLEMS. SINCE 30 SEP WE HAVE HAD THE FOLLOWING FAILURES:

A. 1 OCT, ADU NO 2 INOPERATIVE.
B. 1 OCT, NO RESPONSE TO COMPUTER, ASC/SET 8.
C. 5 OCT, ADU REMOVED BY PROGRAM.
D. 5 OCT, BUS TRANSMISSION PARITY ERROR.
E. 6 OCT, MMU NO 3 OUT DUE TO READ ERRORS.
F. 6 OCT, ADU NO 3 OUT EXCESSIVE CHANNEL ERRORS.
G. 7 OCT, ADU NO 3 OUT DUE TO PARITY ERRORS.
H. 8 OCT, ADU NO 3 OUT LOGIC TROUBLE.
I. 12 OCT, ADU NO 3 OUT EXCESSIVE CHANNEL ERRORS.

2. A POSSIBLE ADDITIONAL JUSTIFICATION FOR THE ASC/UPS IS IT COULD BE USED TO REPLACE THE EXISTING OBSOLETE NO BREAK SET

IN BUILDING 7 (2049 HEADQUARTERS). FACTS ARE AS FOLLOWS:

A. BLDG 7 TECHNICAL CONTROL FACILITY PROVIDES THE ASC CIRCUITS AND WOULD APPEAR TO BE AS CRITICAL AS THE ASC ITSELF. PRESENTLY BLDG 7 HAS A 60KW, CONSOLIDATED DIESEL ELECTRIC CO, MODEL 4222, NO BREAK UNIT. THIS UNIT HAS PASSED ITS ANTICIPATED LOGISTICS SUPPORT LIFE CYCLE.

B. THE MODEL 42222 IS ONLY SUPPLYING A 12KW CRYPTO EQUIPMENT LOAD. IN ADDITION TO CRYPTO, THE FOLLOWING OTHER LOADS IN BLDG 7 REQUIRE HIGHLY RELIABLE POWER, TECHNICAL CONTROL, AERONAUTICAL STATION AND THE MICROWAVE STATION. THE TOTAL LOAD OF THESE 4 FUNCTIONS IS APPROXIMATELY 65K.

C. BECAUSE OF THE CLOSE PHYSICAL PROXIMITY OF THE ASC AND BLDG 7, IT WOULD BE PRACTICAL TO POWER THE BLDG 7 CRITICAL LOAD FROM THE PROPOSED ASC/UPS. THIS WOULD SAVE FUNDS WHICH MUST OTHERWISE BEEXPENDED TO REPLACE THE PRESENT OBSOLETE, UNDERSIZED, MODEL 42222 NO-BREAK IN BLDG 7.

APPENDIX D

DSCS DATA

D-1	SATCOM Station Report No. 165-01F, Illustrating Transmitter Time Delay
D-2	SATCOM Station Report No. 074-01F, Illustrating Parametric Amplifier Vacuum Loss Resulting from Power Outage
D-3	SATCOM Station Report No. 028-01I, Illustrating Effect of Power Outage on Radio Frequency Local Oscillator (RFLO)
D-4	SATCOM Station Report No. 140-01F, Illustrating Effect of Power Fluctuation on Servo Amplifiers and Fuses
D-5	Power Outage Tabulations on each DSCS Terminal
D-6	Power Disturbance Study AN/MSC-46 Satellite Terminal, Woomera, Australia
D-7	DSCS Equipment Power Output Correlations (Scope Creek Evaluation)

APPENDIX D-1

19[illegible] CG/LGMI MSG 272105Z DEC 76

SUBJ: SATCOM STATION REPORT CKK/165-01F

1. TOF 1434Z 27 DEC 76

2. TOR 14 27 DEC 76

3. TIC 001D

4. TO 77ESO1 76JSO1

5. TOTR 1452Z 27 DEC 76

6. FAILURE IDENTIFICATION:

   A. 3101 YKRA12

   B. N/A

   C. INDEPENDENT

7. REPAIR ACTION SEE ADD. INFO

8. TTR OO HOURS 18 MIN

9. SUPPLY TIME N/A

10. CONFIGURATION CHANGE N/A

11. SYSTEM SHUTDOWN/STARTUP N/A

12. SYSTEM STATUS O

13. ADD INFO LOST BASE PWR AT 1434Z 27 DEC. CAME UP ON SITE PWR AT 1436Z. THEN AT 1439Z WE LOST SITE PWR. BUT BACK UP AT 1440Z. LOCKED BACK ON THE BIRD AT 1449Z BUT CAN'T COME UP WITH THE TRANSMITTER UNTIL IT TIMES OUT. AT 1452Z WE BE PASSING TRAFIC AND WE WENT BACK TO BASE PWR AT 1529Z THIS REPORT IS TO STATE THAT WE HAD A BASE PWR FAILURE AT 1434Z ON THE 27 OF DEC. CALLER BASE PWR PLAN AND THEY SAID THE REASON FOR THE PWR FAIL WAS THAT THE GENERATORS TRIPPED OFF LINE DUE TO A OVER CURRENT FAULT.

APPENDIX D-2

TUSLOG DET 75 MIN MSG 281250Z NOV 76

SUBJ: SATCOM EQUIPMENT FAILURE REPORT NO. 074-01 (F)

1. 281834Z NOV 76

2. 281107Z NOV 76

3. 008D

4. 16/610S01

5. 281127Z NOV 76

6.

   A. 31020101

   B. N/A

   C. DUE TO SCHEDULED BASE POWER OUTAGE GENERATORS ONE TWO AND THREE WOULD NOT PARALLEL CORRECTLY TO LOAD SHARE.

7. GENERATORS MAINTENANCE MADE ADJUSTMENTS TO ALLOW GENERATOR ONE AND TWO TO OPERATE CORRECTLY. PUMPED DOWN PARA-AMPS.

8. 53 MINUTES

9 THRU 11. N/A

12. NO

13. DUE TO GENERATOR PROBLEMS VACCUM WAS LOST IN BOTH PARA-AMPS. BOTH PARA-AMPS NEEDED TO BE PUMPED DOWN. GENERATORS ONE AND TWO ARE PARALLELED AND SHARED THE LOAD AT 1120Z.

APPENDIX D-3

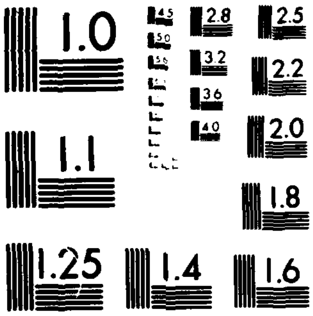
1961 CG/LGMI MSG 250445Z FEB 77

SUBJ: SATCOM STATION REPORT CLL 028-011

1. TOF 25 0104Z FEB 77
2. TOP N/A
3. TIC N/A
4. TD N/A
5. TOTR N/A
6. FAILURE IDENTIFICATION:
   A. 03040203
   B. N/A
   C. DEPENDENT AFTER PWR FAILURE AT 25 0053Z FEB 77, AND RESTORED AT 25 0104Z FEB 77 FOUND THAT RFLO WAS BAD ON D/C 2A3
7. REPAIR ACTION ORDERED NEW RFLO
8. TTR N/A
9. SUPPLY TIME N/A
10. CONFIGURATION CHANGE N/A
11. SYSTEM SHUTDOWN/STARTUP N/A
12. SYSTEM STATUS 0/ ...0
13. ADD INFO AFTER PWR FLOP DESCRIBED IN SSR NBR 027-01F, AND POWER HAD BEEN RESTORED, IT WAS FOUND THAT THE RFLO IN SPARE DOWN CONVERTER 2A3 WAS INOPERATIVE. A NEW RFLO HAS BEEN PLACED ON ORDER AND AN INITIAL ETR OF 12 2400Z MAR 77.

AD-A090 943 AIR FORCE COMMUNICATIONS SERVICE SCOTT AFB IL OPERATI--ETC F/G 10/2
UNINTERRUPTIBLE POWER SYSTEMS: OPERATIONAL AND COST CONSIDERATI--ETC(U)
MAR 77 M MILAKOVICH, C E JACOBS
UNCLASSIFIED 12-ORR-77 NL

3 of 4
AD A
090943



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU

APPENDIX D-4

1961 CG/LGMI MSG 270522Z NOV 76

SUBJ: SATCOM STATION REPORT CKK/140-01F

1. TOF 262345Z NOV 76

2. TOR 270029Z NOV 76

3. TIC C01T C02R

4. TD 77ES01 76JS01

5. TOTR 270029Z NOV 76

6. FAILURE IDENTIFICATION:

   A. 3102

   B. N/A

   C. DEPENDENT

7. REPAIR ACTION REPLACED SERVO FUSES, HAND CRANKED ANTENNA OUT OF LIMITS. ACQUIRED SATELLITE.......

8. TIR 0 DAYS 0 HOURS 44 MINS

9. SUPPLY TIME N/A

10. CONFIGURATION CHANGE N/A

12. SYSTEM STATUS

13. ADD INFO POWER PRODUCTION WAS IN PROCESS OF BRINGING THEIR TERMINAL TO SITE POWER AS BASE POWER WAS MAKING A SCHEDULED OUTAGE. RECEIVED A POWER FLUX AT 262345Z NOV 76 WHICH FAULTED BOTH TRANSMITTERS. AND DROVE THE ANTENNA INTO ELEVATION STOP LIMITS, BLOWING ALL 30 SERVO FUSES. REPLACED 30 SERVO FUSES AND TRIED TO HANDCRANK ANT. OUT OF

LIMITS. HAD TROUBLE GETTING THE ANTENNA BRAKES MANUALLY RELEASED AS THE BRAKE RELEASE STEM WAS FOUND TO BE BROKEN ON THE DOWN MOTOR. USED PLIERS TO RELEASE BRAKE AND CRANKED OUT OF LIMITS. REACQUIRED SATELLITE AND BROUGHT SYSTEM UP AT 270029Z NOV 76.

APPENDIX D-5a

LOCATION: Shemya, Alaska

POWER OUTAGES

1975 Total Events: (T.E.) 15 Total Time: (T.T.) 2886

T.E. Distribution by Time:	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	0	6	1	1	7

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	2	4	2	0	0	0	1	1	0

	Oct	Nov	Dec
	0	4	1

T.E. Monthly Average: 1.25

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1002	231	824	0	0	0	25	280	0

	Oct	Nov	Dec
	0	503	21

T.T. Monthly Average: 240.5

APPENDIX D-5b

LOCATION: Shemya, Alaska

POWER OUTAGES

1976 **Total Events:** (T.E.) 66 **Total Time:** (T.T.) 8816

T.E. Distribution by Time	**1-10 Min**	**11-30 Min**	**31-60 Min**	**1-2 Hr**	**Over 2 Hr**
	13	27	8	6	12

T.E. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	1	2	22	16	8	2	3	0	0	2	5	5

T.E. Monthly Average: 5.5

T.T. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	18	978	5332	795	268	310	857	0	0	79	74	105

T.T. Monthly Average: 734.7

APPENDIX D-5c

LOCATION: Lajes, Azores

POWER OUTAGES

1975 **Total Events:** (T.E.) 2 **Total Time:** **(T.T.)** 223

T.E. Distribution by Time:	**1-10 Min**	**11-30 Min**	**31-60 Min**	**1-2 Hr**	**Over 2 Hr**
	0	0	1	0	1

T.E. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
	0	0	0	0	0	0	0	0	0
	Oct	**Nov**	**Dec**						
	1	0	1						

T.E. Monthly Average: 1

T.T. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
	0	0	0	0	0	0	0	0	0
	Oct	**Nov**	**Dec**						
	180	0	43						

T.T. Monthly Average: 18.6

APPENDIX D-5d

LOCATION: Lajes, Azores

POWER OUTAGES

1976 **Total Events:** (T.E.) 18 **Total Time:** (T.T.) 1601

T.E. Distribution by Time:

1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
1	9	2	2	4

T.E. Dist by Month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2	0	0	2	2	6	3	1	1

Oct	Nov	Dec
0	0	1

T.E. Monthly Average: 1.5

T.T. Dist by Month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
480	0	0	50	379	473	126	14	35

Oct	Nov	Dec
0	0	44

T.T. Monthly Average: 133.4

APPENDIX D-5e

LOCATION: Diyarbakir, Turkey

POWER OUTAGE

1975 **Total Events:** (T.E.) 7 **Total Time:** (T.T.) 1181

T.E. Distribution by Time:

1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
0	1	3	1	2

T.E. Dist by Month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	0	1	0	0	4	0	1	0

Oct	Nov	Dec
0	0	1

T.E. Monthly Average: 1

T.T. Dist by Month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	0	31	0	0	710	0	480	0

Oct	Nov	Dec
0	0	20

T.T. Monthly Average: 98.4

APPENDIX D-5f

LOCATION: Diyarbakir, Turkey

POWER OUTAGES

1976 **Total Events:** (T.E.) 10 **Total Time:** (T.T.) 6338

T.E. Distribution by Time	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	1	2	2	1	4

T.E. Dist by Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1	0	0	2	1	1	0	1	0
	Oct	**Nov**	**Dec**						
	0	2	2						

T.E. Monthly Average: 1

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	35	0	0	92	1158	3550	0	713	0
	Oct	**Nov**	**Dec**						
	0	2	2						

T.T. Monthly Average: 528.2

APPENDIX D-5g

LOCATION: Elmendorf, Alaska

POWER OUTAGES

1975 **Total Events:** (T.E.) 3 **Total Time:** (T.T.) 43

T.E. Distribution by Time	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	1	2	0	0	0

T.E. Dist by Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	1	0	0	0

T.E. Monthly Average: 1

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	9	0	0	34

T.T. Monthly Average: 3.6

APPENDIX D-5h

LOCATION: Elmendorf, Alaska

POWER OUTAGES

1976 **Total Events:** (T.E.) 5 **Total Time:** (T.T.) 726

T.E. Distribution by Time:	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	1	2	0	0	2

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	0	0	0	1	0	1	0	0	1
	Oct	Nov	Dec						
	0	1	1						

T.T. Monthly Average: 60.5

APPENDIX D-5i

LOCATION: Woomera, Australia

POWER OUTAGES

1976 **Total Events:** (T.E.) 2 **Total Time:** (T.T.) 463

T.E. Distribution by Time	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	1	0	0	0	1

T.E. Dist by Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	2	0

T.E. Monthly Average: 1

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	463	0

T.T. Monthly Average: 38.5

APPENDIX D-5j

LOCATION: Clark AB, Philippines

POWER OUTAGES

1975 **Total Events:** (T.E.) 43 **Total Time:** (T.T.) 3935

T.E. Distribution by Time:	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	6	19	8	6	4

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	3	2	2	3	2	8	6	7	0	0	10

T.E. Monthly Average: 3.6

T.T. Dist By Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	164	61	107	49	38	2728	168	185	0	0	435

T.T. Monthly Average: 327.9

APPENDIX D-5k

LOCATION: Clark AB, Philippines

POWER OUTAGES

1976 **Total Events:** (T.E.) 63 **Total Time:** (T.T.) 11,133

T.E. Distribution by Time	1-10 Min	11-30 Min	31-60 Min	1-2 Hr	Over 2 Hr
	5	36	8	6	8

T.E. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	8	5	2	4	12	12	2	4	3	3	4	4

T.E. Monthly Average: 5.3

T.T. Dist by Month:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	150	86	38	4383	677	1470	37	2513	69	91	363	856

T.T. Monthly Average: 927.8

APPENDIX D-51

LOCATION: Sunnyvale, California

POWER OUTAGES

1976 **Total Events:** (T.E.) 1 **Total Time:** (T.E.) 131

T.E. Distribution By Time:	**1-10 Min**	**11-30 Min**	**31-60 Min**	**1-2 Hr**	**Over 2 Hr**
	0	0	0	0	1

T.E. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
	0	0	0	0	0	0	0	0	0
	Oct	**Nov**	**Dec**						
	1	0	0						

T.E. Monthly Average: 1

T.T. Dist by Month:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
	0	0	0	0	0	0	0	0	0
	Oct	**Nov**	**Dec**						
	131	0	0						

T.T. Monthly Average: 10.9

APPENDIX D-6
POWER DISTURBANCE STUDY
AN/MSC-46 SATELLITE TERMINAL
WOOMERA, AUSTRALIA

PREPARED BY: AFCS/DOYMF RICHARDS-GEBAUR AFB MO 64030

SOME TEST NOTES

1. THIS STUDY WAS CONDUCTED ON 4 FEBRUARY 1977.

2. ALL TEST PRINTOUTS WERE PROVIDED BY A SERIES 606 POWERLINE DISTURBANCE ANALYZER MANUFACTURED BY DRANETZ ENGINEERING LABORATORIES AND PROVIDED ON LOAN FROM THE US NAVAL WEAPONS TEST CENTER, CHINA LAKE, CALIF, MR ROBIN HILL

3. THIS TEST WAS CONDUCTED ON ALL THREE PHASES OF THE SITE POWER MAINS.

4. ALL VOLTAGES HAD BEEN APPROXIMATELY 5 VOLTS LOWER ON 3 FEBRUARY 1977 AND POWER TRANSFORMER TAPS WERE ADJUSTED ON THAT DATE TO PROVIDE THE PRESENT VOLTAGE LEVEL READINGS.

5. NUMBER OF CYCLES SHOWN ON ALL SAGS AND SURGES ARE THE ACTUAL NUMBER OF CYCLES DURATION FOR THAT PARTICULAR EVENT.

6. WHEN THE POWER ANALYZER HAD MORE THAN FIFTEEN EVENTS IN ITS MEMORY, BUT COULD NOT PRINT THEM ALL, IT AUTOMATICALLY PRINTED OUT A "SHORT TERM ACCUM". THIS IS A SUMMATION OF ALL EVENTS SINCE THE LAST PRINTOUT.

