SURVEYS OF FACILITIES FOR THE POTENTIAL EFFECTS FROM THE FALLOUT OF AIRBORNE GRAPHITE FIBERS

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The surveys of facilities which covered a representative cross section of the American workplace provided a necessary technical bridge-of-data between the analytical models and the actual working operations. The United States generates a volume of economic data through agencies such as the Bureau of the Census and organizations such as the Chamber of Commerce. Economic modeling must utilize such data in evaluating the potential effects of fiber induced failures. The working operations within the United States generally recognize the potential for a failure within items of electrical equipment and usually take some precaution even if it only amounts to keeping some spare light bulbs. Since airborne graphite fibers have the potential to cause electrical failures, the surveys had to provide the three interrelated elements of data as outlined in Figure 1. The response to a failure in an item of electrical equipment implies an economic impact. The failure site must be located, the failure cleared, and the item repaired. During that period of time operators may be idled, product can be damaged, delayed or both. Such considerations become the basis for assigning a cost to a potential fiber induced failure. The survey effort made an early recognition that failures in some items of equipment could impact lives and these areas received the necessary priority. The third element of data addressed the nature of the operation performed. Airborne fibers represent an increment in the total environment at the workplace and many operations must contend with harsh or unusual environmental conditions. The need for an environmental control as dictated by the workplace could bar the entry of fibers, or conceivably even make the operation more sensitive to fibers.

Surveys of facilities had to cover a representative cross section of the workplaces in the United States; the survey teams made a total of 62 visits to the locations summarized in Figure 2. The approach to the conduct of the surveys first recognized those areas considered most sensitive to influence by airborne graphite fibers and then utilized the result from the first series to focus the direction and detail for the next. The first series of surveys concentrated on hospitals, air traffic controls, telephone exchanges, public communications and the manufacture of electronic equipment. The surveys then broadened to cover the range-of-use for equipment considered sensitive to failures from airborne graphite fibers.

The surveys of manufacturing operations utilized the data from the Bureau of the Census "Standard Industrial Classifications" (SIC) as employed in the "Census of Manufacturers." In these compilations, the census divides manufacturing into 20 general classifications each assigned a two digit code. The code extends to four digits to reach specific product areas. As an example, acrylic fiber manufacture falls under the product designation of "Organic Fibers, Noncellulosic" SIC 2824. All "Plastic Materials Synthetics" are combined as SIC 282 and are part of the total "Chemicals and Allied Products" SIC 28. The census data summarizes total yearly values-of-shipments for each two digit SIC code and then provides a total for the nation. The 20 manufacturing operations surveyed provide a representative sampling of that portion of American industry whose functioning depends upon the use of electrical and electronic equipment. The sample surveyed includes typical industrial operations which account for 85 percent of the total national value-of-shipments as compiled in the last Census of Manufacturers (1972).

The conduct of these surveys acknowledges a cooperation and support from both governmental and private organizations. Municipalities and counties provided access to hospitals, airports, air traffic control towers and their police or fire communication centers. Cooperating federal agencies supported the surveys of air traffic control centers, Amtrak, the Post Office and a Federal Reserve Bank. The private sector supported the full range of survey work from hospitals and airlines through a representative range of manufacturing. The results from all of these surveys shaped the appropriate portions of the economic model for defining the impact cost associated with the risk analysis.

Patterns for protective measures began to show early in the survey process. Figure 3 lists the types or elements of protection which appeared. Much of the office space and a significant portion of the industrial installations require air conditioning. Many of the newer buildings are not usable without air conditioning because their construction does not permit adequate ventilation by natural means. In other cases the nature of the operation performed requires the cleanliness associated with a controlled and filtered ventilation system. Potentially sensitive items such as computers, data processors, signal generators and electronic test racks often impose requirements on temperature controls or shielding which result in specialized isolated installations. For much of the manufacturing industries, the operating environment at the workplaces becomes hostile to electrical and electronic equipment. Such operating environments involve sprays from cutting fluids, corrosive fumes, even explosive atmospheres. The operation of electronic equipment under such conditions requires either tight cabinets or coated circuit boards. In some operations even the best electrical devices can wear, drift, or change in some way that requires attention. Such operations recognize these limitations and either keep a stock of spare parts or employ multiple installations.

