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Managing Hospital Emergency Power Testing Programs

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SUMMARY

This monograph examines a comprehensive approach to Managing Hospital Emergency Power Supply System (EPSS) testing programs in light of the increasing complexity of hospital infrastructures and operational constraints. All hospitals must have an emergency power testing program that includes generator load testing and EPSS maintenance. This comprehensive and proactive utility management program approach uses lessons learned from the testing to improve the hospital's facilities, EPSS reliability and training.

INTRODUCTION

Hospitals must have emergency power testing programs in place to meet the requirements of NFPA 70, NFPA 99 and NFPA 110, as well as standards established by accreditation organizations such as JCAHO. These programs include requirements for generator load testing; also commonly known as 30% testing, and emergency power supply system (EPSS) maintenance. Both topics were well represented in an excellent Joint Commission monograph[1] shortly after the rules for the previously required "30/50" testing were originally promulgated in industry standards. Those requirements have changed several times since their original adoption. Several other comprehensive analyses have dealt with designing the testing program and the code requirements that apply to hospital EPSS testing as well as to the EPSS in general.[2, 3, 4, 5] Other recent publications address code changes and other pertinent issues such as performance improvement.[6, 7, 8, 9] The purpose of this Management Monograph is not to restate the above issues, but rather to discuss a Utility Management Program approach that uses the lessons learned from the emergency power testing program to improve the hospital's infrastructure facilities and training, both for support services and for clinical caregivers. It also updates this document's predecessor[10] to reflect current issues and concepts.

This document also includes some lessons learned from a previously published case study[11] of EPSS testing. The case study discussed issues that might be described as second order consequences[12] of the emergency power testing effort. To the extent that second order consequences can have negative effects on a hospital, steps should be taken to follow up on those issues to identify problems and take corrective action. In many cases, the emergency power testing program's second order consequences also represent problematic system interactions that can negatively affect hospital operations or patient care during a real utility (normal) power outage.

Emergency power testing programs involve transferring the power sources of operating mechanical, electrical, plumbing, vertical transportation and clinical systems from normal power to the emergency generators and then back to normal power. These power transfers can disrupt increasingly more complex and sensitive clinical and building equipment, building automation systems, and hospital operations. When the testing process is managed properly, and proactively followed through, these disruptions are valuable learning experiences that provide opportunities to improve the hospital infrastructure, improve hospital operations and improve EPSS reliability. Lessons learned from emergency power testing also suggest future system design improvements.

It is important to analyze system interactions, test results and trends, not just record generator set parameters or kilowatt test results. Several of the previously referenced publications cover only recording and analyzing the test results for the engine and generator operating parameters. This document will address test results that describe kinds of interactions between the electrical distribution system components and their emergency power loads.

TESTING PROGRAM GOALS

The primary goal of an emergency power testing program is to comply with regulatory requirements without adversely affecting the operation of the hospital or the well being of the patients. Additional goals are to verify the infrastructure's ability to withstand those power transfers that will occur when utility power is lost, and to educate clinical caregivers accordingly so that patient care is not put at risk during utility power outages or internally caused normal power outages. It is important to be as comprehensive as possible, leaving little to chance with these increasingly complex systems.

A comprehensive, proactive emergency power testing program should:

(1) Train maintenance <u>and clinical</u> personnel how to deal with the loss of utility power and power system transfers;
(2) Test the functionality of all equipment related to generation and distribution of emergency power;
(3) Test the mechanical and building system responses to power system transfers;
(4) Test clinical equipment response to power system transfers; and
(5) Avoid conditions that compromise patient treatment and safety.

VALUE OF TESTING AND TRANSFERRING POWER

Monthly emergency power testing will cause emergency power supply system failures to occur.[13] Why? Failures will occur because the equipment is being operated, and that is generally when all electrical and mechanical equipment failures occur. The benefit of this situation is that the failures will be more likely to occur during the test itself, when plant-operating personnel are on duty and focused on the generators, transfer switches, electrical and mechanical systems and buildings being tested. The other important benefit is that normal power will be available during this test. Many hospitals that experienced emergency power equipment failures during tests also report that THE FAILURES WOULD HAVE OCCURRED ANYWAY, probably during the next unanticipated normal power outage. Experienced hospital engineers do not consider emergency power supply system equipment failures during tests as "problems." Their opinion is rather "We found something out and now we can improve or fix it - this is why we test."

Problems that might occur during an actual power outage come to light under controlled conditions while normal power is readily available. Examples of these kinds of problems, which could be devastating if discovered during actual utility power outages, include starting battery and battery cable problems,[14] engine fuel oil pump failures, faulty safety switches that shut down the generator set, engine fluid leaks, engine mechanical failures, transfer switch failures, tripping circuit breakers, and the like.

Other unanticipated problems or events occur which, due to the alertness of personnel involved in the testing process, can be documented and followed up with corrective action. Equipment is exercised and adjustments to control settings can be made to "fine tune" the overall combined mechanical/electrical system for optimum operation.

A carefully thought-out testing program tests emergency power transfers while minimizing disruption to hospital operations. Some hospitals have testing policies stating that selected transfer switches are not transferred if that action will adversely affect patient care. For example, (1) elevators may not be recalled if there is an incoming Med-Flight to a rooftop heliport, (2) critical branch transfer switches supplying Operating Rooms (ORs) with surgery in progress may not be transferred, and (3) transfer switches feeding major radiology equipment such as MRIs may not be transferred unless the equipment is turned off first. Some other hospitals may not transfer critical branch transfer switches at all because of clinical resistance, but this approach simply masks potential latent defects and violates the intent of JCAHO EC.2.10.4.1.[15] The most effective testing process is one that duplicates as closely as possible what happens in a real power failure without compromising patient safety.[16]

Electricians, mechanics, and other maintenance technicians may be stationed in strategic locations during the test to monitor critical equipment and to minimize response time to problems that may occur. Many hospitals use standardized test forms to collect test-related data. Unanticipated occurrences should be reported immediately, or right after the test, for analysis by the facilities supervisor in charge of the test. Additionally, mechanical system interactions can be recorded during the test on simple data recording forms to facilitate both data recording and system recovery.[11]

DESCRIPTION OF EMERGENCY POWER TESTING PROGRAM

The emergency power testing program should not be just the monthly equipment load testing. It should also involve:

- Annual measurement of emergency load profiles,
- Determination of total emergency power supply system loading under emergency conditions,
- Monthly testing of the emergency power supply system using actual installed loads,
- Monthly review and analysis of test results,
- Trend analysis of results and problems for Performance Improvement (PI) purposes,
- Investigation and resolution of training and/or systemic issues identified by the trend analysis,
- Special EPSS extended run load test at least once every 36 to 48 months. (This is a new requirement of the 2002 Edition of NFPA 110.)[17]

The emergency power testing program is not only the vehicle for maintaining the emergency power supply system in a reliable operating state, but can also be a vehicle for maintaining a high state of disaster readiness for the hospital staff insofar as normal power outages affect the Environment of Care. This includes the hospital's clinical staff, not just its facility staff. If equipment is affected by the 10-second outage that normally precedes the power transfer to the emergency generator in case of an actual power outage, then the hospitals' clinical staffs should know how to deal with those effects. Testing without simulating these effects may cause the clinical staff to be unaware of the real impact of a power outage on their clinical equipment and critical processes. When the monthly emergency power supply system testing program is used together with regular electrical system normal power outages (shutdowns)[18] then the hospital's entire staff is better trained for disaster management.

DETERMINING THE ACTUAL EMERGENCY LOAD DEMAND

It is necessary for the hospital to document its actual emergency power demand. It is no longer necessary to calculate 50% of the peak demand load for "30/50 testing" purposes as required by earlier NFPA 110 revisions. However, it is still important to know the peak EPSS demand load both for due diligence and also to satisfy JCAHO Utility Management requirements, as well as the requirements of other Authorities Having Jurisdiction (AHJ's) in many states. It is not enough to assume that the highest emergency generator kW demand during an early-morning monthly test represents the true peak emergency power supply system demand load. This would be a poor assumption due to the variability of mechanical, building, and clinical process loads during a typical hospital workday. The test time was likely chosen due to low clinical activity, and that avoided clinical load will not be reflected in the EPSS test loading. Additionally, some equipment, such as smoke control systems and fire pumps, will not operate except during atypical situations.

