Managing the Impact and Costs of Emergency Power Testing on Hospital Operations
A Case Study

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Introduction

Hospitals are required to have an emergency power testing program 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. The goal of the emergency power testing program should be to comply with regulatory requirements without adversely affecting the operation of the hospital or the well-being of the patients. The specific requirements to be met are referenced by the forerunner[1] to this paper. That technical document addresses the importance of simulating actual loading conditions during the testing period and the necessity of following up on the test results to identify problems and take corrective action. This paper builds upon that publication by detailing a case study of emergency power testing occurring over a significant period of time at The Massachusetts General Hospital (MGH), issues uncovered (which might be described as second order consequences[2] of the emergency power testing effort) and the steps taken to eliminate problematic issues.

Emergency power testing programs involve transferring the power sources of operating systems from utility power to the emergency generators and back. This action can cause disruption to increasingly more complex clinical and building equipment, building automation systems, and hospital operations. When managed properly and proactively followed through, these disruptions are valuable learning experiences and provide opportunities to improve the hospital infrastructure, improve hospital operations and reduce the hidden costs of testing. This case study presents a number of lessons learned and offers proactive strategies for managing the process. The lessons learned also illustrate areas where future system designs should be improved.

Value of Testing and Transferring Power

The monthly testing will cause emergency power system failures to occur.[3] The benefit of this situation is that the failures will be much more likely to occur during the test itself, when plant operating personnel are on duty and focussed on the generators, transfer switches, systems and buildings being tested. The other important benefit is that normal power will be available during this test. Many hospitals that report emergency power equipment failures during tests also report that the failures would have occurred anyway. Equipment failures are not thought of as "problems," rather the response is "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 outages, include faulty safety switches that shut down the generator set, engine fluid leaks, engine failures, transfer switch failures, and the like.

Unanticipated problems or events occur which, due to the vigilance of personnel involved in the testing process, can be documented and followed up for corrective action. Equipment is exercised and adjustments to settings take place to “fine tune” the overall combined mechanical/electrical system for optimum operation.

In keeping with its mission and regulatory requirements, MGH has had a very strong emergency power testing program in place for some time. The major goals of the program remain (1) to train maintenance and clinical personnel how to deal with the loss of utility power and power system transfers; (2) to test the functionality of all equipment related to generation and distribution of emergency power; to test the mechanical system response to power system transfers; and to avoid conditions that compromise patient treatment and safety.

Towards this end, a carefully thought out system has been implemented to test emergency power transfers while minimizing disruption to hospital operations. To achieve this, some transfer switches are not transferred if that action will adversely affect patient care. For example, (1) elevators are not recalled if there is an incoming Med-Flight to the rooftop heliport, (2) critical branch transfer switches feeding operations in progress are not transferred. Also, electricians and other maintenance technicians are stationed in strategic locations during the test to monitor critical equipment and to minimize response time to problems should they occur. Further, data are collected on standardized test forms and all unanticipated occurrences are reported immediately following the test for consolidation and analysis by the Facilities Engineer. Additionally, mechanical system interactions are recorded during the test on test check-off sheets as illustrated in Figure 1. Experience in recording system interactions indicated that simple data recording forms of this nature were necessary to facilitate both data recording and system recovery.

Analysis of Test Results

The test results must be reviewed shortly after each test. One effective method is for the testing personnel to return the signed test procedure (see Reference 1 for a sample) to the supervisor immediately after the test, along with a short verbal report of any unusual or unexpected events that occurred during the test. These events should also be noted on the completed procedure for later 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 whereas without probing it may be interpreted by facilities management as a loss of system function requiring even more corrective action. It is also very important for the HVAC supervisor to be present to receive these reports along with the electrical supervisor. This allows HVAC 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 another cause. Corrective action should then 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 results of previous tests should be reviewed by the hospital engineering staff and supervisor before the next test of each generator. Possible types of failures or other testing events are illustrated in Reference 1, in the following text, and in Figure 2.

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] [4] [5] address recording and analyzing the test results for the engine operating parameters. In the following analysis, we will address test results that describe kinds of interactions between the various electrical distribution system components and their emergency power loads. 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. Reference 1 discussed the use of emergency power testing databases and keywords to analyze monthly tests for failure analysis and trend analysis. The keyword list initially presented has been updated as illustrated in Figure 3 based on the past two years of experience in analyzing monthly test results. Additional keywords should be added to respond to the additional needs of the specific hospital.