The survey program identified ten areas where an electrical failure could impose a major impact. Each of these areas had recognized environmental constraints which would influence their interactions with airborne fibers. Figure 4 summarizes these areas in terms of the concern, the operating environment, the protective measures currently in place and the effect such measures would have on the ingestion of airborne graphite fibers.

The compromise of life-supporting electrical equipment in hospital operating rooms or intensive care units became one of the first major concerns. A patient in an operating room or an ICU must have protection from airborne micro-organisms and a range of ingestible contaminants. In recognition, the

Hill-Burton act which provides federal funding to hospitals also imposes the requirement for high efficiency dust removal filtration in such ventilating systems. High efficiency dust removal filters and filters classified as High Efficiency Particle Arrest (HEPA) effectively bar the entrance of airborne fibers; both types are now in hospital service. For patients in the regular hospital areas, the electronic equipment provides monitoring or support for a specific function. Here, the quantity of bedding in a hospital imposes a lint laden environment. Cases or cabinets which protect against lint also protect against the entry of graphite fibers.

Ground control of aircraft represents a second area where an electrical failure could have a serious impact. The combination of transmitters, displays, and signal conditioning equipment impose thermal loads which result in dedicated air conditioning systems for towers and area air traffic control centers. Remotely mounted beacons and transmitters must be protected from the weather, and these items have particular needs for radio frequency (RF) shielding or isolation. The net result of the combination either prevents fibers from entering the area or prevents fibers from entering a cabinet.

A third area involving a potential hazard to life could be the failure of a communication system in responding to emergency situations such as fires, accidents or even natural disasters. The communication links between a dispatcher and remote vehicles require the use of redundant installations. Communities must be capable of responding to more than one call at a time; thus more than one dispatching radio communicates with more than one remote vehicle. Cities face the problem of signals reflected from buildings and these effects lead to the provision of even more redundancy in the system for communicating with vehicles. (One city employs an electronic logic system which samples a number of radio paths and then selects the one with the best signal quality). Within a police car or fire truck, "harsh" describes the normal environment for an electronic unit in terms of heat, vibration, moisture and corrosive road dirt. The packaging of electronics necessary for successful operation in road vehicles also makes them invulnerable to graphite fibers.

The recent fire in a New York City Central Telephone Exchange raised the concern for a failure incident which could block the operation of a telephone switching center. Surveys have shown that the older stations are more open while the newer electronic systems need the advantages of a closed recirculating air conditioning system. All new construction will have controlled ventilation. It appears that fibers could get into the older stations and potentially interrupt a switching function. On the other hand, telephone stations represent numbers of identical installations each performing the same task. Single fibers could cause wrong numbers or stalled switching in one or more individual elements, but not upset the entire exchange at one time.

The history of blackouts in the Northeast leads to a concern for the circuitry which controls power generation stations, in particular fossil fueled plants. Such installations live with fly ash, and in addition, coal fired plants live with coal dust. Practical considerations led to isolated control rooms with the electrical portions of control circuits contained within the control rooms. The isolation afforded by the control rooms in older stations may admit some airborne fibers. Such stations use voltages in the range 125-200 volts in their control elements; single fibers are not considered capable of precipitating a damaging failure at such voltages. The newer installations employ digital computers as active elements in the control systems. The corresponding ventilation systems employ more than one stage of air filtration with the second stage specified as a high efficiency dust remover. Such systems effectively isolate the control room from the rest of the generation station.