Determining the actual emergency demand load cannot usually be done through one measurement because the emergency power supply system's automatic transfer switches will usually be connected to the normal power system along with other normal power loads. However, portable recording instrumentation can be used to sample the branch loads on each transfer switch for two or three days, a much better approach than short term sampling with a hand-held ammeter. An even better solution is now available. Many hospitals are installing remote metering on their emergency generators and transfer switches, with central data recording and storage capability to retain the peak loads and time-of-use load profiles that the remote meters generate. These modern real time power management systems provide verifiable, repeatable, time-of-use load profiles and clearly the best load information available to modern hospital engineers. [19]

Time of Use Load Profiles

Although the actual type of equipment used in an operating room may vary from case to case and from day to day, a track record of recorded loads built up over time will provide the necessary documentation of maximum load. If the peak load in each 15-minute period is recorded using a sliding 15-minute demand window, along with higher peak loads for the same period from the next several days, the hospital engineer has a high degree of confidence that the total system load profile has been recorded. The differences between the 15-minute demand load and the instantaneous peak loads should be noted so that the hospital engineer can assess how much additional allowance, if any, should be made for short-duration load variations. The assessment should differentiate between the "instantaneous" peak loads that last only a few seconds, typically representing motor starting inrushes, and the longer but still short-duration peak loads that last for one or two minutes. These one or two minute peak loads should be noted for later determination of an overall allowance for short-duration load variations. The equipment discussed above can be programmed to provide these data.

If a power management system is not available, record the load side of each automatic transfer switch for two or three days during normal hospital operating periods. Add the separate transfer switch load profiles together, along with allowances for other unrecorded loads, to determine the total EPSS load. If a power management system is available, then simultaneous time-of-use load readings over a comparable period will provide a reliable load analysis. In BOTH cases, adjustments will have to be made for variations between the loads running when the measurements occurred and loads that would run during a normal power outage as stated below.

Figure 1 illustrates the daily load profiles of separate branches in a typical hospital building. It also illustrates allowances for certain types of loads. Figure 2 then illustrates the total emergency power supply system load profile that results when the individual load profiles and allowances are added to obtain a composite generator load profile for that same building. A simple spreadsheet allows this graphical addition with minimum effort.

The load profiles of one building or branch should not be used to predict the load profiles of other buildings or branches, since variables such as sample building size, specific occupancies, occupancy patterns, and energy conservation features all affect the load profiles. Note that certain types of loads are not likely to be running during normal operating conditions (i.e., the fire pump, the smoke control system, the fire alarm system in "alarm" condition.) These atypical but necessary items can be modeled as shown in Figures 1 and 2.

The mechanical equipment system ATS load profile that is illustrated in Figure 1 is also shown in Figure 3, but this time as 1-minute sampling interval raw data directly from the recording instrumentation. Note the differences in appearance between the motor inrushes (single vertical lines) and the short time variations.

This strategy gives good repeatable values because most hospital loads and processes are repeatable. The author's experience reviewing thousands of load profiles indicates that daily load profiles taken in the same building over time tend to show similar characteristics and values. Only load growth, and space or occupancy changes, will generally cause the load profile to change.

Certain emergency power branch loads do not normally vary during the day. The code limitations on what kinds of loads may be connected to the life safety branch usually make its demand stable, except for the impact of a fire alarm condition on the fire alarm system demand. The author's hospital was recording the load profile on a life safety transfer switch in a high rise building when such a fire alarm condition occurred, fortunately a nuisance alarm, and the load demand profile (see Figure 7) that resulted proved a clear indication of this impact. Similarly, critical branch loads in many patient care areas tend not to change very much throughout the day unless portable radiology equipment is brought into the area and plugged into the critical branch outlets. Operating room critical branch loads, of course, vary significantly depending upon the status of the operating room.

Equipment system loads, however, will often vary during the day. This is particularly true if energy management strategies are used to turn off loads like operating room ventilation fans when the operating rooms are not in use. Elevator and radiology loads are the most variable, even during regular working hours. In addition, elevator and radiology loads can provide the highest inrush impact on the generator. The impact of elevators on an emergency power test is illustrated in Figure 4, where the difference between generator loading with and without elevators can be seen after the elevator transfer switches were returned to normal power halfway through the emergency power test. Figure 5 illustrates the impact of radiology loads. It is obvious from these load profiles that (1) monitoring of elevator loads under normal power conditions does not allow one to predict the elevator loads under emergency power conditions with much accuracy. It can also be seen that several days of radiology load profiles are required before one can accurately model the radiology load impact on the emergency generator.

Does Test Loading Accurately Represent Real Emergency Loading During a Utility Power Failure?

Test loading depends on the time of day of the test. Correspondingly, real generator loading during a utility power failure depends upon the time of day of the power failure. Seasonal loading considerations (heating or cooling loads that are powered by the Equipment System portion of the EPSS, for example) may also apply. Since one purpose of the test is to simulate the maximum emergency demand as much as possible, the hospital engineer should determine the projected emergency demand during a typical day. Figure 4 illustrates a sample emergency power test generator load profile. The hospital engineer should compare such a test load profiles with the composite load profile discussed earlier to get a true understanding of the difference between EPSS test loading and projected maximum loading.

CHOOSING A TEST TIME - MORE PROS AND CONS

Thurston's detailed treatment[4] provided an excellent analysis of the pros and cons of various emergency power test times. He identified several constraints that need to be considered. One additional constraint on the test time is that staff members (hospital electricians) performing the test must be organized and at their posts with the necessary test procedures ready to start the test simultaneously. In larger buildings, or in situations where one generator provides emergency power to more than one building, this requires that many staff members be taken away from their normal operating and maintenance tasks.

With increasing pressure to control operating costs, it makes sense that the best time to collect all testing personnel would be when they arrive to start work. This is when most of the Operating Rooms are not yet occupied for the day. Another option is immediately after lunch. Testing at the end of the lunch period, however, may conflict with the hospital's patient focus. This early afternoon test may be problematic due to the hospital's concern about avoiding elevator recalls when there is a high visitor population riding the elevators. Some hospitals schedule EPSS testing for the third shift, or nighttime. This approach can minimize the impact of the testing on daytime hospital operations, but may become problematic when equipment failures occur during the test and the full daytime shift complement of operations and maintenance personnel are not yet on duty to deal with the failure.

EMERGENCY POWER SUPPLY SYSTEM TEST PROCEDURES

The benefits of written test procedures and test reports are that they:

- Provide control by the hospital's facility managers of the test process itself,
- Require the testing personnel to take responsibility for performing all required tasks,
- Reduce the chances of incorrect actions by testing personnel causing increased risk to the hospital's patients, visitors or staff,
- Provide written documentation of the actions taken during the test in the event that something does go wrong,
- Provide a mechanism for potential trends to be explored, and
- Provide the source documentation for later trend analyses.

Some hospitals may not assign the same testing personnel to the same duties from month to month. The opposite approach is beneficial with larger staffs since the testing itself provides important staff training in the EPSS operation. With hospitals whose EPSS's have evolved over time, many different generations and makes of equipment may be present. Different equipment generations and makes often require different operating procedures. This variation is more controllable with detailed test procedures that stipulate the correct approach for operating each distinct component.

The test procedures for the generator personnel will be specific to the needs of the generator documentation. Those procedures are beyond the scope of this paper, but have been covered very well in several referenced articles and in NFPA 110.

EFFECTS OF MONTHLY TESTING

The normally-off emergency power equipment (the Emergency Power Supply, or EPS) is loaded very sporadically. Most months will find 30 days (43,000 minutes) of standby conditions followed by 30 to 45 minutes at more than 50% rated load. This often causes electrical terminations to work loose due to the expansion and contraction of the sporadic loading. Hospital staff should consider this and use infrared scanners on the normally off portions of the EPS regularly during the tests, and should also use infrared scanners on the EPS during the special extended run load test.

As stated earlier, monthly testing will cause emergency power supply system failures to occur. Equipment failures that occur during regularly scheduled testing are much more benign in terms of their effect on hospital operations and patient care. Incipient failures that occur during a power outage are a much greater hazard to the Environment of Care.