The information typically recorded in the testing database includes 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 is an important tool for focussing 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. The 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 improvement.

A Case Study

Building Overview

Massachusetts General Hospital (MGH) is a Harvard University teaching hospital located in Boston. It is a tertiary and quaternary care hospital in the Boston area. It is of international repute with strong emphasis on all 3 aspects of medicine; patient care, research and teaching. The hospital is a private hospital incorporated by the Massachusetts legislature in 1811 and since that time has been engaged in providing world class patient care. As in the case of many older hospitals, Massachusetts General Hospital (MGH) has been engaged in a very active program of new construction and renovation. One of the fruits of this program has been the construction of new high-rise inpatient towers on the campus which contains 460 of its licensed 800 beds.

The building contains all the features of a patient care space, namely patient bedrooms, operating rooms, support services, diagnostic spaces like radiology, transplant rooms, and isolation rooms. Both positive and negative pressure isolation rooms exist in the building. Since the building was constructed and designed before the 1997 AIA guidelines, it has switching capability to transform isolation rooms from positive to negative pressure and vice versa.

HVAC Systems

The building HVAC systems are installed in the classical manner of the low zone / high zone fashion. That is to say the building has mechanical spaces in the subbasement, 5th floor, 15th floor and 24th floor. There are no major air handlers in the basement. The outside air intakes for air handlers serving patients are at the 5th and 15th floor level. All the air is exhausted at the roof level to prevent re-entry and contamination.

Centrifugal Chillers - Four (4) 800 Ton centrifugal Chillers provide the cooling for the building. These Chillers are independently powered at 4,160 volts. All the auxiliary services, however, are fed by the building electrical distribution system. A chilled water distribution system in the building exists to take chilled water to all user points.

The building HVAC system is an all air system. Figure 4 is the screen capture from the building automation system illustrating a typical air system schematic. Several blow-through/ draw-through air handlers with centrifugal fans, preheat coils, cooling coils and humidifiers provide the make up and ventilation air throughout the building. This air is also in many cases the conditioning air as well. HEPA filters are installed as the last filtration in all the air handlers and an attempt is made to provide as clean air as possible in all sections of the building. The air system is also a VAV (variable air volume) system. Each zone is provided with a variable volume box with terminal reheat. The boxes will modulate down to minimum position to meet the ventilation rate and then the reheat valve will open and modulate the air temperature to maintain the space conditions. The reheat is from a hot water system. On the condition of the temperature increase in the zone, the reheat shuts off and more air is provided from the box to maintain temperature conditions. Fans are also provided with variable speed drives to allow air volume modulation and maintain a steady static pressure in the system.

The design had separated the building automation system (BAS) function from the critical alarm function. This philosophy was to have three stand-alone systems in the building: Building Automation System, Critical Alarm System, and Fire Alarm System. This decision was made to insure that all of our "eggs aren't in one basket". This distinction has served the hospital well over the years and was continued in the design and construction of the high-rise tower.

Emergency Electrical Power System

Emergency power for the building is furnished by three (3) 800KW diesel generators which feed a common bus in a lineup of synchronizing switchgear with associated priority 1,2 and 3 loads. A total of twenty-one (21) automatic transfer switches feed the various life safety, critical, equipment and elevator loads.

Emergency Power Testing Experience

Air Flow In Critical Spaces

Operating Rooms - When the operating room fans are transferred, the power transfer time can cause them to wind down. When power is restored, the concern was raised about the possibility of residual dirt and grease in the ductwork end up in the operating rooms. The concern was valid because if the filtration in the air handling unit were of the traditional bag type, these bags could deflate when loss of air flow took place and then re-inflate when the fan comes back on. This deflation/inflation action could produce shake out of some small dirty particles from the filtration media.

As the final filter media in the air handling unit serving the OR's was of HEPA type, this problem was not expected to occur. However, it was desired that field verification be conducted to verify that the testing did not result in reduced air quality. A consultant was engaged to take the particle readings before and after the tests. It was noticed that the operating room particle count did not significantly change with the stop/start action of the fans. It was determined, therefore, that with HEPA filters installed (that is bag filters not being present) testing does not adversely impact OR air quality.