The financial community and a segment of the manufacturing community depend upon data and records stored in computers. A failure which compromises such records represents a major impact. The term "computer room" as an environmentally controlled area reflects the history of usage for electronic computers. Practical considerations of heat generation and access for cabling lead to installations with dropped ceilings, raised floors and a separate air conditioning system employing filters for dust and lint control. The computer electronics generate heat, the printers can be noisy and tape readers are sensitive to airborne dirt and dust. The trend toward smaller computers has not changed the manner of installation or the needs for protection. Computer manufacturers currently specify a minimum value for the dust removal efficiency of the air conditioning filters, and at these minimum values filters are effective barriers to airborne fibers. While airborne fibers may enter areas containing items such as point-of-sale cash registers or local terminals the main-frame installations appear environmentally isolated.

"Continuous process" describes the manufacture of such items as paper, textile fibers, industrial chemicals, petroleum refining, etc. For such an installation the loss of control at one location could stop the entire operation, and a restart could be costly. Control for such operations depends upon systems built up of specialized elements and displays with the control stations often standing alongside the operating line. The local environment can be benign, just wet, corrosive, or even explosive. A long roster of American companies manufacture control related equipment; most represent specialty items with but a few firms providing the major portions of the integrated control systems used in the continuous process industries. A canvass of the principal manufacturers of control system elements revealed that each recognized the potential applications of his equipment and designed accordingly. One assumed every unit would see service in the extremely corrosive environment of a pulp mill. All circuit boards received a conformal coating. A second manufacturer utilized tightly sealed cases. A third used a mix of both depending upon the installation. The installation of electrical circuitry into industrial buildings utilizes standardized classes of enclosures as defined by the National Electrical Manufacturers Association (NEMA). The classes range from General Purpose Indoor (NEMA Class 1) as the most open and continues through degrees of sealing for rain, dust, immersion and explosive atmospheres. NEMA Class #12 appears as the industrial standard for an installation which needs protection from both moisture and dust. The nature of a continuous process operation seems to preclude any exposure of electrical circuit elements to the ambient environment.

"Automated production" can be envisioned as those operations which machine metal, fill bottles, seal cans or wrap packages. A number of closely controlled steps proceed in sequence. The disruption of one step halts all the others, and an unscheduled halt could result in a damaged product. The environment in such lines can range from benign (as in some food processing lines) up through cutting fluid sprays to explosive as in a line which filled aerosol cans with a hydrocarbon propellant. Automated machining lines employ numerically controlled machine tools and some employ dedicated computers. Equipment operating in such environments finds the need to place high efficiency filters in the ventilated cases or to completely seal the cases. Reviews of maintenance records for machining lines show that sealed units have minimum calls. The records also show that when the environment includes metal chips, a damaged seal usually results in an electrical failure caused by the ingestion of conductive debris. For such installations the measures which seal out the ambient contaminants also seal out airborne graphite fibers.

Assembly line operations involve products which range from automobiles to washing machines. Failure at any step in an assembly line could halt the entire line and idle the work force. Where electrical items play critical roles in the process, the surveys have found either sealed cases, multiple units or ready spares. For some assembly lines such as televisions, or home appliances, a degree of cleanliness becomes a requirement. Cleanliness tends to limit the potential for a line halt caused by graphite fibers. In summary, assembly lines require continuous monitor for potential stoppages or bottlenecks. Problems receive prompt attention. Operations in unprotected environments such as the assembly of automobiles requires ready spares or redundant installations; other assembly lines have the protection afforded by air-conditioning. As a result assembly line operations do not appear vulnerable to stoppage by airborne graphite fibers.

The results from surveys can be summarized in terms of events which will not happen. Figure 5 lists the principal findings for services, for utilities and for commercial institutions. Life-critical functions appear to have the necessary degree of environmental isolation to preclude a threat to life. The police, fire and rescue communication links will function. Generating stations do not appear vulnerable. For telephones one could get a wrong number or not complete a call on the first try, but that happens even now. The banks, the brokerage houses and similar operations appear to have adequate protections.