Indoor Air Quality Effects

Some, usually older, generators may exhaust in locations where building heating, ventilating and air conditioning supply fans have their air intakes. The start of an emergency power test with a diesel engine usually involves a large puff of black smoke that disappears as the unit heats up. This puff of smoke, along with the engine exhaust fumes, may be drawn into the building and result in Indoor Air Quality (IAQ) complaints. Solving this problem involves either relocating the air intakes, relocating the exhausts, other ventilation system modifications, or temporarily turning off the supply fans. Mechanical engineers together with hospital operating engineers must carefully investigate this issue to decide the best short and long-term solutions.

The Clean Air Act requires that sites limit the hydrocarbons and other pollutants that their internal combustion engines emit. This is usually not a licensing problem with standby engine-generator sets, since they do not normally run. However, these regulations will often require additional record keeping by the hospital regardless of how often the generator sets run. These records must be current and available for inspection upon demand by appropriate authorities.

It is also necessary to coordinate the hospital's emergency power system testing program with construction / renovation projects, or infrastructure upgrade projects, that take out of service, replace, overhaul or upgrade generator sets. NFPA 110[20] states "consideration shall be given to temporarily providing a portable or alternate source whenever the emergency generator is out of service." When existing generator sets are taken out of service for any reason, and their loads still require an emergency power supply due to hospital occupancy requirements, the temporary generator sets that are used have to be tested monthly along with the transfer switches that they feed. The EC 3.2.1 construction / renovation project requirements for a Preconstruction Risk Assessment[21] indicate that the hospital needs to take into account the IAQ effects and other effects of running temporary generator sets for regular monthly testing.

Avoiding Elevator Entrapments Due to Testing

The interaction between hospital emergency power supply systems and automatic elevator recall controls is very complex. Most elevator control systems only operate one elevator at a time on emergency power. This requirement meets most high-rise building codes and is necessary to keep generator loading within reasonable limits. Some control systems allow the elevators to go automatically to the next floor and open their doors while waiting for their turn to be returned to the first floor to discharge passengers. If the very complex control system has a problem during this situation, the result will be an elevator entrapment. Even when there is no entrapment, an elevator with automatic voice floor annunciation may have an automatic announcement that states something like "this elevator is responding to an emergency in the building, please remain calm." Patients, visitors and staff may respond with concern, or even panic, to such a situation despite the assurances from the prerecorded message.

Not all elevator failures or entrapments are the result of the testing, particularly with early morning testing. Sometimes elevator door problems, such as dirty tracks or dirty motion sensor screens, may be masked by the emergency power test as test related failures.

ANALYZING MONTHLY TEST RESULTS

Monthly test results should be reviewed shortly after each test. One effective method is for the testing personnel to return the signed test procedure to the supervisor immediately after the test, along with a short verbal report of any important events or surprises that occurred during the test. These events or surprises can be noted in writing on the test procedure form for later reference and inclusion in the testing database.

It is important for the supervisor to probe verbal reports of failures to assure that events are correctly recorded. As an example, probing the report “we had to reset that pump set” may indicate that it was a simple alarm reset requirement. Without probing, the report may have been interpreted by facilities management as a loss of system function requiring even more corrective action. It is also important for the mechanical supervisor to be present to receive these reports along with the electrical supervisor. This allows mechanical equipment reactions and events to be probed as well.

All unexpected events should be analyzed to find out if they were caused by human error, problem system interactions, test procedure inadequacies, equipment malfunction, or other causes. Corrective action should be planned as appropriate. In determining the proper corrective action to be taken, each failure should be considered for its generic relevance, allowing for the circumstances of the failure, and its potential for occurrence elsewhere in the hospital or again under the same set of conditions. The hospital engineering staff and supervisor should review the results of previous tests before the next test of each generator.

Use of Management Databases to Discover Hidden Trends and Common-Mode Failures

It is necessary to analyze test results and trends, not just record test results. Several references[3, 8, 16, 22, 23] address recording and analyzing the test results for the engine operating parameters. In the following analysis, we address test results that describe kinds of interactions between the various emergency power supply system components and their emergency power loads, the second order consequences. The results of the trend analysis can help the hospital's engineers to identify training and/or systemic issues requiring further investigation or resolution.

All unexpected events, failures, and other unexplained occurrences should be entered into a testing event database. A useful list of keywords for analysis, based on several years of experience in analyzing monthly test results, is illustrated in Table 1. Additional keywords should be added to respond to the additional needs of the specific hospital.

The information typically recorded in the testing database should include the test date, building(s) tested, generator(s) tested, transfer switch number, applicable keywords, special action assignments or management attention needed, and comments. Each of these fields is useful for analysis or reporting, depending upon the need.

Different types of database reports can be used for different purposes. Exception reporting, through the use of an “Action Required” field as a reporting toggle, is an important tool for focusing the facilities staff’s attention on those items that need action. The exception report should be reviewed weekly if possible, but definitely after each test in order to identify events that have been corrected. Items should not be marked “Corrected” unless the requisite action was taken and the following test proves that the problem was indeed corrected. Exception reporting, although important from a corrective action perspective, is not useful for trend analysis because the event record gets deleted from the exception report after it is corrected. Other sorts are more useful for trend analysis, including sorts by transfer switch and test date, sorts by generator set and test date, and sorts by keyword and test date with further sub-sorting as appropriate.

Trend analysis is most easily accomplished by sorting the database for the occurrence of keywords by month and year. The number of occurrences of each keyword, or even keywords describing similar issues such as “Bkr” and “Restart” in each month, can then be charted over time. Seasonal patterns can be investigated as well. A declining number of failures provides required proof of Performance Improvement (PI).

Analyzing Equipment Failures

All equipment failures should be analyzed to discover if they were caused by human error, problem system interactions, test procedure inadequacies, equipment malfunction, or another cause. Corrective action should be planned for the failed equipment, of course. Each failure should be considered for its generic relevance as well. Similar circumstances could cause similar failures to occur again elsewhere in the hospital.

The hospital engineering staff and supervisor should review the results of previous tests before the next test of each generator. Possible types of failures, or other testing problems, are listed in Table 2.

Other Examples of Findings From Database Trend Analysis

Power transfers of mechanical system controls can cause unnecessary system tripping despite the fact that the mechanical equipment itself can ride through the transfer time with no apparent problems. Field experience in hospitals has indicated tripping problems during power transfers with such diverse equipment as water pressure booster systems and instrument air compressors. Often, putting UPS's on the control systems can solve these problems.

Some UPS's have input voltage tolerance settings that work fine when the utility source is feeding the UPS but are too sensitive for the condition where the generator is feeding the UPS. Examples of this finding include fire alarm systems that continue to operate, but on battery backup, during the emergency power test, and clinical equipment (such as blood analyzer) UPS's that also transfer to battery during the test. All UPS failures during emergency power tests should be investigated to see if the cause is related to voltage tolerance that is too sensitive for the condition with an engine generator is the power source.

Some clinical equipment, such as anesthesia monitors, may be too sensitive for good operation on older emergency generator systems needing new governors and voltage regulators.

Some older elevator transfer switches may not include the standard elevator control packages provided with modern transfer switches. Without additional time delays, breakers could trip due to the motor inrushes after power transfers. Simply retrofitting some transfer switches with in-phase monitors may solve this problem.

The unanticipated tripping of normal power circuit breakers upon re-transfer back to normal power could be the result of miswired or incorrectly set ground fault controls. Alternatively, the circuit breaker instantaneous trip element may be out of tolerance.

Variable Speed Drive (VSD) Operation During Tests

Sometimes, fan VSD's may trip on "hot-to-hot" transfer of power from normal to emergency (and emergency back to normal) due to back EMF being generated in cases where the transfer switch transfer times were short. Sometimes, increasing the transfer time delay setting can reduce incidence of VSD tripping. Some VSD's may see the momentary loss of power as a fault. If the VSD has an "auto re-start on fault" function, it should be enabled so that the VSD will not have to be manually re-set after each transfer. When supply fans feed a common plenum with crossover dampers, all fans (dual supplies and returns) may all have to be kept active to avoid back flow causing return fans to run backwards and increase their likelihood of tripping when power is re-applied.