7. DUE TO THE NATURE OF THE ANALYZER PRINTER, ALL READINGS ARE READ FROM THE BOTTOM OF THE PAGE UP.

8. ON PAGES THREE AND FOUR, ALL SERIOUS INCIDENTS (i.e. VOLTAGE VARIATIONS GREATER THAN TEN PER CENT AND EVENTS ONE-FOURTH OF A SECOND AND LONGER) ARE NOTED.

```
00:25:10

C 116V AVG +
0002 CYCLES                 THIS SHOWS A SAG DOWN TO 111 VOLTS WITH
A 111V SAG                  A DURATION OF TWO CYCLES.
00:11:35

C 113V AVG -
00:15:37

LO AVERAGE 113V
HI AVERAGE 116V
C 114V AV 00:15:34
LO AVERAGE 112V
HI AVERAGE 114V
B 113V AV 00:15:31
LO AVERAGE 113V
HI AVERAGE 115V
A 114V AV 00:15:28          "TEST" PRINTOUT SHOWING AVERAGE READINGS
LO FREQ 059.9 HZ             FOR FIRST 15 MINUTES OF 4 FEBRUARY 1977.
HI FREQ 060.0 HZ
FREQ 060.0 HZ
TEST DAY 01 ACCUM

PRINT OFF 00:15:20

A 113V AVG -
00:03:17

B 112V AVG -                READINGS THAT ARE FOLLOWED BY "AVG-' or
00:03:02                    "AVG+" ARE UPDATES TO THE ANALYZER THAT
                            SHOW LONG TERM VOLTAGE CHANGES.
IMP 0172V 0010 HTS
SAG 001V 0046 HTS
SUR 140V 0037 HTS
LO AVERAGE 033V
HI AVERAGE 120V             TOTAL ACCUMULATIONS FOR 3 FEBRUARY 1977
C 114V AV 00:00:16
IMP 0116V 0016 HTS          ON THIS DATE, POWER TRANSFORMER TAPS
SAG 001V 0032 HTS            WERE CHANGED TO INCREASE SITE VOLTAGE ON
SUR 139V 0027 HTS            INPUT MAINS BY AN AVERAGE OF FIVE VOLTS.
LO AVERAGE 033V              (ALL LOW SAG READINGS ARE INVALID AS
HI AVERAGE 119V              RECORDER WAS INITIALLY CONNECTED WHEN
B 114V AV 00:00:10           NO POWER WAS AT THE INPUT OF THE ANALYZER.)
IMP 0160V 0009 HTS
SAG 000V 0039 HTS
SUR 121V 0039 HTS
LO AVERAGE 034V
```

```
HI AVERAGE 130V
A 115V AV 00:00:04
LO FREQ 048:7 HZ
HI FREQ 060.2 HZ

0003 CYCLES
A 113V SAG
0008 CYCLES
C 113V SAG
0002 CYCLES
A 113V SAG
0002 CYCLES
A 113V SAG
02:31:05

B 115V AVG+
02:22:16

A 116V AVG+
01:51:40

C 116V AVG+
01:49:00

C 113V AVG-
A 113V AVG-
01:43:40

0002 CYCLES
A 112V SAG
0001 CYCLES
B 111V SAG
01:43:26

0004 CYCLES
C 113V SAG
0003 CYCLES
A 113V SAG
01:42:43

0002 CYCLES
B 111V SAG
0002 CYCLES
A 111V SAG
0001 CYCLES
C 112V SAG
01:41:43
```

← THIS COLUMN
FIRST, THEN THIS
COLUMN →

```
0003 CYCLES
A 117V SURGE
0001 CYCLES
A 117V SURGE
0003 CYCLES
A 117V SURGE
0003 CYCLES
A 117V SURGE
0004 CYCLES
B 116V SURGE
0003 CYCLES
C 117V SURGE
0005 CYCLES
C 117V SURGE
0002 CYCLES
B 116V SURGE
0001 CYCLES
A 117V SURGE
0002 CYCLES
B 116V SURGE
0003 CYCLES
A 117V SURGE
03:26:35

A 116V AVG+
03:26:23

B 112V AVG-
A 113V AVG-
03:18:36

B 115V AVG+
03:07:04

A 116V AVG+
02:55:39

A 113V AVG-
02:50:33

A 116V AVG+
02:43:15
```

```
A 116V AVG+
01:41:42

A 113V AVG-
01:40:50

0003 CYCLES
C 113V SAG
01:29:43

0001 CYCLES
A 113V SAG
01:23:36

0004 CYCLES
B 111V SAG
01:31:48
0003 CYCLES
A 112V SAG
05:12:04

0011 CYCLES
B 111V SAG
04:58:24

0005 CYCLES
A 113V SAG
04:51:22

0001 CYCLES
A 112V SAG
04:49:48

0013 CYCLES
C 113V SAG
0005 CYCLES
A 113V SAG
0002 CYCLES
A 113V SAG
04:30:51

0005 CYCLES
A 113 SAG
0008 CYCLES
C 113V SAG
0004 CYCLES
A 113V SAG
0003 CYCLES
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
A 113V AVG-
03:41:31

0002 CYCLES
C 112V SAG
0002 CYCLES
A 112V SAG
02:40:36

A 116V AVG+
02:40:20

0004 CYCLES
A 112V SAG
02:39:28
B 112V AVG-
A 113V AVG-
02:37:33

0012 CYCLES
A 119V SURGE
0036 CYCLES
A 119V SURGE
0050 CYCLES
C 119V SURGE
0022 CYCLES
A 119V SURGE
0004 CYCLES
A 114V SAG
0003 CYCLES
C 114V SAG
0010 CYCLES
A 114V SAG
0019 CYCLES
B 113V SAG
0011 CYCLES
C 114V SAG
0016 CYCLES
A 114V SAG
0034 CYCLES
C 111V SAG
0032 CYCLES
B 108V SAG
0026 CYCLES
A 112V SAG
B 0108V IMPULSE
0055 CYCLES
A 119V SURGE
```

```
B 112V SAG
04:22:07

0039 CYCLES
B 117V SURGE
0002 CYCLES
C 118V SURGE
0032 CYCLES
C 118V SURGE
0004 CYCLES
A 118V SURGE
0001 CYCLES
A 118V SURGE
0005 CYCLES
A 113V SAG
0017 CYCLES
C 113V SAG
04:18:44

B 115V AVG+
04:18:43

B 112V AVG-
04:18:24

0002 CYCLES
A 113V SAG
03:53:08

B 115V AVG+
03:53:33

C 113V SURGE
A 118V SURGE
0007 CYCLES
C 114 SAG
0025 CYCLES
A 114V SAG
0004 CYCLES
B 113V SAG
0031 CYCLES
C 112V SAG
0024 CYCLES
A 111V SAG
0023 CYCLES
B 110V SAG
A 0096V IMPULSE
0004 CYCLES
```

← THIS COLUMN FIRST, THEN THIS COLUMN →

NOTE SERIOUSNESS, ALMOST A FULL SECOND,

```
0001 CYCLES
C 119V SURGE
0004 CYCLES
C 119V SURGE
0014 CYCLES
B 118V SURGE
0002 CYCLES
C 119V SURGE
0050 CYCLES
B 117V SURGE
0007 CYCLES
C 119V SURGE
0003 CYCLES
C 119V SURGE
0023 CYCLES
A 118V SURGE
0007 CYCLES
C 118V SURGE
0005 CYCLES
C 118V SURGE
05:30:53

0002 CYCLES
C 113V SAG
05:21:25

0005 CYCLES
A 112V SAG
0004 CYCLES
B 111V SAG
0002 CYCLES

A 0060V IMPULSE
0005 CYCLES
A 119V SURGE
0075 CYCLES
B 118V SURGE
0008 CYCLES
A 119V SURGE
0004 CYCLES
C 119V SURGE
0010 CYCLES
A 119V SURGE
0057 CYCLES
C 119V SURGE
0041 CYCLES
A 119V SURGE
05:41:55
```

```
B 117V SURGE
0007 CYCLES
B 117V SURGE
0004 CYCLES
A 118V SURGE
0065 CYCLES
B 117V SURGE
0001 CYCLES
A 118V SURGE
0011 CYCLES
A 118V SURGE
0027 CYCLES
C 118V SURGE
0041 CYCLES
A 118V SURGE
0001 CYCLES
C 118V SURGE
05:32:42

IMP 0104V 0001 HTS
SAG 111V 0008 HTS
SUR 119V 0006 HTS
C 115V AV 05:31:49
IMP 0104V 0001 HTS
SAG 111V 0006 HTS
SUR 118V 0004 HTS
B 114V AV 05:31:44
IMP 0084V 0002 HTS
SAG 112V 0010 HTS
SUR 118V 0003 HTS
A 115V AV 05:31:40
FREQ 060.0 HZ
SHORT TERM ACCUM

0051 CYCLES
C 112V SAG
0028 CYCLES
A 114V SAG
0008 CYCLES
A 113V SAG
B 0080V IMPULSE
0001 CYCLES
A 119V SURGE
0077 CYCLES

C 108V SAG
A 119V AVG+
0001 CYCLES
```

SAME AS BELOW →

ANALYZER STORAGE
CAPABILITY EXCEEDED,
SHORT TERM
ACCUMULATION PRINTOUT
AND THEN MEMORY CLEAR

← THIS COLUMN
FIRST, THEN THIS
COLUMN →

```
IMP 0088V 0002 HTS
SAG 111V 0012 HTS
SUR 119V 0008 HTS
C 115V AV 05:33:41
IMP 0068V 0001 HTS
SAG 110V 0004 HTS
SUR 118V 0005 HTS
B 114V AV 05:33:37
IMP 0152V 0002 HTS
SAG 111V 0007 HTS
SUR 119V 0008 HTS
A 115V AV 05:33:32
FREQ 060.0 HZ
SHORT TERM ACCUM

0032 CYCLES
C 118V SURGE
0001 CYCLES
C 118V SURGE
0004 CYCLES
A 114V SAG
0002 CYCLES
C 114V SAG
0003 CYCLES
B 113V SAG
0053 CYCLES
A 113V SAG
0005 CYCLES
C 114V SAG
0045 CYCLES
B 112V SAG
0037 CYCLES
C 113V SAG
A 0088V IMPULSE
C 0052V IMPULSE
B 0036V IMPULSE

0001 CYCLES
B 117V SURGE
0002 CYCLES
B 117V SURGE
0056 CYCLES
B 117V SURGE
B 0052V IMPULSE
A 0056V IMPULSE
0003 CYCLES
A 119V SURGE
```

```
C 120V SURGE
0010 CYCLES
A 120V SURGE
0005 CYCLES
C 120V SURGE
0001 CYCLES
C 120V SURGE
0002 CYCLES
A 120V SURGE
0001 CYCLES
A 120V SURGE
0003 CYCLES
C 120V SURGE
05:43:31

0006 CYCLES
B 118V SURGE
0001 CYCLES
A 119V SURGE
0068 CYCLES
C 119V SURGE
0069 CYCLES
A 119V SURGE
0068 CYCLES
B 118V SURGE
05:43:23

IMP 0052V 0001 HTS
SAG 112V 0008 HTS
SUR 119V 0004 HTS
C 115V 05:42:31
IMP 0092V 0001 HTS
SAG 113V 0002 HTS
SUR 118V 0002 HTS
B 114V 05:42:26
SAG 110V 0002 HTS
SUR 110V 0006 HTS
A 116V AB 05:42:23
FREQ 060.0 HZ
SHORT TERM ACCUM

0002 CYCLES
A 114 SAG
0011 CYCLES
C 114V SAG
0001 CYCLES
A 114VSAG
0004 CYCLES
```

← THIS COLUMN FIRST, THEN THIS COLUMN →

```
0060 CYCLES
C 120V SURGE
0006 CYCLES
A 119V SURGE
0005 CYCLES
B 118V SURGE
0044 CYCLES
B 119V SURGE
0020 CYCLES
A 120V SURGE
0009 CYCLES
B 118V SURGE
0030 CYCLES
B 104V SAG
0030 CYCLES
V 106V SAG
0029 CYCLES
A 105V SAG
A 0052V IMPULSE
05:45:02

B 115V AVG-
C 116V AVG-
05:44:44

A 116V AVG-
05:44:41

0002 CYCLES
A 116V SAG
C 0056V IMPULSE
A 0052V IMPULSE
05:44:06

SUR 120V 0001 HTS
HI AVERAGE 119V
C 117V AV 05:44:03
SUR 119V 0001 HTS
HI AVERAGE 118V
B 116V AV 05:44:00
A 118V AV 05:43:59
FREQ 060.0 HZ
SHORT TERM ACCUM

0005 CYCLES
B 119V SURGE
0003 CYCLES
A 120V SURGE
```

```
A 114V SAG
0036 CYCLES
B 112V SAG
0033 CYCLES
C 111V SAG
0008 CYCLES
A 114V SAG
0019 CYCLES
0011 CYCLES
A 114V SAG
0001 CYCLES
C 113V SAG
0006 CYCLES
C 114V SAG
0004 CYCLES
C 114V SAG
0039 CYCLES
A 114V SAG
0042 CYCLES
B 113V SAG
0034 CYCLES
C 114V SAG
0004 CYCLES
A 113V SAG
0002 CYCLES
C 114V SAG
A 0112V IMPULSE
A 0056V IMPULSE
0003 CYCLES
B 117V SURGE
0015 CYCLES
B 117V SURGE
0012 CYCLES
A 118V SURGE
0069 CYCLES
B 117V SURGE
0012 CYCLES
A 118V SURGE
0043 CYCLES
A 118V SURGE
0035 CYCLES
C 118V SURGE
05:58:35

0014 CYCLES
B 111V SAG
0010 CYCLES
A 112V SAG
```

← THIS COLUMN FIRST,
THEN THIS COLUMN →

```
0003 CYCLES
A 120V SURGE
0004 CYCLES
A 120V SURGE
0003 CYCLES
C 120V SURGE
0005 CYCLES
C 120V SURGE
0015 CYCLES
B 107V SAG
0016 CYCLES
0004 CYCLES
C 114V SAG
0005 CYCLES
B 113V SAG
0034 CYCLES
C 113V SAG
0029 CYCLES
B 111V SAG
0002 CYCLES
C 111V SAG
C 0056V IMPULSE
B 0072V IMPULSE
0006 CYCLES
B 117V SURGE
0021 CYCLES
A 118V SURGE
0069 CYCLES
B 117V SURGE
0044 CYCLES
C 118V SURGE
0064 CYCLES
A 118V SURGE
0015 CYCLES
B117V SURGE
0001 CYCLES
C 118V SURGE
0003 CYCLES
C 117V SURGE
05:59:40

0001 CYCLES
C 114V SAG
0002 CYCLES
C 114V SAG
0007 CYCLES
A 114V SAG
0001 CYCLES
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
05:58:04

0013 CYCLES
A 114V SAG
0046 CYCLES
C 112V SAG
0044 CYCLES
A 113V SAG
0033 CYCLES
B 113V SAG
0005 CYCLES
B 111V SAG
A 0084V IMPULSE
B 0072V IMPULSE
05:57:23

0005 CYCLES
B 113V SAG
0004 CYCLES
C 114V SAG
05:50:04
0006 CYCLES
C 114V SAG
0043 CYCLES
A 111V SAG
0023 CYCLES
B 113V SAG
0008 CYCLES
C 114V SAG
0017 CYCLES
C 111V SAG
0014 CYCLES
B 109V SAG
C 0060V IMPULSE
B 0108V IMPULSE
0005 CYCLES
B 117V SURGE
0019 CYCLES
B 117V SURGE
0001 CYCLES
B 117V SURGE
0001 CYCLES
A 118V SURGE
0060 CYCLES
A 118V SURGE
0063 CYCLES
B 117V SURGE
0059 CYCLES
C 118V SURGE
```

```
C 114V SAG
0011 CYCLES
C 114V SAG
0048 CYCLES
A 112V SAG
0048 CYCLES
B 112V SAG
0042 CYCLES
C 112V SAG
B 0060V IMPULSE
A 0056V IMPULSE
05:59:14

SAG 109V 0004 HTS
SUR 119V 0005 HTS
C 115V 05:59:11
IMP 0096V 0001 HTS
SAG 111V 0002 HTS
SUR 117V 0003 HTS
A 114V AV 05:59:07
IMP 0064V 0001 HTS
SAG 112V 0004 HTS
SUR 118V 0003 HTS
A 117V AV 05:59:03
FREQ 060.0 HZ
SHORT TERM ACCUM
0035 CYCLES
B 104V SAG
0036 CYCLES
C 106V SAG
0036 CYCLES
A 105V SAG
06:09:54

A 119V AVG+
C 119V AVG+
06:08:26

0086 CYCLES
B 117V SURGE
0003 CYCLES
A 118V SURGE
0010 CYCLES
A 118V SURGE
0012 CYCLES
C 118V SURGE
0058 CYCLES
A 118V SURGE
0051 CYCLES
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
06:00:40

0003 CYCLES
C 113V SAG
0003 CYCLES
C 113V SAG
0009 CYCLES
A 114V SAG
0056 CYCLES
C 114 SAG
0044 CYCLES
A 114V SAG
0037 CYCLES
B 112V SAG
0005 CYCLES
A 114V SAG
A 0080V IMPULSE
B 0124V IMPULSE
0027 CYCLES
B 117V SURGE
0091 CYCLES
B 117V SURGE
0003 CYCLES
C 118V SURGE
0080 CYCLES
A 118V SURGE
0001 CYCLES
C 118V SURGE
0075 CYCLES
C 118V SURGE
0005 CYCLES
C 114V SAG
0003 CYCLES
0011 CYCLES
C 119V SURGE
0076 CYCLES
B 118V SURGE
0070 CYCLES
A 120V SURGE
0065 CYCLES
C 120V SURGE
0002 CYCLES
A 119V SURGE
C 116V AVG-
A 116V AVG-
B 115V AVG-
0036 CYCLES
N 104V SAG
```

```
C 118V SURGE
06:07:52

0001 CYCLES
A 114V SAG
0003 CYCLES
C 114V SAG
0001 CYCLES
C 114V SAG
0059 CYCLES
A 113V SAG
0050 CYCLES
B 112V SAG
0004 CYCLES
C 114V SAG
C 113V SAG
A 0132V IMPULSE
0005 CYCLES
B 117V SURGE
0019 CYCLES
B 117V SURGE
0064 CYCLES
B 117V SURGE
0005 CYCLES
A 118V SURGE
0012 CYCLES
C 118V SURGE
0006 CYCLES
A 118V SURGE
0039 CYCLES
C 118V SURGE
0038 CYCLES
A 118V SURGE
06:01:04

0006 CYCLES
A 114V SAG
0005 CYCLES
B 113V SAG
C 0084V IMPULSE
B 0064V IMPULSE
0005 CYCLES
B 117V SURGE
0112 CYCLES
B 117V SURGE
B 115V AVG+
0011 CYCLES
A 118V SURGE
```

```
0035 CYCLES
C 105V SAG
0035 CYCLES
A 105V SAG
B 0060V IMPULSE
06:43:33

B 118V AVG+
C 119V AVG+
A 119VAVG+
06:42:26

0013 CYCLES
A 115V SAG
0003 CYCLES
B 114V SAG
06:30:53

0001 CYCLES
B 117V SURGE
0006 CYCLES
C 114V SAG
0001 CYCLES
B 113V SAG
0016 CYCLES
A 114V SAG
0006 CYCLES
B 113V SAG
0005 CYCLES
C 114V SAG
06:11:37

0057 CYCLES
B 118V SURGE
0003 CYCLES
A 119V SURGE
0053 CYCLES
C 120V SURGE
0043 CYCLES
A 120V SURGE
0005 CYCLES
A 119V SURGE
C 116V AVG-

0010 CYCLES
A 117 SURGE
0016 CYCLES
B 116V SURGE
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
0083 CYCLES
A 118V SURGE
A 116V AVG+
0007 CYCLES
C 118V SURGE
C 116V AVG+
0005 CYCLES
C 118V SURGE
0045 CYCLES
C 118V SURGE
07:06:57

C 113V AVG-
07:02:37

A 113V AVG-
07L02:35

B 112V AVG-
07-02:26

0004 CYCLES
A 114V SAG
0009 CYCLES
C 113V SAG
0029 CYCLES
B 112V SAG
0009 CYCLES
C 113V SAG
0019 CYCLES
A 114V SAG
0016 CYCLES
C 113V SAG
0014 CYCLES
A 113V SAG
0008 CYCLES
B 112V SAG
B 0092V IMPULSE
0001 CYCLES
C 112V SAG
C 0108V IMPULSE
A 0060V IMPULSE
06:59:16

0002 CYCLES
C 114V SAG
06:55:20
```

← THIS COLUMN FIRST,
THEN THIS COLUMN →

```
0015 CYCLES
A 117V SURGE
0005 CYCLES
B 111V SAG
0001 CYCLES
C 112V SAG
07:36:09

A 113V AVG-
07:31:56

PAPER LOW 07:27:28

IMP 0224V 0013 HTS
SAG 105V 0091 HTS
SUR 120V 0069 HTS
LO AVERAGE 113V
HI AVERAGE 119V
C 114V 07:27:22
IMP 0124V 0017 HTS
SAG 104V 0051 HTS
SUR 119V 0057 HTS
LO AVERAGE 112V
HI AVERAGE 118V
B 113V AV 07:27:16
IMP 0152 0016 HTS
SAG 105V 0087 HTS
SUR 120V 0075 HTS
LO AVERAGE 113V
HI AVERAGE 119V
A 114V AV 07:27:10
LO FREQ 059.9 HZ
HI FREQ 060.2 HZ
FREQ 060.0 HZ
TEST DAY 01 ACCUM
A 116V AVG+
07:17:23

A 113V AVG-
07:08:53

B 112V AVG-
07:09:51

0036 CYCLES
A 107V SAG
0014 CYCLES
B 112V SAG
```

