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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

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SUMMARY

In June 1995, the National Institute of Occupational Safety and Health (NIOSH) received a request to conduct a Health Hazard Evaluation (HHE) at Scientific Application International Corporation (SAIC), National Cancer Institute (NCI) Frederick Cancer Research and Development Center (FCRDC), in Frederick, Maryland. The request concerned an increasing number of cumulative trauma disorders (CTDs) among research technicians working in the In Vitro Cell Line Screening Project Laboratories (Building 434 and 432), commonly known as the "production labs." On August 14-16, NIOSH investigators made an initial visit to the facility and conducted an ergonomic and medical evaluation. On April 16-17, NIOSH investigators conducted a follow-up visit to evaluate changes in job risk factors since the initial NIOSH visit and to present preliminary results of the NIOSH findings.

The medical evaluation consisted of a record review of the Occupational Safety and Health Administration (OSHA) and Summary of Occupational Injuries and Illnesses Log (Form 200), workers' compensation claims (WCC), and individual medical records maintained by the on-site occupational health clinic. For employees of the production labs, informal confidential medical interviews were conducted, and a questionnaire was administered. The questionnaire ascertained data on demographics, work environment, and upper extremity musculoskeletal symptoms. The ergonomic evaluation consisted of a walk-through survey of the production labs, informal interviews of production lab employees regarding ergonomic issues related to their jobs, and videotaping production lab employees performing job tasks. Interim administrative and engineering recommendations to reduce job stressors that may cause musculoskeletal symptoms and/or disorders, were provided at the close of the first visit.

For the six-year period 1990 to 1995, SAIC experienced a total of 72 OSHA recordable cases of upper extremity "disorders due to repeated trauma," commonly known as CTDs. These 72 cases represented 552 lost work days and 1,375 restricted work days. Although the production lab employees represented less than 5% of the entire SAIC workforce, they represented 19 (26%) of the recordable CTD cases, 440 (80%) of the lost work days, and 765 (56%) of the restricted work days. In 1995, the number of production lab cases was reduced to 3 cases with no lost or restricted work days.

Forty-seven of these 72 (65%) CTD cases resulted in a workmens compensation claim. SAIC's insurance carrier accepted 44 (94%) of these claims, costing a total of $132,584, equally divided between medical and indemnity costs. The production labs were responsible for 16 (36%) of all the CTD claims, at a cost of $96,678, or 73% of all SAIC compensation costs for CTDs during this six-year time period.

Occupational health clinic records revealed CTD case medical management consistent with those suggested by the American National Standards, Incorporated (ANSI) draft standard (Z-365) (e.g., early reporting, early evaluation and treatment, follow-up, and if needed, appropriate referrals). During the same six-year time period, three employees were diagnosed with bilateral carpal tunnel syndrome and had bilateral release procedures performed.

All 43 production lab employees completed the NIOSH questionnaire. Twenty (46.5%) met the NIOSH case definition for potential work-related upper extremity (UE) musculoskeletal disorders (MSD) based on the duration or frequency of UE discomfort within the past year. The hand was the area most commonly affected (40% of employees), followed by the elbow (19%), shoulder (16%), and neck (14%). Of the 20 individuals with any UE MSD, 5 (25%) sought evaluation and treatment from a health care provider (HCP).

Ergonomic job analysis of the production labs revealed that employees in Building 434 (Drug Preparation) performed approximately 6,000 repetitive motions involving pipettes per day. Employees in Building 432 (Drug Screening) performed approximately 11,700 repetitive motions involving the pipette per day. In addition, employees in both buildings assumed awkward and static posture of the hand and thumb while activating the pipette plunger, and while extending the arm inside the biosafety cabinet to perform the pipetting operations. These repetitive motions in awkward and static postures during the pipetting tasks put employees at risk for developing UE MSD.

In 1995, several administrative and engineering controls were implemented in Building 432 (Drug Screening) to reduce employee exposure to the repetitive, awkward postures mentioned above. Specifically, more efficient drug screening protocols allowed a 30-percent reduction in laboratory pipetting operations. In addition, more work breaks (5 to 15 minutes) were scheduled during pipetting operations, and all laboratory employees were encouraged not to rush through the pipetting tasks. Engineering controls such as foot-activated pipette liquid dispensers to reduce hand fatigue, and a robot to substitute manual pipetting operations, were also implemented. These administrative and engineering controls may have, in part, resulted in the reduction in the number and severity of OSHA 200 Log CTD cases experienced by the production labs in 1995. This positive trend has continued into the first quarter of 1996.

SAIC's occupational health services recently developed an ergonomics program. This program has an on-going CTD surveillance component, which will help identify potential high-risk departments or laboratories and help evaluate the effectiveness of various engineering, administrative, and case management controls mentioned in the preceding paragraph. Other engineering controls that we recommend be implemented over time include: 1) working with the pipette manufacturer to develop more ergonomically designed pipettes which allow a more neutral posture to operate; 2) purchasing more ergonomically designed biosafety cabinets that have a) adjustable heights, b) reduced reach distances (by shortening the pleneum and downdraft grill areas), c) relocation of the cabinet motor (thereby creating leg room for the operator), and d) different biosafety cabinet tray configurations with insert pans allowing aliquot bottles and other containers to be flush with the work surface; and 3) purchasing ergonomically designed laboratory chairs with more back support.

Based on this HHE, NIOSH researchers determined that a biomechanical hazard exists from exposure to pipetting operations in the production laboratories. In April 1996, a follow-up survey found a reduction in the biomechanical hazards in the production labs due to implementation of engineering and administrative controls initiated by the occupational health services clinic. These changes, in addition to improved case management, probably resulted in a reduction in the severity of CTD cases. While there still is a risk for developing upper extremity musculoskeletal disorders among production laboratory employees, SAIC has developed an ergonomics program which has reduced the biomechanical hazards in theses labs and reduced the number and severity of CTD cases. Additional recommendations are contained in the recommendations section of this report.

Keywords: SIC 8731(Commercial research laboratories), Pipettes, Laboratory workers, Cumulative trauma disorders, CTDs, Carpal tunnel syndrome, Musculoskeletal disorders, Ergonomics

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INTRODUCTION

In June 1995, the National Institute of Occupational Safety and Health (NIOSH) received a management request to conduct a Health Hazard Evaluation (HHE) at Scientific Application International Corporation (SAIC), National Cancer Institute (NCI) Frederick Cancer Research and Development Center (FCRDC), in Frederick, Maryland. The request concerned an increasing number of cumulative trauma disorders (CTDs) among research technicians working in the In Vitro Cell Line Screening Project Laboratories. On August 14-16, NIOSH investigators made an initial visit to the facility and conducted an ergonomic and medical evaluation. On April 16-17, NIOSH investigators returned to Frederick, Maryland, to present our findings and collect additional information regarding workplace modifications.

BACKGROUND

Since 1972, the NCI has contracted with laboratories at the FCRDC to conduct basic science research. During this time, three companies have been awarded the NCI contract: Liton Bionetics from 1972 to 1982, Program Resources Institute (PRI) from 1982 to 1995, and SAIC in March 1995. Despite the change of companies, the employees and laboratories in which they work, have been the same. In 1990, PRI initiated a new project designed to test a large number of substances for the Anticancer Drug Discovery Program. This project was titled the "In Vitro Cell Line Screening Project." Two laboratories, known as the production laboratories, were responsible for this project: the Drug Preparation Lab located in Building 434, and the Drug Screening Lab in Building 432.

Drug Preparation Laboratory (Building 434)

The Drug Preparation laboratory is located in a single office in which four to seven research technicians and senior research technicians have been employed over the past five years. They receive sealed vials of organic and inorganic compounds to be tested for anti-cancer and anti-AIDS cell activity. Employees in this lab have the responsibility of preparing the compounds for use by the Drug Screening lab. Preparation basically involves weighing and placing the compounds into test tubes (Phase I) and solubilizing and diluting the compounds into various concentrations (Phase II). Both phases occur under biosafety cabinets, where approximately 36-40 drugs are prepared per day.

Specific elements of the Phase I process include:

1. Getting an empty, sterile test tube from a package, applying a label, and weighing of the test tube on a scale.
2. Removing the test tube from the scale, and removing the cap.
3. Scooping approximately 20-40 mg of drug compound from 2.5-milliliter glass vial containers with a small laboratory spatula and adding the compound to the test tube.
4. Recapping the test tube and weighing the filled test tube again.
5. Removing the test tube from the scale, marking the weight on the label of the test tube, and placing the tube in a test tube rack.

The cycle time for elements 1-5 is approximately 90 seconds. Additional duties include preparing drugs for secondary testing, and filing and recording data sheets.

Specific elements of the Phase II process include:

1. Recording the weight of the test tube (from Phase I) on a data sheet, and calculating volume of solution to be added to the test tube.
2. Preparing report numbers unique to the compound series.
3. Removing the test tube cap.
4. Adding dimethylsulfoxide (DMSO) solution by pipette to the test tube.
5. Retrieving racks of glass vials with anti-cancer and anti-AIDS compounds from the freezer;

6. Adding small amount of compound to test tube.
7. Recapping the test tube.
8. Using a vortex to dissolve the compounds into solution.
9. Using a sonicator to break up any remaining particles.
10. Uncapping 2-3 vials and transferring aliquots of compound solution to the 2-3 vials.
11. Recapping vials, labeling them, and putting them in the freezer, to be shipped to the in vitro laboratory.

