FIRE DEPARTMENT PARTICIPATION ON A FAST TRACK CONSTRUCTION PROJECT FOR THE SEMICONDUCTOR INDUSTRY

EXECUTIVE DEVELOPMENT

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An applied research project submitted to the National Fire Academy
as part of the Executive Fire Officer Program

July 1998

Abstract

The problem was that the Austin Fire Department (AFD) had been asked to provide construction plan review and inspection services on a semiconductor fabrication plant project, faster and in more detail than was normally expected. The purpose of this study was to provide a template for fire department participation needed by the semiconductor industry in completing new plants. The research method used for this study was the descriptive research method.

There were three research questions to be answered in this paper. What items did the Austin Fire Department provide as part of the team effort on its most recent semiconductor project? How much time was spent by Austin Fire Department personnel as part of the project team? How many inspections and hazards were found by Austin Fire Department personnel during construction? These were answered by providing a monthly description of AFD activities and participation. An accounting of monthly and total hours spent by different AFD staff was provided. An accounting of monthly inspections and hazards found was provided for Fire and Life Safety systems, and Hazmat systems. An informal survey of project managers was also conducted to provide an indication of project team opinion about AFD participation.

The results of this study were that AFD activities provided criteria for successful fire department participation. Monthly hours needed by AFD staff indicated that utilizing specialty contacts in a team concept had benefits to both AFD and the project managers. Monthly inspections and hazards found justified AFD participation, and the informal opinion survey indicated that the project team was satisfied with AFD's level of participation. It was recommended that AFD continue using their present methodologies with some minor additions.

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Introduction

The problem is that the Austin Fire Department was asked to provide construction plan review and inspection services faster and in more detail than was normally expected.

The purpose of this study is to provide a template for providing fire department services needed by the semiconductor industry in completing new fast track facilities.

The research method used for this study is the descriptive research method. It is hoped that by describing a successful method of participation, that other fire departments can successfully participate in future semiconductor fabrication plant projects.

The research questions to be answered in this paper are:

1. What items did the Austin Fire Department provide as part of the team effort to meet the needs of a fast track, semiconductor fabrication plant project?
2. How much time was spent by Austin Fire Department personnel as part of the project team?
3. How many inspections and hazards were found during construction by Austin Fire Department personnel in an effort to help the team be successful?

Background and Significance

The first major high technology company to locate in Austin was IBM in 1967. Its first facility was built on the north side of town. Soon other companies tied to the computer industry built facilities in Austin. In 1969, Texas Instruments also located its circuit board plant on the north side of town. Motorola built its first semiconductor fabrication plant in 1973, on the east side. On the southeast side of town, Advanced Micro Devices, Inc. opened its first semiconductor fabrication plant in 1978.

Austin's reputation as a growing high tech center was given national attention in 1983 when it was chosen to be the location of the Micro Computer Consortium (MCC). This was a government sponsored group of companies organized to collectively research advancements in computer technology. High tech development continued to increase later that year when Advanced Micro Devices, Inc., and Motorola each started their second semiconductor fab sites.

Until 1984, these facilities were built utilizing building permitting and inspection policies that followed a traditional time schedule. The traditional permitting and inspection methods used by the City required formal submittal of plans, review by City officials, revision by the design team, and resubmittal to officials. This procedure was required in succession for subdivision reviews first, zoning second, and finally consideration for building permits. Construction could not be started until all development approvals and building permits were issued. Once construction was finished, and depending on who was available on a particular day, different building inspectors signed off when building systems were completed. A certificate of occupancy was not issued until all work was complete. The company then was allowed to move in and install production equipment. The Austin Fire Department did not participate in plan reviews and performed only minimal inspections during construction of high tech projects. The few fire inspections performed were mainly oriented toward general fire safety issues. The fire codes used during this time were not specific regarding semiconductor fabrication plants or chemical usage. This changed in 1984 when AFD assigned uniformed fire personnel to perform construction plan reviews.

Prior to 1984, two Lieutenants were assigned to review plans for high rise buildings and apartments having more than 50 units. After March 12, 1984 the policy changed to require fire code plan review for all projects over $10,000 in value. The AFD plan review staff was increased to four lieutenants and one fire protection engineer. They were responsible for verifying that fire access was provided, and for review of fire sprinkler systems. In 1985, the uniformed plan reviewers were reduced to one Lieutenant and the others absorbed by the existing inspection section. Four fire protection engineers were hired to perform fire sprinkler and fire alarm plan reviews. This increase in fire prevention technical expertise was accompanied by AFD being given the responsibility for expanding its duties into hazardous material safety.

By 1984, many cities in California's Silicon Valley had adopted local ordinances regulating the use of toxic gases and other hazardous materials. At this same time, Austin experienced two fires at facilities storing hazardous materials. One involved an acid leak and electrical fire at a business called Austin Circuits. Another was a major fire at a solvent blending and repackaging facility called Southwest Solvents & Chemicals. Firefighters did not have information regarding the chemicals located at these facilities, and this reinforced the need for adoption of local ordinances requiring hazardous material reporting and accident prevention. An ordinance requiring chemical inventory reporting was passed by City Council in 1985. Along with this new ordinance, City Council approved a budget amendment that allowed AFD to hire three Environmental/Chemical engineers. The additional hazmat information and technical expertise proved timely, as a pair of semiconductor plant fires occurred over the next two years.

A fire in an exhaust duct at Advanced Micro Devices, Inc. in October 1986 resulted in the evacuation of 125 employees, but no call to 911. The fire was caused by a leak of the pyrophoric gas, silane. This was considered a minor fire by the company as a sprinkler system in the duct controlled the fire immediately with minimal damage, however AFD felt it should have been reported. The local press ran several stories that discussed a need for improvements to the fabrication plant fire alarm system.

Another fire involving silane occurred at the Motorola semiconductor fab in East Austin, in March 1987. Silane leaked from a compressed cylinder in one of Motorola's semiconductor wafer processes and ignited immediately. The fire was reported at 12:22 PM and was not declared under control until 5:09 PM. The release, failure of exhaust equipment, and the inability of fire sprinklers to control the fire indicated that AFD needed to become more involved in the initial installation of chemical safety systems.

In 1988, another national competition resulted in Austin being chosen as the site for a new government sponsored research group. The Sematech consortium was organized to provide research geared toward keeping American semiconductor production ahead of Japan's. As part of the agreement to locate in Austin, community leaders and public officials agreed to provide a facility for the consortium. The time schedule required for completion of the facility necessitated a speeded up approval process, unheard of construction inspection deadlines, and a new concept of allowing production equipment installation and partial building occupancy, prior to completing construction. The City of Austin felt it best to assign on-site inspectors full time to the project for handling building code design and inspection issues. The Uniform Building Code (UBC) and Uniform Fire Code (UFC) organizations had been working on new provisions covering semiconductor fabrication plants and hazardous materials. These code sections had not been completed at the time the Sematech project began, so the consulting firm of Rolf Jenson & Associates provided a Project Safety Program Manual. This included many fire issues that AFD had been reviewing and inspecting on other projects, along with many new safety features for semiconductor hazmat. It became apparent that the Austin Fire Department was going to be much more involved in this high tech project.

The Fire Marshal felt it best to designate a full time lieutenant inspector as the department's single point of contact. This individual was responsible for coordinating the necessary plan reviews with the department's fire protection and hazmat engineers. The lieutenant was also responsible for performing all necessary fire inspections. Having a single point of contact proved inadequate once the fast track construction was started. There were just too many issues, as the Sematech project progressed in continuous cycles of designing-then-constructing each required system. As one part of the building was being constructed, the next was under design. As one system was installed, another was being designed. By default, the lieutenant soon found himself being a full time inspector, with the engineers providing direct coordination. The Sematech project set a precedent in Austin, and it was evident that more fast track projects were on the way.

Motorola began an expansion called MOS 11 adjacent to their existing west Austin fabrication plant in 1989. For this project they asked the City Council to provide approvals and construction inspection using a fast track schedule similar to that used on the Sematech project. The City had recently adopted the new Semiconductor Fabrication Plant, and Hazardous Materials provisions added to the 1988 Uniform Fire Code. It was decided that technical staff would be assigned responsibility for design coordination, and on-site inspectors would be made more accountable for solving problems in the field. This required assigning technical staff to the design team for instant reviews, and full time inspectors to the construction site to handle problems and faster approvals. The Fire Department assigned one full time fire protection engineer, one full time fire inspector, and one part-time hazmat engineer to the project. Unfortunately, turnover in the fire department's inspector and hazmat engineering ranks caused problems. The individual assigned to the lieutenant inspector slot transferred to another position, and the hazmat engineering staff was hit with a series of resignations due to better job opportunities in the private sector. This left one full-time fire protection engineer and a series of part-time lieutenant inspectors to participate. Even so, the project was completed on a positive note with Austin generally gaining a reputation for fast completion of semiconductor facilities. AFD was generally pleased, but the need for someone filling the hazmat coordination role was identified on several occasions where the construction of chemical safety systems did not meet the new UFC provisions. This was not the last chance AFD had to make improvements to its participation on fast track projects.