← "TEST" PRINTOUT
(DEMAND PRINTOUT
FOR 4 FEBRUARY 1977
FROM 0000L HOURS)

```
0003 CYCLES
C 114V SAG
0005 CYCLES
A 114V SAG

0002 CYCLES
B 111V SAG
08:40:38

C 113V AVG-
08:31:58

A 113V AVG-
08:31:56

PAPER LOW 08:22:36

0005 CYCLES
C 112V SAG
0007 CYCLES
C 112V SAG
0006 CYCLES
A 112V SAG
08:22:31

A 116V AVG+
C 116V AVG+
08:10:22

C 113V AVG-
08:08:26

PAPER LOW 08:09:24

A 113V AVG-
08:09:22

0004 CYCLES
A 112V SAG
08:08:53

PAPER LOW 08:04:59

0028 CYCLES
A 117V SURGE
0004 CYCLES
B 116V SURGE
0016 CYCLES
```

```
0032 CYCLES
C 113V SAG
0031 CYCLES

0019 CYCLES
C 117V SURGE
09:16:23

C 113V AVG-
09:14:06

A 113V AVG-
09:14:04

0003 CYCLES
B 111V SAG
09:12:15

PAPER LOW 09:03:26

0037 CYCLES
A 117V SURGE
0003 CYCLES
B 116V SURGE
0002 CYCLES
C 117V SURGE
0024 CYCLES
B 116V SURGE
0018 CYCLES
C 117V SURGE
0002 CYCLES
C 117V SURGE
0030 CYCLES
C 110V SAG
0031 CYCLES
C 111V SAG
0025 CYCLES
A 111V SAG
09:03:11

0004 CYCLES
A 112V SAG
09:01:28

PAPER LOW 09:00:25

0004
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
C 117V SURGE
0015 CYCLES
B 116V SURGE
08:04:52

A 116V AVG+
07:42:34

0003 CYCLES
A 117V SURGE
0002 CYCLES
B 116V SURGE
0009 CYCLES
C 117V SURGE
0010 CYCLES
0006 CYCLES
C 117V SURGE
0005 CYCLES
C 116V SURGE
0012 CYCLES
A 116V SURGE
0014 CYCLES
B 110V SAG
0004 CYCLES
C 111V SAG
0001 CYCLES
A 111V SAG
0005 CYCLES
A 111V SAG
11:48:57

PAPER LOW 11:04:18

A 113V AVG-
11:04:16

A 116V AVG+
11:01:37

0003 CYCLES
B 111V SAG
10:37:10

0002 CYCLES
A 112V SAG

10:27:45
```

```
B 111V SAG
0001 CYCLES
C 112V SAG
0003 CYCLES
A 112 SAG
0002 CYCLES
C 112V SAG
09:00:18

A 116V AVG+
08:44:19

C 116V AVG+
C 112V SAG
13:15:02

PAPER LOW 13:08:24

0004 CYCLES
A 116V SURGE
0002 CYCLES
B 115V SURGE
0003 CYCLES
B 115V SURGE
0004 CYCLES
A 116V SURGE
13:08:17

PAPER LOW 12:55:53

0042 CYCLES
B 116V SURGE
0039 CYCLES
C 117V SURGE
0004 CYCLES
A 116V SURGE
0030 CYCLES
A 117V SURGE
0004 CYCLES
B 114V SURGE
0001 CYCLES
C 116V SURGE
0001 CYCLES
C 116V SURGE
0006 CYCLES
B 114V SURGE
0005 CYCLES
C 116V SURGE
```

← THIS COLUMN FIRST,
THEN THIS COLUMN →

```
PAPER LOW 10:06:08

0004 CYCLES
B 111V SAG
10:06:06

0001 CYCLES
C 117V SURGE
09:25:28

PAPER LOW 09:18:39

0004 CYCLES
C 111V SAG
0016 CYCLES
B 115V SURGE
0034 CYCLES
A 117V SURGE
0027 CYCLES
C 117V SURGE
0020 CYCLES
B 116V SURGE
0005 CYCLES
A 111V SAG
0037 CYCLES
B 109V SAG
0002 CYCLES
C 111V SAG
C 113V SAG
0013 CYCLES
A 114V SAG
0024 CYCLES
B 111V SAG
0007 CYCLES
A 113V SAG
0011 CYCLES
C 114V SAG
0014 CYCLES
A 113V SAG
0008 CYCLES
C 113V SAG
C 0092V IMPULSE
A 0084V IMPULSE
B 115V AVG+
A 116V AVG+
0001 CYCLES
A 118V SURGE
```

← THIS COLUMN
FIRST, THEN THIS COLUMN →

```
0002 CYCLES
C 116V SURGE
0003 CYCLES
B 114V SURGE
0001 CYCLES
B 114V SURGE
0005 CYCLES
C 111V SAG
0032 CYCLES
C 110V SAG
0033 CYCLES
A 110V SAG
0031 CYCLES
B 109V SAG
12:55:08

0004 CYCLES
C 113V SAG
12:36:27

PAPER LOW 11:49:13

0007 CYCLES
C 116V SURGE

SAG 105V 0134 HTS
SUR 120V 0117 HTS
LO AVERAGE 113V
HI AVERAGE 120V
C 115V AV 00:00:17
IMP 0176 0023 HTS
SAG 104V 0085 HTS
SUR 119V 0105 HTS
LO AVERAGE 111V
HI AVERAGE 1119V
B 114V AV 00:00:10
IMP 0152 0023 HTS
SAG 105V 0122 HTS
SUR 120V 0120 HTS
LO AVERAGE 113V
HI AVERAGE 130V
A 116V AV 00:00:04
LO FREQ 059.9 HZ
HI FREQ 060.2 HZ
FREQ 060.0 HZ
DAY 01 ACCUM

PAPER LOW 21:01:40
```

NOTE: SOMETIMES
ANALYZER PRINTED OUT
SHORT TERM ACCUMULATIONS
WHEN THE PAPER WAS LOW

```
0052 CYCLES
A 118V SURGE
C 116V AVG+
0045 CYCLES
C 118V SURGE
0048 CYCLES
B 117V SURGE
31:01:03

PAPER LOW 20:47:50
0004 CYCLES
A 112V SAG
20:47:48

PAPER LOW 20:19:21
PAPER LOW 20:19:19

C 114V AV 20:29:18
B 113V AV 20:19:17
SAG 112V 0001 HTS
A 114V AV 20:19:15
FREQ 060.0 HZ
SHORT TERM ACCUM

PAPER LOW 19:15:06

SAG 111V 0002 HTS
SUR 117V 0002 HTS
C 114V AV 19:15:02
SAG 110V 0002 HTS
SUR 115V 0003 HTS
B 113V AV 19:14:55
SAG 111V 0001 HTS
SUR 117V 0002 HTS
A 114V AV 19:14:56
FREQ 060.0 HZ

SHORT TERM ACCUM

END OF RECORDINGS

SAG 110V 0023 HTS
SUR 120V 0029 HTS
LO AVERAGE 113V
HI AVERAGE 119V
C 115V AV 00:00:40
IMP 0176V 0006 HTS
SAG 111V 0019 HTS
```

```
PAPER LOW 21:01:38

PAPER LOW 21:01:37

SAG 112V 0001 HTS
LO AVERAGE 113V
C 114V AV 21:01:34
SAG 111V 0001 HTS
LO AVERAGE 112V
B 113V AV 21:01:31
SAG 112V 0001 HTS
LO AVERAGE 113V
A 114V AV 21:01:28
FREQ 060.0 HZ
SHORT TERM ACCUM
PAPER LOW 21:01:25

PAPER LOW 21:01:23
```

THIS COLUMN
FIRST, THEN THIS COLUMN

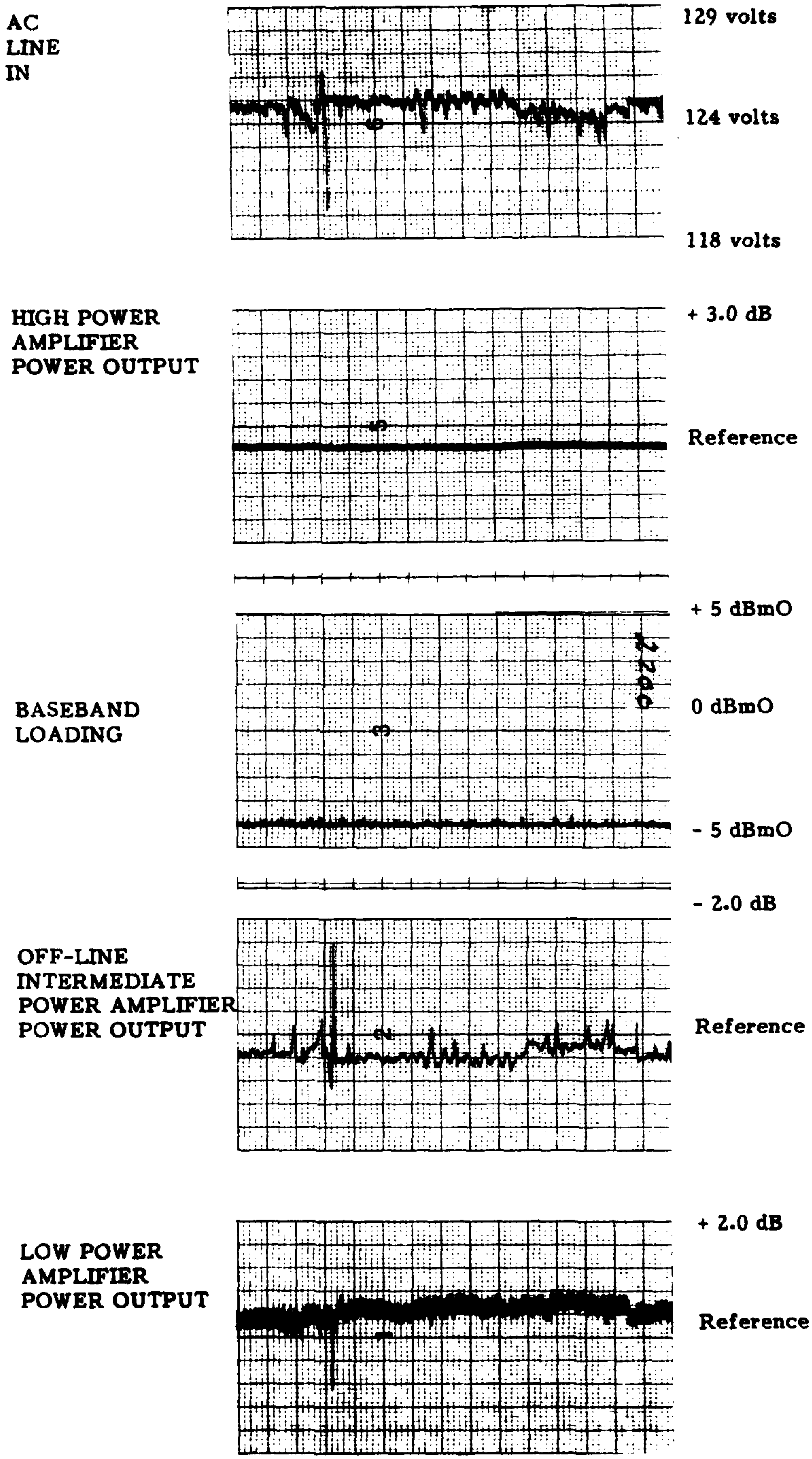
```
SUR 119V 0027 HTS
LO AVERAGE 112V
HI AVERAGE 118V
B 114V AV 00:00:33
IMP 0116V 0006 HTS
SAG 112V 0017 HTS
SUR 120V 0028 HTS
LO AVERAGE 113V
HI AVERAGE 119V
A 116V AV 00:00:27
FREQ 060.0 HZ
SHORT TERM ACCUM

PAPER LOW 00:00:24
```

APPENDIX D-7

DSCS Equipment Power Output Correlations

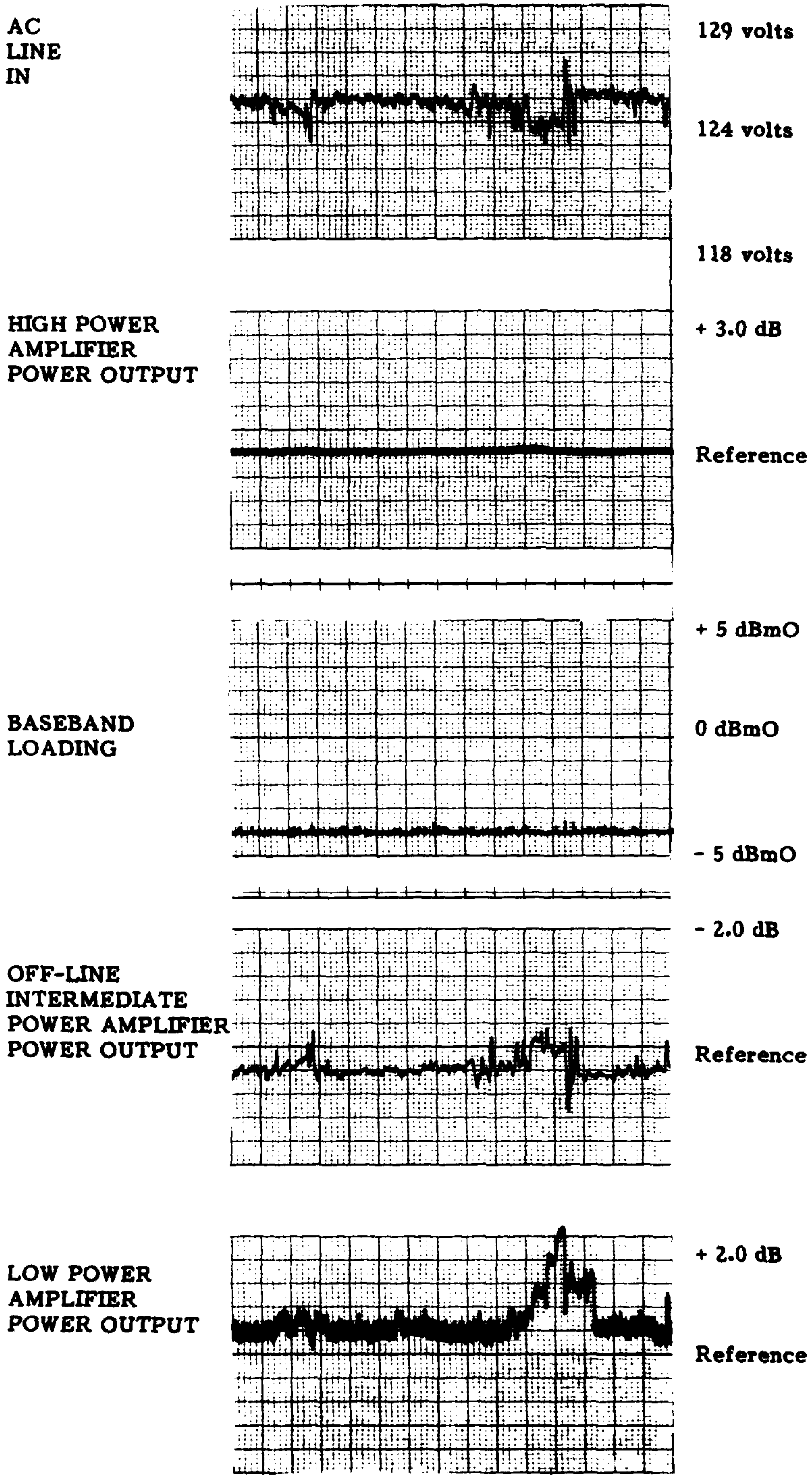
Ref: AFCS Scope Creek Evaluation of Diyarbakir TU AN/MSC-46

DSCS EQUIPMENT POWER OUTPUT CORRELATION VS AC LINE VOLTAGE



D-7a

DSCS EQUIPMENT POWER OUTPUT CORRELATION VS AC LINE VOLTAGE



D-7b

APPENDIX E

ECONOMIC COMPARISON OF POWER SUPPLY SYSTEMS

APPENDIX E

ECONOMIC COMPARISON OF POWER SUPPLY SYSTEMS

1. Purpose. The purpose of this comparison is to examine the cost factors of representative power sources and conditioning systems.

2. Background. Communication equipment/system power requirements are specified in terms of power availability and quality. The primary power source may be either commercial or military generators with a certain cost associated with each. However, if the availability requirements may be met with either, this doesn't necessarily mean the power quality requirements will be met. To achieve this may require power conditioning equipment. The actual cost of conditioning is dependent upon the characteristics and magnitude of the power alterations. Hence, the most cost effective method of providing reliable quality power depends on the unique factors at each individual site. The following compares the costs given for a particular requirement as an example. It must be emphasized that the alternatives presented will apply differently to each particular situation and that what is best in this case may be different from what is best in another.

3. Alternatives: Eight systems were considered in satisfying the requirements. They are as follows:

a. Alternative #1, Figure #1. Single Rotating Flywheel Constant Frequency UPS, Diesel Supported. System consists of an electrical motor coupled to an alternator. A large flywheel is coupled to the motor generator set. A magnetic clutch is attached to one end of the flywheel; other end of clutch is connected to a diesel engine. During normal operation, prime or standby power is supplied to electric motor. If power fails, the momentum of the flywheel keeps the generator running until the diesel can take over.

b. Alternative #2, Figure 2. Fifty Percent Redundant Solid State Uninterruptible Power Supply (SSUPS). System consists of three static inverters and one battery bank capable of fifteen minutes of standby time. During normal operation, inverters operate in parallel. Each inverter supplies one-third of the load. If one inverter fails, remaining two inverters automatically assume one-half of the load. Two or more inverters failing concurrently would result in an outage.

c. Alternative #3, Figure #3. Rotating Constant Frequency Flywheel UPS, Diesel Supported, Plus Maintenance Spare. System consists of two units each as identified in Alternative #1. One unit is operating and other in stand-by mode. Stand-by unit is available for replacement or for scheduled maintenance on prime unit.

d. Alternative #4, Figure #4. Prime Power Plant. System consists of four Class A generators. During normal operation, bus tie breaker is open. Utility load is connected to one bus and technical load to other bus. A generator, which operates continuously, is connected to each bus. Remaining generators are spares, one unit being available for replacement of a failed unit, and the other for scheduled maintenance.

e. Alternative #5, Figure #5. Non-Redundant SSUPS with Internal Static Switch. System consists of an inverter sized for the load served. A battery bank is provided to feed the inverter during input power failures, until generator can assume load or up to 15 minutes, maximum. During inverter malfunction or failure, prime or standby power is supplied automatically to the load via a static switch. Inverter is isolated until it is repaired.

f. Alternative #6, Figure #6. Non-Redundant SSUPS Without Internal Static Switch. System is similar to Alternative #6 less static switch. During inverter failure, a power outage occurs.

g. Alternative #7, Figure #7. Line Voltage Static Regulators. System consists of electronic line voltage regulators. Prime or standby power is supplied to the regulators. Load is connected to regulators which provide regulated voltage. A power outage results during prime or standby power failure and during regulator failure.

h. Alternative #8, Figure #8. Motor Generator Set, Constant Frequency. System consists of a motor connected to a generator. In normal operation, prime or standby power is supplied to the motor which drives the generator. Power is supplied to the load from generator. Load receives regulated voltage and is isolated from input power transients. During power interruption, inherent inertia maintains an acceptable output voltage and frequency up to 100 milliseconds. Failure of M-G set would result in an outage.