Mechanical Plant Operation

Sometimes, mechanical equipment that is powered by normal power rather than normal/emergency (equipment system) power may shut down and have to go through a re-start process if its control circuits (Direct Digital Control [DDC], Building Automation System [BAS], or other controls) are powered from emergency power circuits. It is usually not possible to segregate those controls from emergency power since they may control emergency powered mechanical equipment as well. In such cases, the solution may be installation of uninterruptible power supplies (UPS's) to power the DDC and BAS panels located on each floor and primarily on the mechanical floors. A very short time frame of battery back-up power may be all that is required since the controls need to ride through the applicable transfer switch transfer times.

Even mechanical equipment that is powered from a normal/emergency Equipment System may be made more reliable during power transfers by putting its control transformer on a UPS. The motors and mechanical systems may be able to ride through power transfers if they are permitted to by their control systems.

An example of an equipment system ATS load profile during an emergency power test is illustrated in Figure 6. Note the impact of the initial power transfer from normal power to emergency power at 7:11 AM. Some other mechanical systems take far longer to get back to their steady state than the 5 minutes illustrated in this figure. The retransfer to normal power for this test did not occur until after 8:00 AM, so the effect of that retransfer is not shown.

Mechanical equipment system time delays should not be any longer than necessary to prevent fan motor trip-out so that fans serving critical spaces like OR's and Isolation Rooms do not completely stop before power is re-applied.

GENERATOR SET FUEL OIL STABILITY

Concerns about the negative impact of dirty or aged fuel oil on generator set operability have resulted in a tightening of fuel oil criteria in NFPA 110.[24] Previous recommendations have now become requirements. Fuel must be consumed within its storage life or stale fuel must be replaced, and NFPA 110 now includes the ASTM diesel fuel oil aging rating table for reference in Annex A. The inclusion of this informational table now guides owners towards fuel oil testing programs. Fuel system designs must provide for a supply of clean fuel to the engine, but even the best designs should be followed through by appropriate management controls to ensure that engines have an adequate supply of fresh, clean fuel throughout the operating life of the fuel oil system. Hospitals that were not previously monitoring fuel oil condition as a part of the Utility Management Program should consider improving their programs.

Degradation of emergency generator fuel oil systems is not a new concern. There is ample historical literature on the subject, primarily federal publications responding to stringent testing, analysis, and reporting requirements that apply to the civilian nuclear power industry as well as federal facilities.[25, 26] Concerns and/or diesel engine failures have resulted from water and impurities in fuel oil due to system condition, maintenance error, fuel stagnation, day tank corrosion, clogged or fouled fuel oil filter, excessive fuel oil filter replacement interval, workmanship during fuel oil system renovation, fuel oil truck operator error, day tank micro-organism contamination, inconsistent fuel oil quality from the supplier, incorrect biocide usage, and even inadequate sampling techniques.

Why have the fuel oil condition requirements become more stringent? Fuel contamination has been called the second leading cause of Emergency Power Supply failures.[14] Many hospitals are increasing their onsite fuel oil storage capability as a part of their emergency preparedness improvements, so the issue of fuel aging is becoming more critical. The clean fuel criteria apply not only to the large fuel oil storage tanks but also to the local day tanks. Water and other contaminants can occur in both locations, and natural fuel degradation from aging affects fuel oil throughout the storage and piping system.

Emergency generator manufacturers have historically published recommended changing intervals for oil and for oil filters. Some manufacturers, suppliers, and service companies have oil analysis trending programs available that are a useful predictive maintenance tool. Some manufacturers may allow regular oil analysis programs to determine oil-changing intervals, whereas others may not.[27] This issue is being debated within the industry and bears close watching. Meanwhile, many hospitals may undertake regular fuel oil testing programs and fuel oil tank cleaning[28] programs in order to ensure and document that their fuel oil is fresh and clean.

CONTAINING THE DIRECT AND INDIRECT COSTS OF EMERGENCY POWER TESTING

There are both direct and indirect costs to the Emergency Power Testing Programs. The direct costs are those of the test personnel, their supervisors, and those who track and control the test documentation, including the trend analysis. Indirect costs include the labor costs of those who must reset equipment after its power source is transferred twice every month, once at the beginning and once at the end of each test. Other indirect costs include the costs of clinical personnel or technicians who move equipment plugs from the emergency power outlets to normal power outlets before the tests, and then back again if that approach is taken by the hospital. Assuring that the only equipment connected to emergency power is that equipment which must be connected, either due to code requirements or hospital operational requirements can reduce these costs. It is also important to ensure that building designers are aware of the monthly testing and consider the impact of the power transfers on all equipment intended to be connected to the emergency power supply system. This may affect procurement specifications for mechanical and clinical equipment.

Some hospitals require that each item of equipment to be powered from the emergency power supply system be provided with a UPS to avoid equipment problems when the transfer switches transfer between power sources. A small UPS is not very efficient, and its energy losses will result in increased utility cost to the hospital. Although the increased energy cost from an individual UPS is not substantial, the total hidden cost of these devices throughout the hospital can become substantial.

Strategies for Reducing the Hidden Costs of Emergency Power Testing

Some sensitive computer-based clinical and research equipment resets when its power source is transferred from normal to emergency power and back, losing alarm limits and other programmed settings. This causes problematic equipment malfunctions whenever the emergency power supply system is tested, or until the equipment has been reset whenever normal power system failures occur.

As a result of this effect, many hospitals' clinical and research personnel keep their most sensitive instrumentation plugged into the normal power outlets unless there is a normal power outage. This requires that personnel be present at the beginning of an outage, which is not always possible. It also does not give the maintenance and engineering personnel a clear picture of the real generator loading, since much equipment would not be plugged into the critical branch or equipment branch when they are monitored to prepare for the monthly testing. Alternatively, some hospitals use UPS's (with their operating losses and resulting impact on hospital energy costs), or simply have additional personnel present to reset equipment (with their hidden impact on operating costs in a time of downsizing.)

This type of equipment could be specified and purchased with self-contained battery backup. The battery backup will allow the equipment to sustain the power transfers without requiring manual restarts and reconfiguration. Regular PM on this equipment will then have to include battery condition of course. Another strategy would be for this equipment to be manufactured electrically more rugged, so that it can survive these power transfers.

SPECIAL EMERGENCY POWER SUPPLY SYSTEM EXTENDED RUN LOAD TEST

The 2002 Edition of NFPA 110 also included a new requirement[17] for at least one complete test every three to four years of the entire EPSS for the duration of its assigned Class or as otherwise agreed to by the Authority Having Jurisdiction provided that the test is 4 hours or longer. The Class of an EPSS is defined in NFPA 110[29] as the amount of time that the EPSS is required to operate at its rated load without being refueled.

The load to be tested this way is the entire EPSS load running at the time of the test, but only that load. In other words, it is not necessary to turn on such EPSS loads as smoke exhaust fans, fire pumps, stairwell pressurization fans, and the like if they were not running for other reasons at the test time. Circuit breakers and switches that provide normal power to the EPSS transfer switches must be opened for this test so that all EPSS-powered loads are indeed powered by the Emergency Power Supply for the entire test duration. This is similar to the initial EPSS acceptance test required by NFPA 110 insofar as the requirement for powering all operating EPSS loads is concerned. The difference between this test and the initial acceptance test, however, is that the initial acceptance test involves a complete building normal power shutdown followed by a full rated load test. This new extended run load test does not involve such a shutdown, with NFPA 110 stating that a power interruption to non-EPSS loads is not required. It also does not require supplemental load banks to increase the running load to the full rated EPSS load.

As explained in the NFPA 110 Annex, this test was added to NFPA 110 in order to provide reasonable assurance that the EPSS, including all of its auxiliary subsystems, is capable of running for its assigned Class (see above) with its running load. The Annex further explains that a total facility normal power shutdown (outage) is not required for this test, but is recommended if one has not occurred within four years. This new test appears to be as reasonable as such new requirements could be, given the lessons learned from all of our Y2K preparations and the events of September 11, 2001. Some of these lessons learned[8, 9] might suggest that four hours may be insufficient, that the test should be at full rated EPSS load, that all normal power should be turned off during the test, and so forth. Instead, NFPA 110 has given us a full system extended run load test that minimizes the impact on normal facility operations, particularly for those who may not have already gone through complete normal power shutdowns in preparation for Y2K.