The cycle time to prepare each compound ranges from 2 to 4 minutes depending on solubility of the experimental compound into DMSO. The total time spent at the hood is 1 to 2 hours per day. Another, infrequent biosafety cabinet activity includes anti-AIDS screening, which involves pipette aliquoting solution to compounds in glass vials to check for pH and precipitation. The balance of the day is occupied by weight calculation time, computer time, and printout of bar code labels for experimental compounds.

Drug Screening Laboratory (Building 432)

The drug screening laboratory is located in four offices (two on the first floor and two on the second floor) of Building 432. Since 1990, the four offices have employed between 34 and 43 research technicians and senior research technicians. The drug screening process consists of seven steps:

Tumor Cell Culture

Several tasks are involved in this step. These include: 1) the removal of culture media by aspiration vacuum and manual pouring, 2) rinsing via pipette, 3) addition of tyrpsin/EDTA via the Stripettor®, 4) media addition via the Stripettor®, 5) cell passage via a Strippetor® into flasks for cell culture. Each research technician typically processes three to nine cell lines on Thursday and Friday mornings.

Tumor Cell Line Inoculation

Three to four tumor cell lines are grown in flasks with culture media. The cells are aspirated from the flasks with a pipette (Strippetor®) to perform cell counting and dilution. Plating of the diluted cells onto a 96 well tissue culture plate is performed using the Electronic Electrapette® or manual Titertek®. Research technicians typically perform this step on Monday and Tuesday mornings.

Drug Addition

Serial dilutions are made of each drug using the Strippetor®. Once diluted, the drugs are dispensed onto the cell plates with an 8- or 12-channel Costar® pipette. Drug addition is typically performed on Tuesday and Wednesday afternoons.

In-Situ Fixation

To fix the tumor cells onto the culture plates, trichloroacetic acid is added to the well plates using the Electrapette or Titertek. After one hour, the TCA is removed by aspiration. Each plate is hand washed/rinsed three to four times, then tapped and/or blotted. In-situ fixation is typically performed on Thursday and Friday afternoons.

Staining

Twice a week staining of the drug-treated cells is performed. Stains are added to the 96-well plates via the Costar Transtar® pipette. The stain is removed automatically by the Denley 5000® or Biotek plate washer. After staining, all plates are manually tapped on a blotter to remove the excess liquid.

Stain Solubilizing

One hundred microliters of TRIS buffer solution is added to the wells via the Denley 5000® or manually via the Titertek.

Reading the Results

The 96-well plate is placed on a plate "reader," which measures the tumor cell activity. These results are manually entered into a database by the technician using a computer keyboard.

Figure E-1 shows the primary drug evaluation laboratory's in-vitro screening project's weekly work schedule as of April 1996.

METHODS

The HHE request focused on biomechanical hazards and resulting CTDs in the production laboratories. This concern was based on management and employees reports of potential musculoskeletal hazards and several CTD cases among research technicians in these labs.

Medical

Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200)

Since 1990, the SAIC OSHA 200 Logs have been maintained in a computerized database by a registered nurse located in the occupational health services clinic. For the years 1990 to 1995, this database was reviewed for cases of cumulative trauma disorders (CTD). From this database, a subset of upper extremity (UE) CTDs were analyzed. For this same six-year time period, the personnel department generated employee hours for the production laboratories, for all other departments, and for all SAIC employees. Incident rates were calculated as the number of UE CTD cases divided by the number of employees hours, expressed per 100 full-time-workers (ftw) per year.

Workers' Compensation Claims

For this same six-year period 1990 to 1995, SAIC's workmen's compensation insurance carrier provided claims data for UE CTDs. Actual and anticipated medical and indemnity costs were extracted for this six-year period. We will report the mean and median costs for these cases.

Occupational Health Services Clinic Records

The individual medical records of cases of UE CTD identified by the OSHA 200 Logs were reviewed by the NIOSH medical officer. This review was conducted in a qualitative manner to ascertain the appropriateness of the evaluation, treatment, referral, and follow-up.

Questionnaire

A questionnaire was administered to all 43 production lab employees. The questionnaire collected information on demographics, potential psychosocial stressors, and symptoms of upper extremity musculoskeletal (MS) discomfort. The criteria defining a potential work-related UE MS disorder are:

- Symptoms of pain, aching, stiffness, burning, tingling, or numbness, and
- Symptoms occurred within the past year, and
- No previous accident or trauma to the symptomatic joint area, and
- Symptoms began after employment with SAIC, and
- Symptoms occurred on the current job, and
- Symptoms lasted for more than 1 week, or occurred at least once a month.

This definition, although not validated, has been used, in other NIOSH HHEs [Burt 1990; Baron 1992, Hales 1994, Bernard 1994, Hoekstra 1995, Baron 1996].

In addition, the questionnaire contained questions about the physical work environment and the psychosocial work environment. The psychosocial

component of the questionnaire contained 16 questions grouped into the following categories: 1) work demand/control factors, 2) workplace social support, 3) career and job security, 4) job satisfaction, and 5) absenteeism. All responses were scored on a five-point scale: 1=strongly disagree, 2=moderately disagree, 3=neither agree nor disagree, 4=moderately agree, and 5=strongly agree. All "don't know" responses are excluded from the analysis, and mean scores are reported. The questions were worded such that higher scores are the more desirable from the psychosocial stress perspective.

Ergonomic

The ergonomic evaluation consisted of a walk-through survey of the production labs; including informal interviews of production lab employees regarding ergonomic issues related to their jobs, and videotaping production lab employees performing job tasks. Interim administrative and engineering recommendations to reduce job stressors that may cause musculoskeletal symptoms and/or disorders were provided, and their effectiveness assessed on the follow-up visit.

Job Analysis

Videotapes of representative workers performing their jobs in the laboratories were analyzed at: a) regular speed to determine job cycle time, b) slow-motion to determine musculoskeletal hazards to the upper limbs, and c) stop-action to sequence job steps and perform evaluations of working postures. All of these video analysis procedures were used to assess potential musculoskeletal hazards while performing job tasks. Time and motion study techniques were used for the first phase of job analysis [Barnes 1972]. Work methods analysis was used to determine the work content of the job.

The second phase of job analysis was to review the job for recognized occupational risk factors for work-related UE MSD. These risk factors include repetition, force, posture, contact stress, low temperature, and vibration [Putz-Anderson 1988]. This two-phase approach for job analysis and quantification of forces which act upon the body during materials handling forms the basis for proposed engineering and administrative control procedures aimed at reducing the risk for musculoskeletal stress and injury.

Follow-up

A follow-up evaluation was conducted April 16-17, 1996, to assess control measures taken to reduce the biomechanical hazards, and thereby reduce the risk of musculoskeletal stress and injury.

EVALUATION CRITERIA

Upper Extremity Musculoskeletal Disorders (or Cumulative Trauma Disorders)

In 1717, Ramazini noted the relationship between musculoskeletal disorders and "certain violent and irregular motions and unnatural postures of the body" [Bernardo Ramazini 1717]. However, it was not until the 1970s that a large number of epidemiologic studies examined the relationship between job risk factors and musculoskeletal disorders. Several recent publications have reviewed this literature and concluded that the vast number of studies support an association between various UE MS disorders and (1) repetitive movements of the upper limbs; (2) forceful grasping or pinching of tools or other objects by the hands; (3) awkward positions of the hand, wrist, forearm, elbow, upper arm, shoulder, neck, and head; (4) direct pressure over the skin and muscle tissue, and (5) use of vibrating hand-held tools [Stock 1991, Gordon 1995, Kuorinka and Forcier 1995, Riihamki 1995]. Occupations at risk for work-related UE MS disorders include meatpacking employees, automobile manufacturers and assemblers, electrical assemblers, metal fabricators, garment makers, food processors, grocery checkers, typists, musicians,

housekeepers, and carpenters. Laboratory technicians have been reported to be in this "at risk" group due to their performing repetitive movements and static postures [Bjorksten 1994].

Although not one of the most common disorders in terms of number of cases, carpal tunnel syndrome (CTS) is one of the most familiar and recognized work-related UE MS disorder. CTS is a neurological disorder of the wrist that can be caused, precipitated, or aggravated by repetitive, awkward postures and forceful motions [Feldman 1983]. CTS symptoms may include pain, numbness, and weakness of the hand, as a result of compression or irritation of the median nerve as it passes through the carpal tunnel at the wrist. The diagnosis is suggested by the quality and distribution of hand symptoms and confirmed by electrodiagnostic studies. In the vast majority of cases, CTS can be managed with conservative measures, such as wrist immobilization (wrist splints), nonsteroidal anti-inflammatory medications (aspirin, ibuprofen, etc), and a reduction in activities that precipitate symptoms. However, these treatments may be unsuccessful unless work-related risk factors are identified and controlled. Engineering controls are the preferred control measures, followed by administrative controls, such as work enlargement, job rotation, worker training, rest pauses, etc. Without early intervention, CTS can lead to severe discomfort, impaired hand function, and disability.