4. Assumptions:

a. The following criteria apply:

(1) AFM 88-15, Air Force Design Manual Criteria and Standards for Air Force Construction.

(2) MIL-HDBK-411, Long-Haul Communications (DCS) Power and Environmental Control for Physical Plant.

(3) AFR 91-4, Maintenance and Operation of Electric Power Systems.

(4) DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

(5) AFR 85-19, Maintenance and Operation of Electric Power Generating Plans.

b. Electrical parameters shall comply with MIL-HDBK-411.

c. Prime power will be obtained from a commercial source.

d. System physical life is twenty years.

e. SSUPS and Generator physical life is twenty years.

f. Rotary UPS and M-G Set physical life is ten years.

g. Facility Design Criteria, AN/MSC-61 Earth Terminal Complex Fixed Site Configuration, November 1976.

h. Equipment efficiency:

(1) SSUPS - 88 percent.

(2) Electro-Mechanical - 77 percent.

(3) Line voltage regulator - 95 percent.

5. Facts:

a. Analysis is based on new AN/MSC-61 SATCOM terminal installation, any site/base having a cost index factor of 1.

b. Only technical loads were considered, since utility loads will vary depending on location.

GENERAL:

1. Class C Plant Operation:

   a. Engine operating hours - 400 hours/year.

   b. Annual fuel cost - (II)
   154 KW x $0.34/gal x 400 hrs/year x 0.0833/gal/KWH - $1,745/year.

   c. Annual commercial power cost - (II)
   Cost of commercial power - $0.03/KWH
   Annual Cost - 154 KW x $0.03/KWH x 8350 hrs/yr - $38,577

   d. Total annual cost

Fuel	$1,745
Commercial Power	38,577
	$40,322

   e. Annual manpower cost - (I)

AFCS	Grade	Number Auth	Composite Total	Mil Pers Benefits	Total
543X0	E6	1	$12,509	$5004	$17,513
	E5	2	10,646	4259	29,810
	E4	2	9,342	3737	26,158
	E3	2	7,563	3025	21,176
					$94,657

2. Class A Plant Operation:

   a. Engine operating hours

   8760 hours/year - operating hours
   200 hours/year - parallel operation, testing, etc.
   8960 hours/year - TOTAL

   b. Annual fuel cost - (II)
   Engine fuel consumption rate (DF-2 diesel fuel oil) - $0.0833 gal/KWH
   Cost of DF-2 fuel oil delivered - $0.34/gal.
   154 KW x $0.34/gal x 8960 hrs/yr x $0.0833 gal/KWH = $39,080/yr

   c. Annual manpower cost - (I)

AFCS	Grade	Number Auth	Composite Total	Mil Pers Benefits	Total
543X0	E7	1	$14,509	$5,804	$23,403
543X0	E6	1	12,509	5,004	17,513
543X0	E5	2	10,646	4,259	29,810
543X0	E4	3	9,342	3,737	39,237
543X0	E3	3	7,563	3,025	31,764
TOTAL					$141,727

ALTERNATIVE #1: SINGLE ROTATING FLYWHEEL CONSTANT FREQUENCY UPS, DIESEL SUPPORTED.

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$511,835		$511,835	0.954	$488,290
2		$175,035	173,035	0.867	150,021
3		"	"	0.788	136,351
4		"	"	0.717	124,066
5		"	"	0.652	112,818
6		"	"	0.592	102,436
7		"	"	0.538	93,092
8		"	"	0.489	84,614
9		"	"	0.445	77,000
10	$226,000	"	399,035	0.405	161,609
11		"	173,035	0.368	63,676
12		"	"	0.334	57,793
13		"	"	0.304	52,602
14		"	"	0.276	47,757
15		"	"	0.251	43,431
16		"	"	0.228	39,451
17		"	"	0.208	35,991
18		"	"	0.189	32,703
19		"	"	0.172	29,762
20		"	"	0.156	26,993
TOTAL		"	$4,025,000	8.933	$1,960,456

TOTAL PROJECT COST (DISCOUNTED) 1,960,456

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE) $219,462

ALTERNATIVE NO 1: SINGLE ROTATING FLYWHEEL UPS - DIESEL SUPPORTED

NON-RECURRING COSTS:

MATERIAL

QUANTITY	ITEM	WASH COST ITEM
1	625 KVA, 3-Phase, Substation	X
2	500 KW, Class C, Generators	X
5	800 A., 600V., Drawout Air Circuit Breakers	X
2	600 A., 600 V., Drawout Air Circuit Breakers	
2	400A., 600V., Drawout Air Circuit Breakers	
2	225 KVA, 3-Phase, Dry Type Transformers	
1	200 KW, Rotary Diesel Supported UPS	
2	800 A., 250 V., Drawout Air Circuit Breakers	
2	800 A., 250V., Molded Case Circuit Breakers	
2	Cabinets	
	Miscellaneous Cable and Conduit	

TOTAL INITIAL INSTALLATION COSTS

2 - 500 KW, Class C, Plant	$270,000	(V)
1 - 200 KW, Rotary UPS	181,000	(VI)
Switchgear	24,868	(III)
Cabling and Conduit	6,217	(IV)
	$482,085	
UPS Initial Spare Parts and Tools .17 x $175,000	29,750	
	$511,835	

RECURRING COSTS

a. Electro-Mechanical Parts:
Acquisition Cost x 10%
$175,000 x 0.10 - $17,500

b. Operating Cost Due to Inefficiency:

(1) Commercial Power
KW Loss x $/KWH x (8760 hrs)/Yr - Downtime)
46 x 0.03 x 8350 - $11,523

(2) Generator Power
46 x 0.34 x 0.0833 x 50 = $65 TOTAL: $11,588

c. Manpower - $94,657

d. Fuel Cost
UPS Diesel Engine - 154 KW x $0.34/Gal x 50 Hrs/Yr x 0.0833 = $218
Generator - $1745 TOTAL: $1963

e. Commercial Power - $38,577

f. Depot Level Maintenance
Acquisition Cost x 0.05
$175,000 x 0.05 = $8750

g. Total O&M Cost:	$17,500
	11,588
	94,657
	1,963
	38,577
	8,750
TOTAL	$173,035

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - January 1975.

VI. King-Knight.

BENEFITS: Low First Cost

LIMITATIONS:

1. One change for diesel to start before frequency drops below 58 Hz.
2. Noisy and large.
3. Significant amount of routine maintenance.
4. In case of failure or during maintenance, critical load must be fed raw or generator power.
5. Low efficiency.
6. Large amount of working space required around equipment.

ALTERNATIVE #1: DIESEL SUPPORTED SINGLE ROTATING FLYWHEEL CONSTANT FREQUENCY

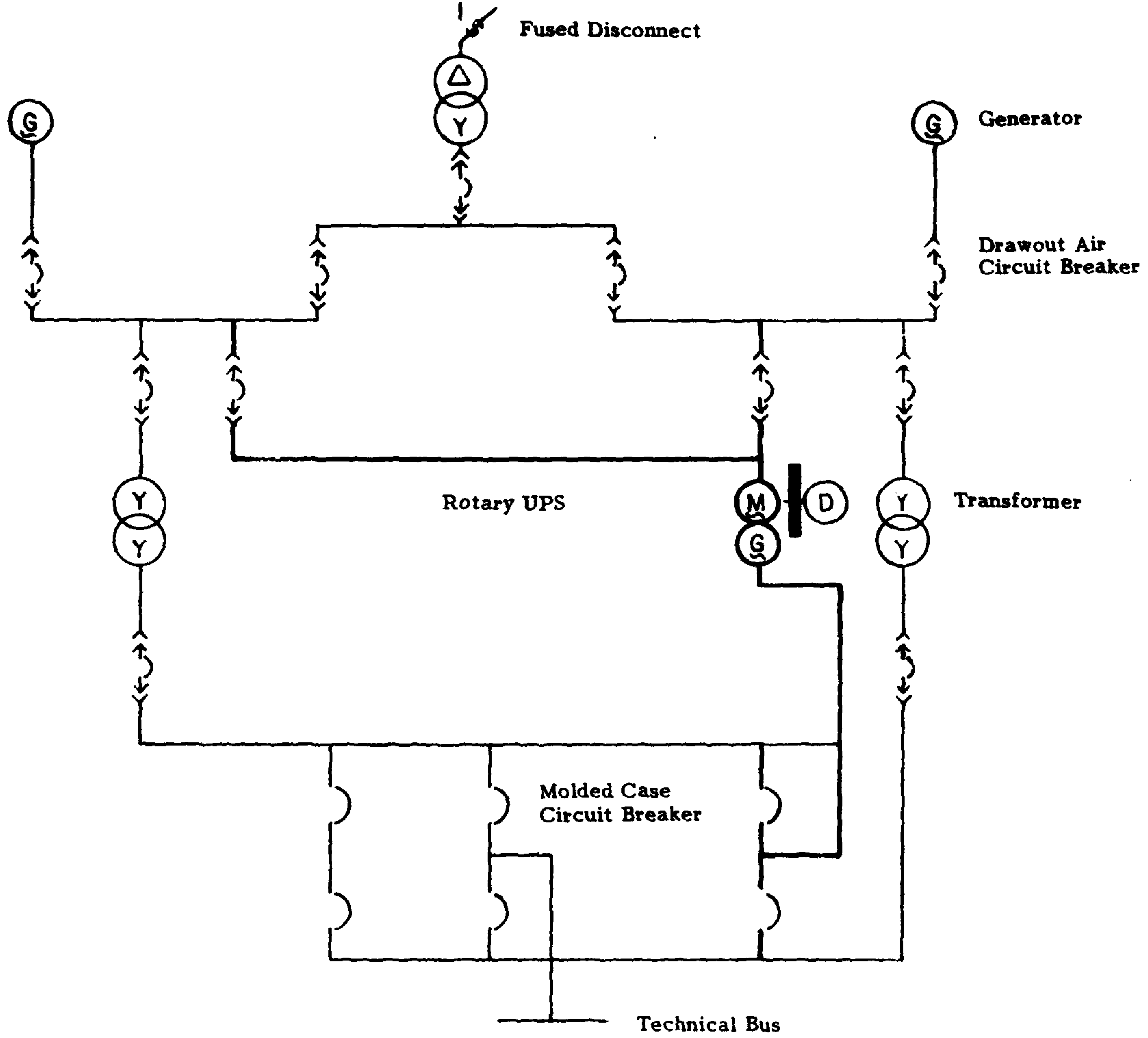
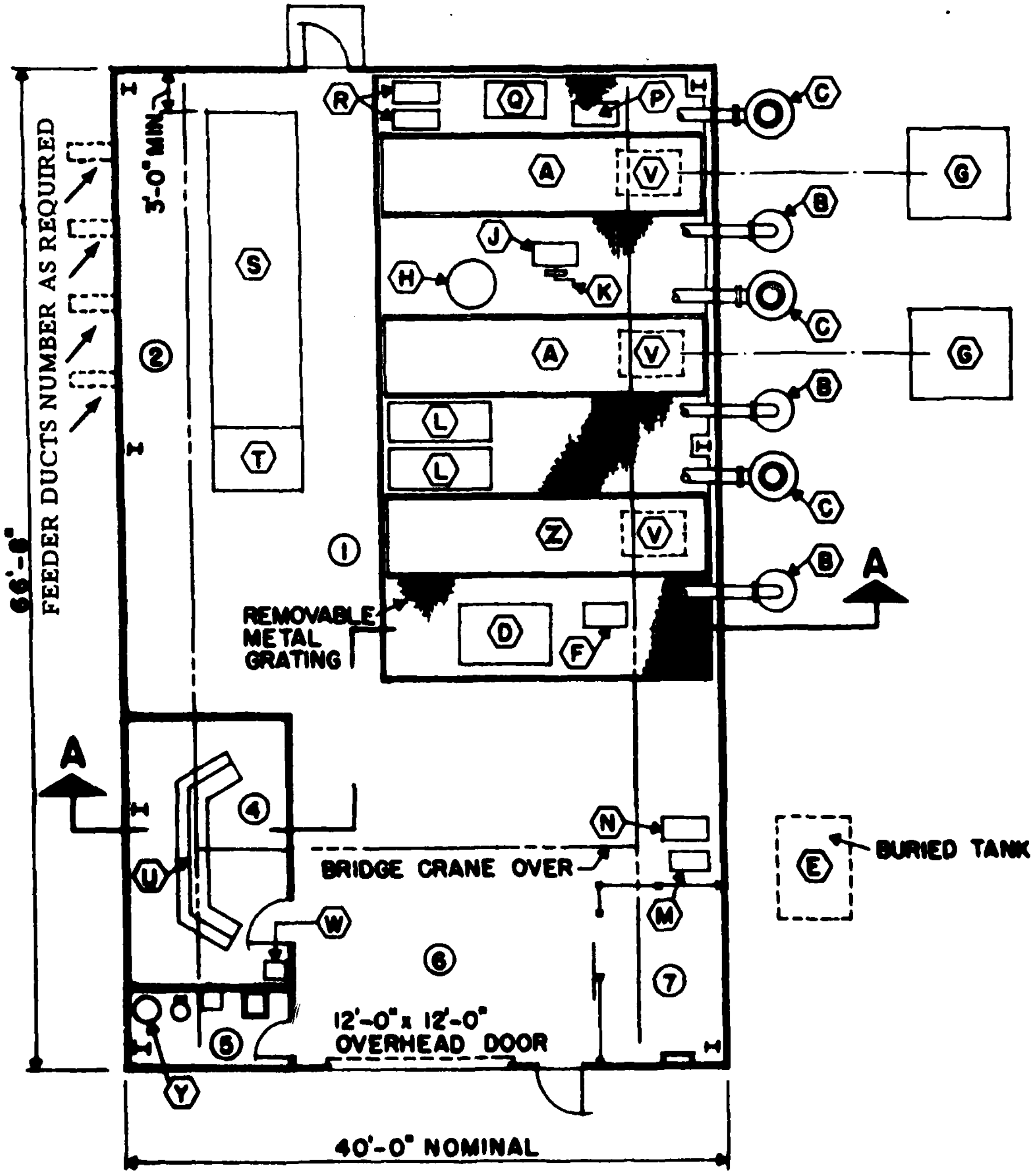


Figure #1

ALTERNATIVE #1

FIGURE 1a. SINGLE ROTATING FLYWHEEL UPS, DIESEL SUPPORTED



FLOOR PLAN

SCALE: 1/8" = 1'-0"

ALTERNATIVE #2: FIFTY PERCENT REDUNDANT SSUPS

NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
$616,050	$163,117	$616,050	0.954	$587,711
	"	163,117	0.867	141,422
	"	"	0.788	128,536
	"	"	0.717	116,954
	"	"	0.652	106,352
	"	"	0.592	96,565
	"	"	0.538	87,756
	"	"	0.489	79,764
	"	"	0.445	72,587
	"	"	0.405	66,062
	"	"	0.368	60,027
	"	"	0.334	54,481
	"	"	0.304	49,587
	"	"	0.276	45,020
	"	"	0.251	40,942
	"	"	0.228	37,190
	"	"	0.208	33,928
	"	"	0.189	30,829
	"	"	0.172	28,056
	"	"	0.156	25,446
TOTAL		$3,715,273	8.933	$1,889,215
TOTAL PRODUCT COST (DISCOUNTED)				$1,889,215

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $211,487

RECURRING COSTS

a. SSUPS Parts: Acquisition Cost x 5%
$230,667 x 0.05 = $11,533

b. Operating Cost Due to SSUPS Inefficiency:

(1) Commercial Power (II)
KW Loss x $/KWH x 8760 Hrs/Yr - Downtime
19 KW x $0.03 x 8760 = $4993

(2) Generator Power (II)
19 KW x $0.34 x 0.0833 x 200 = $108 TOTAL: $5101

c. Air Conditioner Operation: (II)
KW x Cost/KWH x 8760 Hrs/Yr
35 x 0.03 x 8760 = $9198
Downtime and Operating Time on Generators Negative

d. Manpower: Class C Plant - $94,657 (I)

e. Fuel Cost: Class Plant - $1745 (II)

f. Commercial Power: Class C Plant - $38,577 (II)

g. Depot Level Maintenance: $230,667 x 0.010 = $2306

h. Total O&M Cost $11,533
5,101
9,198
94,657
1,745
38,577
2,306
$163,117

NON-RECURRING COSTS

QUANTITY	ITEM	WASH COST ITEM
2	500 KW Class C Generators	X
1	625 KVA Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
2	350 A., 600 V., Drawout Air Circuit Breakers	
2	300 KVA, 3-Phase, Dry-type Transformers	X
2	800 A., 250 V., Drawout Circuit Breakers	X
6	500 A., 250 V., Molded Case Circuit Breakers	
4	600 A., 250 V., Molded Case Circuit Breakers	
6	350 A., 250 V., Molded Case Circuit Breakers	
4	Cabinets	
	Cabling and Conduit	
3	125 KVA SSUPS/15 Minute Standby Battery Bank	

TOTAL INITIAL INSTALLATION COSTS

EMERGENCY POWER PLANT w/BUILDING

2 x 500 KW Class C Plant 2 x 500 KW x $270/KW =	$270,000 (V)
SSUPS:	230,667 (VI)
Switchgear	21,136 (III)
Misc Cabling, Conduit, Etc	5,284 (IV)
TOTAL	$542,087

UPS/BATTERY ROOM 600 Ft^2	$21,000
UPS AIR CONDITION SYSTEM	13,750
UPS INITIAL SPARE PARTS AND TOOLS 0.17 x $230,667	39,213
TOTAL	$616,050

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 60060-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - Janaury 1975.

VI. Teledyne Inc.

ALTERNATIVE #2 FIFTY PERCENT REDUNDANT SSUPS

BENEFITS:

1. Precise uninterruptible power.
2. *Any one unit may fail or be removed from service for maintenance.* Remaining units will support load.
3. Low noise.
4. Low maintenance.
5. High efficiency.
6. High reliability.