What might this test not show? It might not indicate an item of generator auxiliary equipment, such as a fuel oil transfer pump or a remote radiator fan, which somehow became improperly connected to normal power and was not caught by an NFPA 110 initial acceptance test. It might not indicate a restricted generator set cooling airflow path that only becomes problematic near full rated load or on high ambient design days. It might not indicate a fuel oil storage tank level indicator that reads incorrectly. It will not indicate if other critical equipment is not powered by the EPSS but should be.

But these other items should show up if we exercise due diligence in our overall management of this critical utility system of the Environment of Care and are regularly conducting normal power shutdowns as recommended. Many facility managers who went through extended generator run periods and normal power shutdowns in preparation for Y2K would agree that conditions came to light during those extended tests and normal power shutdowns that made all that effort worthwhile.[9, 18] The extended run test discussed here could bring out some potential problems with EPSS auxiliary subsystems while normal power is still available.

Disclaimer: Although the author is a member of the NFPA Technical Committee on Emergency Power Supplies, which is responsible for NFPA 110, the views and opinions expressed in this Management Monograph are purely those of the author and shall not be considered the official position of NFPA or any of its Technical Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation. Readers are encouraged to refer to the entire text of all referenced documents.

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FIGURE 1 - SAMPLE HOSPITAL EMERGENCY POWER SYSTEM ATS LOAD PROFILES USING 15 MINUTE DEMANDS