Figure 5 summarizes the results from surveying manufacturing installations, and these show a range in potential for impact. The potential for impact may be addressed in terms of industry types as defined by the two digit SIC code. Eight of the SIC classes for manufacturing industry operate under environmental conditions which result in an effective isolation of electrical items from the ambient environment. The Food Processing Industry, SIC 20, lives with a cleanliness requirement. In these industries operations must proceed in environmentally controlled areas. As examples, in a frozen food plant, equipment has to proceed in refrigerated areas, meat packing equipment has to permit wash down, etc.

The printing plants, SIC 27, must control humidity just to keep paper moving through their presses. Their sensitive electrical equipment becomes environmentally isolated. The other 6 classes represent the continuous process industries working in corrosive environments. The two classes of manufacturing which machine metal and thereby must contend with conductive debris include the fabrication of machinery and the fabrication portion of the automobile, airplane, and railroad equipment industries. These two together with the first eight show value-of-shipments totalling 55 percent of all manufacturing as compiled by the last Census of Manufacturers.

The manufacturer of electronic and electrical circuitry items requires a degree of cleanliness for control of contaminants and debris. These factories take advantage of air conditioning or air filtration as a measure of control. The air conditioning reduces the probability for entry of fibers and thereby reduces the economic impact for another 10 percent of industrial installation. Where assembly lines and fabrication lines operate with ready spares such as observed in the controllers for spot welding of auto bodies, the potential for economic impact is also reduced. Another 7 percent of American industry carries this type of protection.

The total experience from surveying a cross section of the workplaces in the United States leads to a series of conclusions relative to the degree of economic impact which can result from the entry of airborne graphite fiber into a workplace. Figure 6 lists these conclusions. The life critical areas may be excluded from any impact considerations. Emergency services, utilities and commercial institutions could suffer non-disruptive failures. For the manufacturing industries half the total value-of-shipments comes from factories which may be eliminated from impact projections. The surveys did not see any failure sites within factories where airborne fibers could cause a total factory shutdown. For manufacturing, impact will be in terms of single machines. The losses will be costs for troubleshooting and repair with some operators temporarily idled and some product damage or production loss. The surveys found that manufacturing operations must contend with a number of randomly occurring failures in items of electrical equipment. The potential number of additional failures caused by fibers would not be recognized against the background of the present random failures. In a discussion after a tour, one plant engineer summarized the potential impact in the words, "We probably would not even know if it had happened."

THE SURVEYS OF PUBLIC, UTILITY, COMMERCIAL AND INDUSTRIAL INSTALLATIONS PROVIDED THREE ELEMENTS OF DATA:

- ECONOMIC MODELLING: DATA TO ESTIMATE THE IMPACT OF A FIBER INDUCED FAILURE AS COSTS OF REPAIR, REPLACE, LOST TIME, ETC.
- HAZARD SENSITIVITY: DATA TO IDENTIFY WAYS FIBERS COULD INTERFERE WITH LIFE CRITICAL OR EMERGENCY SERVICES.
- OPERATION SENSITIVITY: DATA TO DEFINE THE EFFECTS OF AN IN-PLACE PROTECTION OR HIGHLIGHT A PARTICULAR SENSITIVITY TO AIRBORNE FIBERS.

Figure 1.- Survey of facilities for potential effects from airborne graphite fiber.