Isolation Rooms - Also of concern was the potential loss of flow or air pressure in Isolation Rooms, of which there are a large number. To avoid tripping of drives during transfer, a time delay of thirty (30) seconds was deemed necessary. To assure that negative (or positive) pressure in Isolation Rooms was not lost during these power transfers, the pressure in a typical Isolation Room was monitored during a test. This testing proved that negative pressure was maintained.

Variable Speed Drive (VSD) Operation During Tests

With fans in operation, “hot-to-hot” transfer of power from normal to emergency (and emergency back to normal) caused tripping of some variable speed drives (VSD’s) on overcurrent due to back EMF being generated in cases where the transfer switch transfer times were short. It was discovered that most of the equipment branch ATS’s had a 3 or 5 second time delay setting. They have subsequently been re-set to 30 seconds with a marked reduction in the tripping of drives.

In addition to transfer switch time delays being increased, adjustments to some drive units were also required. The "moving motor capture" toggle switch was found to be in the off position in some drives. This feature allows a drive to "lock on" to a motor which is still coasting after loss of power without having to wait until it stops to avoid back EMF problems.

In another case, it was found that momentary loss of power was recognized as a fault but the "auto re-start on fault" function was in the disabled position. This function was enabled to result in the fan not having to be manually re-set after each transfer.

Where two (2) supply fans feed a common plenum with cross-over dampers, it was found that all fans (dual supplies and returns) must be kept active to avoid back flow causing return fans to run backwards and increase their likelihood of tripping when power was re-applied.

Unintended Alarms

The Critical Alarm System reported multiple no air-flow alarms in various isolation rooms. It was noticed however that there was never a no-flow condition. The variable speed drive at the loss of power reduced the speed and gradually picked them up to full speed as design apparently allowed. It was found a fan speed in both supply and exhaust fan operation, the fan speed never did go down to zero. It was reduced due to loss of voltage across the fan winding. However, the rotational inertia kept the fan operating and there was a low flow condition but never a no-flow.

In reviewing the alarms associated with emergency power testing, it was discovered that the nomenclature is sometimes misleading. As described above, where a "No-flow" condition is alarmed, there may in fact still be air flow. It depends upon what parameters are being monitored. Investigation revealed that current transformers are installed to sense current being drawn by the motor, and the measured parameter at the BAS is a 4 to 20 ma signal that is an output from the variable speed drive. As was discovered in monitoring the operation of supply air fans serving the OR's , during the 20-second outage of power in going between normal and emergency, the CFM from the unit dropped from 20,000+ CFM to 5,700 to 7,000 CFM (not zero) as illustrated in Figure 5. Before alarm time delays were introduced, unnecessary "no flow" alarms regularly occurred.

The solution to this nuisance condition was the addition of software time delays programmed into the main system with delays which slightly exceeded the auto transfer switch delays of approximately 30 seconds. The alarms now occur only when a true or extended alarm condition occurs and those (i.e. loss of flow) associated with power transfer from normal to emergency are not recorded.

Chiller Plant Operation

Early in the emergency power testing process it was observed that, even though the chiller plant was fed from normal power rather than normal/emergency (equipment system) power, it invariably would shut down and have to go through a programmed 20-minute re-start process.

The cause of this shutdown was the brief interruption of power to the chiller plant control circuits that are powered from emergency power circuits. The brief interruption of power during the hot-to-hot transfer as illustrated in Figure 6 was enough to signal the DDC controllers to require system re-start.

The shutting down of the chiller plant, besides the nuisance factor, can cause overheating of what could be critical spaces during peak warm weather periods. One such instance was the tripping out of a radiology room main computer due to overheating prior to a back-up chiller being able to compensate. There may be other types of adverse impacts associated with interruption of building automation system power.

The solution that was implemented was the installation of uninterruptible power supplies (UPS's) to power the Building Automation System (BAS) and Critical Alarm System panels located on each floor and primarily on the mechanical floors. A very short time frame (less than 10 seconds) of battery back-up power was required for these UPS's which were sized to power several panels.

A special situation was discovered in another building where a chiller was powered from a normal/emergency "equipment" branch. In that case, control power for the chiller is obtained from a 480 volt: 120 volt control transformer located in the unit controller. Here a separate 2 KVA UPS was installed to maintain control power and prevent system tripping and 20-minute down time to an area with critical air conditioning needs.