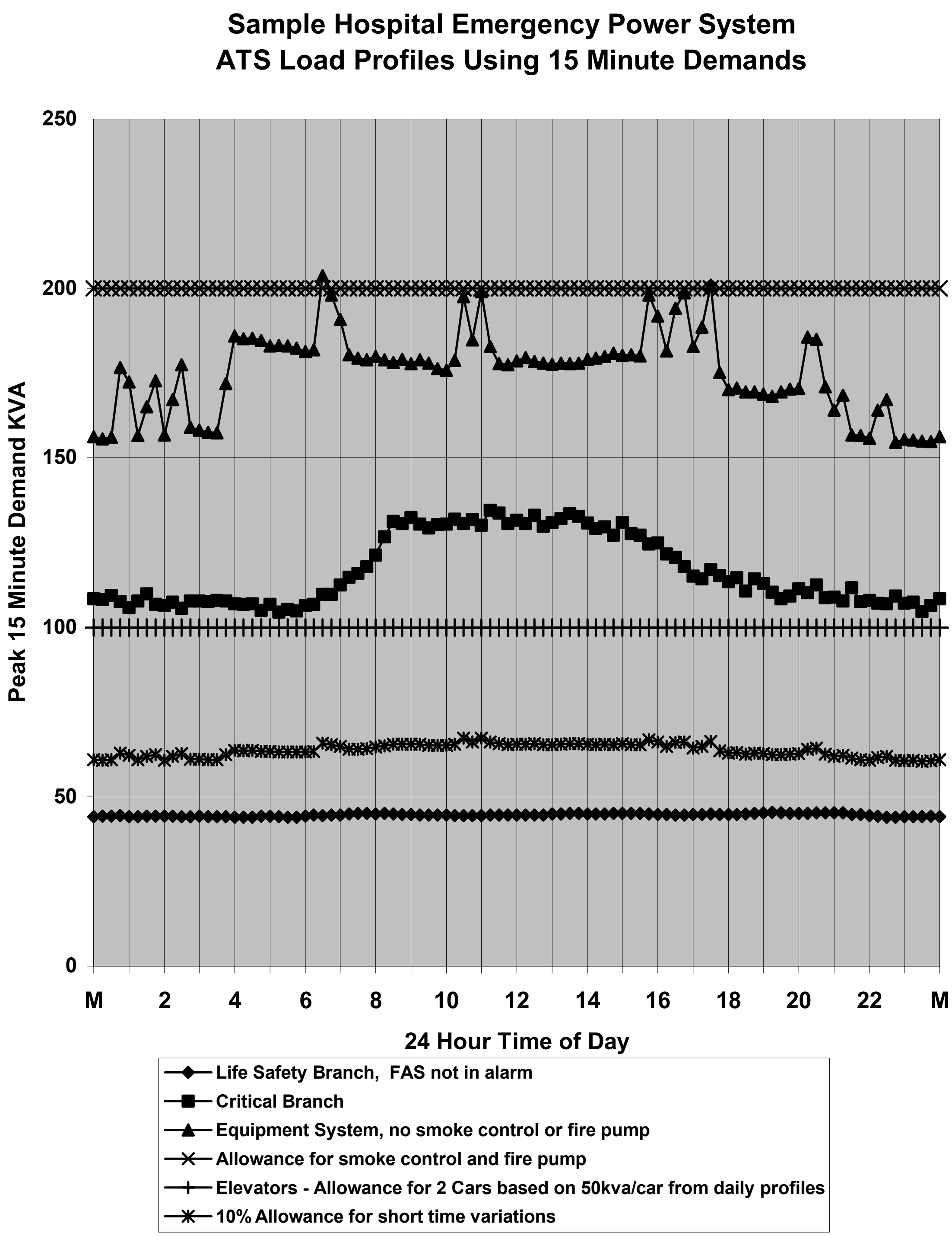


FIGURE 2 - SAMPLE HOSPITAL EMERGENCY POWER SYSTEM EPSS LOAD PROFILE USING 15 MINUTE DEMANDS

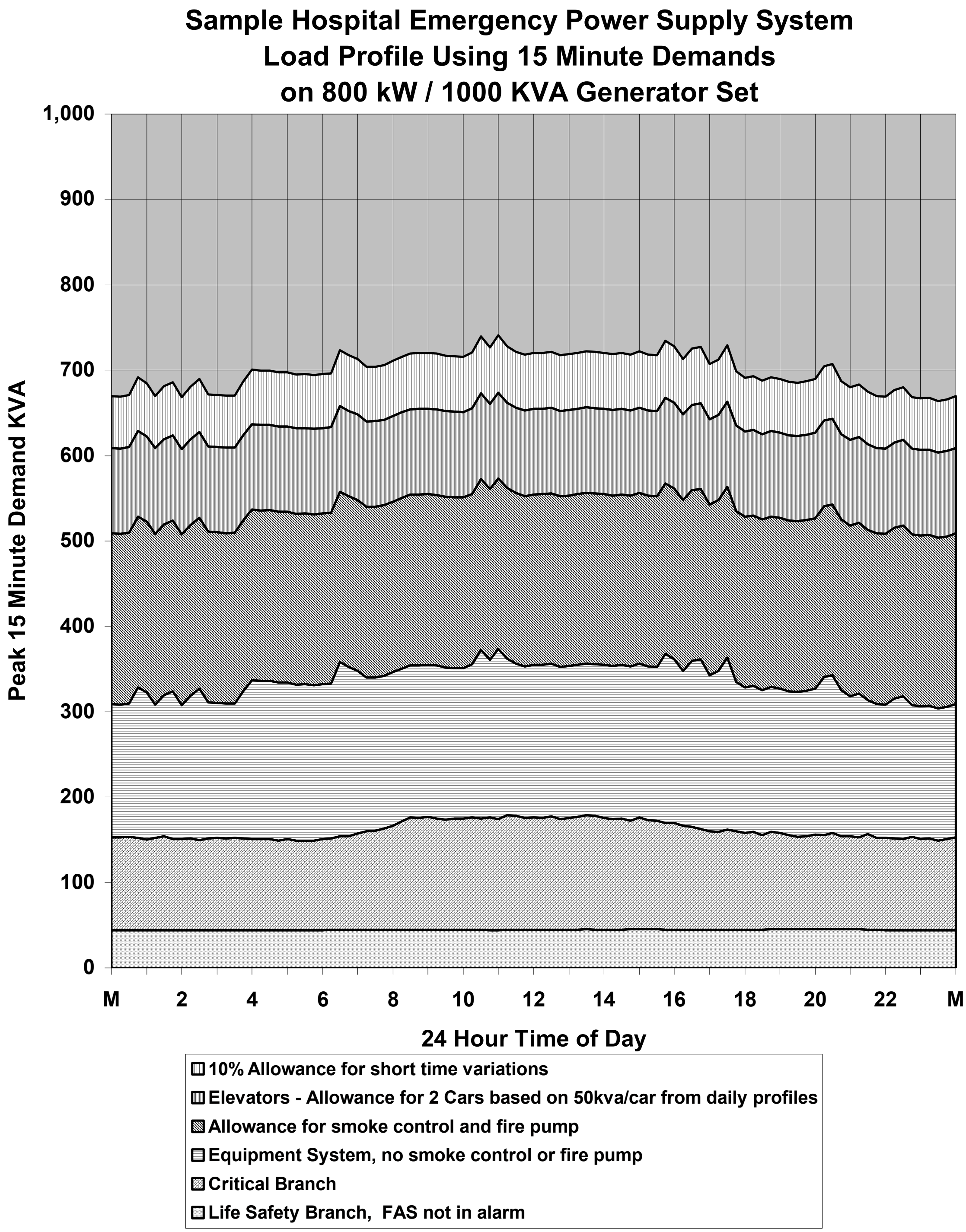


FIGURE 3 – SAMPLE TWO DAY LOAD PROFILE FOR MECHANICAL EQUIPMENT SYSTEM ATS USING ONE MINUTE DEMANDS

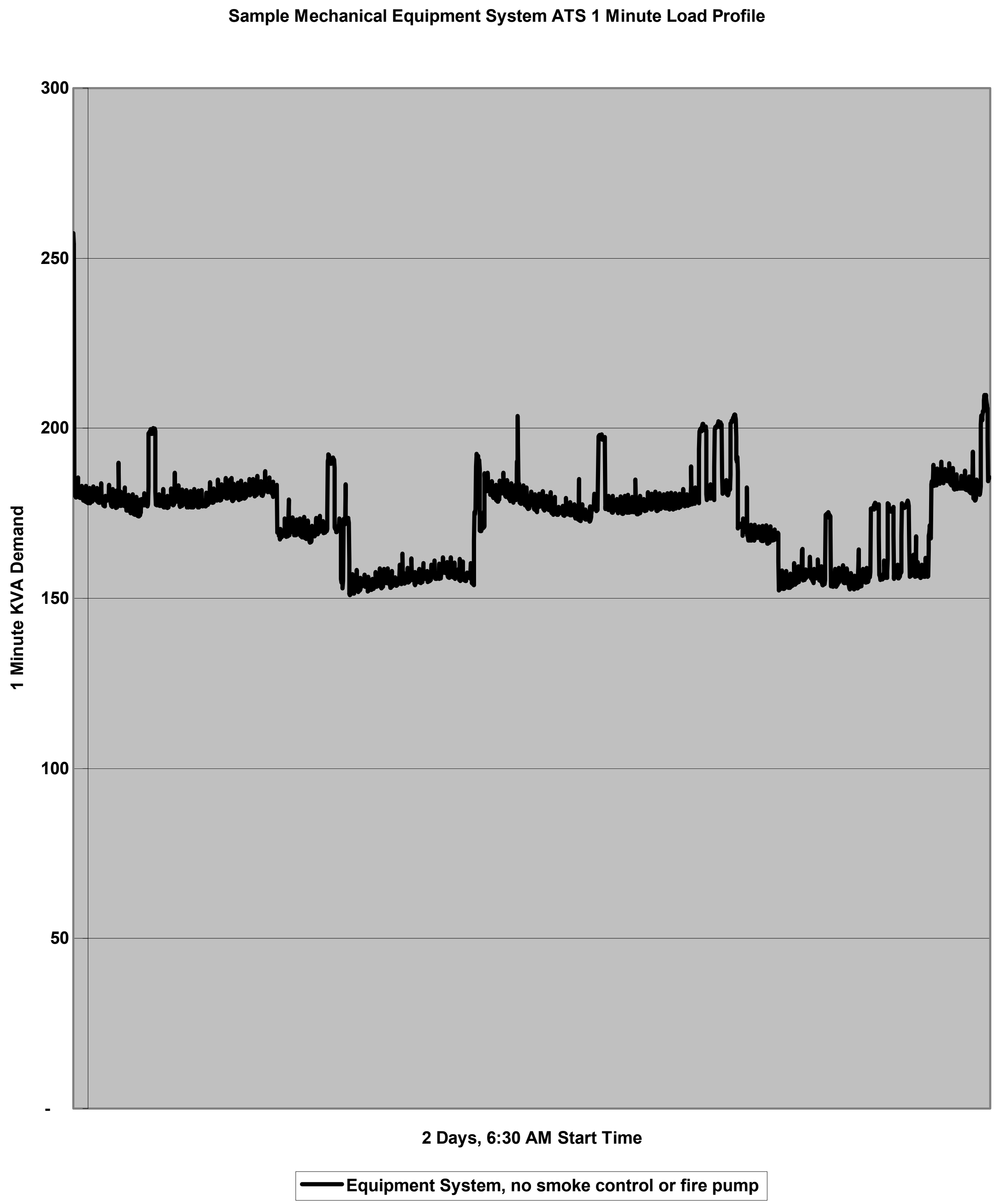


FIGURE 4 – PLOT OF ELEVATOR LOADING DURING AN EMERGENCY POWER TEST