LIMITATIONS:

1. Requires air conditioning.
2. Large battery system required.

ALTERNATIVE #2: FIFTY PERCENT REDUNDANT SSUPS

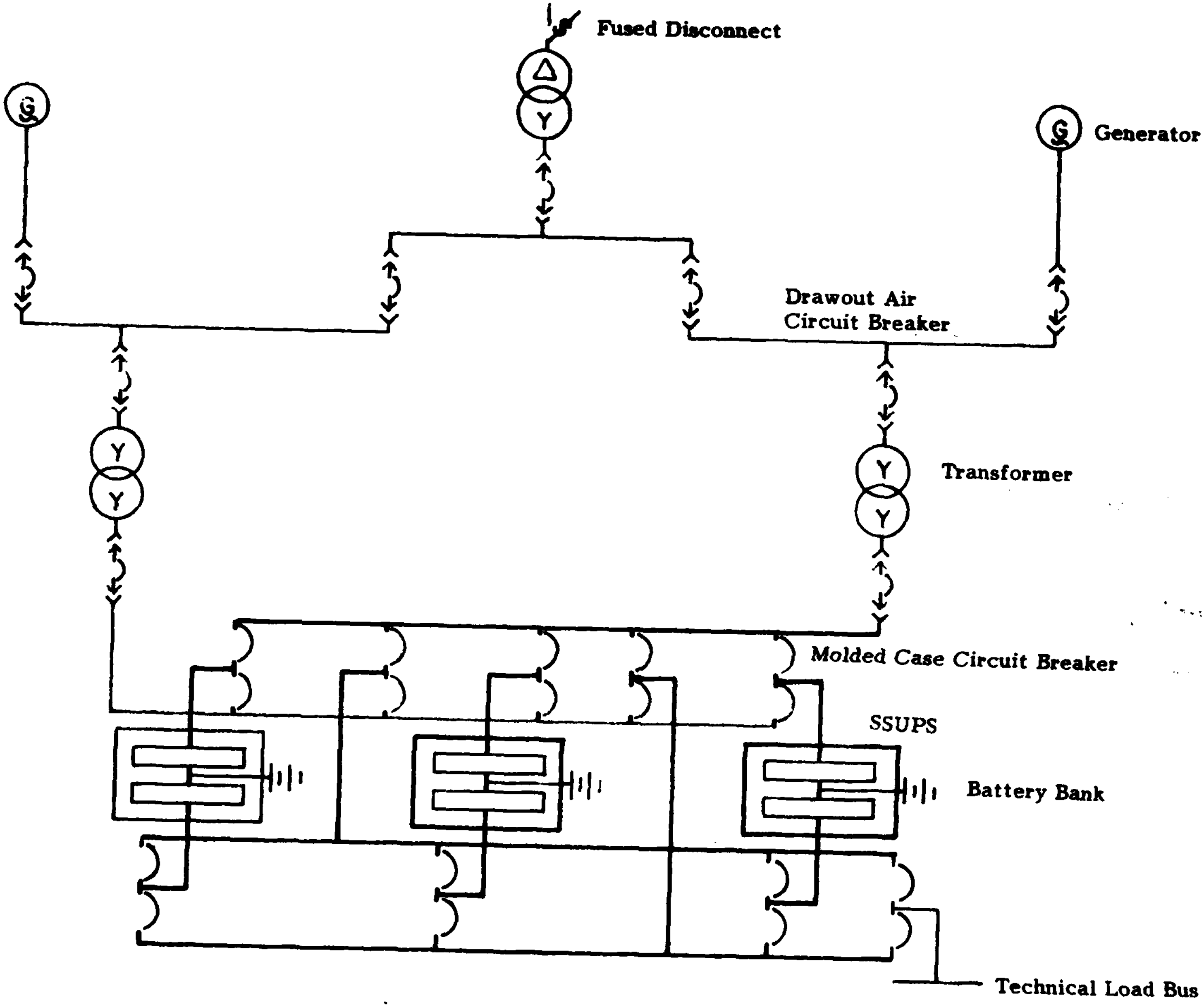
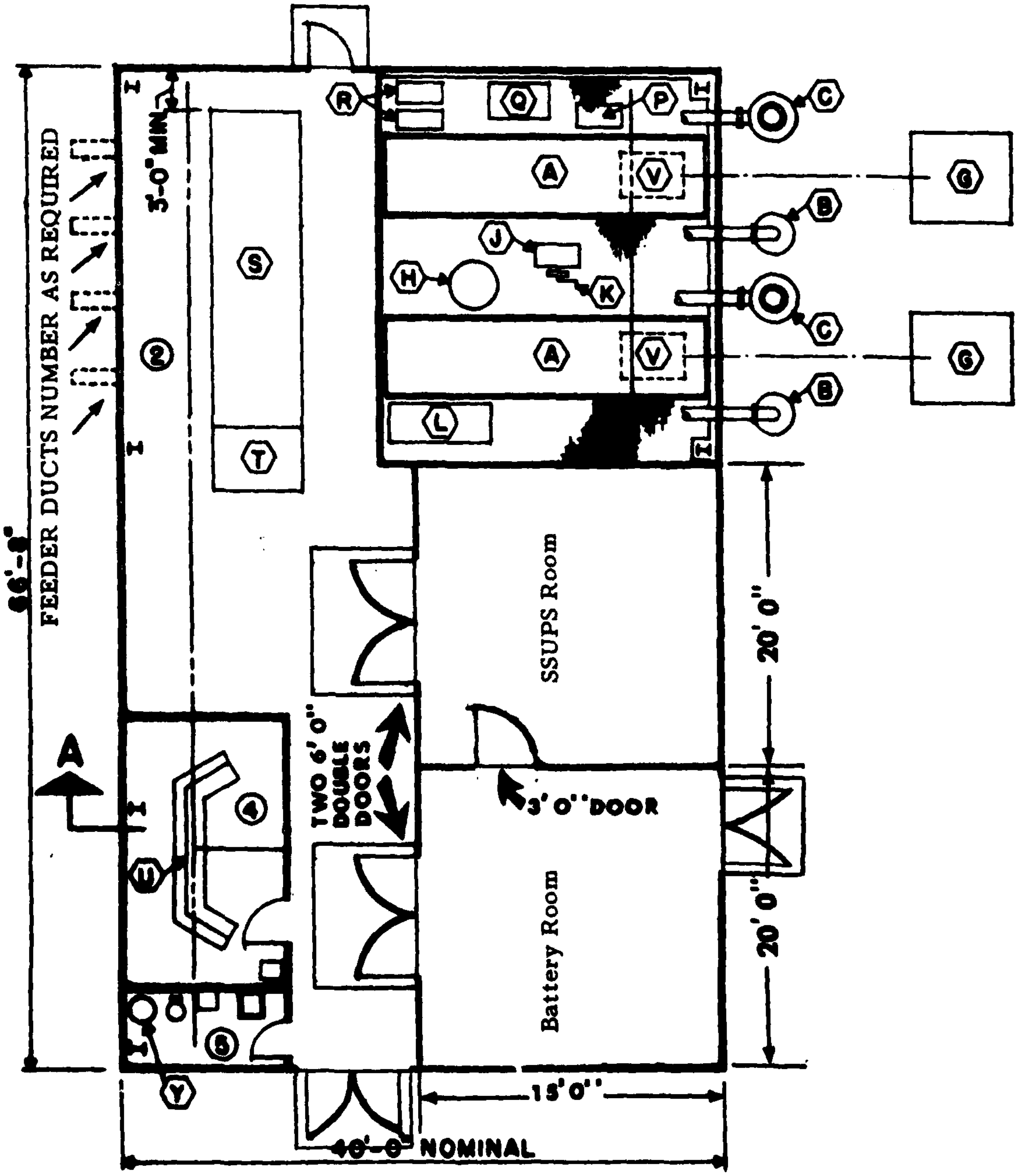


Figure #2

ALTERNATIVE #2

FIGURE 2a FIFTY PERCENT REDUNDANT SSUPS



FLOOR PLAN
SCALE: 1/8" = 1'-0"

LEGEND

ITEM	DESCRIPTION	QUAN	AF/CO	CO/CO	CAPACITY
Ⓐ	DIESEL ENGINE GENERATOR UNIT	4	X		
Ⓑ	AIR INTAKE CLEANER	4	X		BASED ON ENGINE MANUFACTURE'S RECOMMENDATIONS
Ⓒ	EXHAUST SILENCER	4	X		BASED ON ENGINE MANUFACTURE'S RECOMMENDATIONS
Ⓓ	LUBE OIL STORAGE TANK	1		X	500 GALLONS
Ⓔ	WASTE LUBE OIL STORAGE TANK	1		X	500 GALLONS
Ⓕ	LUBE OIL FILL PUMP	1		X	ROTARY, 10 G.P.M.
Ⓖ	RADIATOR AND CONDENSER	4	X		BASED ON ENGINE MFR. RECOMMENDATIONS
Ⓗ	COOLANT MIXING TANK	1		X	140 GALLONS
Ⓙ	COOLANT MAKE-UP PUMP	1		X	CENTRIFUGAL, 10 G.P.M.
Ⓚ	MANUAL COOLANT MAKE-UP PUMP	1		X	HAND-OPERATED, 10 G.P.M., CRANK HANDLE
Ⓛ	COMPRESSED AIR RECEIVER	2		X	BASED ON ENGINE MFR. RECOMMENDATIONS
Ⓜ	ELECTRIC MOTOR-DRIVEN AIR COMPRESSOR	1		X	250 P.S.I.
Ⓝ	GASOLINE ENGINE-DRIVEN AIR COMPRESSOR	1		X	250 P.S.I.
Ⓟ	FUEL OIL RETURN PUMP	1		X	ROTARY, 10 G.P.M.
Ⓠ	FUEL OIL PLANT TANK	1		X	275 GALLONS
Ⓡ	FUEL OIL SUPPLY PUMP	2		X	ROTARY, 10 G.P.M.
Ⓢ	SWITCHGEAR	1	X	X	
Ⓣ	LOAD CENTER	1			
Ⓤ	CONSOLE	1			
Ⓥ	FUEL OIL DAY TANK IN ENGINE SKID				FURNISHED WITH ENGINE
Ⓦ	DRINKING FOUNTAIN			X	
Ⓨ	WATER HEATER			X	
Z	ROTARY UPS	1		X	
AA	MOTOR-GENERATOR	1		X	

ROOM SCHEDULE

①	GENERATOR BAYS
②	SWITCHGEAR AREA
③	BAFFLE
④	CONTROL ROOM
⑤	TOILET
⑥	MAINTENANCE AREA
⑦	MAINTENANCE STORAGE

EXPLANATION OF COLUMN ENTRIES

AF/CO - DENOTES ITEMS SUPPLIED BY THE AIR FORCE USING PROCUREMENT BUDGET FUNDS AND INSTALLED BY THE CONSTRUCTION CONTRACTOR.

CO/CO - DENOTES ITEMS SUPPLIED AND INSTALLED BY THE CONSTRUCTION CONTRACTOR.

ALTERNATIVE #3: ROTATING FLYWHEEL CONSTANT FREQUENCY UPS, DIESEL SUPPORTED WITH MAINTENANCE SPARE

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$748,485		$748,485	0.954	$714,054
2		$186,740	186,740	0.867	161,903
3		"	"	0.788	147,151
4		"	"	0.717	133,892
5		"	"	0.652	121,754
6		"	"	0.592	110,550
7		"	"	0.538	100,466
8		"	"	0.489	91,315
9		"	"	0.445	83,099
10		"	639,240	0.405	258,892
11		"	186,740	0.368	68,720
12		"	"	0.334	62,371
13		"	"	0.304	56,768
14		"	"	0.276	51,540
15		"	"	0.251	46,871
16		"	"	0.228	42,576
17		"	"	0.208	38,841
18		"	"	0.189	35,293
19		"	"	0.172	32,119
20		"	"	0.156	29,131
TOTAL			$4,749,045	8.933	$2,387,306

TOTAL PROJECT COST (DISCOUNTED) $2,387,306

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $267,245

ALTERNATIVE #3: ROTATING FLYWHEEL CONSTANT FREQUENCY UPS, DIESEL SUPPORTED WITH MAINTENANCE SPARE

NON-RECURRING COSTS

MATERIALS

QUANTITY	ITEM	WASH COST ITEM
1	625 KVA, 3-Phase Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
4	600 A., 600 V., Drawout Air Circuit Breakers	
2	225 KVA, 3-Phase, Dry Type Transformer	X
2	400 A., 600 V., Drawout Air Circuit Breakers	X
2	200 KW, Rotary Flywheel UPS, Diesel Supported	
2	800 A., 250 V., Drawout Air Circuit Breakers	X
4	800 A., 250 V., Molded Case Circuit Breakers	
	Cabinet	
	Conduit and Cable	

TOTAL INITIAL INSTALLATION COSTS

2 - 500 KW Class C Plant	$270,000	(V)
Rotary UPS	362,000	(VI)
Switchgear	45,588	(III)
Miscellaneous Cable & Conduit	11,397	(IV)
TOTAL	$688,985	
UPS Initial Spare Parts & Tools .17 x $350,000	59,500	
	$748,485	

ALTERNATIVE #3

RECURRING COSTS:

a. Electro Mechanical Parts
$350,000 x .075 = $26,250 (Estimated)

b. Operating Cost Due to Inefficiencies

(1) Commercial Power
46 x 0.03 x 8770 - $12,103 (II)

(2) Generator Power
46 x 0.34 x 0.833 x 50 = $65 (II)

TOTAL: $12,168

c. Manpower - $94,657 (I)

d. Fuel Cost: UPS Diesel Engine - $218.00
Generator 1745.00

TOTAL: $1963

e. Commercial Power - $38,577 (II)

f. Depot Level Maintenance:
Acquisition Cost x 0.0375
$350,000 x 0.0375 = $13,125

g. Total O&M Costs: $26,250
12,168
94,657
1,963
38,577
13,125
$186,740

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - January 1975.

VI. King-Knight.

ALTERNATIVE #3: ROTATING FLYWHEEL CONSTANT FREQUENCY UPS, DIESEL SUPPORTED WITH MAINTENANCE SPARE

BENEFITS

1. An alternate unit is available if prime units fail or when maintenance is required on prime unit.

2. High first cost.

LIMITATIONS

1. One chance for diesel to start before frequency drop.

2. Noisy operation.

3. Large amounts of space required.

4. Significant amount of routine maintenance.

5. Low efficiency.

DIESEL SUPPORTED ROTATING FLYWHEEL CONSTANT FREQUENCY UPS WITH MAINTENANCE SPARE

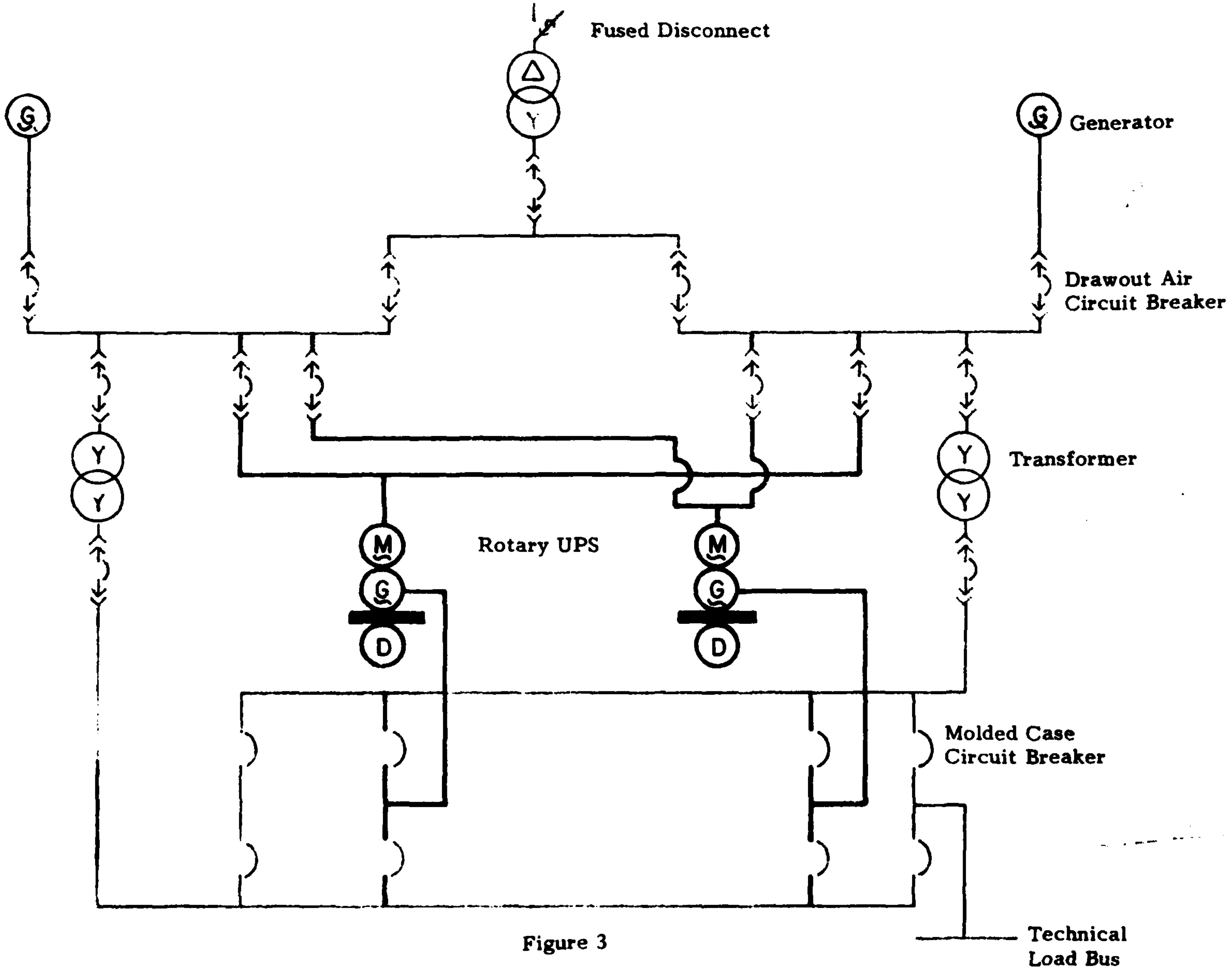
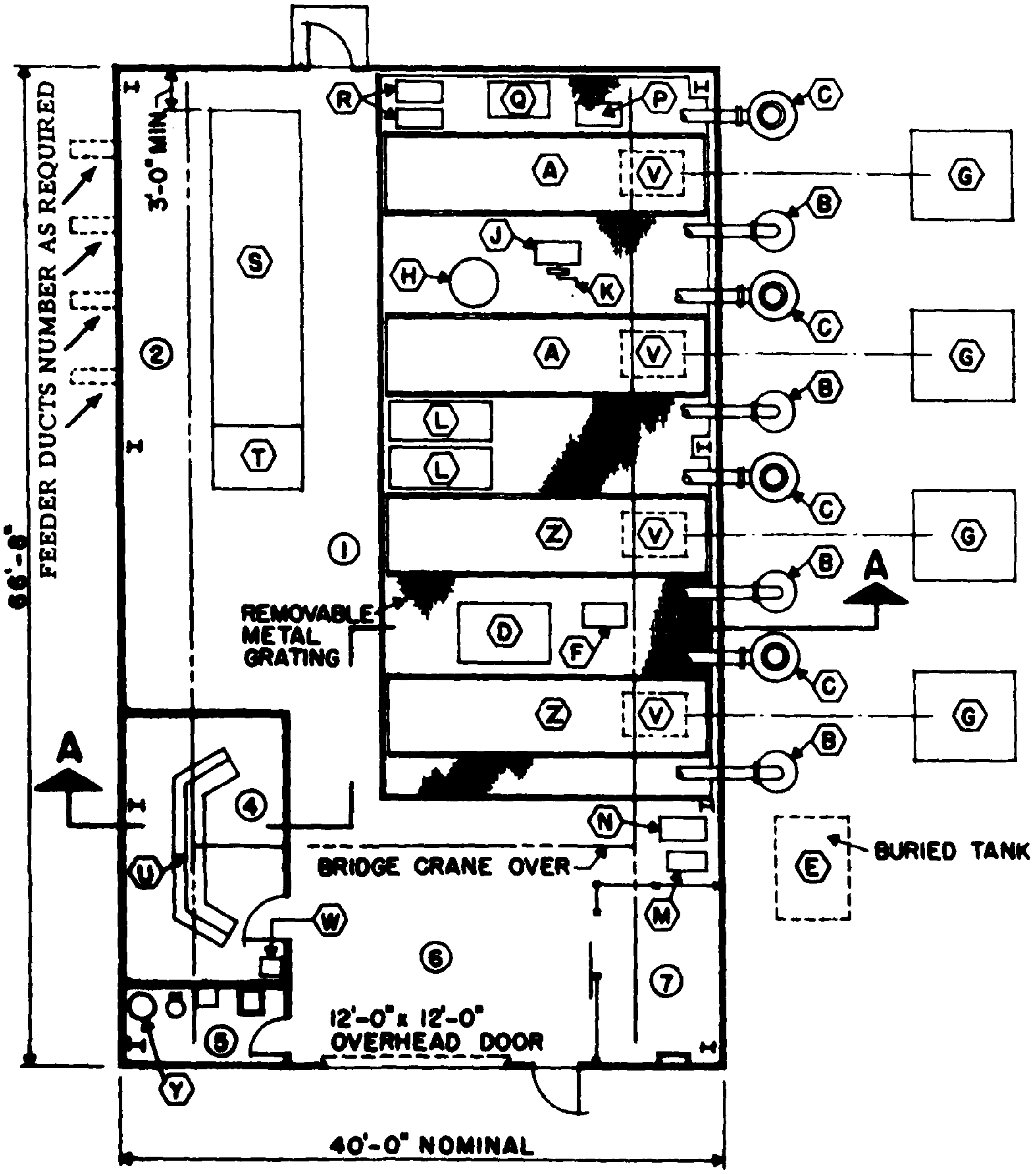