Other Unnecessary System Restarts

In high-rise buildings, fire control systems are very important. The emergency testing process allowed an opportunity to insure that system was in fact operational and trouble free. During one of the tests, it was noticed that a stair pressurization fan and its corresponding make up air unit operated during the emergency power test despite the fact that there was no smoke condition. Upon further investigation, it was found that the fan control was set in "default to ON" this setting was changed to "default to OFF".

The way certain hardware is installed can also make an enormous difference in reliability of system operation. For example, most of the building's air handlers were designed with high static pressure cut out switches. These switches happened to be automatic reset type. So, in order not to automatically restart, a relay was incorporated in the control circuit to insure that the fan tripping off will remain off. During emergency power testing, the brief power interruptions due to transfer switch operation activated this relay, causing the fans to shut off. This condition occurred even though high static pressure was not experienced. The problem which occurred during testing was solved by installing manually reset high static pressure cut out switches.

Unanticipated Supply Fan Operation (Double-Dipping)

During the course of observing the operation of O.R. supply air fans during emergency power testing, it was noticed that the fan CFM dipped significantly not once, but twice when normal power was interrupted while transferring to emergency power. This response is illustrated in Figures 5 and 7.

Due to concerns that the reduction in air flow to approximately 5,700± CFM during the 20 second transfer time delay, followed by a fairly rapid ramping back up to a nominal 20,000± CFM, would cause a reduction in O.R. air quality, the quality of air in the affected O.R.'s was recorded during a three (3) hour window encompassing the testing. It was determined that the dips in CFM did not significantly alter the air quality. The reason for multiple dips was an unexpected phenomena however, and an investigation of factors affecting the fan's operation was undertaken.

It was first felt that operation of another element (i.e. floor smoke dampers controlled by additional switches) might be causing increased static to cause the fans to back down. This was proved to be not the case. Hospital HVAC technicians did report having observed on a regular basis the speed indicator on the drives going to 100% immediately after power was restored prior to it backing down then gradually ramping up to its steady state setting. This observed operation was subsequently confirmed with the drive manufacturer.

It was then theorized, but has not yet been verified, that this anomaly in drive operation cause the static pressure control to see momentary high static (due to fan running at 100%) which caused it to back down only to find that the fan speed had re-set to a lower level to start its ramping up process. The comparatively slow response of the controller may be causing the second dip. A solution to this phenomenon, short of changing the normal operation of the drive, could be to introduce a lower limit on the CFM through the control software so the response to a short-time (100% motor speed high static) signal will be much less dramatic. At the time of submission of this paper, there is as yet no definitive conclusion to the double-dipping phenomenon. This is not a problem under steady-state conditions, and very interestingly, this same response has also been found at other institutions as well.

Other Types of Findings From Database Trend Analysis

The 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. Examples of this finding include the following events. Water pressure booster systems in two buildings would trip upon system transfer. Instrument air compressors in several buildings would trip during transfers. These problems were solved with no further difficulties by putting UPS's on the control systems.

Some UPS's can 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. After several events that resulted in this finding, all UPS failures during emergency power tests are now investigated for this condition.

Some clinical equipment is just too sensitive for good operation on older emergency generator systems. Investigation into events with anesthesia monitors and other clinical equipment resulted in this finding. As a result, some older generator sets were upgraded with new governors and voltage regulators.

Some fan static pressure safety controls in other buildings include automatic reset. To prevent automatic reset, a control relay must be included. Under this condition, the control relay can drop out upon transfer of the power source, shutting down the fan. The safeties were changed to manual reset, thereby eliminating the need for the relays and eliminating this problem during testing.

Some older elevator transfer switches do 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 can 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. Investigation into several events of this nature resulted in improvement in the ground fault protection systems. Other investigations found that the instantaneous trip element was out of tolerance.

Reports regarding electrically operated doors resulted in the finding that the clinical staff needs to know the location of the door control reset buttons, along with the correct procedure to reset the doors.

Load Profile Changes With Electrical Industry Restructuring

Unanticipated system interactions can cause equipment to trip off, resulting in unwanted modifications to the hospital's electrical load profile. Depending upon the nature of the hospital's contract for deregulated electrical power, the hospital may pay a cost penalty for these events. The database analysis helps to find and prevent these kinds of failures, thus potentially saving the cost penalties.

Items Recommended as Good Practice

OR's should be powered from automatic transfer switches separate from those serving other areas so one can abort the OR transfer switch for a specific test if necessary because there are operations going on that could be adversely affected by the test.