The following load profile is that of a generator set load during an actual hospital emergency power test. This particular test lasted 48 minutes. Note that the elevator load (the variable load) was removed after approximately 23 minutes.

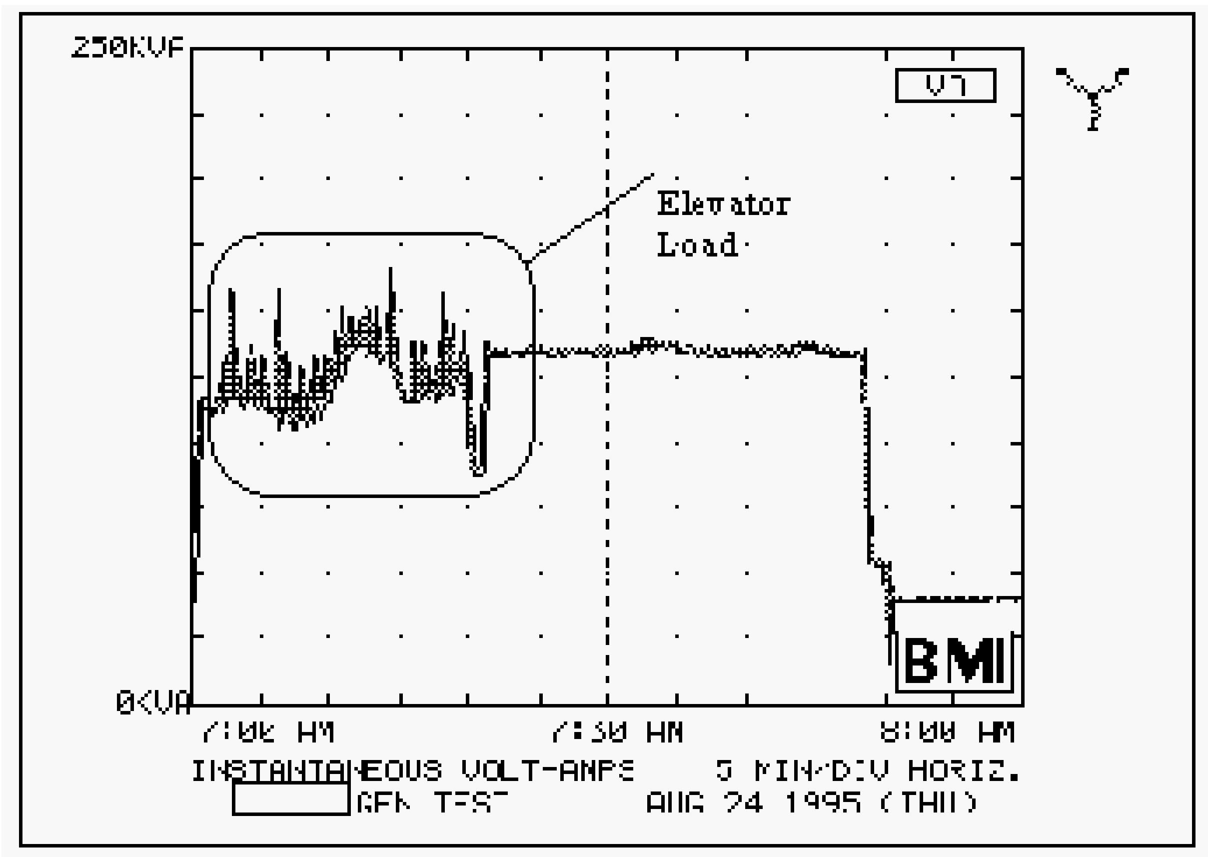
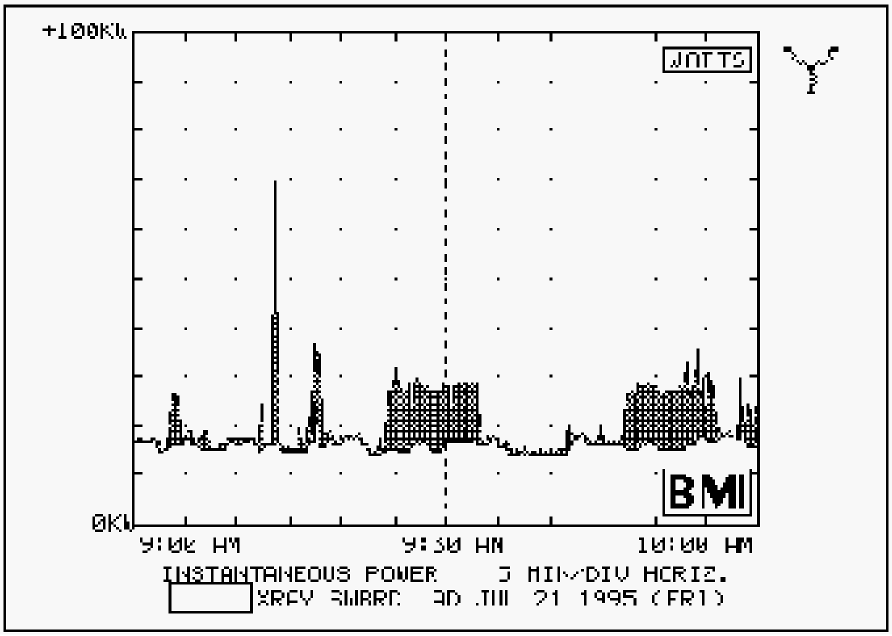