The City of Austin experienced an increase in requests from developers and businesses for what many considered, was preferential treatment. This necessitated adoption of a formal fast track approval process by the City in 1992. Three of the major requirements for qualification to use the new Fast Track Program included:

1. Hiring a certified Fast Track Coordinator responsible for providing liaison between the owner, architects, engineers, contractors, and City staff.
2. Approval of a construction schedule by the City Council as being feasible.
3. Completing minimum site utility work, environmental protections, and fire safety construction prior to beginning any building construction.

This formal process was used by the semiconductor industry in 1992 and 1993 for two major expansions of existing semiconductor fabrication plants in Austin.

Motorola began design and construction of its MOS 13 project in 1992 adjacent to its existing plants in east Austin. Advanced Micro Devices, Inc. began its Fab 25 project in July, 1993 adjacent to its existing plants in southeast Austin. City staff had to provide fast track participants for two projects that would be staggered by only a few months. The building department was given approval to hire two additional inspectors to help handle the anticipated load. A full-time building, plumbing, and electrical inspector were assigned to be on-site as requested by the semiconductor companies. The fire department did not request additional personnel as it had a full staff of five fire protection and three hazmat engineers. It was felt engineering duties could be prioritized. Those day-to-day workload items with higher priorities could be shifted to the other engineers, and those lower priority items could be delayed until the end of the semiconductor project. AFD also felt it could handle the demands of the two jobs by utilizing a team approach rather than a single-point-of-contact policy. Each project was assigned a part-time fire protection engineer, a part-time hazmat engineer, and two part-time inspectors. The engineers were responsible for design issues and special inspections such as hazmat systems. The lieutenant inspectors were responsible for job-site fire safety and fire system inspections. Both of these semiconductor facilities progressed along similar construction schedules though completion of the base building structures. The building finish-out, fit-up of production equipment, and chemical system installation were different in each case due to changes in the semiconductor business economy. A down-turn in demand for semiconductors caused Motorola to suspend their construction of MOS 13 once the structure was up and fire protection systems were installed. They currently are installing production tools and equipment for future production. Advanced Micro Devices completed the structure for all of Fab 25 and then installed production equipment and chemicals systems in half of the building to allow chipmaking in 1994. The other half of Fab 25 was finished out in 1995 with the rest of production starting that year. Even though both projects were down sized, AFD felt it could easily hand a single semiconductor plant construction project by utilizing the team approach.

Advanced Micro Devices, Inc. evidently agreed, and in 1994 when that company announced plants to begin construction of a new plant in Dresden, Germany. They brought Dresden city officials to the new Fab 25 project for a visit. The Dresden officials were given a chance to talk with City of Austin building and fire officials. The Dresden group did not include a member of their fire service however, and most the questions involved environmental issues. Representatives from the City of Eugene, Oregon also visited with AFD to discuss fast track semiconductor projects in 1994. Hyundai had announced plans to build a large semiconductor plant in Eugene and they were concerned that their small staffs would not be able to meet project demands. The Eugene Deputy Fire Marshal was also very concerned about his department's technical ability to assure code compliance of the high tech chemical systems. Similar concerns were echoed in 1995 when Motorola brought the Fire Department Chief and Fire Marshal from Henrico County, Virginia to visit their facilities and talk with AFD. Motorola was planning a semiconductor plant called White Oak to be build in the Richmond, Virginia area. The Henrico County Fire Department officials were concerned mostly about the response issues that a large semiconductor plant would bring to their Virginia community. They were also concerned about their ability to provide the technical expertise necessary to ensure that chemical safety was achieved.

The summer of 1996 brought news to Austin that it was being considered for a new semiconductor fabrication site that eventually could have three fabs, each providing approximately 250,000 square feet of production floorspace. The South Korean company, Samsung announced it would build this plant on Austin's northeast side of town just outside the City limits. Samsung decided to request annexation into the City and was given approval to build its first fabrication plant under the fast track program. City staffing assignments similar to the two previous projects were made with one change. The building department had noted the fire department's ability to meet the owner's needs without full-time, on-site inspectors at MOS 13 and Fab 25. For the Samsung project, they too assigned part-time design coordinators and inspectors to work as a team. During this project, a group of City officials from Tulsa, Oklahoma toured the Samsung construction and visited with Austin building and fire officials. The

Chamber of Commerce in Tulsa had hired a consultant to help promote their City for a future semiconductor facility. The Tulsa Building Official was most concerned with the amount of staff need to meet the project's demands. The Tulsa Fire Marshal was concerned that his department did not participate in addressing chemical safety issues, as these were part of the building code in his City. Both asked about approximate time and staffing required for completing such a project.

It is hoped that this paper will help provide fire officials in similar circumstances, answers about what it is like to participate in a fast track construction project with a semiconductor business. The National Fire Academy course, Executive Development, includes subject matter relating to enhanced team development, problem solving, leading, ethics, creativity, and innovation. The research problem in this paper concerns fire department participation in a type of project that requires knowledge and ability in all these areas.

Literature Review

A review of available literature concerning construction of new semiconductor fabrication plants, large projects, and fast track projects revealed several areas of available information. These included the benefits of a new plant to a community, the needs of the semiconductor fabrication industry, the safety concerns that such fabs posed for local officials, and how local officials could deal with everyone's needs and concerns.

Benefits to Community

Adding a major business to the taxbase of a community is of interest to most elected officials. The new Advance Micro Devices, Inc. (1997) semiconductor fab built in Austin, Texas in 1996, added to the property tax base 950,000 square feet of buildings worth $1.5 billion. In addition to tax base, the semiconductor industry in Austin, Texas is one of the area's largest employers (Gallaga, 1997). More than 25,000 people are employed at semiconductor fabs or other chip related companies that supply the fabrication plants. Motorola, with two fabrication plants in Austin, is the largest semiconductor company, employing more than 10,000 workers. A new semiconductor fab in the Richmond, Virginia area was reported to have received 9,000 job applications. From this initial pool, 300 were selected for training (Greater Richmond Partnership, 1997). It was further reported that besides the new semiconductor fab, several new businesses had located in Richmond to act as suppliers and vendors for the new plant.

The desirability of attracting semiconductor plants and support businesses was further illustrated by the description of three tracts of land in Richmond, Virginia ranging from 365 acres to 2225 acres, that had been evaluated by consultants working for the Greater Richmond Partnership, Inc. The evaluation was performed in an effort to draw new semiconductor business to the Richmond area. These tracts were scrutinized in regard to numerous variables critical to the fast track construction requirements of fab plants. These tracts were compared to 23 other locations in communities that presently have semiconductor companies. This analysis showed Greater Richmond was ranked as the 5th most competitive location in terms of operational costs in the United States.

The findings above show that attracting tax base and potential jobs is a basic concern of local elected officials. When efforts to obtain such business for a community are successful, the local business community, potential employees, and elected officials all want the new business to be successful. This puts additional pressure on local building and fire officials to provide excellent customer service while still enforcing the local building and safety codes.

Fast Track Needed by Semiconductor Industry

The tremendous cost of building a semiconductor fabrication plant has made it increasingly harder to achieve an acceptable financial return. The need to bring a fab on-line in a short period of time was illustrated by a comparison of the cumulative cash flows for a typical and a "fast-track" fab (Ward, Horwath, Hayes, Bracamonte, 1997). A fabrication plant producing chips in half the normal time was calculated to have the potential to reap an additional $20 billion in cash flows. The time to recover initial investment costs were shown to be roughly half, from 32 months for a normal scenario, to 18 months for a fast-track project. These numbers were documented based on present technology being produced. It was predicted that to accomplish such financial returns in the future will require further decreased design and construction time, along with decreased process fit-up and production ramp-up time. A comparison between current and needed time schedules showed that current time to produce the first chip was about 2 years. Predicted future technology needs to have this time reduced to 1 year.

Burns (1997) describes how the semiconductor industry is a cyclic industry. He further related how the relatively long planning and construction times for semiconductor fabs sometimes results in new fabs being completed just after the boom in chip revenues has passed. The results of not meeting a fast track schedule were further described in a newspaper article by Mahoney (1998) concerning Cypress Semiconductor's Fab 2. The company missed $10 million in sales due to their Fab 2 plant not being able to convert to a new chip process in time. Dan Scovel of Fahnestock & Co. in New York was quoted as saying, "It's not like they were trying to fill an inside straight or something, they were trying to do something that should have been fairly attainable. They just didn't get it done soon enough."