Chiller controls, if on normal/emergency power, should be on a UPS so the brief outage during power transfer does not cause chiller plant shutdown and re-start.

Air handling unit final filters should be rigid filter type, not the traditional bag type to minimize the introduction of dirt/dust into the air stream as the pressure in the duct(s) changes during fan speed variations due to the 20 to 30 second power loss during transfer switch operation.

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. A maximum delay time of approximately 30 seconds is recommended based on the case study experience.

Containing / Managing Direct and Indirect Costs of Emergency Power Testing

Thurston (Reference 3) provided an excellent analysis of the pros and cons of various emergency power test times. Another constraint on the test time is the fact that the staff members performing the test must all be at their posts 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 other tasks. The cost of this disruption can be reduced if the test occurs when the test personnel arrive to start work, or immediately after lunch.

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. These costs can be reduced by 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. It is also important to ensure that building designers be aware of the monthly testing and consider the impact of the power transfers on all equipment intended to be connected to the emergency power system.

Some hospitals require that each item of equipment to be powered from the emergency power 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 clinical and research equipment manufacturers are doing a disservice to modern hospitals by continuing to sell super-sensitive computer-based clinical and research equipment to unsuspecting buyers. Such equipment resets when its power source "blips," or transfers from normal to emergency power and back, losing alarm limits and other programmed settings. This causes problematic equipment malfunctions whenever the emergency power system is tested, or until the equipment has been reset whenever normal power system failures occur.

The downside of this situation is that 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.)

One strategy would be for the medical community to lobby for clinical and research equipment with self-contained battery backup. The battery backup will allow the equipment to sustain the "blips" or power transfers without requiring manual restarts and reconfiguration. Another strategy would be for such equipment to be manufactured electrically more rugged, so that it can survive these "blips."

List of Figures

Endnotes:

[1] Stymiest, David L., PE SASHE. Managing Hospital Emergency Power Testing Programs, *Healthcare Facilities Management Series* (No. 055142). Chicago: ASHE, April 1977.

[2] Bauer, R. A., Second-Order Consequences: A Methodological Essay on the Impact of Technology, Cambridge, MA: M.I.T. Press, 1969. Simply put, the consideration of second-order consequences recognizes that "any action, no matter how beneficial its purpose, has wide-ranging consequences beyond its primary intent."

[3] Thurston, Benjamin E. **How to Test Out Your Emergency Generators,** *Health Facilities Management*. **Chicago: AHA, October 1992.**

[4] **Emergency Power: Testing And Maintenance,** *PTSM Series*, **The Joint Commission on Accreditation of Healthcare Organizations, 1994 Series, No. 1.**

[5] Nash, Jr., Hugh O. PE. Hospital Generator Sizing, Testing, and Exercising, *Healthcare Facilities Maintenance Series*, (No. 055851). Chicago: ASHE, February 1994.

FIGURE 1

Emergency Power Test Check-Off Sheet for Normal/Emergency Powered Mechanical Equipment

Name: ________________________ Date: ____________________

Level	Equip. Desig.	Fed From EMCC Desig.	ATS	Priority	Serves	TEST	RESULTS O.K.	Trip O/C	Trip O/V	No Flow Alarm	Other	Comments
5th Fl	HV-3	5A	ATS3EB	1	Stair B	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-2	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	RF-2	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-3	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	RF-3	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-3A	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-3B	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	RF-3B	5B	ATS4EB	2	Fl. 6-9	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-5	5B	ATS4EB	2	Fl. 1-3	Begin (N to E) →						
						End (E to N) →						
5th Fl	RF-5	5B	ATS4EB	2	Fl. 1-3	Begin (N to E) →						
						End (E to N) →						
5th Fl	AHU-4	5B	ATS4EB	2	Fl. 1-3	Begin (N to E) →						
						End (E to N) →						
5th Fl	EF-4	5B	ATS4EB	2	Fl. 1-3	Begin (N to E) →						
						End (E to N) →						

FIGURE 2
Emergency Power Testing HVAC Event Summary

Test Summary for Test Date 5/14/98

ATS's not transferred for this test were ATS3EB, ATS0EB, 10014CB, and ATS4EB (required a hold). All others were reported to have been transferred. A summary of the test sheet recorded results is as follows:

Normal to Emergency & Emergency to Normal

ATS	Fan	Level	Bldg 1	Bldg 2	Action			Comments
					Trip O/C	Trip O/V	No Flow Alarm	
ATS4EB	RF-3	5	✓		✓		✓	*N to E and E to N
ATS4EB	EF-14	5	✓				✓	E to N only. Trip on Fault indication.
ATS4EB	EF-58	5	✓				✓	
ATS9EB	RF-18	5		✓		✓		** E to N only: trip on o/v
ATS9EB	AHU-19	5		✓			✓	
ATS9EB	RF-19	5		✓	**			** Tripped out on fault due to controller drop-out. See Note
ATS5EB	RF-8	15	✓		✓		✓	
ATS5EB	RF-9	15	✓		✓		✓	
ATS5EB	EF-76	15		✓			✓	

Note: Brought unit back on line by pushing DCP reset button which toggles re-start signal. By scrolling functions, determined that "power up re-start" is enabled but "fault re-start" is disabled.

* No indication of failure ("no flow" alarm did not register).

** Did not trip out going from E to N initially, but then tripped out 5 or 6 minutes later at a second dip. This applies to RF-18 and RF-19.

FIGURE 3
Recommended Keywords For Emergency Power Testing Database

KEYWORD	DESCRIPTION OR USE
30/50	Generator test load violates 30/50 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, 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.

FIGURE 4
Building Automation System Screen Capture
Illustrating Typical Air System Schematic