Figure 3

ALTERNATIVE #3

FIGURE 3a
ROTATING FLYWHEEL UPS, DIESEL SUPPORTED WITH MAINTENANCE SPARE



FLOOR PLAN
SCALE: 1/8" = 1'-0"

ALTERNATIVE #4: PRIME POWER PLANT

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$828,335		$828,335	0.954	$790,231
2		$264,807	264,807	0.867	229,587
3		"	"	0.788	208,667
4		"	"	0.717	189,866
5		"	"	0.652	172,654
6		"	"	0.592	156,765
7		"	"	0.538	142,466
8		"	"	0.489	129,490
9		"	"	0.445	117,839
10		"	"	0.405	107,246
11		"	"	0.368	97,448
12		"	"	0.334	88,445
13		"	"	0.304	80,501
14		"	"	0.276	73,086
15		"	"	0.251	66,466
16		"	"	0.228	60,375
17		"	"	0.208	55,079
18		"	"	0.189	50,048
19		"	"	0.172	45,546
20		"	"	0.156	41,309
TOTAL			$5,859,668	8.933	$2,903,114
TOTAL PROJECT COST (DISCOUNTED)				$2,903,114	

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $324,987

ALTERNATIVE #4: PRIME POWER PLANT

NON-RECURRING COSTS

Total Initial Installation Costs:

4 - 500 KW, Class A Generator Plant	$820,000 (V)
Switchgear	6,668 (III)
Miscellaneous Cable and Conduit	1,667 (IV)
TOTAL	$828,335

RECURRING COSTS

a. Electro Mechanical Parts
Acquisition Cost x 10%
$560,000 x .10 = $56,000

b. Manpower - $141,727 (I)

c. Fuel Cost - $39,080 (II)

d. Depot Level Maintenance
Acquisition Cost x 5%
$560,000 x 0.05 = $28,000

e. Total O&M Cost	$28,000
	141,727
	39,080
	56,000
TOTAL	$264,807

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - January 1975.

LIMITATIONS:

1. Continuous maintenance required.
2. Manpower is greater.

ALTERNATIVE #4: PRIME POWER PLANT

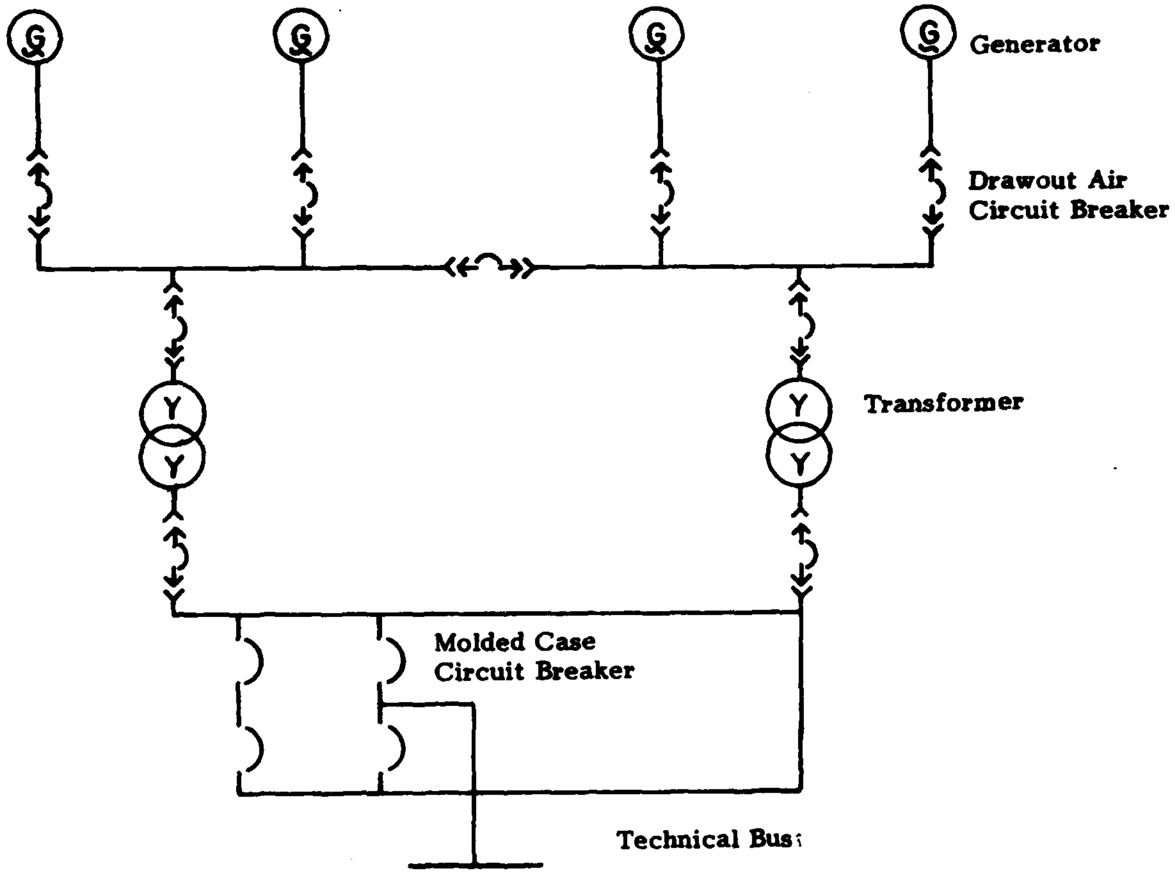
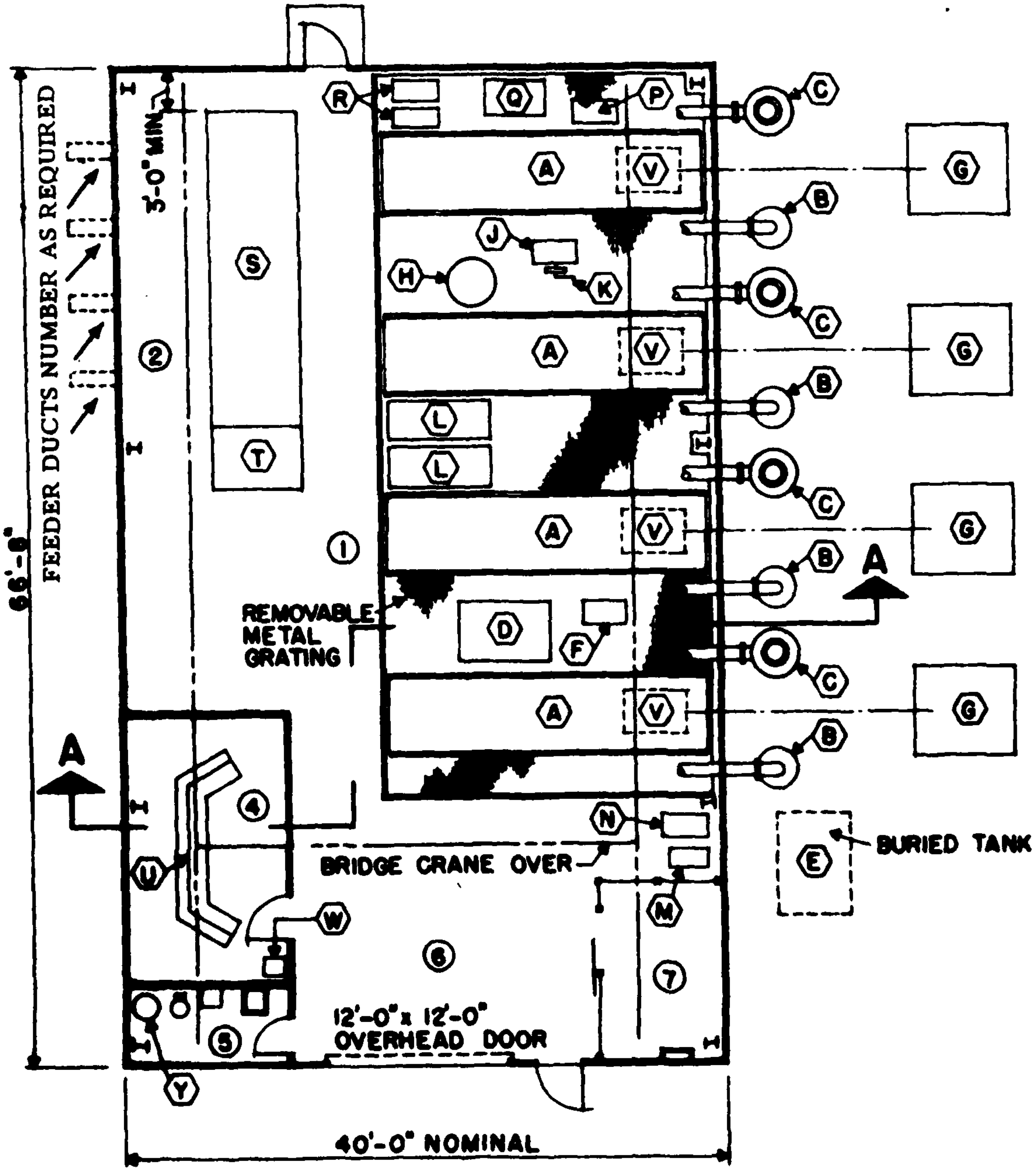


FIGURE 4

ALTERNATIVE #4

FIGURE 4a PRIME POWER PLANT



FLOOR PLAN

SCALE: 1/8" = 1'-0"

ALTERNATIVE #5: NON-REDUNDANT SSUPS WITH INTERNAL STATIC SWITCH

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$480,139		$480,139	0.954	$458,052
2		$156,583	156,583	0.867	135,757
3		"	"	0.788	123,387
4		"	"	0.717	112,270
5		"	"	0.652	102,092
6		"	"	0.592	92,697
7		"	"	0.538	84,241
8		"	"	0.489	76,569
9		"	"	0.445	69,679
10		"	"	0.405	63,416
11		"	"	0.368	57,622
12		"	"	0.334	52,298
13		"	"	0.304	47,601
14		"	"	0.276	43,216
15		"	"	0.251	39,302
16		"	"	0.228	35,700
17		"	"	0.208	32,569
18		"	"	0.189	29,594
19		"	"	0.172	26,932
20		"	"	0.156	24,426
TOTAL			$3,455,216	8.933	$1,707,420
TOTAL PROJECT COST (DISCOUNTED)					$1,707,420

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $191,136

ALTERNATIVE #5: NONREDUNDANT SSUPS WITH INTERNAL STATIC SWITCH

NON-RECURRING COSTS

QUANTITY	ITEM	WASH COST ITEM
2	500 KW, Class C Generators	X
1	625 KVA 3 Phase Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
2	500 A., 600 V., Drawout Air Circuit Breakers	X
2	300 KVA, 3-Phase, Dry Type Transformers	X
2	800 A., 250 V., Drawout Air Circuit Breakers	X
1	250 KVA SSUPS with 15 Min Battery Bank	
8	800 A., 250 V., Molded Case Circuit Breakers	
	Cabinets	
	Miscellaneous Cable and Conduit	

TOTAL INITIAL INSTALLATION COSTS

2 - 500 KW Class C Plant	$270,000	(V)
SSUPS, 250 KVA/Static Switch	133,922	(VI)
Switchgear	16,592	(III)
Misc Cable and Conduit	4,148	(IV)
TOTAL	$424,662	
UPS/Battery Rm - 600 Ft^2	21,000	
UPS Air Condition System	13,750	
UPS Initial Spare Parts and Tools 0.17 x $121,922	20,727	
TOTAL	$480,139	

RECURRING COSTS

a. SSUPS Parts
$121,922 x 0.05 = $6,096

b. Operation Cost Due to SSUPS Inefficiency

(1) Commercial Power (II)
19 KW x $0.03 x 8742 = $4983

(2) Generator Power (II)
19 KW x $0.34 x 0.0833 x 200 = 108 TOTAL: $5091

c. Air Conditioner Operation: $9198

d. Manpower - $94,657 (I)

e. Fuel Cost - $1745 (II)

f. Commercial Power - $38,577 (II)

g. Depot Level Maintenance
$121,922 x 0.010 = $1219

h. Total O&M Cost $6,096
5,091
94,657
9,198
1,745
38,577
1,219
$156,583

SOURCES/DERIVATION OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - January 1975.

VI. Teledyne, Inc.

BENEFITS

1. Precise uninterruptible power.
2. High reliability.
3. High efficiency.
4. Low noise.
5. Low maintenance.
6. During inverter failure, load is transferred to prime or generator power in 5 ms or less.

LIMITATIONS

1. Air conditioning required.
2. Large battery system required.
3. Loads must be supplied raw power when performing maintenance on system.

ALTERNATIVE #5: NON-REDUNDANT SSUPS WITH INTERNAL STATIC SWITCH

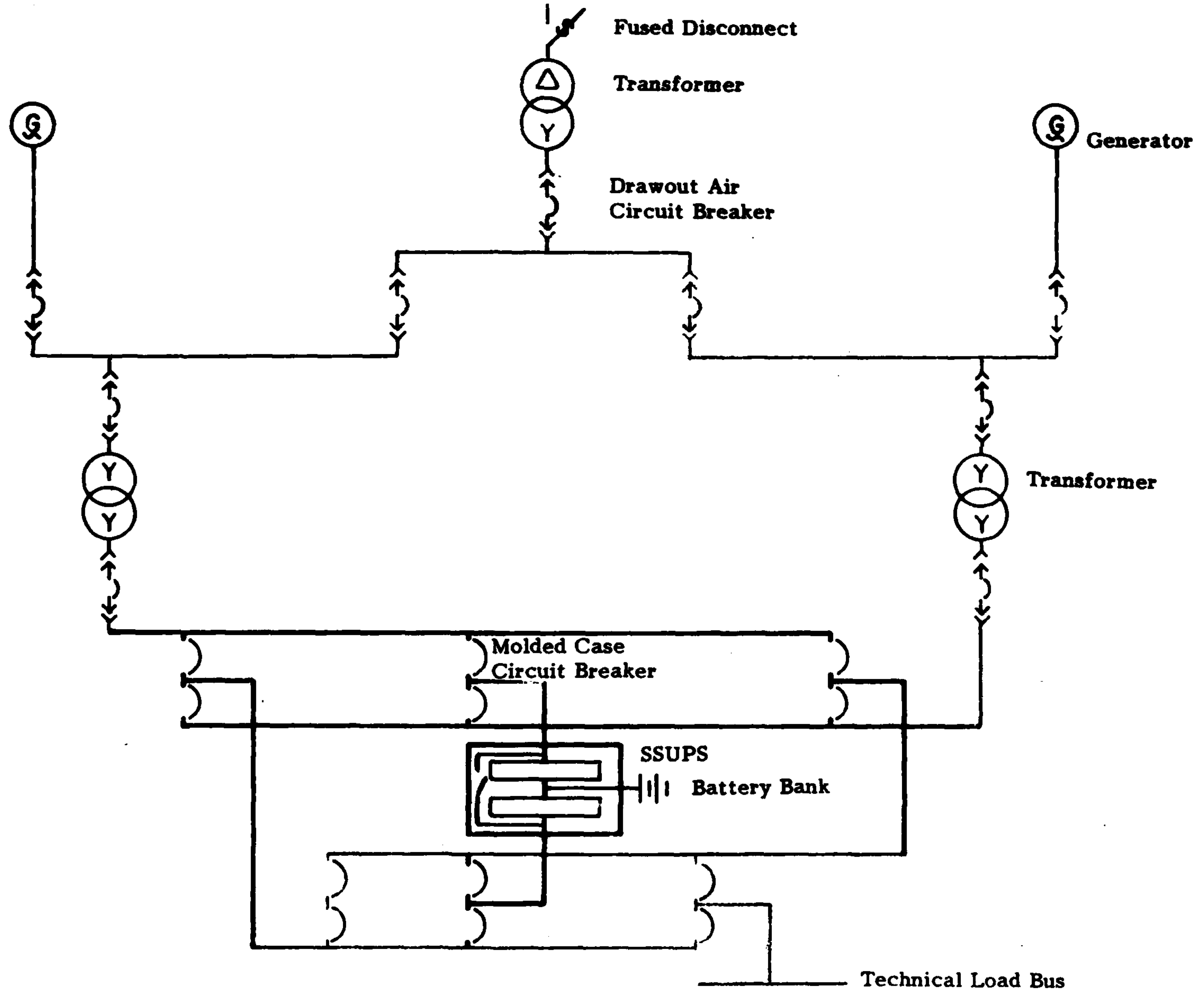
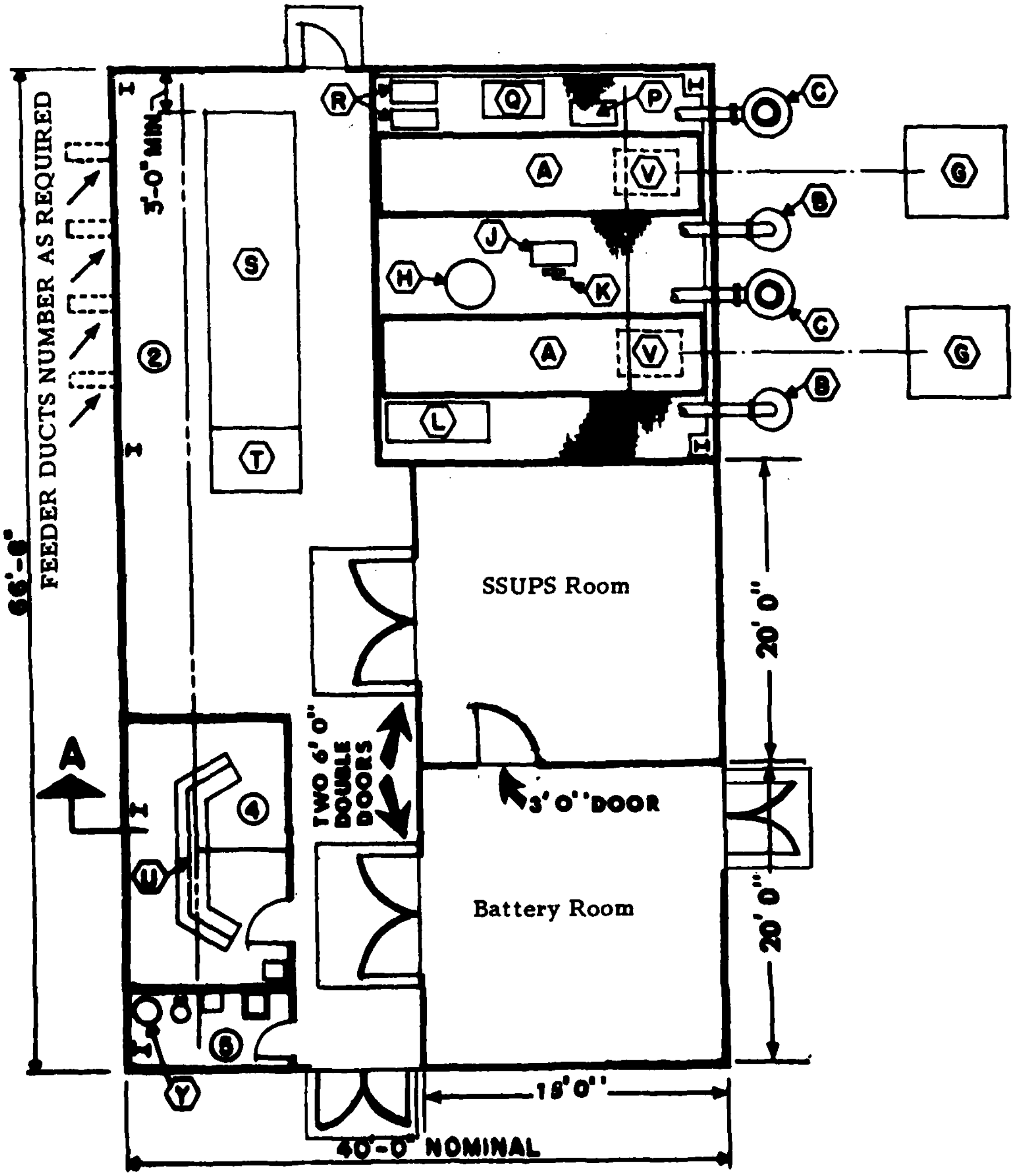