Sung Lee, Chairman for Samsung Austin Semiconductor, was interviewed on December 29, 1997. Mr. Lee indicated that his parent company, the Korean based Samsung Corp., evaluated many factors in making their decision as to where to locate their first semiconductor fabrication plant in the United

States. It was generally known that Austin, Texas was in competition with Portland, Oregon for the new plant. Mr. Lee revealed that Austin and Portland were tied in many of the categories considered. He felt that Austin won Samsung's new location, due to three factors. First, existing fabs in Austin were using older style technology. Samsung felt they could draw qualified employees easier than in Portland, where several new fabs were currently under construction. Second, two fabs had just been completed in Austin and Samsung felt experienced contractors would be available. This was a problem in Portland due to the projects under construction in that area. Third, Mr. Lee related that the sites available in the Portland area were in suburban areas where city officials were not experienced in dealing with needs of a fast track semiconductor construction project. Samsung knew that officials with the City of Austin had participated in several successfully completed semiconductor projects. Samsung felt this familiarity would reduce the risk of their project schedule being delayed.

McLaughlin (1997) related how the semiconductor industry is one of the most regulated by the Uniform Building and Uniform Fire Codes. Code changes were felt to not occur fast enough to accommodate the constantly evolving processes required for manufacturing semiconductor chips. The rate of change was indicated to be so rapid, that before a semiconductor fab is completed, the characteristics of the next generation of fab have evolved. It was felt that current code requirements reflect the fab designs of the mid-1980's while today's fabs are much larger, require greater building height, and more floor levels. All this for additional equipment and utilities to support the fabrication (clean room) area. This lack of updated fire codes, makes the ability to evaluate performance rather that prescribed codes, a necessity for semiconductor construction projects.

The fast track demands were described from an architects view (Texas Architect, 1996) of a recent project at Motorola's largest ever construction undertaking. Graber, Simmons & Cowan partner

Al Simmons described how his firm had to focus more closely on integrated project management procedures. He described how GSC found itself developing a relationship with their client, and as the two companies found their respective ways of communicating very complementary, GSC became involved earlier in the project development loop. "We are generalists first, and that's the reason why we have been able to be successful," said Simmons. This need to be involved early, and the need to be flexible carried over into the construction phase as described by GSC's Jim Overton. He described the schedule from a field perspective that included numerous design items that had to be changed during construction on a daily basis. He relayed that despite changes in design, the schedule did not change. The need for flexibility and the need to meet deadlines are major considerations in a fast track project of any kind.

The findings above show that a semiconductor company preparing to build a new plant, just like any business, is interested in the financial savings and accelerated cash flow that a fast track process allows. The magnitude of financing and return involved, makes it imperative that local fire officials provide the new semiconductor company excellent customer service as it regards flexibility of time schedules, a familiarity with the processes involved, and an excellent working relationship with not only the company, but also its designers and contractors. While accommodating the design and construction team, the local fire official must also remember his or her primary safety role.

Concerns about Semiconductor Industry

The tremendous costs, loss of profits, and demands for faster than normal construction can cause a perception among the public and fire officials, that lapses in safety can occur. The need for assurance that this doesn't happen is documented in the literature.

An article describing the evolution of hazardous materials regulation (Hanselka, 1993) mentions that the groundwork for federal underground storage tank laws where founded as a result of long-term leakage from a 5,000 gallon underground solvent tank located at a South San Jose, California semiconductor factory in December, 1981. The release was estimated to have taken place over a number of years resulting in almost 50,000 gallons of chlorinated solvents leaking into an aquifer used by the San Jose area for drinking water. Preliminary studies attributed an increased incidence of birth defects in the area to the chemical storage system at a semiconductor facility

The “Clean” cyber industry was covered over six months in a series of newspaper stories (Jurgensen, 1998). This series included information that documented ten out of the 36 plants in California’s silicon valley as being cited for health and safety problems from 1993-1997. It concluded that the industry is now building in locations where environmental and safety regulations are less strict. It also cited information showing a variance in the number of enforcement inspections between jurisdictions in Arizona, and how some fire officials there moonlight for the chipmakers that they’re supposed to regulate. These accusations are unsettling, considering the fire service role in responding to hazardous material incidents at facilities involved in semiconductor fabrication.

Emergency responder concerns at semiconductor facilities were described (Fogarty, 1994) in an article that included a description of the seven main processes used in making semiconductor wafers. The epitaxial growth process was described as using hydrogen gas, trichlorosilane, arsine, and tetrachlorosilane. The diffusion process was described as using arsenic trichloride, boron trioxide, phosphorous oxychloride, diborane, and phosphorous pentoxide. The metallization process description included heating and introduction of chrome, gold, silver and titanium to form the chip’s circuits. A description of the plating process included chemical immersion in poly tanks with heating elements that increase the risk of ignition. Etching was described as removing portions of the chip and included the use of hydrofluoric acid, ammonium fluoride, phosphoric acid, and nitric acid. The dry etch process was described as incorporating gases that include boron trichloride, chlorine, trifluoromethane, and tetrafluoromethane. Cleaning was the final process described and is performed in wet bench stations using sulfuric acid and hydrogen peroxide. Firefighting problems due to failure of a plant's compressed air systems, exhaust systems, and production chemical systems were pointed out. The article also described unique issues at semiconductor plants in handling gas leaks, rescues in confined spaces, and dealing with bulk fuels for emergency power generators. This tour of a typical semiconductor facility included a description of the elaborate security systems used by the industry to protect themselves from theft and espionage. The high degree of security was pointed out as necessitating a high degree of cooperation between the facility's safety personnel, and the responding fire department. Concerns by the public, semiconductor plant workers, and emergency responders stem from the perceived hazards associated with numerous hazardous materials used in the process of building semiconductors. A primary concern to the insurance industry however, is the potential catastrophic dollar loss due to an accident.

It can take three months or more to make a semiconductor wafer. The different manufacturing stages each involve sophisticated and expensive equipment called workstations, or tools. According to recent predictions (Skinner & Gettel, 1998), a fabrication facility could cost $10 billion in 2005. It was estimated that equipment as a percentage of total factory cost will continue to rise and reach about 80% by 2000. These costs cause insurable values at a semiconductor facility to be high. Even so, the insurance industry ("Semiconductors", 1996) found that the time it takes to repair a serious loss at a plant, may be longer than the life expectancy of the semiconductor being manufactured. This high facility and product loss potential has forced insurers to take precautions. Some join forces with other insurers to underwrite accounts on a quota share basis. Some impose loss-limit policies or increased deductibles in the $500,000 to $1,000,000 range. Business interruption deductibles in the $20 million to $30 million range are not unrealistic. One IRI account was documented as sustaining a $5 million loss because a four hour electricity interruption resulted in a four day shutdown to recalibrate production equipment. The article described how these potential costs require loss prevention to be a primary concern to an insurance company's risk manager.

One risk manager's nightmare (Dunn, 1998) occurred in a Hsinchu, Taiwan semiconductor fabrication plant owned by a joint venture of United Microelectronics Corp. and six other North American chipmakers. A catastrophic fire occurred on October 3, 1997 and caused an estimated $421 million dollars in smoke and water damage after burning uncontrolled for about 36 hours. All semiconductor production equipment was destroyed but there were no injuries. It was predicted that the plant might be shut down for a year. Both the building and equipment were fully insured, according to company officials. Taiwan's Council of Labor Affairs called for safety upgrades throughout the nation's semiconductor industry. According to the Council, Taiwan's production lines had experienced fires at least twice a year.

The findings above show that fast track construction of a semiconductor facility includes building a specialized production building, installing highly technical production equipment, and ramping up production all in a very tight time schedule. Getting a new plant ready concentrates many man-hours of work toward that goal. Public concerns, responder concerns, and the high loss potential make it imperative that someone fill the role of providing loss prevention oversight.

Dealing with Large Fast Track Projects

The literature does not provide direction specifically aimed at how a fire department can ensure a successful semiconductor plant construction project. There are however, numerous examples of business friendly philosophies used or suggested by fire departments and fire officials.

How the Boston Fire Department deals with special workloads relating to large construction projects was discussed in an interview (Touger, 1998) with Fire Marshal/Deputy Chief Joseph M. Fleming. When asked if massive construction projects placed any burdens on his department, Fleming had some solutions. Regarding special equipment or training needs for response to a special facility, the project management was asked for compensation. When decisions on compliance issues exceeded the expertise of his department, the project management was asked to hire an outside consultant to submit a report dealing with the department's concerns. This article was not specifically about semiconductor plant construction, but it indicates that perhaps a fire department should consider relying more heavily on the owner to provide the technical oversight and pre-construction quality control that some Fire Departments prefer to accomplish themselves through detailed plan reviews.