RESULTS

Medical

OSHA 200 Logs

For the six-year period 1990 to 1995, SAIC recorded a total of 72 cases of upper extremity "disorders due to repeated trauma" on the OSHA 200 Logs, for an average incidence rate of 1.0 per 100 full-time-workers (ftw) per year (Table M-1). The number of cases jumped dramatically in 1993, then leveled off (Figure M-1). The production labs accounted for 19 (26%) of the cases, yet only represented less than 5% of the workforce. Therefore, when CTD incidence rates were calculated, the production labs had a rate nine times that of other SAIC departments (Figure M-2).

The 72 CTD cases represented 552 lost work days and 1,375 restricted work days. Fifty-five of these 72 cases (76%) had no lost work days (range 0-272). For the 17 cases with lost work days, the mean was 33 [standard deviation (SD) = 69 days]. Thirty-three of these 72 cases (46%) had no restricted work days (range 0-182). For the 39 cases with restricted work days, the mean was 35 (SD = 44days).

The production labs were responsible for 80% of the lost work days and 56% of the restricted work days (Table M-1). In 1995, however, there were no lost or restricted work days in the production labs and there was a reduction in number of CTD cases (Table M-1).

Workers' Compensation Claims

Forty-seven of the 72 (65%) CTD cases filed for workmen's compensation. SAIC's insurance carrier accepted 44 (94%) of these claims, costing a total of $132,584 (Table M-2). This cost was equally divided between medical and indemnity costs. Twelve of these 44 claims (27%) had no medical costs; the remaining 32 claims had medical costs up to $11,049, with a mean of $2,059 (SD=$2,477). Thirty-four of the 44 claims (77%) had no indemnity costs; the remaining ten claims had indemnity costs up to $37,903 with a mean of $6,670 (SD=$11,724).

The production labs were responsible for 16 (36%) of all the CTD claims, at a cost of $96,678, or 73% of all SAIC compensation costs for CTDs.

Occupational Health Clinic Records

Occupational health clinic records revealed management consistent with those suggested by the American National Standards, Incorporated (ANSI) Z-365 draft standard for the "Control of Cumulative Trauma Disorders" [ANSI 1996]. This standard emphasizes early reporting, early evaluation and treatment, follow-up, and if needed, appropriate referrals. During the same six year time period, three employees were diagnosed with bilateral carpal tunnel syndrome and had bilateral release procedures performed.

Questionnaires

Musculoskeletal Disorders

All 43 production lab employees completed the NIOSH questionnaire. Twenty (47%) met the NIOSH case definition for potential work-related UE MS disorders. The hand was the area most commonly affected (40% of employees), followed by the elbow (19%), shoulder (16%), and neck (14%). Of the 20 individuals with any UE MSD, 5 (25%) sought evaluation and treatment from a health care provider (HCP).

Work Environment

Employee assessments of the physical and psychosocial work environment are listed in Tables M-3and M-4. All scores for the physical work environment were above 3.0. Work area cleanliness and lighting were given particularly high ratings (mean 4.5 and 4.6 respectively). Most of the scores of the psychosocial factors were above 3.0, but a few factors were given a rating of 2.0 or less. These low scores suggest that the sedentary (mean 1.3), monotonous, repetitive nature of the jobs (mean 0.3), combined with few opportunities for advancement (mean 2.0) are factors that are of concern to production lab employees. While the mechanism between psychosocial factors and MSD remains to be elucidated, several studies have noted a relationship [Hales 1994, Bongers 1993]. On the positive side, job expectations were very clear (mean 4.7), and the workload was reasonable (mean 4.1).

Employees in the Drug Screening lab (Building 432) were asked to assess the physical and mental demands of their six job tasks using the same 1-to-5 scale (Table M-5). Drug addition was considered the most physically and mentally demanding (mean 4.0 and 3.2, respectively). Staining was considered the least physically and mentally demanding (mean 2.7 and 2.0, respectively).

Ergonomic Results

Drug Preparation Laboratory (Building 434)

Drug preparations laboratory technicians make approximately 6,000 hand manipulations involving pipettes per shift. Ergonomic stresses associated with specific elements of Phase I and Phase II job tasks are listed in Tables E-1a and E-1b.

Drug Screening Laboratory Technicians (Building 432)

Drug screening laboratory technicians make approximately 11,750 hand manipulations involving pipettes per shift. Ergonomic stresses associated with specific elements of are listed in Table E-2. Figures E-2 and E-3 illustrate the awkward and sustained postures during the pipetting tasks. The extended reach of approximately 14 - 16" to perform pipetting tasks in the biosafety cabinet is needed because the design of the cabinet has an 8" plenum (which also serves as an arm railing) and a 6" downdraft slot (see Figure E-1) at the front. Laboratory tasks involving UE ergonomic stresses include the high repetition in "plating" the cell cultures, ulnar flexion of the wrist during pipetting, prolonged static posture of the closed hand around the pipette, extended thumb over the pipette plunger, and the use of a forceful pinch posture during ejection of the pipette tips (Figure E-4).

During the initial NIOSH visit, the laboratory hood was evaluated for ergonomic hazards, and several were identified.

- The arm has to be in extended position to perform pipetting tasks. This extended static posture may cause fatigue in the shoulder, as blood demand is high, but blood circulation in the static posture is low (Figures E-5 and E-6).

- The metal bar on the glass sash of the hood may cause awkward postures, as the sight line of the laboratory worker may be disrupted. The laboratory worker has to look over or under the bar to see some of the pipette work, and this may cause discomfort (Figure E-6).

- Leaning forward to see pipetting work results in the lack of lumbar and neck support and can lead to fatigue and muscle discomfort (Figures E-6 and E-7).

- The work surface crowded with cell plates causes an awkward posture and extended reach. (Figure E-7). Use of a stainless steel turntable for cell plates can be used to place finished plates and rotate them away from immediate work area.

- Knees must be spread because of lack of knee space below hood. The lack of opportunities to change this posture while working at the hood can lead to leg and back fatigue and possible cramping (Figures E-5, E-7, and E-8).

- The laboratory technicians lean their fore arms on the front edge of the laboratory hood. Contact with cold surfaces such as this has been associated with MSD (Figures E-5 and E-7).

- The non-adjustable hood can cause posture discomfort for most laboratory workers as they have to "fit" around the hood, rather than the hood being adjusted to fit them. Also, the bottom of the biosafety cabinet may cause a pinch point for the upper leg (Figure E-7 and E-
The follow-up survey conducted in April 1996 found a process change and a number of administrative controls had been instituted. One of the most significant was a process change in the testing protocol, resulting in a 30% reduction in pipetting tasks. This reduced the repetitive motions in the drug preparation lab from approximately 6,000/day/worker to 4,200/day/worker. For the drug screening, the repetitive motions were reduced from 11,700/day/worker to 8,190/day/worker. This reduction in the number of repetitions per day also allowed more recovery time between experiments and encouraged better self-pacing as pipetting was done. Lab technicians were also encouraged to take more frequent, but shorter work breaks throughout the day, and a more frequent job rotation program was implemented. Engineering controls were also implemented, such as more foot-activated pipette dispensing units, and a robot to perform some of the same drug screening tasks as the laboratory technicians.

DISCUSSION

In the study of laboratory technicians, Bjorksten et al. (1994) found that when laboratory technicians pipetted for more than 300 hours per year there was a significant increase in risk of hand and shoulder ailments. At SAIC, pipetting in the production labs exceeded 500 hours/year (i.e., 2 hours/day x 5 days/week x 50 weeks/year) for most of these technicians. Considering the number of pipette activities per day, approximately 1,500,000 and 2,925,000 repetitions per year occurred for the average laboratory technician in the drug prep and drug screening areas, respectively. [These rates were determined from SAIC internal evaluations and the NIOSH job evaluation in August 1995.] Based on the exposure time, workload, and number of repetitions performed by the production laboratory technicians, it is logical to attribute work-related UE symptoms to the biomechanical stresses encountered on the job.

Between the two NIOSH visits, several administrative, process, and engineering control changes had been instituted. The most important was the reduction in the number of laboratory pipetting operations in the production laboratories

(450,000 and 877,500 less pipetting activities per year per laboratory technician for the drug prep and drug screening production laboratories, respectively). As mentioned earlier, much of this was brought on by more efficient drug testing protocols (i.e., less replicate sampling, and focusing on drugs that inhibited specific tumor cell growth). In addition, an improvement in the work-rest cycle occurred due to the more frequent rest breaks and job rotation. The foot-activated pipette dispensing units and a robot to perform some of the same drug screening tasks as the laboratory technicians were engineering improvements.

While there was a reduction in ergonomic stresses for the production technicians, it is important to note that the development and implementation of an ergonomics program is needed to achieve long-lasting results. In addition to the above mentioned administrative and engineering controls, a control program will encourage those responsible for its administration not only to have better medical management of workers, but to work with suppliers of pipettes and biosafety cabinets to design better products which improve work efficiency and reduce work-related MSD. In 1995, SAIC's occupational health services developed an ergonomics program. This program has all the elements of a comprehensive program (listed below for emphasis).

Ergonomic Control Program Guidance

The first step in forming an ergonomics team is to make sure all personnel resources in the plant are represented, including management, labor, engineering, medical, and safety personnel. The team establishes a training schedule in which an outside expert, familiar with the plant operations, teaches ergonomic principles to management and workers.