Figure 5

ALTERNATIVE #5

FIGURE 5a NON-REDUNDANT SSUPS WITH STATIC SWITCH



FLOOR PLAN

SCALE: 1/8" = 1'-0"

ALTERNATIVE #6: NON REDUNDANT SSUPS WITHOUT INTERNAL STATIC SWITCH

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$483,238		$483,238	0.954	$461,009
2		$156,373	156,373	0.867	135,575
3		"	"	0.788	123,221
4		"	"	0.717	112,119
5		"	"	0.652	101,955
6		"	"	0.592	92,572
7		"	"	0.538	84,128
8		"	"	0.489	76,466
9		"	"	0.445	69,585
10		"	"	0.405	63,331
11		"	"	0.368	57,545
12		"	"	0.334	52,228
13		"	"	0.304	47,537
14		"	"	0.276	43,158
15		"	"	0.251	39,249
16		"	"	0.228	35,653
17		"	"	0.208	32,525
18		"	"	0.189	29,554
19		"	"	0.172	26,896
20		"	"	0.156	24,394
TOTAL			$3,454,325	8.933	$1,708,700
TOTAL PROJECT COST (DISCOUNTED)					$1,708,700

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $191,279

ALTERNATIVE #6: NON-REDUNDANT SSUPS WITHOUT INTERNAL STATIC SWITCH

NON-RECURRING COSTS:

MATERIALS

QUANTITY	ITEM	WASH COST ITEM
2	500 KW, Class C, Generators	X
1	625 KVA, 3-Phase, Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
2	400 A., 600V., Drawout Air Circuit Breakers	
2	500 A., 600 V., Drawout Air Circuit Breakers	X
2	225 KVA, 3-Phase, Dry Type Transformers	X
2	800 A., 250 V., Molded Case Circuit Breakers	
1	250 KVA SSUPS, 15 Minute Battery Bank	
2	Cabinets	
	Miscellaneous Cable and Conduit	

TOTAL INITIAL INSTALLATION COSTS

2 - 500 KW, Class C, Plant	$270,000	(V)
250 KVA SSUPS/15 Min Standby Battery Bank	130,422	(VI)
Switchgear	22,348	(III)
Misc Cable, Conduit, etc.	5,587	(IV)
TOTAL	$428,357	
UPS Air Condition System	13,750	(V)
UPS/Battery Room - 600 Ft^2	21,000	(V)
UPS Initial Spare Parts & Tools .17 x $118,422	20,131	
TOTAL	$438,238	

ALTERNATIVE #6.

RECURRING COSTS:

a. SSUPS Parts:
$118,422 x 0.05 = $5,921

b. Operating Cost Due to SSUPS Inefficiencies:

(1) Commercial Power	$4983	(II)
(2) Generator Power	108	(II)
TOTAL	$5091	

c. Manpower - $94,657 (I)

d. Air Conditioner Operations - $9198 (II)

e. Fuel Cost - $1745 (II)

f. Commercial Power - $38,517 (II)

g. Depot Level Maintenance
$118,422 x 0.010 - $1184

h. Total O&M Cost:	$5,921
	5,091
	94,657
	9,198
	1,745
	38,517
	1,184
TOTAL	$156,373

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - Janaury 1975.

VI. Teledyne, Inc.

BENEFITS

1. Precise Uninterruptible Power.

2. High Reliability.

3. High Efficiency.

4. Low Noise.

5. Low Maintenance.

LIMITATIONS

1. During failure of UPS or when maintenance is required, loads must be supplied raw power.

2. Air conditioning required.

3. Large battery system required.

ALTERNATIVE #6: NON-REDUNDANT SSUPS WITHOUT INTERNAL STATIC SWITCH

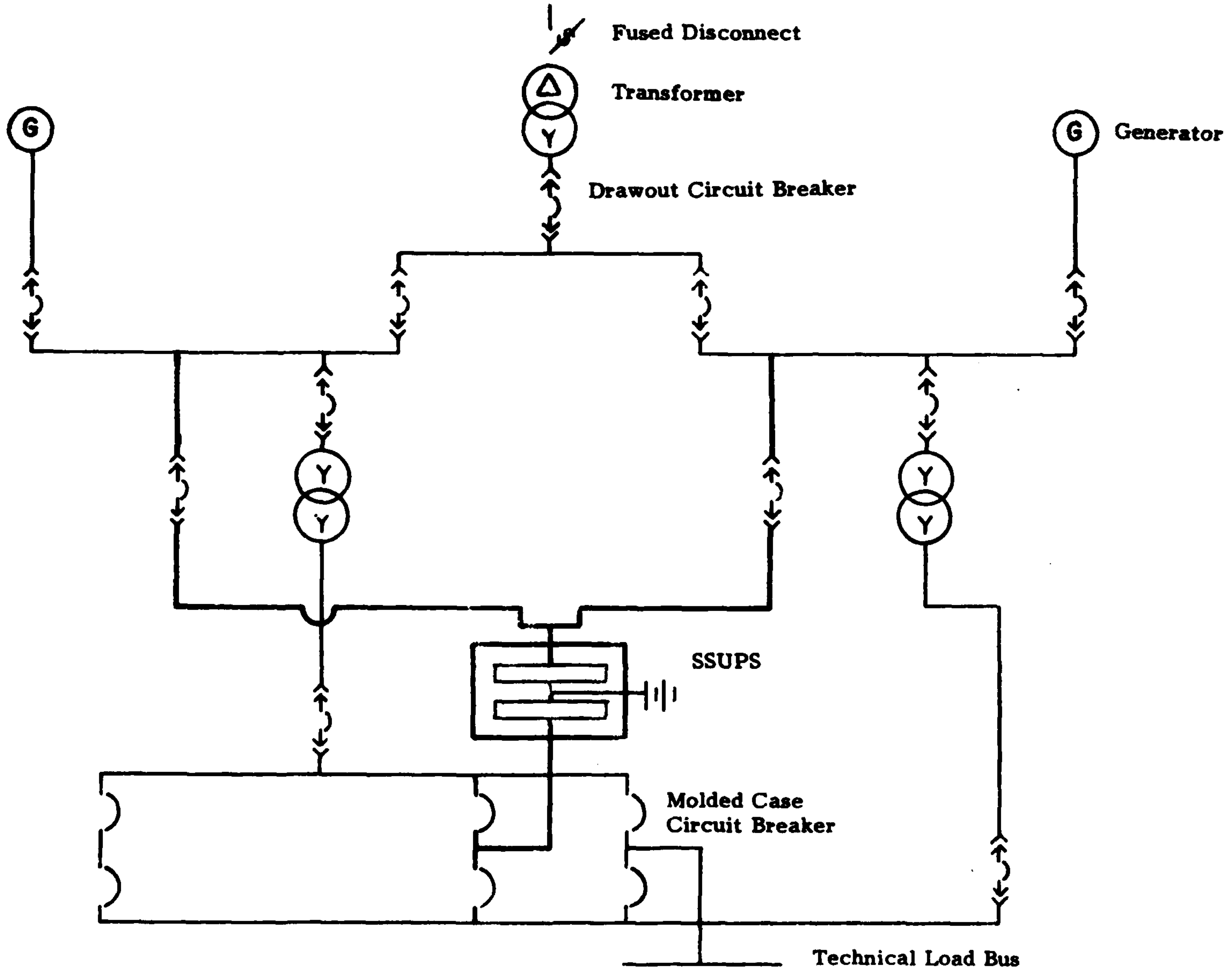
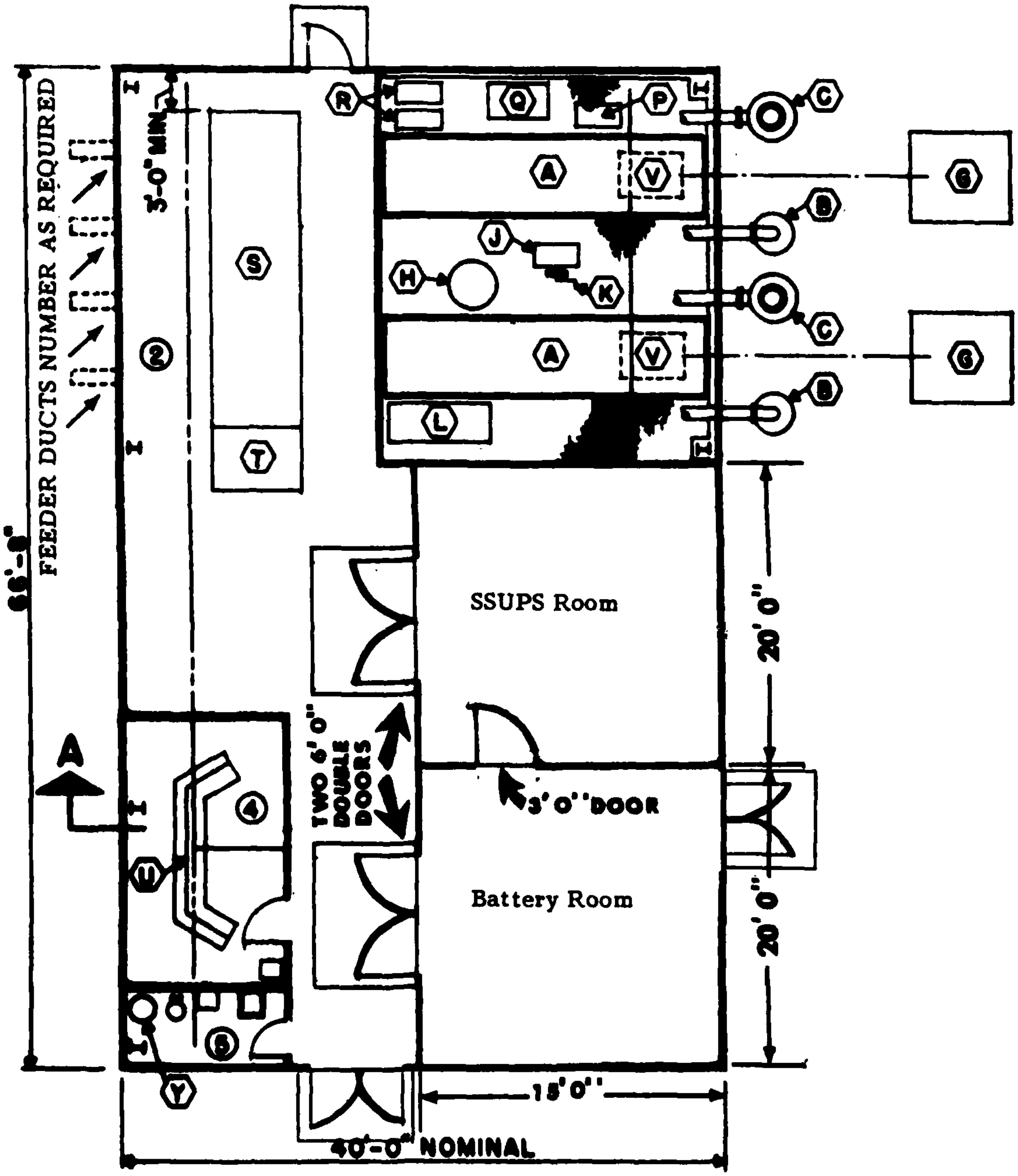


Figure #6

ALTERNATIVE #6

FIGURE 6a NON-REDUNDANT SSUPS WITHOUT STATIC SWITCH



FLOOR PLAN

SCALE: 1/8" = 1'-0"

ALTERNATIVE #7: LINE VOLTAGE STATIC REGULATORS

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$310,697		$310,697	0.954	$296,404
2		$138,324	138,324	0.867	119,926
3		"	"	0.788	108,999
4		"	"	0.717	99,178
5		"	"	0.652	90,187
6		"	"	0.592	81,887
7		"	"	0.538	74,418
8		"	"	0.489	67,640
9		"	"	0.445	61,554
10		"	"	0.405	56,021
11		"	"	0.368	50,903
12		"	"	0.334	46,200
13		"	"	0.304	42,050
14		"	"	0.276	38,177
15		"	"	0.251	34,719
16		"	"	0.228	31,537
17		"	"	0.208	28,771
18		"	"	0.189	26,143
19		"	"	0.172	23,791
20		"	"	0.156	21,578
TOTAL			$2,938,853	8.933	$1,400,083
TOTAL PROJECT COST (DISCOUNTED)					$1,400,083

UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE): $155,685

ALTERNATIVE #7: LINE VOLTAGE STATIC REGULATORS

NON-RECURRING COSTS

MATERIALS

QUANTITY	ITEM	WASH COST ITEM
2	500 KW, Class C, Generators	X
1	625 KVA, 3-Phase, Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
2	400 A., 600 V., Drawout Air Circuit Breakers	X
2	800 A., 250 V., Drawout Air Circuit Breakers	X
2	225 KVA, 3-Phase, Dry Type Transformers	
8	800 A., 250 V., Molded Case Circuit Breakers	
6	Cabinets	
	Miscellaneous Cable and Conduit	
3	225 KVA, 1-Phase, Static Line Voltage Regulators	

TOTAL INITIAL INSTALLATION COSTS

2 - 500 KW, Class C, Plant	$270,000 (V)
Regulators	27,177 (VI)
Switchgear	10,816 (III)
Misc Cable and Conduit	2,704
Regulator Spare Parts	Negligible
TOTAL	$310,697

RECURRING COSTS

a. Voltage Regulator Parts
$24,927 x 0.05 = $1,246

b. Operations Cost Due to Regulator Inefficiency

(1) Commercial Power (II) 8 KW x $0.03 x 8560 =	$2054
(2) Generator Power (II) 8 KW x $0.34 x 0.0833 x 200	45
TOTAL	$2,099

c. Manpower - $94,657 (I)

d. Fuel - $1,745 (II)

e. Commercial Power - $38,577 (II)

f. Depot Level Maintenance - Negligible

g. Total O&M:

	$1,246
	2,099
	94,657
	1,745
	38,577
TOTAL	$138,324

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance, January 1975.