Reliance on local fire officials for hazmat incident prevention, instead of federal and state agencies was discussed (Hanselka, 1993) in an article that pointed out benefits the local fire department can provide regarding hazmat risk reduction. The article relates how the local fire department can provide one-on-one interaction with local business, and points out that state and federal agencies have no mechanisms for timely response to local emergencies. These factors allow a fire department to strengthen its relationship with local business and improve risk management. This is in comparison to hazmat prevention programs in state and federal government that typically call for only paperwork compliance. Accountability is a key factor that the fire department can provide. Consultations, discussions, explanations and approval of alternative methods are presented as fire department responsibilities. It is also pointed out that project requirements dictated by the fire department, must also be tempered in a cost-effective manner. This suggests that the fire department look for ways to developed a trusting relationship with the new semiconductor business, its design team, and its contractors. It indicates that the fire department can accomplish this by providing risk reduction consulting services to the new semiconductor business, along with the project's design consultants and contractors.

Private/Public partnership is the topic of an article (Loesch & Hammerman, 1997) that describes the working relationship developed between a county building department and a local research facility. The Howard County, Maryland Department of Inspections, Licenses and Permits (DILP) worked out a mutually beneficial system for ensuring building code compliance at The John Hopkins University Applied Physics Laboratory. The system established a rigorous in-house quality control assurance procedure followed by the Laboratory. It also provided for random inspections by the DILP. This partnering system incorporates the use of a Master Building Permit. This permit allows the Laboratory the freedom needed to complete continual in-house alterations that are required to meet research goals. It also ensures DILP that a documented quality assurance system is being followed for design review, construction document code compliance, and in-house inspections with written certifications that construction has been completed in accordance with plans and specifications. Essentially, DILP allows the Laboratory to complete all design and construction, then ensures accountability by relying on random spot checks. It was noted that trust is sometimes a problem. It seems some builders fear that second-guessing by the building officials during the random final inspections, could require major changes after construction is completed. This concern was addressed by clearly establishing the requirement for accountability during design and construction. This was a shared responsibility between the Laboratory and the Building Department. The Laboratory ensured accountability during design and construction by use of check lists that require a series of sign offs by qualified personnel. The County ensured accountability by checking qualifications, and random inspections of the work completed. This type of process indicates that a performance oriented system of final checks, rather than a prescriptive system of detailed plan review by a government agency, might be applicable for construction environments requiring constant change.

Two consultants wrote a guidebook (Goldberg & Fluer, 1986) about new semiconductor fabrication plant safety requirements that were added to the Uniform Building and Uniform Fire Codes in 1983, 1984, and 1985. This guidebook was written in a format that printed direct code wording, then followed the quoted provision with a discussion that was intended to clarify the provision. This clarification helped to provide rational to a code requirement. The outline format of the guidebook and the discussions could easily be followed by design professionals trying to design a semiconductor fabrication plant to meet the new codes. The discussions in particular, many times suggested a solution. The authors state in the guidebook's preface, "A description or diagram should not be seen as the solution but rather one of several possible solutions." The forum for solving problems is presented in the guidebook as it was normally accomplished in the 1980's. As described in the book, the designer presented detailed construction plans to a code official, who in turn performed a detailed review, negotiations occur, changes to the plans are made, the whole process documented for the record, all this before a building permit could be approved. This guidebook does not include permit approval scheduling needed by a fast track project, and many of the code discussions are based on semiconductor production technology that is obsolete. Even so, its format does suggest an idea that could be useful to a fast track semiconductor project. A working relationship between design professionals and fire officials requires a basis for understanding of how the code will be applied. Just as in this guidebook, it could be provided in a simple outline form.

The fire inspector's job has changed over the last 20 years from being an enforcer, to being a highly skilled professional adept in all aspects of fire prevention. An article on this topic (Scott, 1997) provided several examples of how inspectors must prove their value to the community by being seen as partners and consultants to business. The article explains that the fire prevention officer of the 1990's must not only be the traditional hard-nosed cop enforcing the fire code, but also possess the skills and knowledge of a chemical engineer, structural engineer, and fire protection engineer. In addition, an inspector must be an educator, business consultant, and occasionally, a linguist. The inspector must not only be able to speak the technical language of an engineer, but must also be able to work increasingly with business owners for whom English is a second language. The article also discusses the growing trend towards fire inspection duties being performed by building inspectors. Accountability is addressed by Barbara Koffron of the Phoenix Fire Department. She feels that an electrical inspector could be trained to review fire alarm systems and a plumbing inspector could be trained to check sprinkler plans. But she points that the fire department has a vested interest in seeing it done right. This need for technical expertise and accountability during a fast track project is not only important to the fire department but also to the semiconductor company. Especially when the project involves highly technical systems such as those required for a semiconductor fabrication plant.

Accountability during a current fast track project in Austin, Texas was placed squarely on the shoulders of the city inspectors (Hiott, 1997). The new Austin-Bergstrom International Airport is a high profile, public project utilizing fast track scheduling to meet a completion date in May 1999. Fifteen full time city inspectors were made responsible for 90 infrastructure projects and the new 450,000 square foot terminal building. Their jobs involved more than inspecting, they were required to provide oversight for quality control and also safety. Their daily duties involved meeting with not only contractors, but also the laborers. The laborers are described as the people who let city inspectors know if they are being made to work in unsafe conditions. Other airport projects have experienced fatalities, and an excellent safety record on this project was a goal for airport officials. Inspectors were given the responsibility of deciding between a workers livelihood, or his safety. If workers got enough safety violations, they would get their badges pulled. If the violations were wide spread enough, a supervisor lost a badge. No badge meant no work in the heavily secured area of a new airport. Accountability for quality control and safety during a fast track project was accomplished by the inspectors on this project. The City of Austin had learned this from earlier fast track projects involving the semiconductor industry.

Full time inspectors were utilized by the City of Austin on its second fast track project with the semiconductor industry. Motorola was prepared to spend $100 million on its new MOS 11 plant expansion in the Oak Hill area of Austin. The City had instituted several management initiatives that promoted worker empowerment and it was felt a fast track project would benefit both the City and Motorola. The results of this were documented in a video (Siedor & Byerly, 1991) that interviewed the design professionals and representatives of the City. The incorporation of City reviewers and inspectors into the design team was discussed as one of the reasons for a successful project. It was felt that having full time city representatives dedicated to this fast track project was also a key to success. Their availability to designers and contractors saved time and made necessary changes easier to accomplish. The procedures followed during this project were repeated on another semiconductor project, however the assignment of full time City representatives was not feasible due to shrinking budgets and workforce.

The references indicate that fire department representation on a fast track project involving the semiconductor industry might benefit community development leaders, the semiconductor business community, public safety needs, and possibly even the department itself. The benefits seem to be contingent upon a fire department's ability to contribute to a successful project rather than be a hindrance to the team. It must also have the ability to provide accountability that other project team members are not trained to perform. In order to accomplish these, it must also have available personnel to dedicate. That in itself can be a problem, especially considering the shrinking resources that many fire departments face today.

Procedures

The descriptive procedure used for this paper documents the fire department participation in the Austin area's most recent semiconductor plant construction project. The project described is the Samsung Austin Semiconductor fabrication plant that began design in January, 1996 and received its certificate of occupancy from the City in October, 1997. This description includes a monthly log of the Austin Fire Department (AFD) participation, an accounting of monthly time, and an accounting of monthly inspection information. Also included is an informal opinion survey, presented in an effort to help judge the project team satisfaction with the AFD participation on this project. This information hopefully will be useful to other communities participating in similar projects, and to participants in future projects in Austin.

Description of Fire Department Participation

The procedure for this paper begins with a monthly description of design and construction activities on this project. The building status information is summarized from progress meeting minutes. The AFD participation information is summarized from project design correspondence, project meeting minutes, and AFD inspection reports. The AFD emergency response information is summarized from run reports. The monthly description this information provides is an outline of the progress milestones and issues to be expected by a fire department.

Fire Department Hourly Workload

The number of hours spent each month by AFD's Fire Protection Engineer, Hazmat Engineer, and Lieutenant inspectors are described in a table along with project totals. The hours spent by each group of AFD staff are summarized from AFD time logs kept during this project. This information provides the schedule of time required by fire department staff over the project life. It also provides total project time estimates needed for determining alternative project staffing on future projects.

Fire Department Inspection Output

The number of inspections performed and the number of hazards found are summed for those months that required construction inspections. The monthly totals are taken from the inspection reports filed by AFD staff. These are presented in a table, along with the project totals. The inspection and hazards found are presented to help describe the necessity for fire inspections during a project of this complexity and magnitude.