Over time, medical surveillance is used to determine the effectiveness of the ergonomic interventions. Medical surveillance can be active or passive. Active surveillance is usually conducted by administering standardized questionnaires to workers in problem and non-problem jobs. Passive surveillance is conducted by examining medical injury or illness records, such as OSHA 200 Logs, workers' compensation reports, and attendance records for absenteeism. Analysis is done on both approaches to identify patterns and changes over time.

Decreases in the incidence and severity of musculoskeletal disease and injury serve as one measure of success. Increases in productivity and product quality serve as another. In many instances, workers' awareness of their musculoskeletal disease and injuries will show an increase in incidence rates early in the ergonomics program. However, as the program matures, both incidence and severity usually decrease. The length of time required to observe such effects can be a function of the company resources, worker participation, company size, corporate culture, and type of product produced. On average, it takes 2 to 3 years before "real" effects are seen. The two most important lessons learned from ergonomics programs are: 1) It should not be created as an entity separate from the mission of the facility. Rather it should be woven into existing programs such as safety and medical programs; and 2) The ergonomics program must be sustained, as it is an iterative process that incorporates the philosophy of continuous improvement, transfer of technologies from one department to another, and documentation of ergonomic success and failures.

CONCLUSIONS

NIOSH researchers determined that a biomechanical hazard existed from exposure to pipetting operations in the production laboratories at SAIC. In April 1996, a follow-up survey found a reduction in the biomechanical hazards in the production labs due to implementation of engineering and administrative controls initiated by the occupational health services clinic. These changes, in addition to improved case management, probably resulted in a reduction in the number and severity of CTD cases. While there still is a risk for developing upper extremity

musculoskeletal disorders among production laboratory employees, SAIC has developed a comprehensive ergonomics program, which has reduced the biomechanical hazards in theses labs, as well as the number of CTD cases.

RECOMMENDATIONS

Organizational

1. Develop a written ergonomics program which includes the following components: surveillance, management of CTD cases, job analysis/design, training and education of workers and management, implementation of controls, and feedback from the workforce on the effectiveness of controls. Consider using self-directed work teams in each department after ergonomic training to discuss hazardous jobs, and to discuss solutions using ergonomic controls. Develop a budget for purchasing controls and compose a time line for when the controls will be implemented. To document hazards, and the effectiveness of controls, the worker's jobs may be videotaped before and after ergonomic changes are implemented. The videotape can be used as an orientation for new employees and for other departments as a place to begin their own program. Evaluating medical surveillance records for changes in the incidence and severity in various departments is one mechanism by which to evaluate the success of ergonomic interventions. Injury and illness rates should be standardized with respect to production rates, time of year, and age and gender of workforce.

Engineering and Administrative

Pipetting

1. Retrofit pipette with pippetor adaptor using a finger trigger strip, rather than thumb activation (Figure E-9). Another option is to work with pipette manufacturers to redesign the pipette to have the ergonomic aspects designed as shown in Figure E-9.

2. Because of high pinch grip forces of the thumb and index finger to release used pipette tips from the multichannel pippetor, a tip removal and disposal unit should be developed, such as that shown in Figure E-10. This will reduce the forceful motions and awkward postures required to release the pipette tips with the manual multi-channel pippetor.

3. Make available more pipette foot switches and foot stools to give workers the option of performing pipette functions with their hand or foot. For employees that prefer the pipette liquid dispensing unit foot switch (Figure E-10), an adjustable foot rest with imbedded pipette switch should be installed at their work stations (Figure E-11). For newer biosafety cabinets that have leg room, a device similar to the one shown in Figure E-12 may be fabricated by the maintenance department.

4. Because the left hand is used to hold multiple cell plates (Figure E-2 and E-3), the hand should hold no more than 3 cell plates at one time. Holding up to 6 plates at one time increases the biomechanical load and prolongs static and awkward postures of the hand.

5. Encourage micro-breaks of 2 minutes for every 20 minutes of pipetting. Mild hand exercises (per physical therapist's instructions) are beneficial.

6. Clean pipettes on a scheduled basis. This reduces "sticking" and improves the quality of work.

Biosafety Cabinets

1. To reduce the technician's forearm contact with the cold front metal edge of the biosafety cabinets, padding should be taped on the front edge away from the downdraft as shown in Figure E-13. Bubble pack can be purchased from market vendors and modified by cutting the material into strips 8" wide x 2' long, heat sealing the edges, and taping them down for better fit and comfort (Figure E-14).

2. New biosafety cabinets which address the issues below should be purchased as time and financial

resources allow. Desirable features for the new safety cabinets include:

- A hinged forearm rest so technicians can get closer to the work platform inside the biosafety cabinet;
- A perforated front grill reduced by 1 to 2 inches to bring the work platform closer to the end.

- Non-glare glass on the sliding window and/or adjustable plexiglass barriers;

- Arm support slings mounted on roller track, with counter balancers inside in the front edge of the biosafety cabinet;

- Closed-cell silicone padding or "bubble pack" strips for forearm support;

- Adjustable height (hand-crank or hydraulic lift);

- Foot rests with imbedded foot switches;

- Optional biosafety cabinet platform configuration with "wells" for placement of tall containers. Tall containers that hold dispensed pipettes cause the technician to assume awkward postures to dispense pipettes (Figure E-15). The base of the work area should be designed for easy installation of a flat platform when wells are not needed.

3. Other Cabinet Issues

- A circular turn table on ball bearings to store equipment. This can help keep the work area from becoming crowded with laboratory equipment. By rotating the plate, the equipment can be within easy reach, thereby reducing awkward postures.

- Where possible, remove doors off the bottom of laboratory hoods (such as the chemical hood) to allow more leg room.

Cell Plate Preparation

Manually "tamping" cell plates to remove excess moisture is done by mildly violent and irregular motions of the hand and forearm. More disposable towels can be stacked on top of each other to pad the contact surface and reduce the shock to the hands as the excess moisture is removed. An option is to use an air blower (such as the ones used in rest rooms to dry hands). The plates can be mounted on drying racks and positioned in front of the air blower. The option of an electronic eye will allow a no hands operation for drying the plates.

Encourage increased use of the Beckman Biomek 2,000. While slower, it could be used by laboratory workers on restricted duty for UE MSD.

Drug Preparation Lab

1. Use new plastic vials with fewer threads. This will reduce twisting motions during capping and uncapping lids.

2. In the drug preparation area, the glass vials containing anti-cancer and anti-aids compounds are sealed with a drop of "hot melt" glue. A razor knife should be used to cut through the glue. Alternatively, use of two soft grip pliers (one to grip the cap, the other to grip the base) could be used to break the seal and remove the cap from the vial. Another option is to make a small "socket tool" to break the vial seal.

Other

1. Anti-fatigue mats can be used to reduce lower extremity discomfort associated with standing at reading stations.

2. Obtain adjustable-height laboratory chairs with low-back-support (i.e., back rests that rotate in and out as well as up and down).

3. Consider upgrading computer and office equipment with ergonomic design in mind. Testing

equipment from vendors and evaluating such equipment should be considered before purchasing.

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Table M-1: Cumulative Trauma Disorder (CTD) Cases, Incidence Rates, Lost and Restricted Work Days by Employee Group: 1990-1995
SAIC, Frederick, MD
HETA 95-0294-2594

	1990	1991	1992	1993	1994	1995	TOTAL
CTD Cases							
Other SAIC*	0	2	2	12	20	17	53
Production Lab**	2	1	2	6	5	3	19
TOTAL - All SAIC	2	3	4	18	25	20	72
CTD Incidence Rate***							
Other SAIC	0	0.2	0.2	1.0	1.7	1.5	0.8
Production Lab	5.1	2.4.	4.3	11.9	10.1	7.1	7.0
TOTAL - All SAIC	0.2	0.3	0.4	1.5	2.1	1.7	1.0
Lost Work Days							
Other SAIC	0	53	0	23	9	27	112
Production Lab	0	3	144	281	12	0	440
TOTAL - All SAIC	0	56	144	304	21	27	552
Restricted Work Days							
Other SAIC	0	175	5	179	169	82	610
Production Lab	10	111	255	191	198	0	765
TOTAL - All SAIC	10	286	260	370	367	82	1375

* Other SAIC = Scientific Application International Corporation employees excluding those employed in the production labs.

**Production Lab=Employees in Buildings 432 and 434.

***Incidence rate is calculated per 100 full-time-workers.

Table M-2: Workmen' Compensation Claims (WCC), Indemnity and Medical Costs for Cumulative Trauma Disorder (CTD) by Employee Group: 1990-1995
SAIC, Frederick, MD
HETA 95-0294-2594

	1990	1991	1992	1993	1994	1995	TOTAL
WCC							
SAIC*	0	1	1	9	10	7	28
Production Lab**	2	1	2	5	5	1	16
TOTAL - All SAIC	2	2	3	14	15	8	44
Indemnity Costs (in $)							
SAIC	0	2,400	0	5,304	505	1,699	9,908
Production Lab	0	0	42,153	13,940	694	0	56,787
TOTAL - All SAIC	0	2,400	42,153	19,244	1,199	1,699	66,695
Medical Costs (in $)							
SAIC	0	6,215	0	7,866	5,417	6,500	25,998
Production Lab	898	5,565	10,878	15,295	6,787	468	39,891
TOTAL - All SAIC	898	11,780	10,878	23,161	12,204	6,968	65,889

* SAIC = Scientific Application International Corporation employees excluding those employed in the production labs.