FIGURE 5 – RADIOLOGY LOAD PROFILES

The following graph illustrates the varying RADIOLOGY load in one hospital building.
Note that some pulses last fractions of a second or minute, while other pulses last up to 10 minutes.



The following graph represents the varying RADIOLOGY load in a hospital building. Note that the 15 minute peak was followed by more than 20 minutes of effectively "standby" loading.

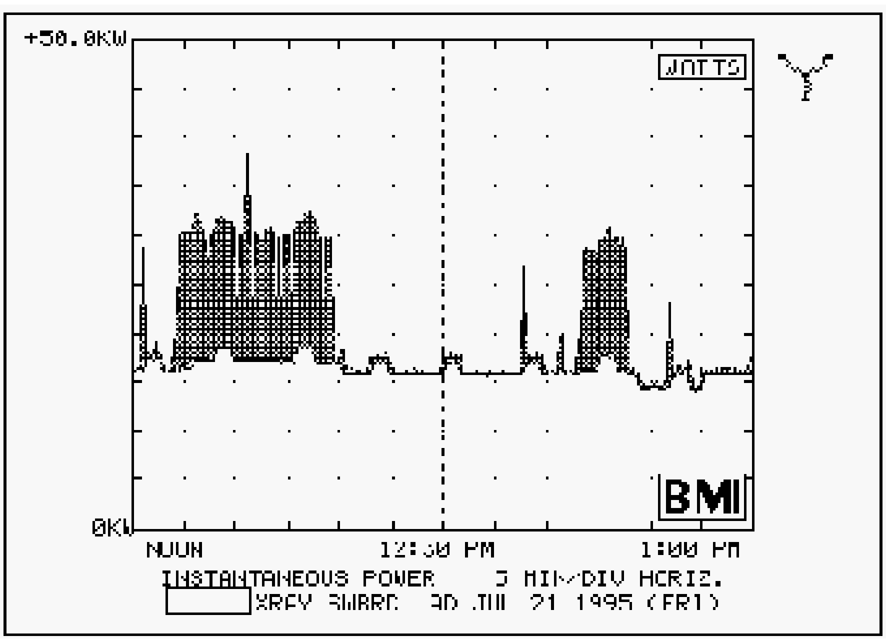


FIGURE 6 - PLOT OF AUTOMATIC TRANSFER SWITCH CURRENT DURING EMERGENCY POWER TEST

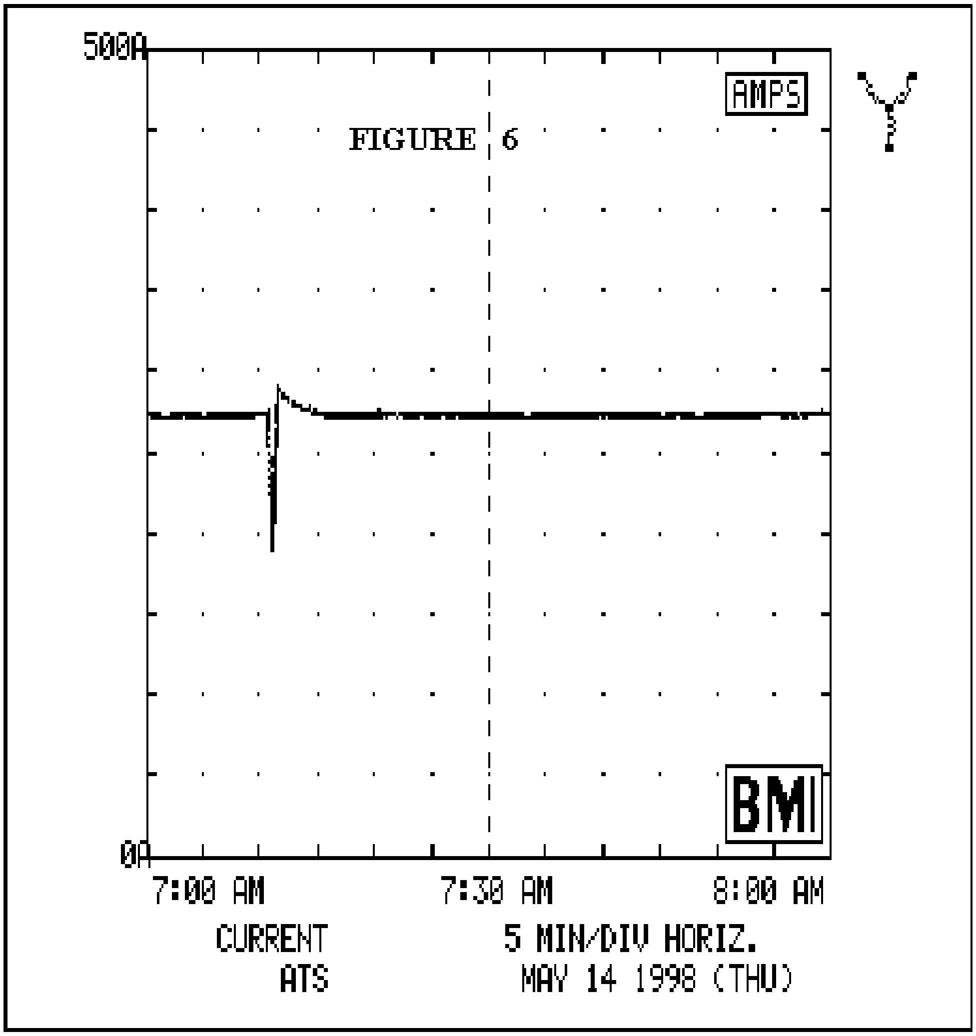


FIGURE 7 – IMPACT OF FIRE ALARM CONDITION ON LIFE SAFETY ATS LOAD PROFILE

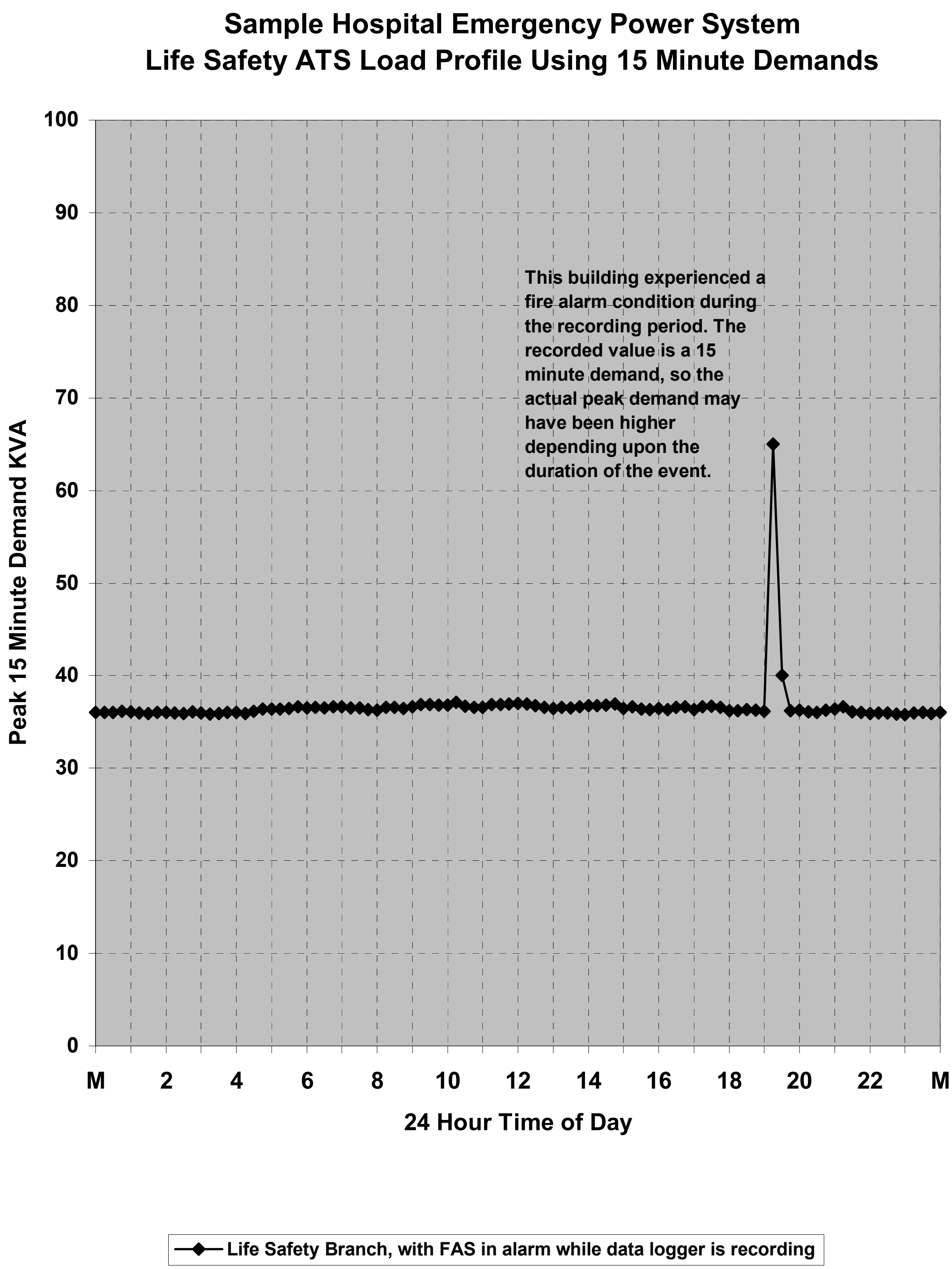


TABLE 1 - SAMPLE KEYWORDS FOR EMERGENCY POWER TESTING DATABASES

KEYWORD	DESCRIPTION OR USE
30%	Generator test load violates 30% requirement.
ATS	Automatic transfer switch failure or control malfunction, engine start wiring failure from specific ATS.
Elev	Elevator control system failure during power transfer, elevator entrapment.
Lamp	Lamp burned out, discovered during test.
Oper	Operator error, unauthorized action taken that resulted in equipment or test failure.
Meter	Meter failure, bad or questionable reading.
Bkr	Circuit breaker trip.
Init	This ATS initiated this specific test (proves engine start circuit function).
Genset	Generator set problem, includes engine, alternator, governor, voltage regulator, starting battery, fuel oil system problem, ambient conditions.
Pretest	Problem found during routine pre-test surveillance, such as an emergency power breaker found open or emergency power control switch not in the automatic mode.
Trng	Testing personnel did not follow test procedure, record required information, etc.
Hold	Test procedure hold point was not satisfied, resulting in deviation from full test intent but within predetermined hospital administrative parameters.
Abort	Test personnel or foreman decided not to transfer a specific ATS or run a specific generator due to unpredicted conditions at test time.
Sign	Complaint received from patient, visitor, or staff due to lack of appropriate signage explaining the test and its impact.
Reset	Equipment (not circuit breaker) failed due to lack of power and went into alarm condition, requiring annunciator acknowledge and reset.
Restart	Equipment turned off due to test and required a manual restart to return to its normal operating condition, no alarm generated.
IAQ	Indoor air quality complaint caused by test.
Excluded	Specific ATS excluded from test by official policy due to extenuating circumstances.
UPS	UPS failure during test, may not be due to test itself but personnel became aware due to test conditions.
Comm	Complaint received by testing personnel, due to lack of communication within the hospital community.
Proc	Problem or unexpected occurrence in test can be rectified for next test by changing the test procedure.
Door	Door found in wrong security mode (access vs. secure), may be due to test.
Modify	Problem found during test requires equipment modification.

TABLE 2 - SOME TYPES OF ISSUES THAT CAN BE FOUND DURING EMERGENCY POWER TESTING

1. Starting: Test switch does not start generator. Battery has insufficient cranking or starting power. Battery cables fail or are loose. Generator fails to start.
2. Elevator control systems: Elevator recall function does not work. Some cars do not work when selected while on emergency power. Car station indicator lights do not work. Cars do not run automatically on emergency power, but will run okay when selected manually. Older motor generators all run when on emergency power, even though only one car in bank is running at a time. Elevator entrapment occurs due to test (many cars in use on starting test, then only one at a time during test.) A member of the public panics due to a misleading elevator voice announcement at start of test. Many complaints occur when elevators recall then go into emergency operation at high traffic periods.
3. Lamp problems: Normal power available lamp is burned out, emergency position lamp is burned out. Normal power & emergency power lamp jewels are wrong colors (switched).
4. Breaker trips: Circuit breaker trips due to (1) motor starting inrush, (2) transformer energizing current*, (3) ground fault relay sensing imbalance during transfer. **Note that the standard NEC transformer primary overcurrent protection requirements (150% with no secondary O/C protection, 250% with secondary O/C protection) may be too low for dry type transformers on emergency power supply systems. Inrushes on power transfers can far exceed these values under certain conditions.*
5. ATS issues: Return to normal power circuit fails when emergency breaker tripped. ATS does not operate properly after modification. Return to normal power takes too long (Adding a "bypass time delay button" for faster returns after testing can solve this problem.) Time delay relay fails, causing failure to transfer to emergency power.
6. Pretest Issues: Emergency power breaker found open before test starts.
7. Operator and training errors: Incorrect control switch is operated. Bypass switch is operated instead of ATS test switch.
8. Communications issues: Clinical equipment resets itself during a procedure, requiring reboot and reconfiguration. Personnel claim that they "did not know" the test was to occur. Clinical personnel who are transferred from off-hours shift with no testing into a shift with testing, not familiar with equipment reactions to testing. Equipment from one area (with one type of reaction) is moved into a new area where personnel do not know how it reacts to testing. Different brands (makes) of clinical equipment react differently to power transfers, confusing caregivers.
9. UPS issues: UPS switches to battery power when on generator power, then works fine on AC when on normal power (can indicate that UPS voltage or frequency tolerances are set too tightly.) UPS fails due to bad battery.
10. Reset/Restart issues: Fire doors or smoke doors close during each power transfer, and must be re-opened to fire alarm magnets after each transfer. Some automatic doors must be manually reset after power transfers. Adjustable speed drive trips off due to transfer of power.

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