Project Team Opinion Survey

Last, the results of an informal opinion survey are presented. These results describe the opinions held by those managers attending the last project meeting on November 14, 1997. Its intent is to help describe the other team member's perception of the AFD staff's participation. This survey serves as a time saving device in lieu of individual interviews with managers from the companies responsible for the design and construction. It is not intended as a formal scientific evaluation or statistically valid analysis of opinions from all individuals involved in the project. A larger scope survey is not possible due to the transient nature of individual designers and contractors on this job. The intent of the survey is to informally gauge manager satisfaction. The total number of surveys obtained is 23, with individual affiliations of 3 Owner Employees, 10 Consulting Engineers/Architects, and 10 Construction Contractors. Due to this small survey size, 95 percent confidence intervals, survey testing, and bias adjustments are not determined for this paper.

The wording and evaluation for the Samsung survey is modeled after previous AFD employee surveys, with questions being slightly revised to account for specific details pertinent to the Samsung project. Like these larger departmental surveys, the informal Samsung opinion survey procedures follow those found in an International City Management Association special report (Miller & Miller, 1991) on customer surveys. The informal Samsung opinion survey consists of two questions designed to anonymously categorize project duties, and eight questions concerning AFD participation. The eight opinion questions require a response to one of four symmetrical options, two negative and two positive. There is not an answer option shown for no opinion. However, a response showing no answer or no opinion is anticipated as described below. The survey questionnaire used is shown in Appendix A.

Analysis of the survey starts with the calculation of raw percentages for those responding to each answer option. Those responding to the two negative answer options are assigned scores of 1 and 2 respectively. Those not responding to a question, or those indicating a response between the negative and positive options, are assigned the score of 3. Those responding to the two positive options are assigned scores of 4 and 5. This is accomplished for all team members, and for each of the three team member affiliations noted in Question 1. The raw percentages are then multiplied by the applicable points, and then summed to obtain average scores for each question.. The average scores greater than 1 but less than 2 are considered very negative. Those greater than 2 but less than 3 are considered negative. The average scores greater than 3 but less than 4 are positive. Those greater than 4 but less than 5 are very positive. Depending on the question, this analysis should provide an informal gauge as to the project team's satisfaction with AFD assistance. Differences between the three groups of member affiliation might help to identify potential needs that AFD could address on future projects.

Results

Description of Fire Department Participation

Austin Fire Department (AFD) design assistance and construction inspection at the Samsung Austin Semiconductor fabrication plant began in January, 1996 and lasted until October, 1997. A monthly summary of the Fire Department's involvement in the $1.3 billion project is described below.

January, 1996. Austin Fire Department (AFD) staff attend a meeting to kick off the recently announced production facility. It is agreed to use the 1991 Uniform Building and Fire Codes for this project. Discussion concerns the City's fast track approval process, subdivision platting, zoning designation, and annexation. The site is located just outside the Austin City Limits, and Fire Department response is of concern to Samsung officials. Without annexation, the AFD Hazmat Team cannot respond to the Samsung site. A special arrangement or contract with the area Volunteer Fire Department would be necessary if Samsung proceeds without being annexed.

February, 1996. Samsung proceeds with annexation, and other land development approvals. The Fire Chief instructs the Fire Marshal to assign first line supervisors to assist Samsung. The Fire Marshal decides to assign the Fire Protection Engineering Supervisor, a veteran Lieutenant inspector, and the Hazmat Engineering Supervisor to the project. They act as single point of contact for their area of responsibility, but must share responsibility for project team satisfaction. In case the primary contact is unavailable, each designates a backup who is responsible for assisting the others. Design team meetings are held to introduce members and discuss initial improvements such as a new highway to the site, extension of utilities to the site, and the site plan for buildings. AFD activities center mainly on water supply and site access for fire apparatus. The Samsung design team consists of their corporate project managers and technical staff, a local architectural firm, a national consulting engineering firm, and a local land development law firm.

March, 1996. Samsung holds a groundbreaking ceremony attended by City, County, and State officials including the Mayor of Austin, County Judge of Travis County, State Legislators, and the Governor of Texas. Numerous corporate Samsung officials are also present. AFD attends as the South Korean tradition for groundbreaking includes the use of explosives rather than shovels. Site contractors begin to clear the site and excavate for building foundations, roads, and site utilities. AFD Fire Protection and Hazmat Engineers attend project team meetings to answer code and project coordination questions from Samsung and its design consultants.

April, 1996. AFD Lieutenant works with design team on layouts for fire apparatus access. AFD Fire Protection and Hazmat Engineers begin working closely with building designers to help indicate code issues on preliminary building floorplans. AFD and Building Department representatives explain to the project team that all life safety systems will need to be installed prior to hazardous production chemicals being bought onto the site. This has been a basic priority on all other projects in Austin. It is determined that part of the Central Utility Building (CUB) will need to be constructed as a hazardous occupancy due to chemical usage in the deionized water (DI) process. This was unanticipated by Samsung, and specific information concerning the DI process is not available. Samsung has not yet picked a DI Subcontractor. It also becomes evident that water supply to the site will not be available before structural construction is completed. AFD Fire Protection Engineer and Lieutenant work out solution of temporary water tanks and access roads.

May, 1996. Construction of footings and foundations for the Administration, Semiconductor fabrication building (Fab), and the CUB buildings are proceeding. Consultants are preparing architectural designs, structural designs, and bidding documents. AFD Fire Protection Engineer coordinates with building designers and the Fire Sprinkler Subcontractor on options for protecting different areas. AFD Hazmat Engineer coordinating with Consulting Engineers on chemical issues relating to building design. Chemical quantities inside Fab are presented and chemical quantity limitations are evaluated. Samsung's need for large quantities of pyrophoric gas indoors is identified. This will necessitate an alternative method of compliance with the UBC and UFC. The Consulting Engineers begin working on a solution that requires hiring outside help for technical reports.

June, 1996. Architectural and structural design work by local consultants is completed with bid documents issued. The local architectural firm fades from participation in design meetings. This firm has worked previously with AFD on the last three Fabs completed in Austin. Project management shifts to the national engineering firm hired by Samsung. AFD staff works with project management that has never completed a semiconductor facility in Austin. AFD Fire Protection Engineer begins reviews of site water supply lines, and building exit systems. Design discussions concern alarm system requirements with the Alarm Subcontractor, CO_2 suppression systems with the Fire Sprinkler Subcontractor, and smoke control issues with the Consulting Engineers. AFD Hazmat Engineer begins work with Samsung Process Managers concerning code requirements to allow use of production gas that is not used at other plants in Austin, and is new to AFD. This reactive gas is highly toxic, water reactive, and requires special hazmat response suits. Samsung agrees to purchase additional suits for the AFD Hazmat Team. It is determined this will necessitate another alternative method of compliance. Design team coordination on an alternative safety system for this and the pyrophoric gas continues.

July, 1996. Samsung announces that over $200 million in primary subcontracts are available. They sponsor a local seminar for businesses wishing to bid on this work. The design team shifts to work concerning mechanical and electrical issues. Site utility construction is beginning and the AFD Fire Protection Engineer and Lieutenant are involved in underground fire line issues. Plan submittals for building sprinkler systems and alarm systems are reviewed by AFD. Design team is preparing bid documents for chemical storage and dispensing building. They do not require assistance from AFD Hazmat Engineer this month. AFD emergency medical response is required to a fall from a drilling rig that is placing foundation footings.

August, 1996. Concrete framing and structural supports for the Administration, CUB, and Fab buildings are going up. AFD Fire Protection Engineer and Lieutenant concerned with site fireline construction problems. AFD plan review continues on fire systems. AFD Hazmat Engineer works with Consulting Engineers on requirements for flammable liquid dispensing from the Contained Chemical Storage System (CCSS) building. The Consulting Engineers do not know answers to several important process questions, as Hazardous Production Material (HPM) Subcontractors have not been selected by Samsung for supplying chemical systems. Hazmat work also continues toward identifying possible alternative compliance systems for the pyrophoric and reactive gas quantities. These are also hindered by process information not yet being available.

September, 1996. Building structures are still under construction along with site utilities, roads, and parking lots. AFD Fire Protection Engineer and Lieutenant work with consultants concerning location and protection of temporary offices and trailers. These are for additional subcontractors that will soon be on the construction site. Plan review of building fire systems continues. AFD Hazmat Engineer works with Consulting Engineers concerning routing of flammable liquid lines through the CCSS building. Gas and Liquid HPM Subcontractors, and a DI Water Subcontractor are still not participating in the design.