**Production Lab=Employees in Buildings 432 and 434.

Table M-3. Physical Work Environment
SAIC, Frederick, MD
HETA 95-0294-2594

Question	Mean Score*	Std. Dev.**
Work area is clean	4.5	0.7
Work area is quiet	3.2	1.3
Air quality if comfortable (temperature, circulation, moisture, odors)	3.1	1.4
Work area is well-lit	4.6	0.7
Work space is appropriate to the job	3.7	1.2

* See text.

** Standard Deviation.

Table M-4. Psychosocial Work Environment
SAIC, Frederick, MD
HETA 95-0294-2594

Question	Mean Score*	Std. Dev.**
Social Support		
Employees cooperate with/support each other	3.8	1.1
There are effective communication channels between managers and workers	3.8	1.2
Managers recognize employee contributions	3.5	1.3
Work Demands/Control		
Work is not sedentary	1.3	0.4
Work is non-strenuous	2.3	0.9
Work is not monotonous or repetitive	0.3	0.1
Work is mentally demanding	2.7	0.9
Workers have control over the work process	3.5	1.1
Resources for performing work are adequate	3.9	0.9
Job expectations are clear	4.5	0.7
Workload is reasonable	4.1	1.0
Workers have input in how their jobs are done	3.7	1.1
Career/Job Security		
Workers have opportunities for advancement	2.0	1.1
Job security is good	2.9	1.1
Job Satisfaction		
Workers are satisfied with their jobs	3.1	0.9
Absenteeism		
Absenteeism does not seem high	2.7	0.9

* See text.
** Standard Deviation.

Table M-5. Physical and Mental Demands for Drug Screening Job Tasks (N=34) SAIC, Frederick, MD HETA 95-0294-2594

Job Tasks	Physically Demanding	Mentally Demanding
Cell Preparation	2.7	3.0
Tumor Cell Inoculation	3.7	3.1
Drug Addition	4.0	3.2
In Situ Fixation	3.6	2.2
Staining	2.7	2.0
Stain Solubilizing	2.8	2.3

Table E-1a: Drug Preparation Laboratories (Bldg. 434) - Phase I Basic Work Elements and Potential Risk Factors for Musculoskeletal Disorders
SAIC, Frederick, MD
HETA 95-0294-2594

Basic Work Elements - Phase I	Potential Ergonomic Stresses
1. Getting an empty, sterile test tube from a package, applying a label, and tearing the weight of the test tube on a weigh scale.	None apparent.
2. Removing the test tube from the scale, and removing the cap.	None apparent.
3. Scooping approximately 20-40 mg of drug compound from 2.5-milliliter glass vial containers with a small laboratory spatula and adding the compound to the test tube.	Pinch posture of right and left hand while scooping compound from container and holding vials (UE-CTD risk for this activity is low).
4. Recapping the test tube and weighing the filled test tube again.	Forceful pinch posture in recapping the test tube (UE-CTD risk for this activity is low).
5. Removing the test tube from the scale, marking the weight, on the label of the test tube, and placing the tube in a test tube rack.	None apparent.
The process is then repeated. The cycle time to do this is approximately 90 seconds. Additional duties by this technician include preparing drugs for secondary testing, and filing and recording data sheets.	Filling and recording data sheets may be time consuming and may aggravate a UE-CTD.

Table E-1b: Drug Preparation Laboratories (Bldg. 434) - Phase II Basic Work Elements and Potential Risk Factors for Musculoskeletal Disorders
SAIC, Frederick, MD
HETA 95-0294-2594

Basic Work Elements - Phase II	Potential Ergonomic Stresses
1. Recording the weight of the test tube compound from the first technician on a data sheet, and calculating how much volume of anticancer or antiaids compound to add to the test tube.	Potential writer's cramp if a lot of documentation is done.
2. Preparing report numbers that are unique to the this compound series.	Potential for writer's cramp if a lot of documentation is done.
3. Removing the cap.	Pinch posture to remove cap. If cap is sealed with glue this can involve high forces for the hands. (UE CTD risk factor potentially high).
4. Adding dimethylsulfoxide (DMSO) solution by pipette to the test tube.	Awkward posture of right hand and thumb in pipetting solution. Left hand sometimes used to hold tube.
5. Putting cap back on	Pinch posture. (UE CTD risk factor is low).
6. Putting the test tubes in a vortex to mix up the compound into solution.	None apparent.
7. Then putting the test tube in a sonicator to break up any little particles.	None apparent.
8 . Getting a rack of glass vials with anticancer and antiaids compounds from a freezer.	None apparent.
9. Uncapping the 2-3 vials and transfers aloquats of compound to the 2-3 vials.	Pinch posture to remove cap. If cap is sealed with glue, this can involve high forces for the hands. (UE CTD risk factor is high).
10. Recapping vials, making sure they are properly labeled, and putting them in the freezer, to be shipped to the in vitro laboratory.	Pinch posture. (UE CTD risk factor is low).
The process is then repeated.	
The cycle time to prepare each compound ranges from 2 to 4 minutes depending on solubility of the compound into solution. The total time spent in the hood is 1 - 2 hours per day. Other, but infrequent laboratory hood activities include anti-AIDS screening, which involves pipette aliquoting solution to compounds in glass vials to check for pH and precipitation.	Job is not highly repetitive, but fatigue can occur if laboratory technician does not take 1-2 minute breaks every 20 minutes.

Table E-2: Drug Screening Laboratories (Bldg. 432) - Basic Work Elements and Potential Risk Factors for Musculoskeletal Disorders SAIC, Frederick, MD HETA 95-0294-2594

Basic Work Elements	Potential Ergonomic Stresses
1. Uses right and left hand to manually uncap small container and fills trough with media and cells.	Pinch posture with fingers to remove lid from container. (UE CTD risk factor is low).
2. The media and cells are drawn up into the multi-channel pipette with right hand (enough media to fill about 4 plates with two lines of cells).	Static arm and hand posture to draw up media and cells. (UE CTD risk factor is high).
3. The 100 microliters of media and cells are then dispensed with the right hand into each of the plate cells. The left lifts and holds the plates after the media has been added to the cell lines.	Awkward and static posture of arm, wrist, and hand (especially thumb) to dispense media and cells into plates. Left hand used to hold stack plates while media and cells are added to plate cells.
4. The process is repeated until all 64 plates have the media and cells added to them.	Repetition of step 3 above, involves combination of awkward and static postures to perform pipetting activity over time.

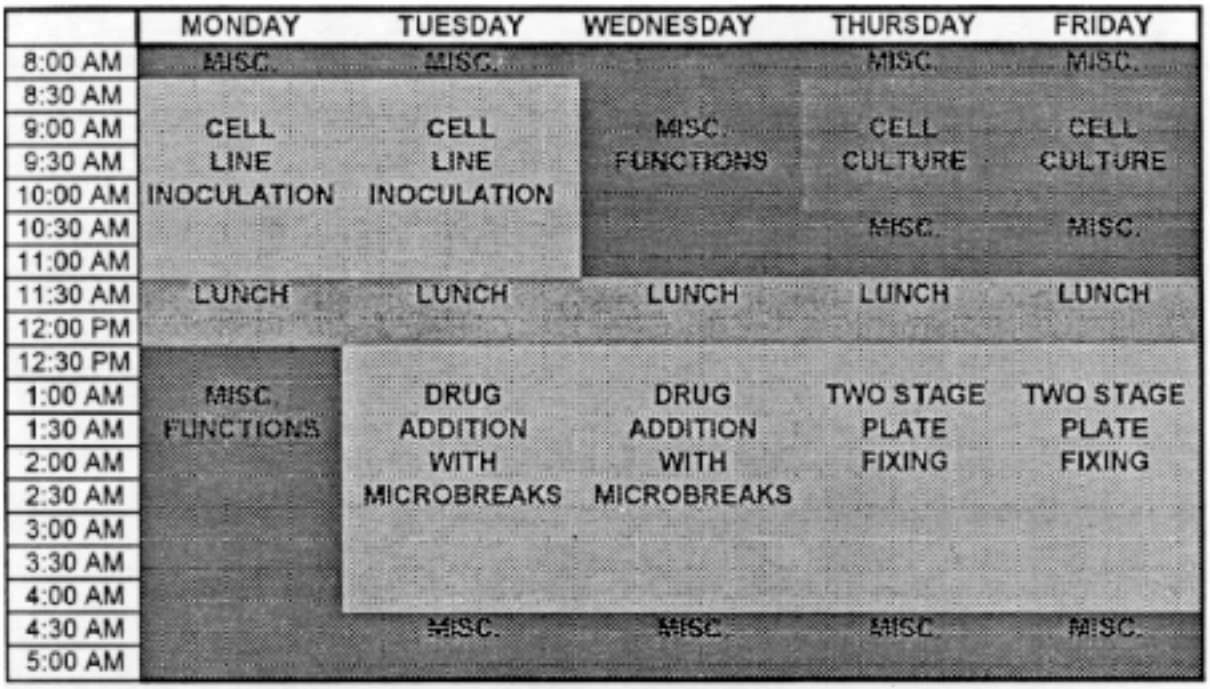

Figure E-1: The primary drug evaluation laboratory's in vitro screening project's weekly work schedule.
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HETA 95-0294-2594