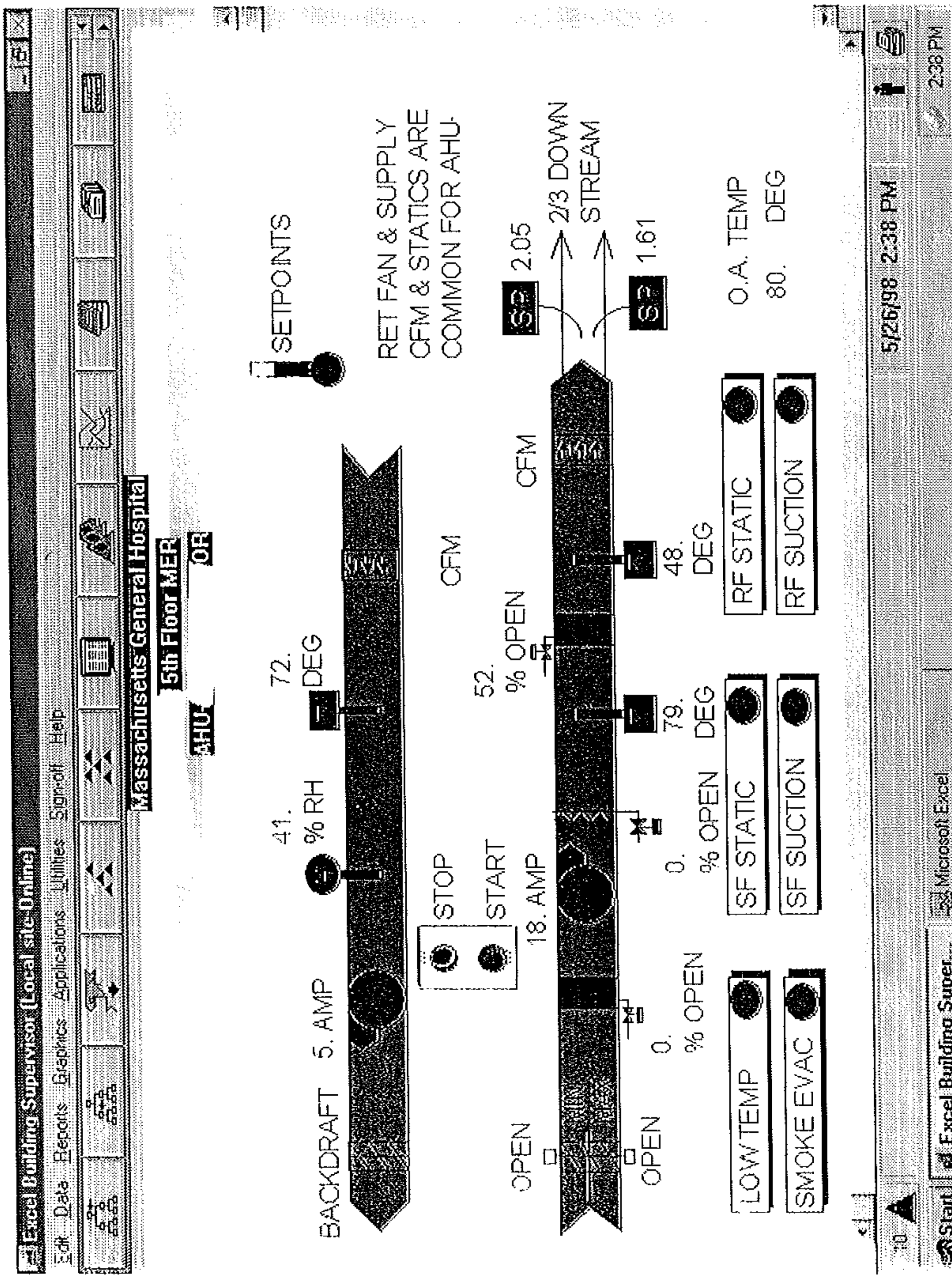

FIGURE 5
Plot of Air Handling Unit CFM During Emergency Power Test

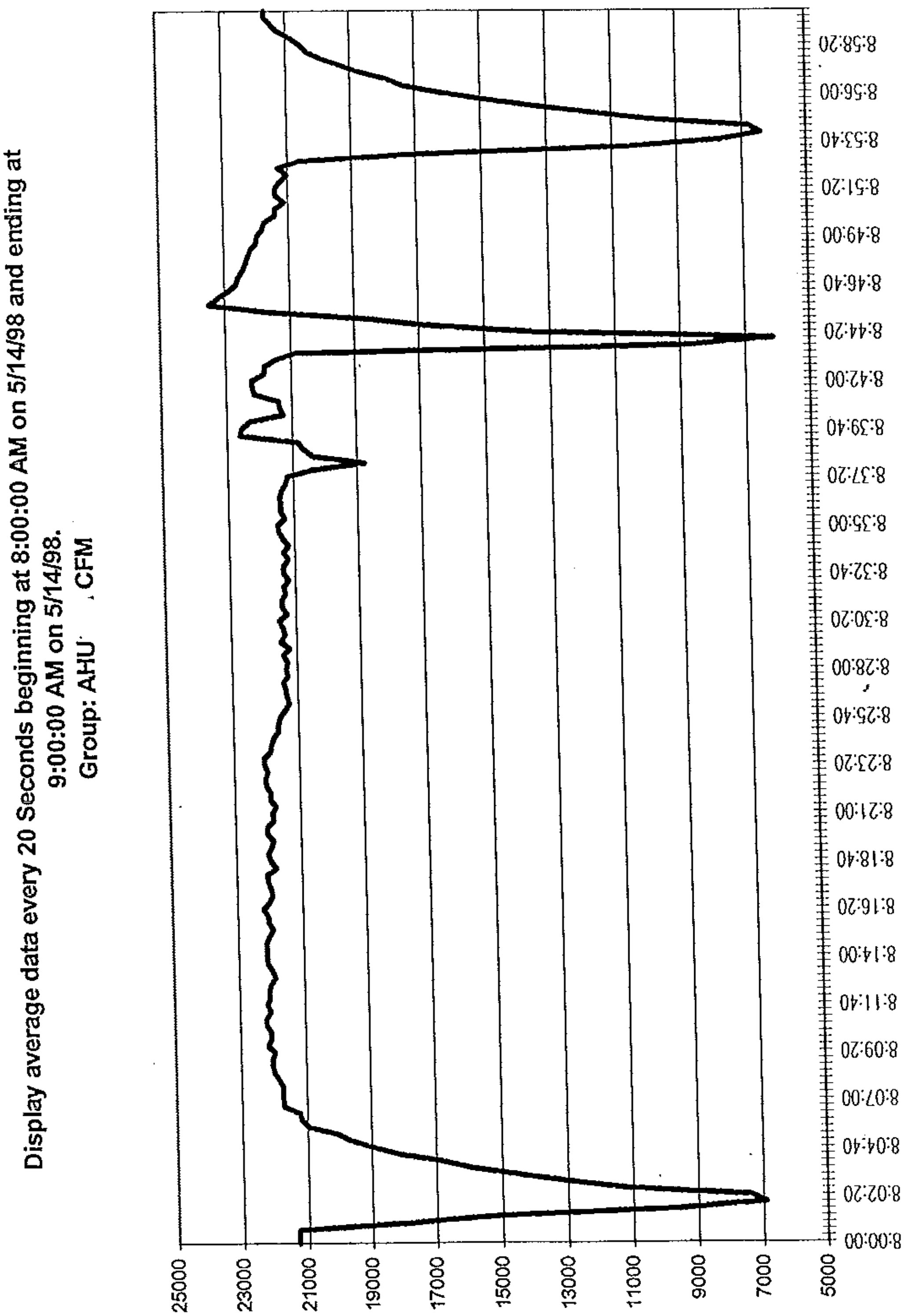

FIGURE 6