October, 1996. Sides are going up on the buildings, and exterior precast panels are filling in the completed structures. Site utilities, roads, and parking are about 75% complete. New members of project team include Electrical Subcontractors and Mechanical Subcontractors. HPM Subcontractors who will be supplying the gas and liquid chemical systems are also selected. Project management transitions to Samsung corporate manager. Heavy rains have caused concerns about site access by fire apparatus. AFD Lieutenant works with General Contractor to provide stable access roadways. AFD Fire Protection Engineer reviewing underground fireline installations and reports. AFD Hazmat Engineer working with Gas HPM Subcontractor on requirements for bulk cryogenic gas systems and the specialty gas systems that will be located inside the Fab and CCSS buildings. AFD emergency rescue response required for a construction truck rollover.

November, 1996. Construction for the Industrial Wastewater Treatment (IWT) plant is started. AFD Fire Protection Engineer working with Fab and CUB fire sprinkler designers. AFD Hazmat Engineer working with the Consulting Engineer on the chemical waste drain lines and chemical safety requirements inside the Fab. Hazmat coordination also involves chemical storage at the IWT and answering questions from the IWT Subcontractor. HPM Piping pressure test requirements are reviewed with Gas HPM Subcontractor. AFD emergency medical respond required to an incident involving two fall victims, from 12 feet onto concrete.

December, 1996. Interior structural work is progressing in all buildings. Roads are complete. Still working on some site utilities. AFD Fire Protection Engineer reviews fire sprinkler and alarm plans for the Administration and CCSS buildings. Sprinkler plans for cooling towers are discussed. Lieutenant reviews changes to interior roadways. AFD Hazmat Engineer begins discussing safety requirements with Liquid HPM Subcontractor. The Liquid HPM representative has virtually no information concerning the design to be installed. This concerns AFD. Samsung Process Managers identify a semiconductor production tool that contains more HPM than allowed by the UFC. A third alternative compliance design is needed. The pyrophoric gas, reactive gas and production tool alternative compliance designs are continuing projects. AFD emergency medical responses include an individual experiencing dizziness, another having a seizure, two more incidents for falls from scaffolding, and one call for a foot injury.

January, 1997. Mechanical and electrical construction starts inside all the buildings. Clean room area construction including massive air handling and filter systems started. AFD Fire Protection Engineer reviews more alarm plans. The AFD Hazmat Engineer informs the Fire Department Chief of concerns related to lack of information on chemical system designs. There is a possibility of AFD being put in the position of turning down requests for introduction of chemicals into the Fab later. The AFD Fire Chief asks the Hazmat Engineer to meet with Samsung project management and explain the concern. Samsung Project Management is made aware of need for specific chemical system information. They and the rest of the project team are reminded that HPM chemicals will not be allowed in the Fab unless all life safety features are completed. This had been discussed last year, at the beginning of the project design, but many new faces have joined the team and are unaware of this requirement.

February, 1997. Interior structural work is complete and finishout started. Mechanical and electrical construction continues. A program is started by Samsung and contractor safety staffs in an effort to limit construction accidents. AFD Fire Protection Engineer attends meetings concerning completion of sprinkler and alarm systems in time to allow introduction of chemicals into the Fab. Consulting Engineers also discuss requirements for being allowed to occupy the Administration building in phases. Lieutenant begins meeting with City Building Department inspectors to coordinate building and life safety inspections. AFD Hazmat Engineer prepares a spreadsheet of all UFC requirements that shows the status of each item on this project. The spreadsheet includes testing and performance expected prior to being given AFD inspection approval. This is given to Samsung Project Management and is used in future progress meetings to update project status toward getting approval for chemicals inside the Fab.

March, 1997. AFD Fire Protection Engineer and two part-time Lieutenants are visually inspecting sprinkler systems, witnessing hydrostatic testing of interior sprinkler piping, and continuing inspection of exterior fireline installations. Most of their work is in the Administration, CUB, and Fab buildings. AFD Hazmat Engineer begins working with DI Subcontractor concerning code requirements for chemicals used in the deionized water production process located in the CUB. This will be one of the first systems brought on line as DI water is used in virtually all production. It is also needed for initial chemical system purification.

April, 1997. Special procedures for entering the fab areas are now in effect. All workers, including AFD personnel, must don clean room garments and follow ulta-purity protocols for inside the fab building. AFD Fire Protection Engineer helps answer Consulting Engineer questions concerning the backup battery room and the fire protection systems required inside the semiconductor production tools. Lieutenants are inspecting fire systems in the CCSS, CUB, and the cooling towers. AFD Hazmat Engineer meeting with DI Subcontractor, IWT Subcontractor, and Gas HPM Subcontractor regarding their chemical system designs. The Liquid HPM Subcontractor does not request any design reviews or provide information. A meeting with contractor safety representatives is held to outline the introduction of chemicals into the buildings while construction is still in progress. AFD staff meets with Fire Marshal and Building Official to discuss and approve the alternative compliance designs for the pyrophoric gas, reactive gas, and production tool that did not meet code.

May, 1997. Construction on building interiors continues. There are now approximately 1,640 workers on the site. This causes a parking problem resulting in access roads regularly being blocked by parked cars, delivery trucks, and equipment containers. After taking 20 minutes to access the site for a meeting, AFD staff consults with the Fire Marshal. Samsung Project Management is notified that no further inspection approvals will be given until fire apparatus and ambulances can be assured access to the site. Within two days, additional equipment laydown areas are provided and fire lanes are marked. AFD Fire Protection Engineer reviews revisions to sprinkler plans that are needed now that specific planning and layouts for production equipment are being completed. Lieutenants inspecting fire systems primarily inside the Fab. AFD Hazmat Engineer reviews and approves toxic gas exhaust calculations. These are required by the UFC to limit emergency release concentrations to less than one half that deemed Immediately Dangerous to Life and Health (1/2 IDLH). Construction requirements for the pyrophoric gas rooms, deionized water, and the liquid chemical systems are discussed. A new representative from the Liquid HPM Subcontractor does not know all details about system to be used, so goes back to main office to find out answers.

June, 1997. Major construction inside buildings is complete so clean protocols are raised to a higher level. Work crews continuously roam the interior sweeping and wiping all surfaces. Temporary tent structures are placed on the northwest and southwest sides of the Fab for protection while unpacking production tools. Tools are moved inside for installation on the second floor of the Fab. Conditional approval for use of occupying specific areas of the Administration building is given for additional workers due to fit-up of production equipment. AFD Fire Protection Engineer assists the two Lieutenant inspectors with questions they have on fire sprinkler installations in the Administration, CCSS, and IWT. AFD Hazmat Engineer inspects and approves use of aboveground fuel tanks for the emergency generators, cryogenic oxygen vessel, and corrosive liquids in the CUB for starting production of DI water. Meetings with Liquid HPM Subcontractor proceed and it is found that they have already purchased much of the chemical dispensing equipment. However, some dispensing units don't meet UFC code requirements for automatic shutoffs and flammable liquid tanks. AFD is told alternative designs will be presented. AFD Hazmat Engineer receives an open record request from USA Today regarding Samsung's chemical inventory. City Attorney and State Attorney General's office get involved before the inventory is ruled confidential. AFD emergency medical responses required for two incidents involving chest pain. One response due to a fire alarm malfunction.

July, 1997. The Samsung site emergency response team participates in its first mock drill to show it is prepared for chemicals being brought into the facility. AFD now utilizing two to four part time inspectors. In addition to fire sprinkler risers, they are now testing elevator recalls, heat detectors, smoke detectors, smoke dampers, air handler shutdowns, pull stations, audio/visuals, and emergency lighting. They are working mostly in the Fab, but also in Administration and CUB. They have found hydrants obstructed by construction containers and others with valves closed. AFD Hazmat Engineer approves cryogenic hydrogen vessel. Installation of Liquid HPM dispensing equipment began without final resolution of issues with AFD. To meet project schedules, Samsung Project Management requests inspection to allow liquid chemical introduction into the CCSS and Fab. Hazmat inspection identifies 51 hazards regarding incomplete life safety systems and liquid chemical dispensing systems in the CCSS building and the Subfab level. The Subfab level is the first floor of the Fab and is the location for chemical piping, chemical valve manifold boxes (VMBs), and associated equipment needed by the production tools on the Fab's second floor. Samsung Project Management and the Vice President for the Liquid HPM Subcontractor begin working on solutions and many items are fixed before the end of the month. Many unprotected piping penetrations through fire rated walls are fixed. Life safety hazards in the Subfab level include fire rated doors in exit corridors not shutting due to inadequate closers. Also, one exit corridor has been converted to a temporary gowning area for donning ultra-clean garments. Both impact approvals for chemical distribution in the Subfab. An attorney for a local activist group files a complaint with the City and State regarding Samsung's introduction of chemicals into buildings. AFD staff is able to clarify situation and verify that all is under control. AFD emergency response required for two false alarms due to fire alarm testing. AFD hazmat team response required due to worker smelling paint and mistaking it for production chemicals. No production chemicals approved to be in that area at this time. Later in month, AFD emergency medical response required for person having difficulty breathing, unrelated to any chemicals.