1) PUBLIC SUPPORT	NO.
HOSPITALS	7
AIR TRAFFIC CONTROLS	6
AIRPORTS-AIRLINES	3
POLICE HEADQUARTERS	2
FIRE DISPATCH	2
POST OFFICES	1
TRAFFIC CONTROL	1
2) UTILITIES	
TELEPHONE EXCHANGES	3
POWER GENERATOR, DISTRIB.	3
REFUSE INCINERATORS	2
AMTRAK	1

3) COMMERCIAL INSTALLATIONS		NO.
DEPARTMENT STORES		2
FINANCIAL INSTITUTIONS		2
RADIO AND TV STATIONS		6
ANALYTICAL LABORATORIES		1
4) MANUFACTURING OPERATIONS (SIC)		
MEAT PACKING	(20)	1
TEXTILE MILL	(22)	1
GARMENTS	(23)	1
PULP AND PAPER	(26)	1
PUBLISHING	(27)	2
TEXTILE FIBERS	(28)	1
TOILETRIES	(28)	1
STEEL MILLS	(33)	2
WIRE, CABLE	(33)	1
ELECTRICAL EQUIP.	(36)	6
AUTOMOTIVE FAB/ASSY	(37)	4

Figure 2.- Summary of facilities surveyed.

- ON-SITE TECHNICAL SURVEYS COVERED 62 LOCATIONS AS PUBLIC, UTILITY, COMMERCIAL AND MANUFACTURING FACILITIES
- PRESENT OPERATING REQUIREMENTS RESULT IN FACILITY CONFIGURATIONS OR FEATURES WHICH PROTECT AGAINST FIBER ENTRY OR INTERACTIONS.

  -AIR CONDITIONED BUILDINGS WITH FILTERS FOR INTAKES AND RECIRCULATION.

  -SENSITIVE EQUIPMENT IN SEPARATE ROOMS WITH INDEPENDENT ENVIRONMENTAL CONTROL.

  -SENSITIVE EQUIPMENT IN CLOSED OR FILTERED VENTILATION CABINETS.

  -ELECTRONIC CIRCUIT BOARDS WITH CONFORMAL COATINGS.

  -FAILURE PRONE EQUIPMENT BACKED BY READY SPARES.

Figure 3.- Surveys of facilities, general findings.

AREA OF CONCERN	PRESENT OPERATING CONCERN
1. HOSPITAL OPERATING ROOMS AND CRITICAL CARE AREAS	. AIRBORNE INFECTIONS CONTAMINANTS
2. HOSPITAL ROOMS	. LINT
3. AIR TRAFFIC CONTROL TOWERS AND EQUIPMENT	. OPERATING TEMPERATURE . ELECTROMAGNETIC INTERFERENCE
4. POLICE/FIRE EMERGENCY COMMUNICATION SYSTEMS	. RF SIGNAL QUALITY . IN-VEHICLE OPERATION
5. TELEPHONE EXCHANGE CENTERS	. AIRBORNE PARTICULATES . NEED FOR MULTIPLE INSTALLATION
6. POWER GENERATION CONTROL SYSTEMS	. FUEL DUST . FLY ASH
7. DATA STORED IN CENTRAL COMPUTERS	. HEAT GENERATION - HUMIDITY . AIRBORNE CONTAMINANTS
8. CONTINUOUS PROCESS CONTROL SYSTEMS	. CORROSIVE FLUIDS AND SPRAYS . EXPLOSIVE ATMOSPHERES
9. AUTOMATED PRODUCTION CONTROL SYSTEMS	. CUTTING FLUID SPRAY . EXPLOSIVE/CORROSIVE ATMOSPHERES
10. ASSEMBLY LINE OPERATING AND CONTROL ELEMENTS	. EQUIPMENT BREAKDOWN . AIRBORNE CONTAMINANTS

Figure 4.- Critical failure areas and present protection.