Figure E-2: Lab technician dispensing aloquots of media and cells into cell plates with multi-channel pipette. Note the awkward, static posture of the right hand to dispense the liquid and the left hand used to stack and hold cell plates.
SAIC, Frederick, MD
HETA 95-0294-2594

Figure E-3: Lab technician dispensing media and cells into plates. Note the extended reach with right arm to perform this activity due to 8" slot ventilation in front edge of biosafety cabinet.
SAIC, Frederick, MD
HETA 95-0294-2594

Figure E-4: Lab technician manually ejects pipette tips from this multi-channel pipette.
Note, to perform this task high pinch forces are needed to eject the tips, especially if the walls of the plastic tips are thick.
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HETA 95-0294-2594

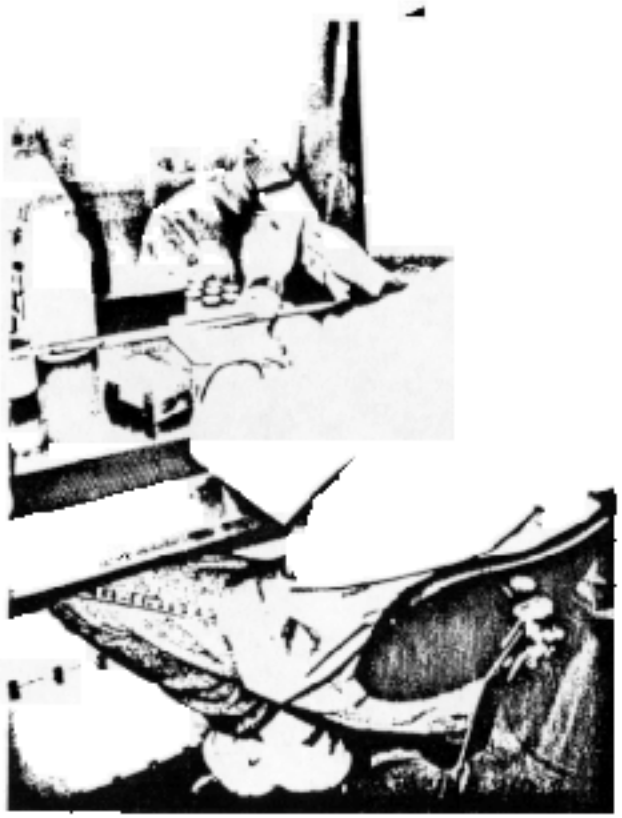

Figure E-5: Lab technician has to sit in awkward postures because there is no leg room below work surface for legs.
SAIC, Frederick, MD
HETA 95-0294-2594

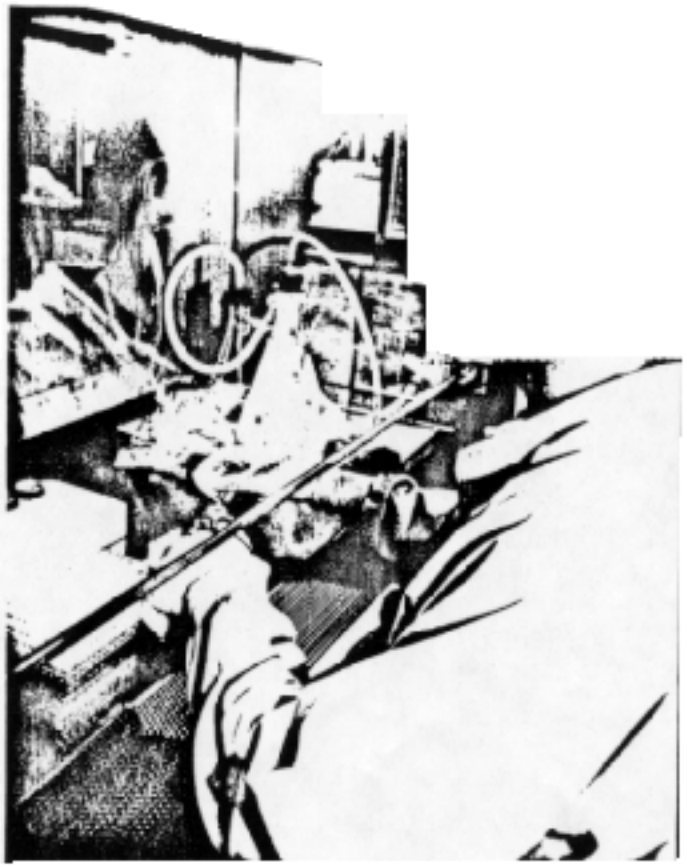

Figure E-6: Metal bar on bottom edge of glass sash causes visual sight line problems and lab technician has to extend arms to see work.
SAIC, Frederick, MD
HETA 95-0294-2594

igur E- Crowded work ea may cause awkwar postures and ext ended ch for ab techn A all stainl eel table put laces and and tat twsy from work ea will deer wkwar ostures and ended h lems
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gu E-8 ixed height biosafety cabinet does ot allow easy sitti comfo and ay se pinch point with ab echnician pper
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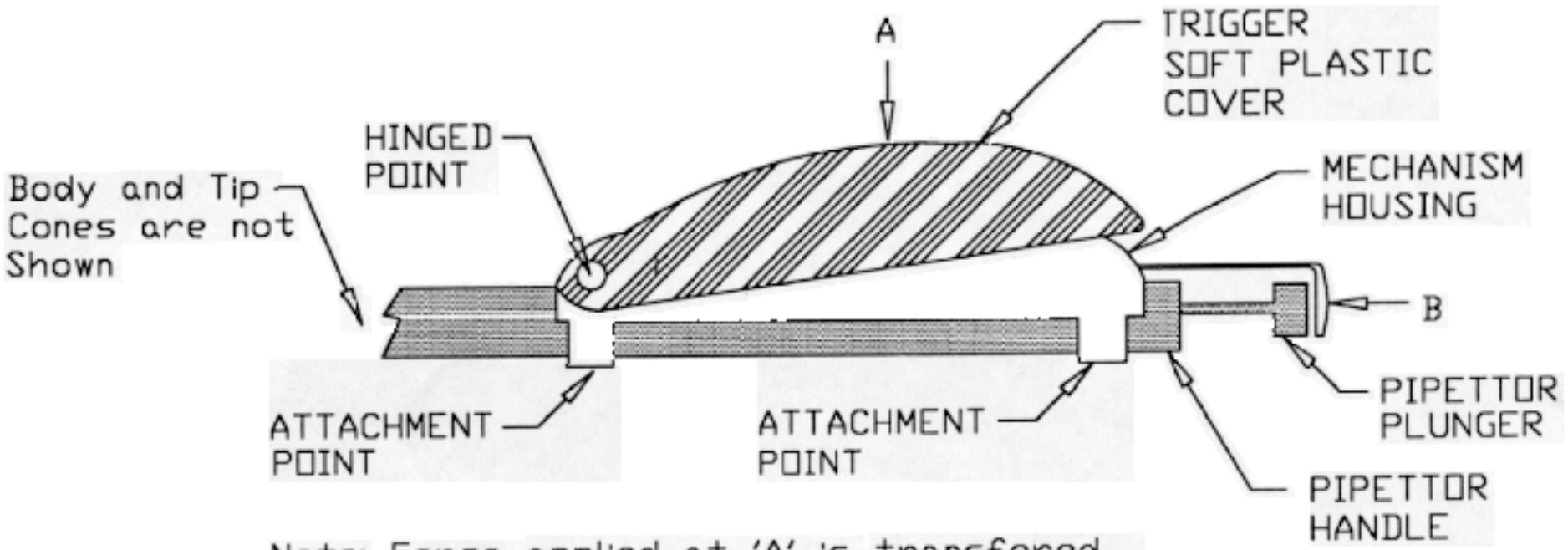

Figure E-9: Pippetor adaptor for adapting thumb plunger to finger strip type plunger.
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HETA 95-0294-2594