August, 1997. The Mayor and City Council tour the site and Fab. The number of construction personnel is dwindling, but Samsung employees now total 750 on the site. Semiconductor tool installers are working around the clock. AFD and City Building Department agree to allow third party inspection of tool installations that will be in accordance with an approved checklist. AFD Fire Protection Engineer reviews problems with fire alarm audibility in CUB and Subfab, helps design team decide corrective options. Lieutenants allow conditional occupancy of additional areas in the Administration building, still some areas needing sprinklers, alarms, and exiting completed. Inspections also include Vesda smoke alarm system in the Subfab, exhaust scrubber heat detectors, gas cabinet sprinklers checked. Fire dampers separating the chemical storage areas in CCSS, and fire pumps in the CUB are tested. More underground fireline connections are being made to building risers. These are tested and the Lieutenants find more fire hydrant valves closed outside. AFD Hazmat Engineer approves some chemical storage of acids, bases, and oxidizers in CCSS upon completion of life safety and chemical system features. There are still problems with flammable liquid systems as tanks installed do not meet national standards. Later in month, oxidizer and acid introduction from CCSS into the Subfab is allowed up to the VMBs. Acid and solvent waste tanks are reviewed. Acid systems approved but solvent tanks do not meet national standards. They also must have overflow protection installed. AFD emergency response to four false alarms due to system malfunctions. One response to alarm activation due to construction spray painting. Another AFD hazmat team response due to medical problem erroneously attributed to production chemicals. AFD response to electrical transformer fire and again later to problem with emergency generator system. This later necessitates removal and replacement of an emergency generator set.

September, 1997. There are now over 360 semiconductor production tools installed in the fabrication area. First silicon is introduced into the production line as the first step in qualifying the Fab for producing marketable chips. AFD Fire Protection Engineer reviews additional plans for fire alarm, and CO_2 fire protection system upgrades. These are added in some tools to meet insurance carrier requirements. Lieutenants finish up reinspections and retest the new emergency generator set that was damaged by the transformer fire in August. AFD Hazmat Engineer inspects and approves use of most gas and liquid HPM from VMBs in the Subfab. Items required for the three alternative compliances are inspected. One control system for the pyrophoric gas alternative is found sabotaged, Samsung officials speculate it was done in retaliation for using non-union electrical contractors. AFD emergency response required for two alarm system malfunctions and two false alarms activated by pull stations.

October, 1997. The County Judge and Commissioners tour the essentially completed Fab and site, along with member of the national technical press. Lieutenants complete a fire final inspection and give their approval for the fire protection systems. AFD Hazmat Engineer completes final inspections, automatic shut off capabilities, and approvals on all gas and liquid systems. City issues a final certificate of occupancy for Samsung's first fabrication plant in Austin. AFD emergency medical responses for a non-chemical related seizure, and for three activations due to final fire alarm testing.

November, 1997. Production of chips ramps up. Current production is estimated at 12,000 wafers per month. Samsung plans to install another phase of production tools in 1998 that will increase production capability to about 25,000 per month. AFD staff attends meeting where it is agreed that installation of additional tools next year, will be under a second building permit. In addition, it is clarified that all other improvements will follow the applicable code editions in effect at that time. Site safety during construction is calculated, and the lost time due to accidents is determined by Samsung safety as one tenth that of the national average.

December, 1997. AFD and Building Department staff attend a luncheon with the Chairman of Samsung Austin Semiconductor. He thanks all for their help, and expresses his satisfaction with the project team. He indicates that Samsung made the right decision in coming to Austin.

Fire Department Hourly Workload

The number of hours attributed to each AFD staff position and the total for each month is shown in Table 1. The total project hours expended by the AFD staff from January, 1996 to November, 1997 is shown as 1,266 hours.

Table 1

Summary of Fire Department Personnel Project Hours

Month, Year	*Fire Protection Engineer (Hours)*	*Hazardous Materials Engineer (Hours)*	*Lieutenant Inspector (Hours)*	*Total Personnel (Hours)*
January, 1996	0	2	0	2
February, 1996	4	4	4	12
March, 1996	6	4	1	11
April, 1996	13	7	1	21
May, 1996	12	9	1	22

June, 1996	27	3	3	33
July, 1996	11	3	3	17
August, 1996	33	9	5	47
September, 1996	10	5	2	17
October, 1996	7	15	4	26
November, 1996	2	16	2	20
December, 1996	15	33	6	54
January, 1997	3	17	2	22
February, 1997	1	29	10	40
March, 1997	6	29	20	55
April, 1997	13	47	28	88
May, 1997	3	51	24	78
June, 1997	3	63	32	98
July, 1997	8	66	144	210
August, 1997	12	73	172	257
September, 1997	5	49	24	78
October, 1997	2	41	8	51
November, 1997	0	7	0	7
Total by Position	188	582	489	1266

Fire Department Inspection Output

The number of inspections and hazards found by AFD staff are shown in Table 2. These numbers reflect the results for Fire & Life Safety inspections and Hazmat inspections. These are shown for each month of the project. The total Fire & Life Safety inspections for the project equal 69 with 136 hazards found. The total project Hazmat inspections equal 95 with 195 hazards found. These numbers reflect the performance accomplished by the AFD staff from January, 1996 to November, 1997.

Table 2

Summary of Fire Department Inspections and Hazards Found

Month, Year	Fire & Life Safety Systems		Hazardous Material Systems	
	Number of Inspections	*Number of Hazards Found*	*Number of Inspections*	*Number of Hazards Found*
March, 1997	3	1	0	0
April, 1997	4	2	0	0
May, 1997	3	2	0	0
June, 1997	4	5	14	28
July, 1997	21	67	19	78
August, 1997	30	46	24	55
September, 1997	3	13	29	33
October, 1997	1	0	9	1
November, 1997	0	0	0	0

Total	69	136	95	195

<u>Project Team Opinion Survey</u>

The informal opinion analysis results are presented following the original survey question shown below. The average opinion is shown for those manager affiliations given as an Owner Employee, a Contractor/Construction company, or a Consulting Engineer/Architect. The average opinion for all respondents is labeled below as the total.

<u>Question 3.</u> Austin Fire Department interaction with the design team was insufficient and required more time solving problems and assisting the project team.

Owner Employee (Corporate) = Very Negative

Contractor/Construction = Negative

Consulting Engineer/Architect = Very Negative

Total = Very Negative

<u>Question 4.</u> The Austin Fire Department should provide the design team additional, detailed information regarding specific Fire Code requirements.

Owner Employee (Corporate) = Negative

Contractor/Construction = Positive

Consulting Engineer/Architect = Negative

Total = Negative

<u>Question 5.</u> More information concerning past projects and problems was needed from AFD so that the design team could make better informed decisions.

Owner Employee (Corporate) = Negative

Contractor/Construction = Positive

Consulting Engineer/Architect = Negative

Total = Negative

<u>Question 6.</u> Austin Fire Department personnel adequately informed contractors about items needing to be inspected and tested.

Owner Employee (Corporate) = Very Positive

Contractor/Construction = Very Positive

Consulting Engineer/Architect = Very Positive

Total = Very Positive

<u>Question 7.</u> Austin Fire Department personnel passed inspections frequent enough for this project.

Owner Employee (Corporate) = Very Positive

Contractor/Construction = Very Positive

Consulting Engineer/Architect = Very Positive

Total = Very Positive

<u>Question 8.</u> An adequate quality control pre-inspection or pre-test was performed before requesting AFD inspection.

Owner Employee (Corporate) = Very Positive

Contractor/Construction = Negative

Consulting Engineer/Architect = Positive

Total = Positive

Question 9. Fire Department participation improved safety on the project during construction.

Owner Employee (Corporate) = Very Positive

Contractor/Construction = Very Positive

Consulting Engineer/Architect = Very Positive

Total = Very Positive

Question 10. Safety items identified by the Fire Department were necessary for successful operation of the Fabrication Plant.

Owner Employee (Corporate) = Very Positive

Contractor/Construction = Very Positive

Consulting Engineer/Architect = Very Positive

Total = Very Positive

Discussion

Comparison to Findings of Others

The project descriptions for the Samsung facility show a parallel to the referenced benefits that a new semiconductor fab brings to a community. The additional taxbase, new jobs, and business development desires of the community place additional pressures on the Fire Chief and Fire Marshal. This is shown by their assignment of supervisory staff to the Samsung project. Local government officials touring the Samsung site reinforces community support for the project. The immediate response from City and State officials when an open records request was filed, and an environmental complaint was received, is an example of the desire for success. At times, it seems the Fire Department is being asked to take on additional responsibilities that include community business development. That certainly was the case regarding the Samsung project.