PRESENT PROTECTION	EFFECT
. "ABSOLUTE" AIR FILTRATION (HILL-BURTON REQUIREMENT)	. FIBERS DO NOT ENTER AREAS
. CLOSED CASES	. ITEMS NOT VULNERABLE
. RECIRCULATING FILTERED AIR . RF SHIELDED CABINETS	. FIBERS DO NOT ENTER AREA . ITEMS NOT VULNERABLE
. MULTIPLE UNITS . CLOSED CASES	. SYSTEM ACCEPTS SINGLE FAILURES . ITEMS NOT VULNERABLE
. RECIRCULATING FILTERED AIR . REDUNDANT EQUIPMENT	. LIMITED FIBER ENTRY . SYSTEM ACCEPTS SINGLE FAILURES
. CONTROL ROOMS SEPARATED WITH RECIRCULATING FILTERED AIR	. OLDER STATIONS: LIMITED FIBER ENTRY CONTROL VOLTAGES NOT SENSITIVE TO FIBERS . NEW STATIONS: ENVIRONMENTALLY ISOLATED
. ROOM-WITHIN-ROOMS . RECIRCULATING FILTERED AIR	. FIBERS DO NOT ENTER COMPUTER AREAS
. COATED CIRCUIT BOARDS . SEALED CASES (NEMA #12)	. NO ELECTRICAL CIRCUIT ELEMENTS OPEN TO FIBERS
. HIGH EFFICIENCY FILTERS OR SEALED CASES	. FIBERS DO NOT ENTER CASES
. READY SPARES . RECIRCULATING FILTERED AIR	. SYSTEM ACCEPTS SINGLE FAILURES . LIMITED FIBER ENTRY

Figure 4.- Concluded.

• INDUSTRIAL OPERATIONS	PERCENT OF NATIONAL VALUE-OF-SHIPMENTS
- NO IMPACT BECAUSE OF PROTECTION FROM PRESENT OPERATION ENVIRONMENT: SIC 20 FOOD, 22 TEXTILE MILLS, 26 PAPER, 27 PRINTING, 28 CHEMICALS, 29 PETROLEUM AND COAL, 30 RUBBER, 31 LEATHER	40
- NO IMPACT BECAUSE OPERATIONS NEED LOCAL PROTECTION FROM CUTTING FLUIDS, CONTAMINANTS: SIC 35 MACHINERY, 37 TRANSPORTATION (PARTIAL)	15
- REDUCED IMPACT BECAUSE OPERATIONS NEED AIRCONDITIONING OR SOME CONTROL OF AMBIENT CONDITIONS: SIC 36 ELECTRICAL, 38 INSTRUMENTS	10
- REDUCED IMPACT BECAUSE OPERATIONS ARE SUPPORTED BY READY SPARES: SIC 37 TRANSPORTATION (PARTIAL) SIC 33 PRIMARY METAL (PARTIAL)	7

- LIFE CRITICAL FUNCTIONS HAVE IN-PLACE PROTECTIONS AGAINST THE ENTRY OF AIRBORNE GRAPHITE FIBERS.
- EMERGENCY SERVICES WILL NOT BE INTERRUPTED BY AIRBORNE GRAPHITE FIBERS.
- ELECTRICAL UTILITIES WILL NOT BE DISRUPTED BY AIRBORNE GRAPHITE FIBERS.
- TELEPHONE SYSTEMS WILL NOT BE DISABLED BY AIRBORNE GRAPHITE FIBERS.
- COMMERCIAL INSTITUTIONS WILL NOT LOSE THEIR ESSENTIAL RECORDS STORED IN COMPUTERS.

Figure 5.- Results from surveys.

- LIFE CRITICAL FUNCTIONS: EXCLUDE FROM IMPACT PROJECTIONS.
- EMERGENCY SERVICES: ECONOMIC IMPACT LIMITED TO SINGLE ITEMS OF EQUIPMENT.
- UTILITIES: ECONOMIC IMPACT IN TERMS OF A LOCAL OUTAGE/REPAIR.
- COMMERCIAL INSTITUTIONS: IMPACT IN TERMS OF PERIPHERAL EQUIPMENT.
- INDUSTRIAL INSTALLATIONS:
  - FOR HALF OF INDUSTRY, NO ECONOMIC IMPACT.
  - NO FACTORY SHUTDOWNS.
  - ECONOMIC IMPACT IN TERMS OF SINGLE FAILURES AND REPAIRS.

Figure 6.- Conclusions.