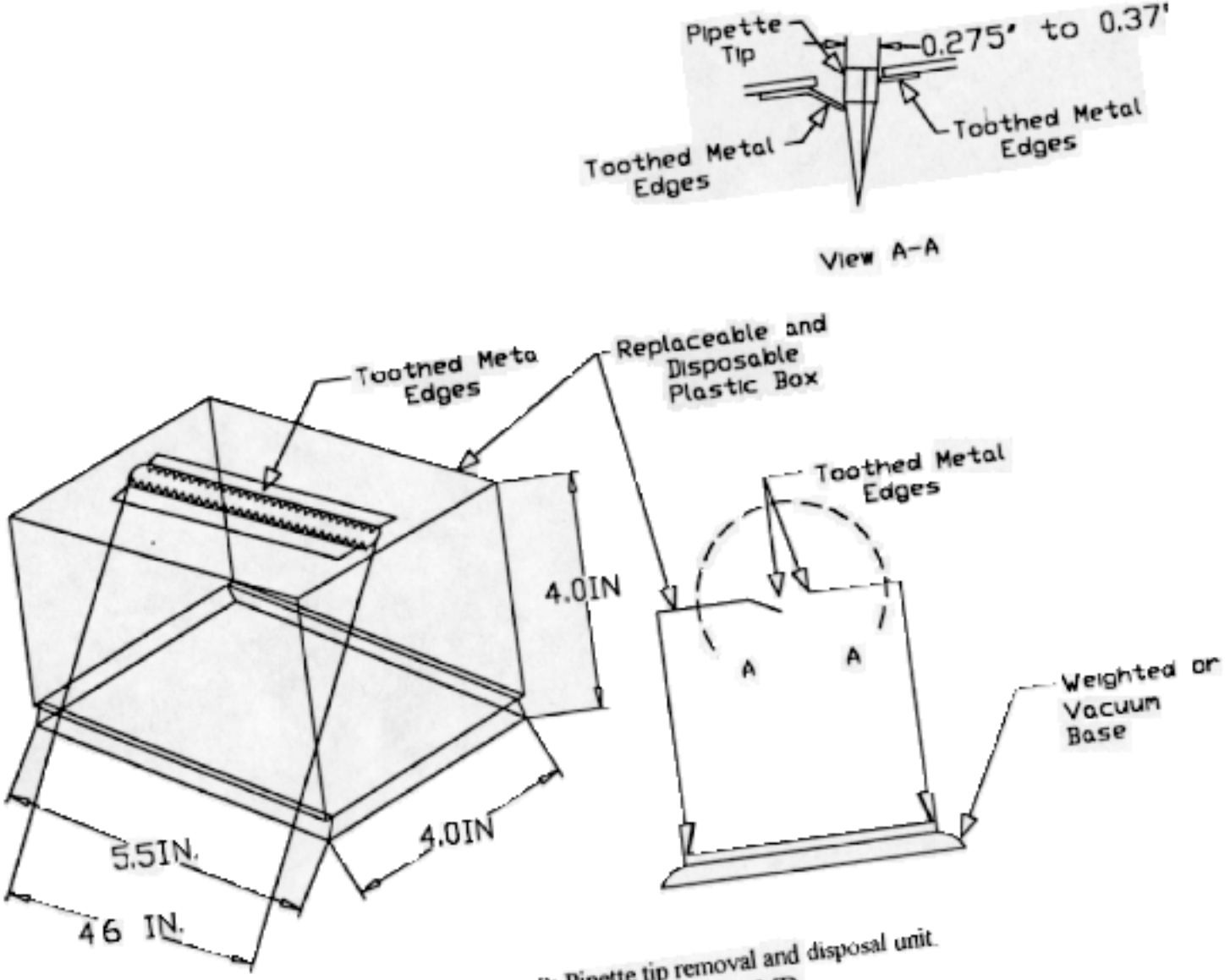

Figure E- 0: Pipette tip removal and disposal unit.
SAIC, Frederick, MD
HETA 95-0294-2594

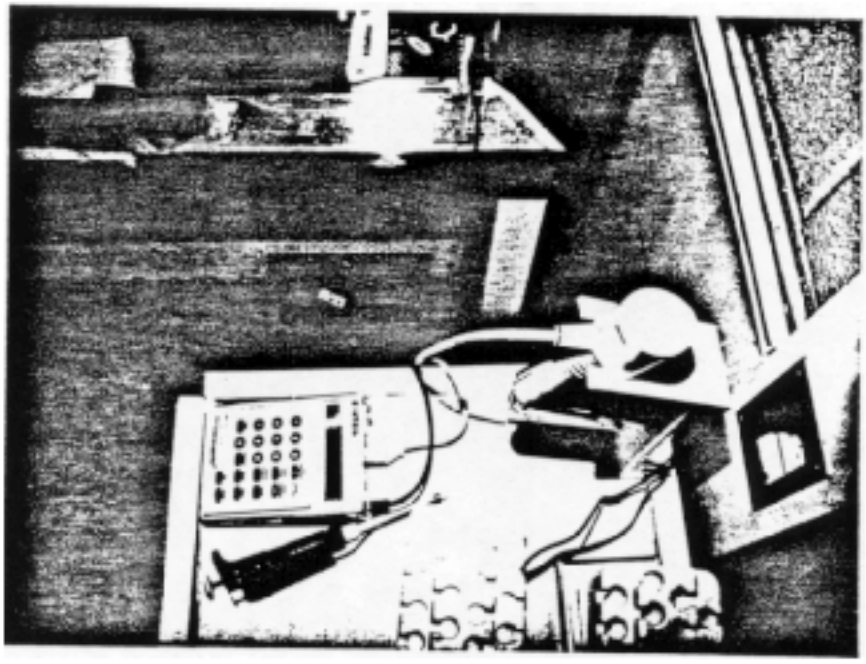

Figure E-11a: Pipette fluid dispensing unit used in conjunction with foot switch.
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HETA 95-0294-2594

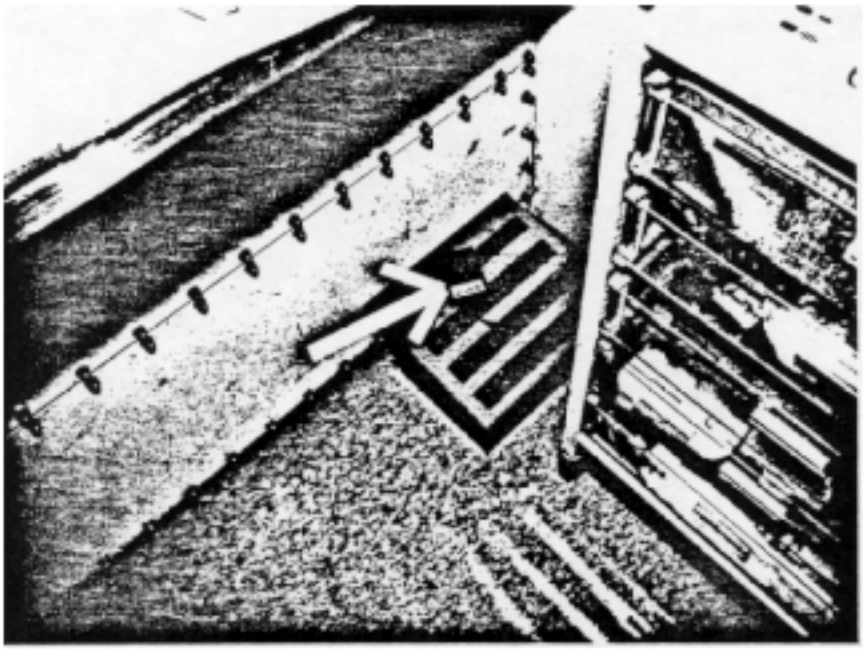

Figure E-11b: Foot switch used to dispense pipette fluid.
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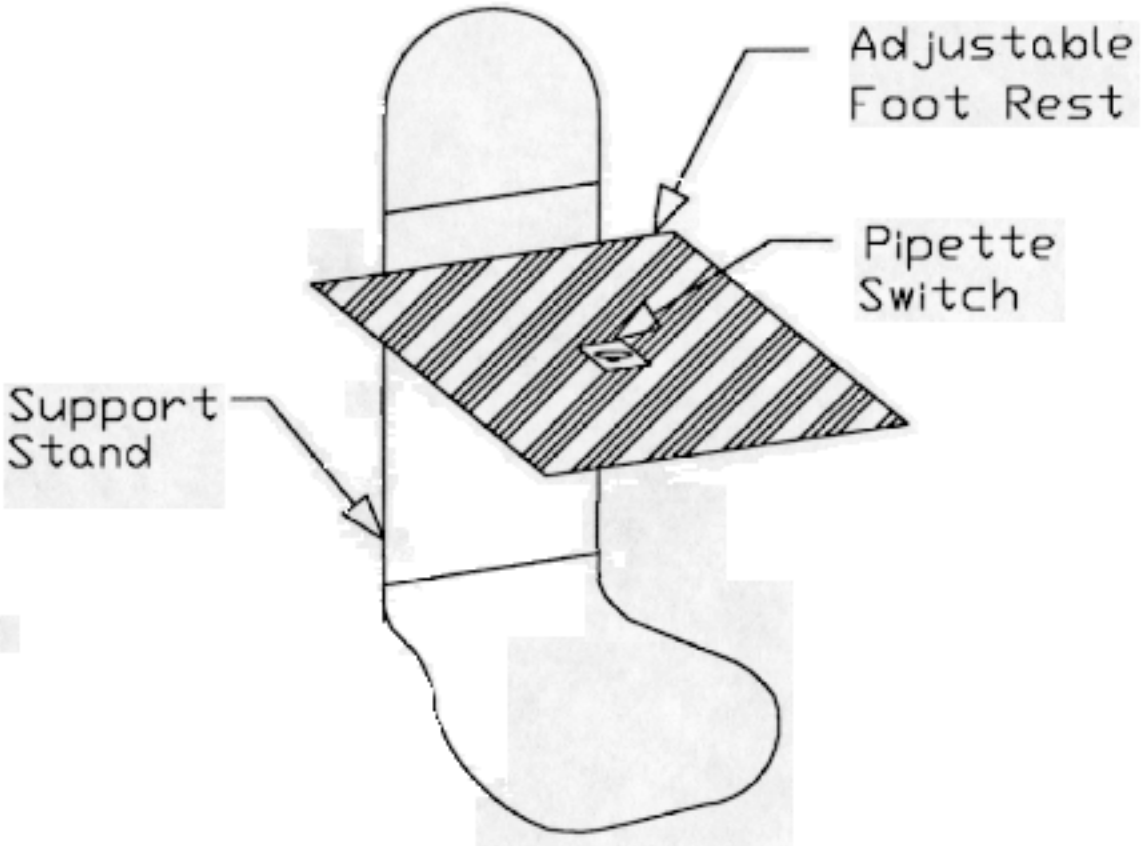