The references describe the need for fast tracking semiconductor related projects. The economic viability of a plant depends on how fast it can be brought up to full production. The need for teamwork to accomplish this was evidenced on the Samsung project. Project Management had to utilize not only designers and contractors, but also AFD personnel, for solutions to problems. The need for acceptance of systems not covered by present fire codes was evident on the Samsung project. Three requests for alternative compliance were requested and worked out.

The referenced publications explain areas that the semiconductor industry has generated safety concerns. Samsung experienced several false alarms attributed to worker inexperience and concerns about nonexistent chemical exposures. Due to a new reactive gas being used at the Samsung plant, emergency responders voiced concerns that had not been discussed since the first fabs were built in Austin. The insurance industry concern about catastrophic fire loss was experienced on the Samsung project with their carrier requiring redundant fire suppression systems for specific processes.

The referenced methods of dealing with a large fast track project were all part of the AFD participation. The owner and consultants being expected to provide much of their own technical expertise was followed by Samsung and their consultants providing outside studies to justify several alternative compliances. The reference indicating that Fire Departments are best suited to provide accountability for life safety and hazmat issues proved true. The Samsung project team learned that life safety and hazmat decisions needed to include AFD staff. When AFD staff was not part of the decision, there usually was a delay. The reference explaining public and private partnerships was put into action on the Samsung project by establishing design team roles from the beginning. Everyone is responsible for safety as evidenced by the excellent safety record on the Samsung project. The consultants and contractors are held accountable for providing designs that meet the established codes prior to construction. They are also accountable for construction performance prior to getting AFD approvals. AFD is held accountable for providing timely design assistance and inspections. AFD is also accountable for assisting in finding acceptable temporary solutions that will avert potential delays. The reference providing a guide to the fire codes provided another solution for AFD. A similar document was provided to the project team when it became evident that some team members were not familiar with the UFC and AFD expectations. The reference that described future fire inspectors as needing to be skilled professionals rather than enforcers, was on the mark. AFD staff became consultants-to-the-consultants on numerous occasions. These included many cases where it was required that the rational behind a code requirement be explained. The reference regarding City inspectors being responsible for safety and quality control at a large project was also applicable. The City Council, City Manager, and Fire Chief all placed responsibility for safety and quality control on the Building Department and AFD. They also held the City participants accountable for ensuring that the project was completed without unjustified delays.

Interpretation of Study Results

The presentation of monthly activities shows that AFD's participation has to include the needs of others holding an interest. The necessary components expected of AFD staff include:

1. Fire staff understanding that they have been delegated responsibility from the community leaders.
2. Fire staff being open to new ideas and methods for accomplishing equivalent safety.
3. Fire staff anticipating concerns from the public, workers, and emergency responders.
4. Fire staff possessing and displaying exceptional technical expertise.

5. Fire staff being able to accept accountability, and being able to educate other team members about AFD wanting the job done right.
6. Fire staff that can communicate what they expect of others in a timely manner. Likewise they must be able understand what others expect from them.

The presentation of hours spent by each Fire Department staff type shows that the demands of a fast track semiconductor project can best be handled by a diverse group. This is shown by the variation in hours required in 1996 for design, and the steady increase in hours required during 1997 for construction. The total hours that one employee can work without overtime is approximately 173 hours per month. The monthly totals show only two months where more than one person would be required. This might indicate that one single-point-of-contact might be sufficient. It is not however, due to the demand for instant information by the design team. It is not uncommon to have several technical specialties meeting at the same time. AFD also found that using the team concept kept one group from being burdened with all the workload. This allowed work outside the Samsung project to be accomplished by the AFD project staff.

The presentation of inspection data justifies the main role of the fire department in identifying Fire & Life safety hazards such as fire sprinkler and fire alarm problems. It also justifies Fire Department responsibilities for hazardous material systems. Due to the Fire staff entering different parts of buildings, at different times, additional hazards can be identified that most building inspectors would not have the occasion to inspect. It is interesting that the number of inspections and the number of hazards found are almost equal when comparing Fire & Life Safety with Hazmat. This corresponds with the number of pages in the 1991 Uniform Fire Code being about half fire codes and the other half hazardous material codes.

The informal opinion survey resulted in general approval by project team members about the AFD participation. There were some differences in opinion however. Question 4 concerned the amount of information provided to the designers about fire code requirements. Contractor/Construction opinion indicated that not enough was given while the Owner Employees and Consulting Engineer/Architect managers felt the amount was adequate. Question 5 concerned the amount of information about previous projects and problems that AFD provided. Again the Contractor/Consultant opinion indicated that not enough was given while the others felt AFD provided enough information. Question 8 concerned whether adequate pre-inspections were performed prior to AFD approval being requested. Once again the Contractor/Construction managers felt pre-inspections were not adequate. The Owner Employees and Consulting Engineer/Architect managers responded that pre-inspections were adequate.

These differences in opinion might be attributed to a basic conflict between designers and builders. These responses might be attributed to the Contractor/Construction managers seeing the result of design failures when AFD was not able to approve systems on the first inspection. The difference in opinion concerning pre-inspections might reflect a need for construction personnel to feel more comfortable about what is required to obtain approvals. . It also might be attributed to the Contractor/Construction managers not being privy to many of the discussions early in the project between AFD and the design managers.

Organizational Implications

Review of the results shows that the AFD staffing, policies, and participation on this fast track project have been successful. The use of a team concept in staffing such a project allowed the AFD

Fire Prevention Division to operate without any significant workload problems. Shifting and prioritizing outside work, combined with spreading the project workload kept AFD from requesting additional personnel from City Management. The success of the project team and the cooperative attitude reflected in a positive manner on the Fire Department. Another indication of this was expressed by the Samsung Austin Semiconductor Chairman, when he announced at the final meeting that Samsung had made a good decision by locating in Austin.

Recommendations

The Austin Fire Department was being asked to provide construction plan review and inspection services faster, and in more detail, than what was normally expected on other projects. The staffing and policies used for the Samsung project proved successful so no major changes are recommended for AFD. Other fire departments may not have staff with fire protection engineering and hazmat engineering capabilities. They may want to consider contracting for these services if the opportunity to participate in a fast track semiconductor project comes to their community.

The purpose of this study is to establish a template for providing fire department services needed by the semiconductor industry in completing new production facilities. An outline of Fire Code requirements and required inspections was provided during this project as a reaction rather than a proactive information exchange. In future projects, AFD should have such a document ready at the beginning of project team coordination. Later, when contractors begin participating, review of this document should be made a part of the progress meetings. While the results of the project team opinion survey are not conclusive. The conflicting responses by the managers regarding design, prior experience, and preinspects indicate that AFD might serve in a role as facilitator in communicating expectations to the designers and contractors. This might result in less problems and delays later.

It is recommended that other fire departments plan their participation carefully, as they likely will be held more accountable for success of such a project. The local demands for community development and community safety are likely to expand a fire department Chief Officer's responsibilities into business development.

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Appendix 1 - Informal Opinion Questionnaire

Austin Fire Department Questionnaire
SEMICONDUCTOR FABRICATION PLANT CONSTRUCTION

1. Check your company affiliation:

Owner Employee (Corporate)
Contractor/Construction
Consulting Engineer/Architect

2. Check your project responsibility:

Project Management
Environmental, Health or Safety
Building Construction
(Grounds, Structures, Mechanical, Electric, Plumbing, Fire Sprinklers, Fire Alarms)
Process Construction
(Tools, Chemical/Gas Storage, Chemical/Gas Piping, DI Water, Waste Treatment)

Please circle your <u>opinion</u> concerning the project design .

3. Austin Fire Department interaction with the design team was insufficient and required more time solving problems and assisting the project team.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

4. The Austin Fire Department should provide the design team additional, detailed information regarding specific Fire Code requirements.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

5. More information concerning past projects and problems was needed from AFD so that the design team could make better informed decisions.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

Please circle your <u>opinion</u> concerning the project construction.

6. Austin Fire Department personnel adequately informed contractors about items needing to be inspected and tested.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

7. Austin Fire Department personnel passed inspections frequent enough for this project.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

8. An adequate quality control pre-inspection or pre-test was performed before requesting AFD inspection.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

Please circle your <u>opinion</u> concerning Austin Fire Department project team contribution.

9. Fire Department participation improved safety on the project during construction.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

10. Safety items identified by the Fire Department were necessary for successful operation of the Fabrication Plant.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*