VI. Sola Line Voltage Regulator Catalog #618.

BENEFITS

1. Very low initial cost.
2. Practically no maintenance.

LIMITATIONS

1. Cannot eliminate problems due to prime power blackouts.

ALTERNATIVE #7: LINE VOLTAGE STATIC REGULATORS

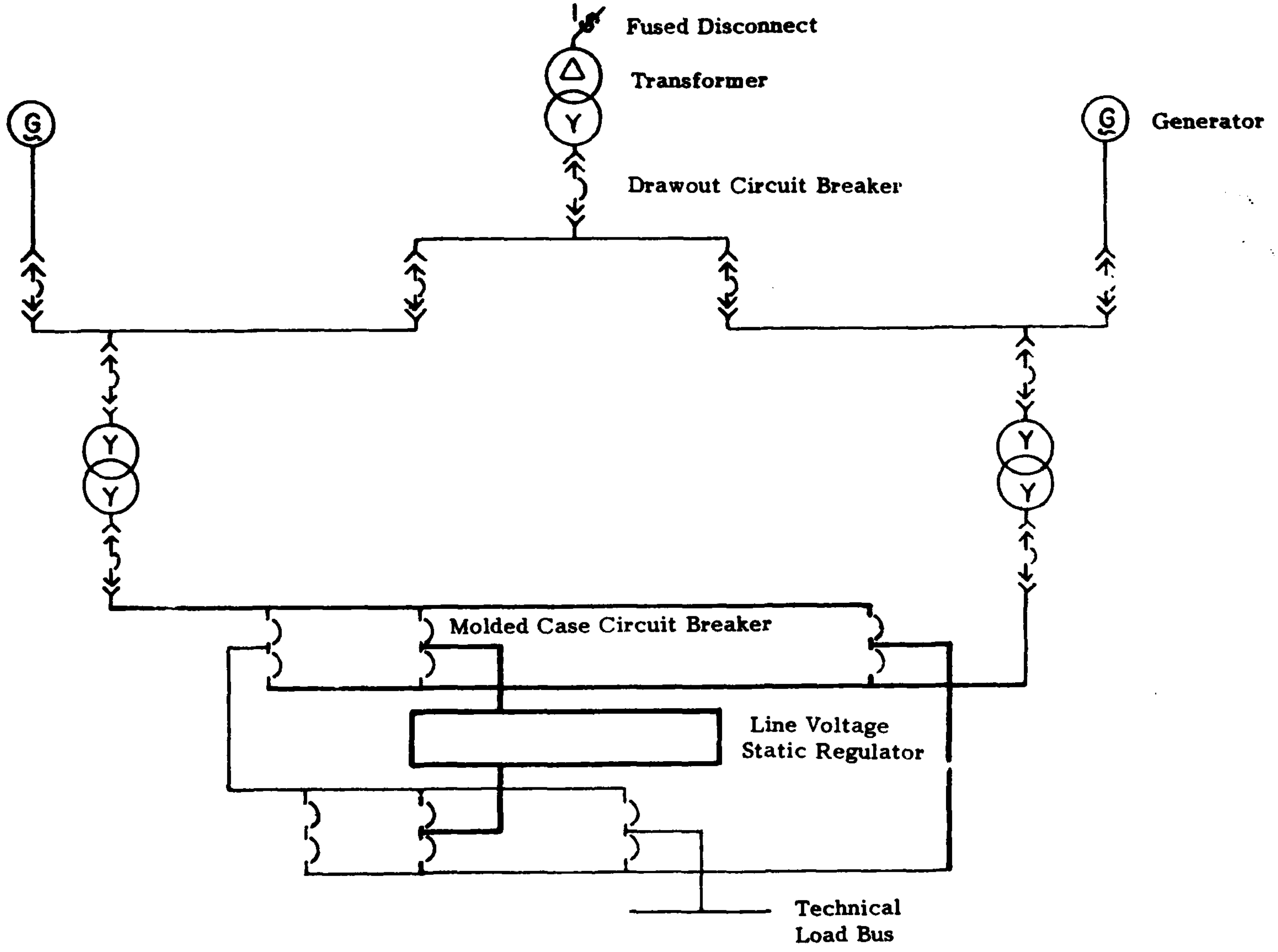
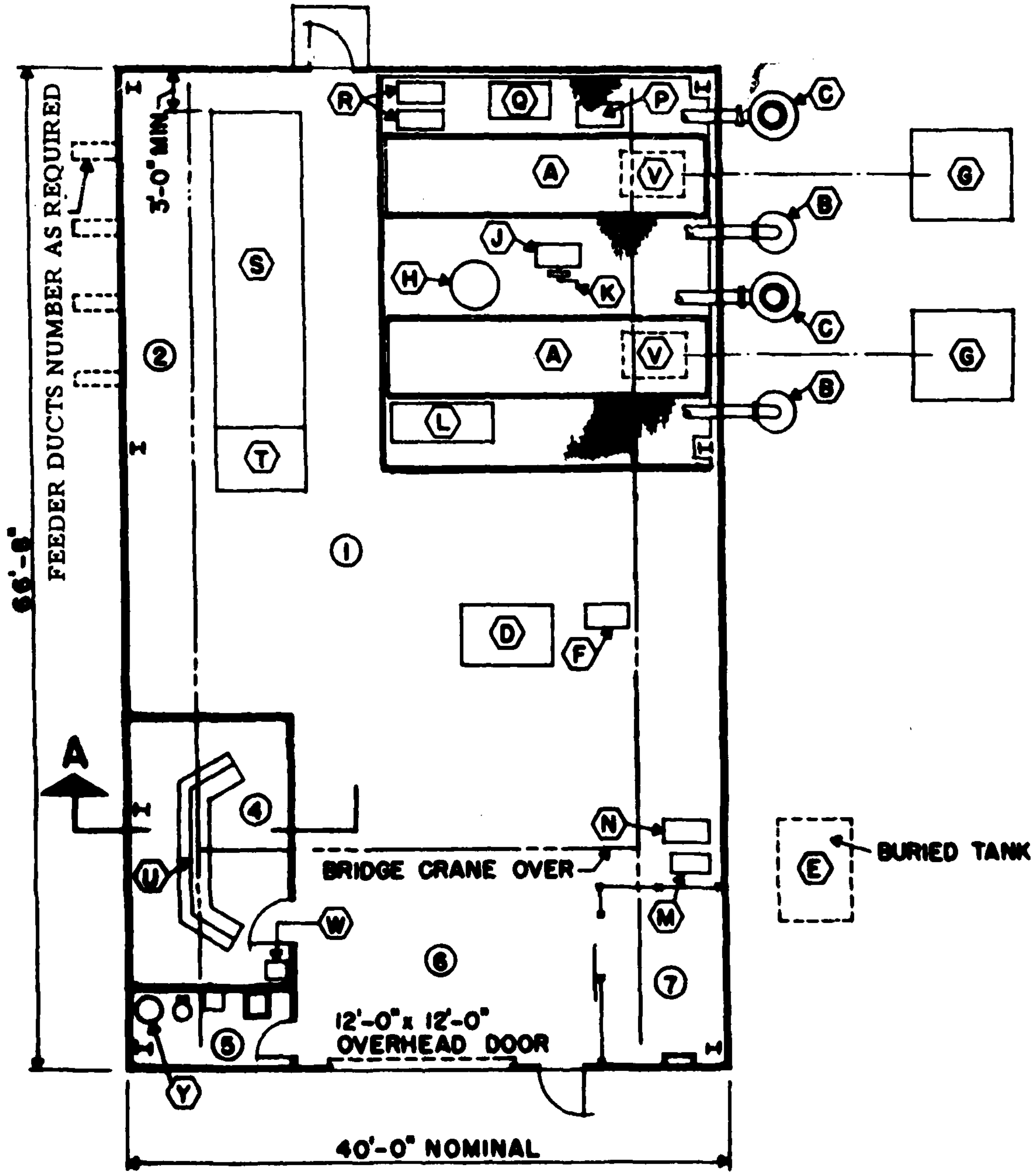


Figure #7

ALTERNATIVE #7

FIGURE 7a. LINE VOLTAGE REGULATOR



FLOOR PLAN

SCALE: 1/8" = 1'-0"

ALTERNATIVE #8: MOTOR GENERATOR SET, CONSTANT FREQUENCY

PROJECT YEAR	NONRECURRING COST	RECURRING COST	ANNUAL COST	DISCOUNT COST	ANNUAL COST DISCOUNTED
1	$368,909		$368,909	0.954	$351,939
2		$152,206	152,206	0.867	131,962
3		"	"	0.788	119,938
4		"	"	0.717	109,131
5		"	"	0.652	99,238
6		"	"	0.592	90,105
7		"	"	0.538	81,886
8		"	"	0.489	74,428
9		"	"	0.445	67,731
10	76,735	"	228,941	0.405	92,721
11		"	152,206	0.368	56,011
12		"	"	0.334	50,836
13		"	"	0.304	46,270
14		"	"	0.276	42,008
15		"	"	0.251	38,203
16		"	"	0.228	34,702
17		"	"	0.208	31,658
18		"	"	0.189	28,766
19		"	"	0.172	26,179
20		"	"	0.156	23,744
TOTAL			$3,337,558	8.933	$1,597,456
TOTAL PROJECT COST (DISCOUNTED)					$1,597,456
UNIFORM ANNUAL COST (WITHOUT TERMINAL VALUE):			$178,826		

ALTERNATIVE #8

RECURRING COSTS:

a. Electro Mechanical Parts
$56,388 x 0.10 = $5,639

b. Operating Cost Due to Inefficiencies (II)
Same as Alternative #1 - $11,588

c. Manpower - $94,657 (I)

d. Fuel - $1,145 (II)

e. Commercial Power - $38,577 (II)

f. Depot Level Maintenance
$56,693 x 0.05 = $2,819

g. Total O&M	$ 5,639
	11,588
	94,657
	1,745
	33,577
TOTAL	$152,206

ALTERNATIVE #8: MOTOR GENERATOR SET, CONSTANT FREQUENCY

NON-RECURRING COSTS:

MATERIALS

QUANTITY	ITEM	WASH COST ITEM
2	500 KW, Class C, Generators	X
1	625 KVA, 3-Phase, Substation	X
5	800 A., 600 V., Drawout Air Circuit Breakers	X
2	400 A., 600 V., Drawout Air Circuit Breakers	X
2	600 A., 600 V., Drawout Air Circuit Breakers	
2	800 A., 250 V., Drawout Air Circuit Breakers	X
2	800 A., 250 V., Molded Case Circuit Breakers	
2	Cabinets	
1	Motor Generator Set	

TOTAL INITIAL INSTALLATION COST

2 - 500 KW Class C Plant	$270,000	(V)
1 - 200 KW, Motor Generator Set	61,388	(VI)
Switchgear	22,348	(III)
Misc Cable and Conduit	5,587	(IV)
	$359,323	
Motor Generator Spare Parts & Tools .17 x 56,388	9,586	
TOTAL	$368,909	

SOURCES/DERIVATIONS OF NON-RECURRING AND RECURRING COSTS

I. AFM 173-10, US Air Force Cost and Planning Factor Manual (HQ AFCS/ACMC Letter, 7 December 1976, Personal Cost Factor).

II. DCAC 600-60-1, Defense Communications Agency Cost and Planning Factors Manual.

III. Westinghouse Quick Selector Catalog 25-000, 1975.

IV. Means Building Construction Cost Data, 1976.

V. US Air Force Military Construction Cost Guidance - January 1975.

VI. Power Systems and Controls, Inc.

LIMITATIONS

1. Low efficiency.
2. High maintenance cost.

ALTERNATIVE #8: CONSTANT FREQUENCY MOTOR-GENERATOR SET

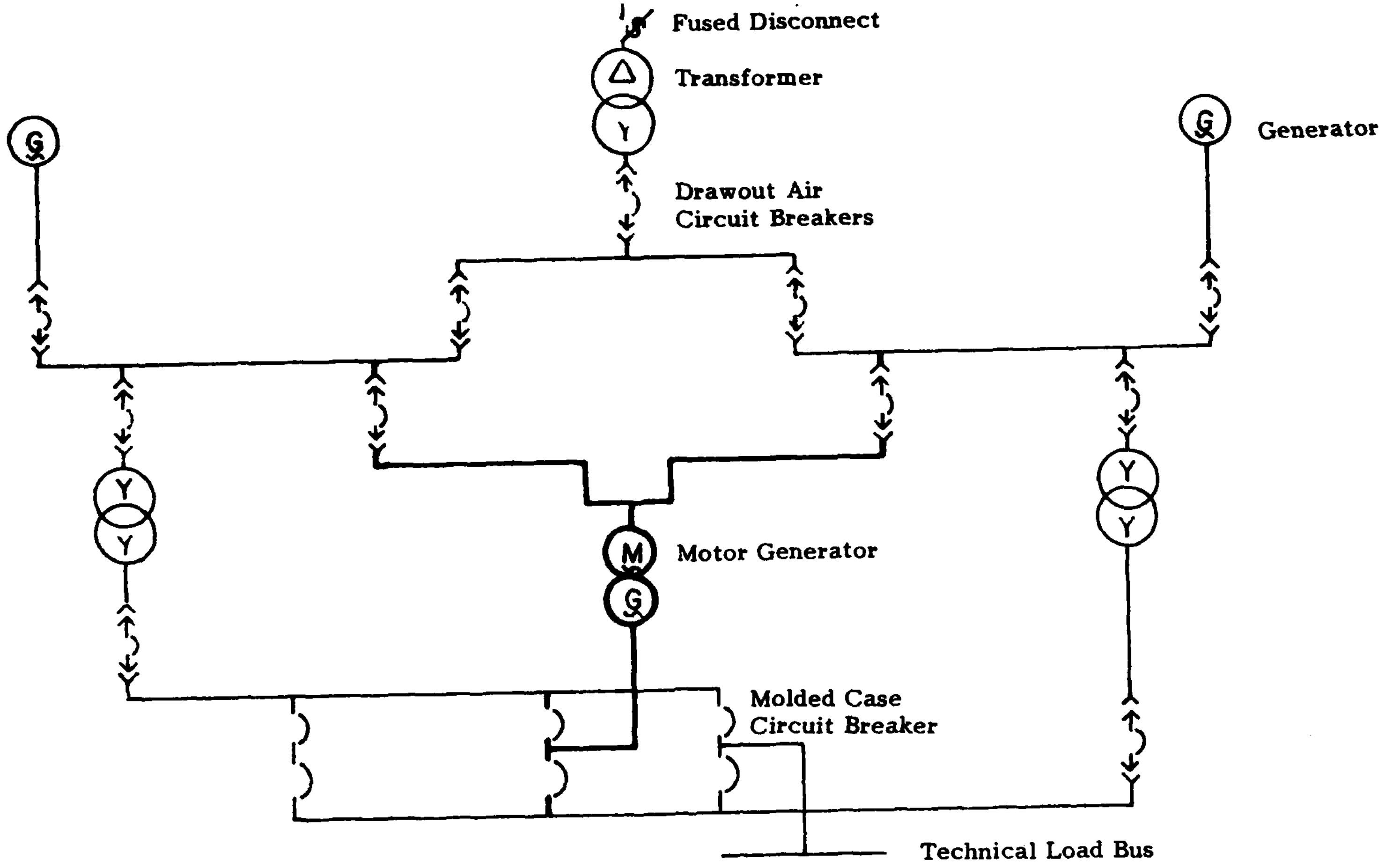
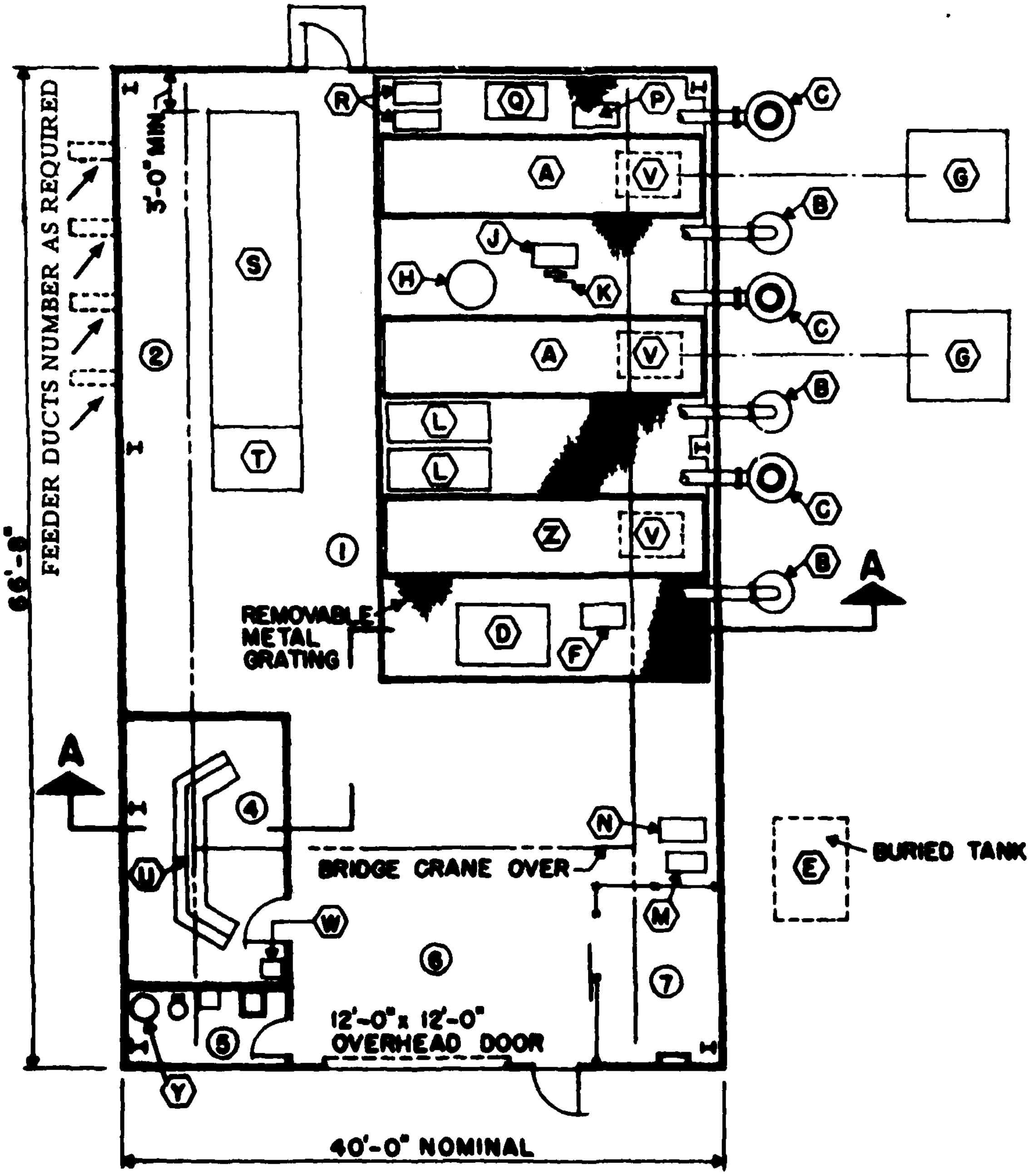


Figure #8

ALTERNATIVE #8

FIGURE 8a. MOTOR GENERATOR



FLOOR PLAN
SCALE: 1/8" = 1'-0"

COST RANKING OF SYSTEMS:

RANK	ALTERNATIVE	NET TOTAL PROJECT COST	NET UNIFORM ANNUAL COST
1	7	$2,938,853	$155,685
3	5	3,455,216	191,136
4	6	3,454,325	191,279
5	2	3,715,273	211,487
2	8	3,337,558	178,826
6	1	4,025,500	219,462
7	3	4,749,045	267,245
8	4	5,859,668	324,987

MEAN TIME BETWEEN FAILURE (MTBF) RANKING OF SYSTEMS:

RANK	ALTERNATIVE	MTBF
1	7	30 Years (estimated)
2	2	187,000 hrs, or 21.34 yrs
3	5	114,500 hrs, or 13.0 yrs
4	4	35,040 hrs, or 4.0 years
5	6	22,000 hrs, or 2.5 yrs
6	8	8,713 hours
7	3 and 1	5,000 hours

TYPICAL EQUIPMENT COST

a. Line Voltage, 3-Phase, Static Regulators

Size	Net Price
10 KVA	$3,313
15 KVA	3,708
25 KVA	4,084
50 KVA	6,521
75 KVA	9,782
100 KVA	12,421
150 KVA	18,042
225 KVA	24,927

b. Solid-State Uninterruptible Power Supply Set and 15 Minute Battery Bank

Size	Net Price
7.5 KVA	$50,370
12.5 KVA	52,003
25.0 KVA	59,026
37.5 KVA	68,731
62.5 KVA	81,488
125 KVA	76,889
250 KVA	118,422

c. Rotary Flywheel Constant Frequency UPS Diesel Supported

Size	Net Price
150 KW	$130,000
250 KW	175,000
500 KW	250,000

REFERENCES

IEEE Std 446 - 1974, Recommended Practice for Emergency and Standby Power systems.

National Electrical Code, 1975, National Fire Protection Association.

SUMMARY - RECURRING COSTS

Alternative	Spare Parts	Operating Cost Due to Inefficiency	Manpower	Fuel	Commercial Power	Depot Level Maintenance	Air Conditioning Operating Cost	Total
1	$17,500	$11,568	$94,657	$1,963	$38,577	$8,750	——	$173,035
2	11,533	5,101	94,657	1,745	38,577	2,306	$9,198	163,117
3	26,250	12,168	94,657	1,963	38,577	13,125	——	186,740
4	56,000	——	141,727	39,080	——	28,000	——	264,807
5	6,096	5,091	94,657	1,745	38,577	1,219	9,198	156,583
6	5,921	5,091	94,657	1,745	38,577	1,184	9,198	156,373
7	1,246	2,099	94,657	1,745	38,577	Negligible	——	138,324
8	5,689	11,588	94,657	1,745	38,577	2,819	——	152,206

SUMMARY - NON-RECURRING COST

Alternative	Generator and Building	Pwr Cond Equipment	Switchgear	Cable and Conduit	Initial Spare Parts	UPS Battery Room	Air Conditioning System	Total	Rotating Units Replacement
1	$270,000	$181,000	$24,868	$6,217	$29,850	—	—	$511,835	$226,000
2	270,000	230,000	21,136	5,284	39,213	$21,000	$13,750	616,050	452,500
3	270,000	362,000	45,588	11,397	59,500	—	—	748,485	—
4	820,000	—	6,668	1,667	*	—	—	828,335	—
5	270,000	133,922	16,592	4,148	20,727	21,000	13,750	480,139	—
6	270,000	130,422	22,348	5,587	20,131	21,000	13,750	483,238	—
7	270,000	27,177	10,816	2,704	Negligible	—	—	314,697	—
8	270,000	61,383	22,348	5,587	9,586	—	—	368,909	76,735

* Included in generator and building cost

APPENDIX F

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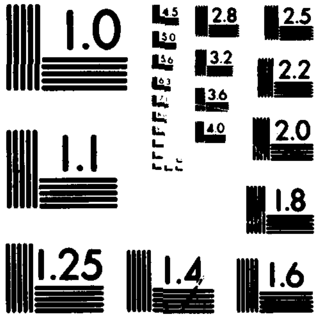

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