Plot of Automatic Transfer Switch Current During Emergency Power Test Illustrating "Blip"

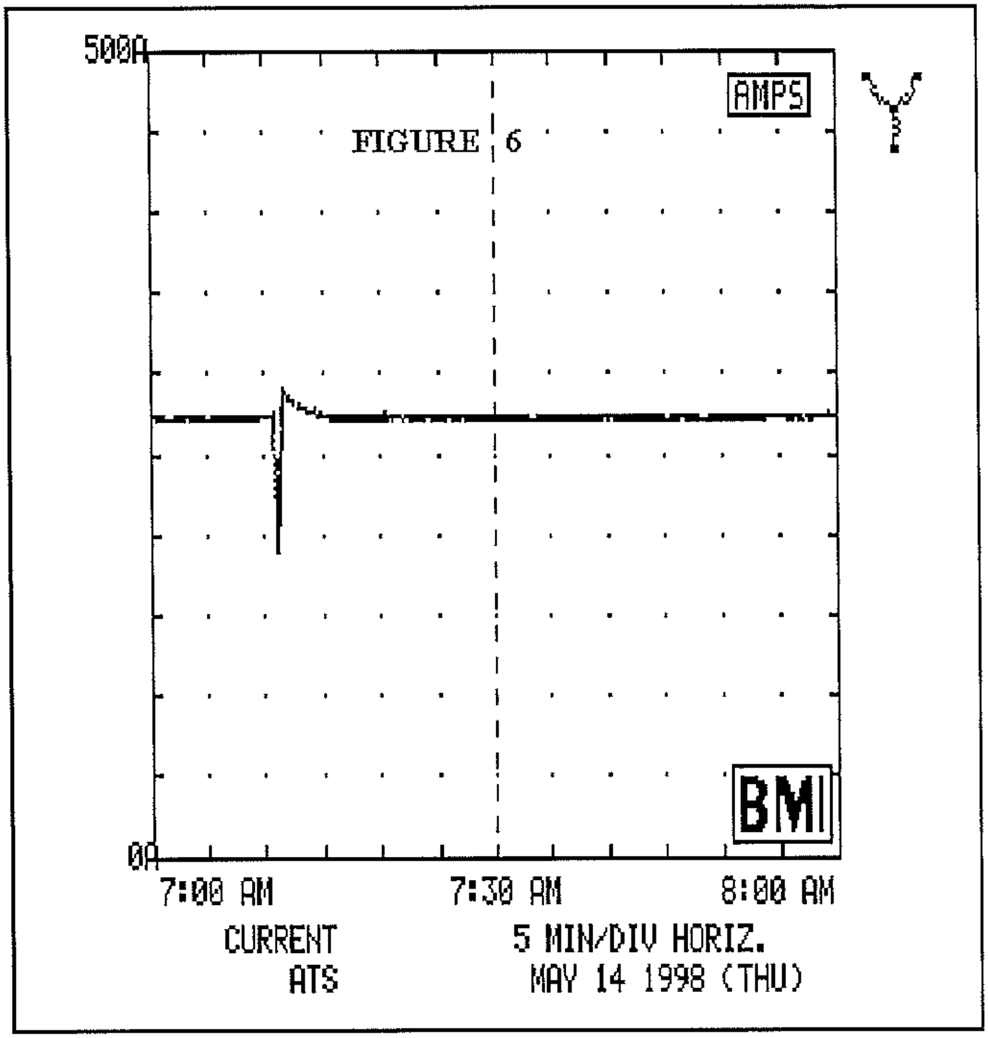

FIGURE 7
Plot of Air Handling Unit Motor Current During Emergency Power Test