Figure E-12: Foot rest with embedded pipette switch.
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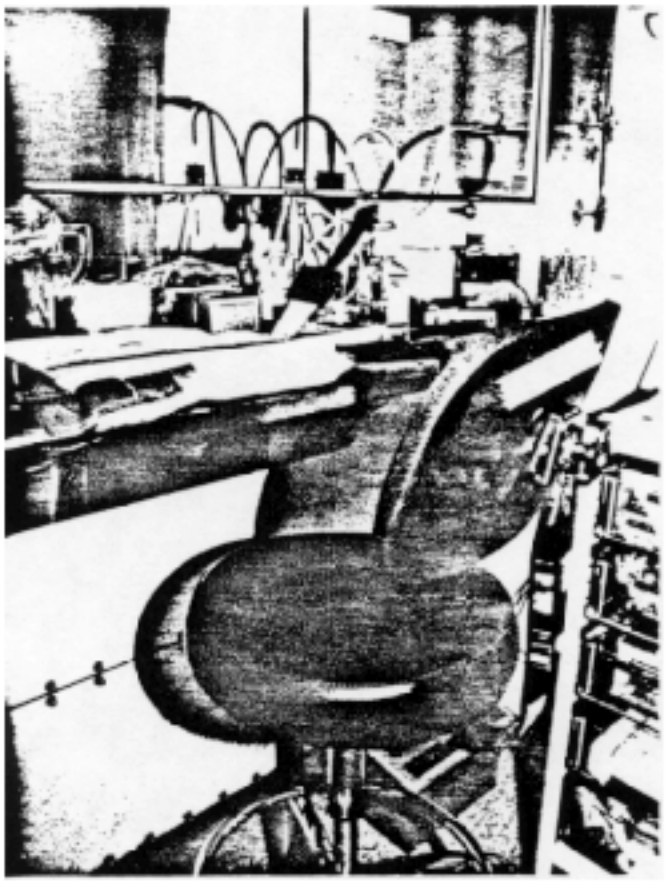
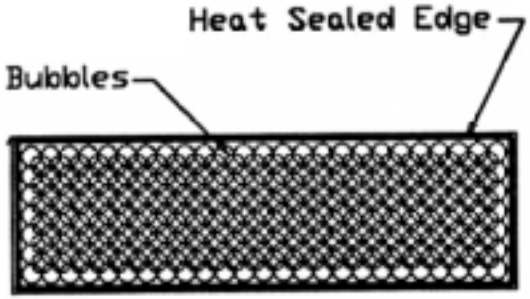
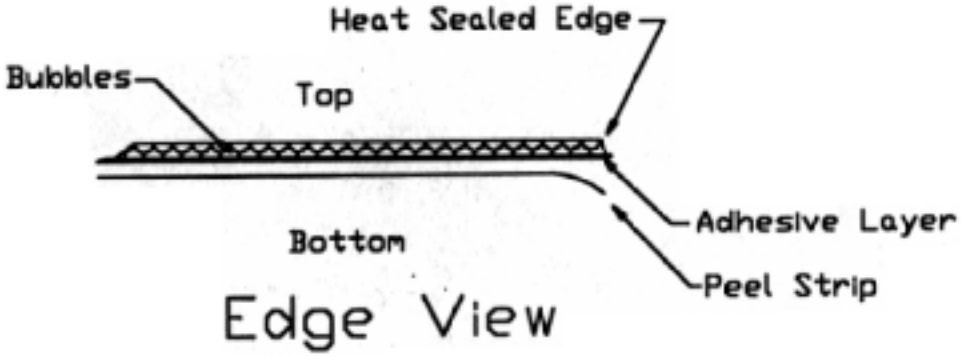


Figure E-13: Foam pad insulation covering metal biosafety cabinet plenum and elbow rest. Note the foam pad reduces mechanical pressure to the forearms also reduces cold temperature conduction.
SAIC, Frederick, MD
HETA 95-0294-2594



Material: Polyethylene Film
Bubbles: 3/8" Half Spheres

Plan View



Edge View

Figure E-14: Bubble pad insulation and edge protection tape pack as an alternative to foam pad insulation shown in Figure E-13.
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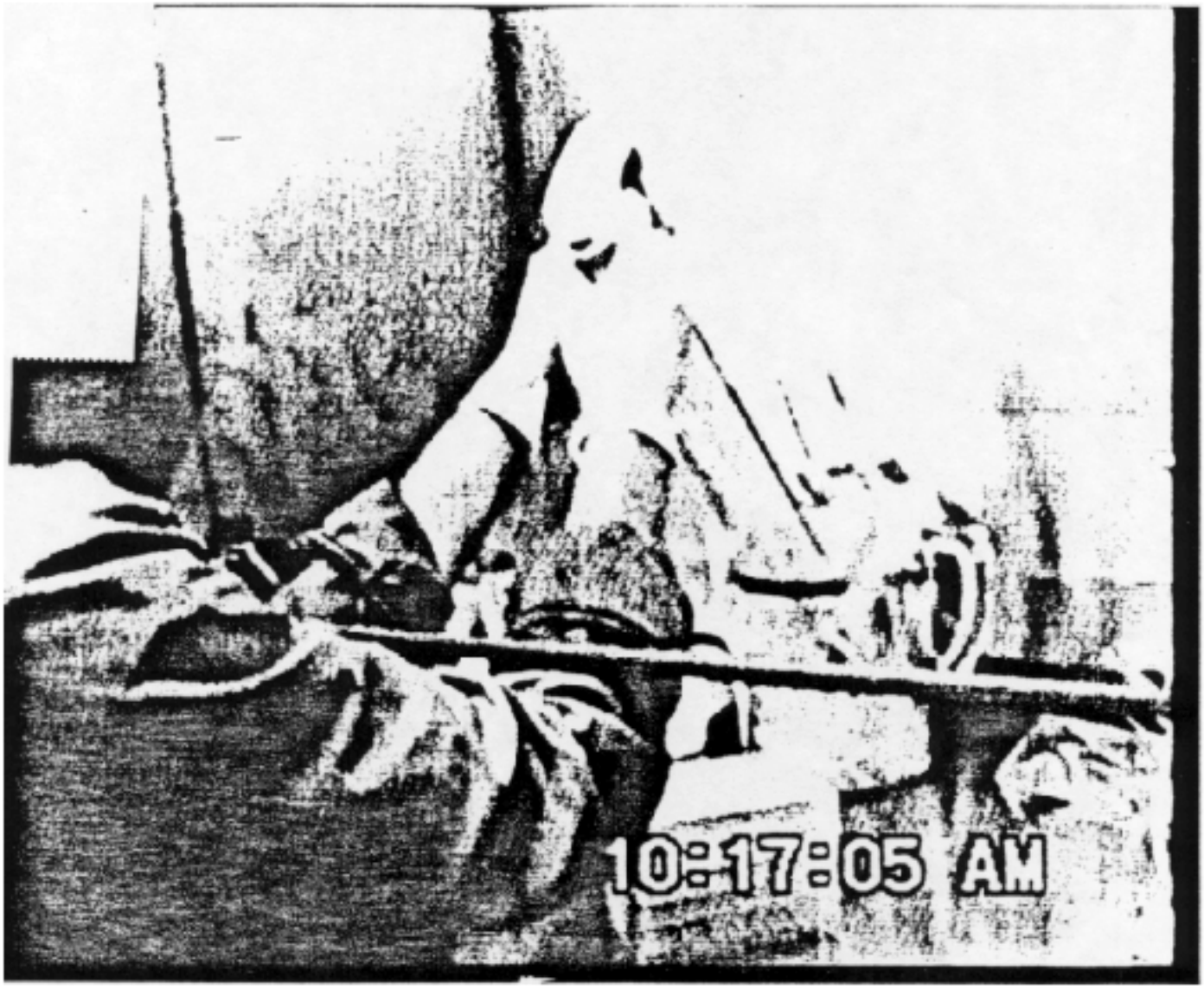

Figure E-15: Lab technician has to dispense used pipette tips in extended and awkward postures because of disposal containers which cause an uneven work surface. Newer biosafety cabinets can be ordered with wells cut out in the work surface to insert disposal containers to make work surface even and help reduce awkward postures.
SAIC, Frederick, MD
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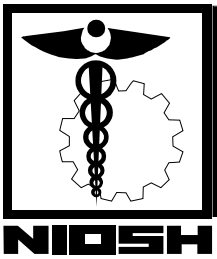

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