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CHARACTERIZATION OF AEROSOLS PRODUCED BY SURGICAL PROCEDURES

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FINAL REPORT

Characterization of Aerosols Produced by Surgical Procedures

by

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EXECUTIVE SUMMARY

In many types of surgery, especially orthopedic procedures, power tools such as saws and drills are used. These tools can impart considerable energy in disrupting tissue and may produce aerosolized blood and other material from bone and other tissues. Surgical lasers and electrocautery tools can also produce aerosols due to vaporization of blood and tissues. A number of studies have been reported in the literature concerning production of aerosols during surgery, and that some of these aerosols produced may contain infectious materials.

Health care workers have expressed concern and questions pertaining to the occupational transmission of blood-borne pathogens including the human immunodeficiency virus (HIV) and hepatitis B virus (HBV) via blood aerosols during surgery. Little or no data existed characterizing the aerosols produced performing surgical procedures. Because of this lack of data, the National Institute for Occupational Safety and Health (NIOSH) funded a project at the Inhalation Toxicology Research Institute (ITRI) to assess the extent of aerosolization of blood and other tissues during surgical procedures. This document reports the details of the experimental and sampling approach, methods, analyses, and results on potential production of blood-associated aerosols from surgical procedures, in the laboratory and in the hospital surgical suite.

Aerosols generated during 10 surgical procedures were sampled at the Lovelace Medical Center (LMC) (name changed to Lovelace Health System after conclusion of our site studies) as follows: five total hip replacements, one back vertebral fusion, three total knee replacements, and one hip reconstruction. No unusual amount of bleeding was reported during the 10 surgical procedures. No two operations were identical. Surgical activities changed frequently and were not always predictable; different tools were used, and surgeons or nurses changed locations within the room from time to time. Due to the changing nature of the operations, the aerosol mass concentration and the size distribution varied widely from procedure to procedure and from time to time during the same procedure. However, some general observations can be made. The respirable aerosol (mass) concentration was higher

during the total hip replacement procedures than during the total knee replacement procedures. Among the people in the surgical suite wearing the Marple personal cascade (MPC) impactors, the three surgeons had measurable amounts of aerosol, although the amounts were very low (on the order of few tens of micrograms). Analyses for hemoglobin with Chemstrip 9 (or Hemastix) consistently indicated that blood-associated aerosol particles were detected (positive results of 3+, 2+, and 1+, corresponding to about 250 ery/μL, 50 ery/μL, and 10 ery/μL, respectively, as specified by the manufacturer) for the first four to five MPC impactor stages which correspond to an aerodynamic particle size of 3.5 μm to over 21.3 μm. During the knee surgery, a tourniquet was applied, and no blood was observed during most of the procedure. Filter samples obtained during the time the tourniquet was applied showed non-detectable or very low blood content as determined by Chemstrip 9 analyses. On the other hand, the Chemstrip 9 analyses on the filter samples obtained after the release of the tourniquet, followed by irrigation/suction to clean the site for suturing, showed a response higher than 1+, similar to observations during the total hip replacement procedure. From these observations, we hypothesize that most of the blood-associated aerosols might be produced during the irrigation/suction procedure. Quartz crystal microbalance (QCM) cascade impactor data indicated that aerosol mass concentration was highest (although the absolute values were very low) during the earliest stage of surgery, i.e., the opening of the surgical site when a scalpel accompanied by the use of an electrocautery, and the occasional use of irrigation/suction. The other procedures produced a much lower mass concentration of aerosols. Occasionally, area filter samples and one or two stages of MPC impactor samples from personnel other than surgeons showed positive responses from Chemstrip 9 (either trace or 1+). This was probably due to splashing during the irrigation/suction procedure. Post-surgery room clean-up did not re-suspend any blood-associated aerosols (negative results from Chemstrip 9 analysis).

Chemstrip 9 (or Hemastix), a product commonly used to detect hemoglobin in urine, was used in this study to assess the blood-associated aerosol particles. However, the aerosols produced from surgical procedures using power tools might contain muscle, and Chemstrip 9

will respond to either the hemoglobin or myoglobin and cannot differentiate between the two. To positively identify the blood-associated aerosols, a laboratory study with ^{51}Cr labeled red blood cells was conducted in dogs, using total hip replacement procedures similar to the human procedures. The most important results from the dog study were that: (1) it confirmed that blood-associated aerosols were produced during the orthopedic surgery using power tools, (2) the degree of Chemstrip 9 response on samples correlated to the ^{51}Cr radioactivity measurements very closely, indicating that positive responses of the Chemstrip 9 measured from human studies at LMC probably represented blood-associated aerosols, and (3) it provided a basis for quantifying the number of red blood cells (RBCs) associated with each aerosol particle size range; thus the total inhalable RBCs could be estimated. Under the assumptions that 1) the results of the laboratory studies and the aerosol characterization at the LMC surgical room are similar, and 2) the surgeon's minute volume is 20 L/min (corresponding to moderate activity), we estimated that the total number of RBCs a surgeon might inhale would be $\approx 3 \times 10^5$ (or ≈ 9 μg of RBCs). HIV is carried primarily through the lymphocytes, not through the RBCs. The ratio between the RBC and lymphocytes is about 2200:1 for humans (Wintrobe *et al.*, 1981). Therefore, the estimated number of lymphocytes available for inhalation by a surgeon would be $\approx$ 135 during the course of an orthopedic surgical procedure.

Surgical personnel wear surgical masks to protect the patient and to protect themselves from splashes and droplets. Surgical masks are not approved as respiratory protection devices. The surgical mask will probably prevent some aerosol particles from reaching the nose or mouth for inhalation. The filter efficiency of a surgical mask, which does not take into account face-seal leakage, has been reported to range from a few percent to 50% for submicrometer-sized particles and from 20% to near 100% for micrometer-sized particles, depending on the type of surgical mask, flow rate, and particle size (Chen and Willeke, 1992; Tuomi, 1985).

If particles are inhaled, the deposition efficiency within the respiratory tract is dependent on particle size and breathing pattern (flow rate). Our results indicated that about

60% of RBCs are associated with particles larger than 10 μm and about 8% of RBCs are associated with particles less than 0.5 μm. The majority of the particles less than 0.5 μm probably originated from the use of electrocautery. Johnson and Robinson (1991) reported that no infectious HIV-1 was detected in aerosols generated by an electrocautery. The probability of a lymphocyte carrying HIV also needs to be taken into account when assessing the potential inhalation hazard. From all of these considerations, the potential inhalation risk from aerosols produced during orthopedic surgery seems very low. One should note that the existing literature did not provide evidence that blood-borne pathogens, such as HIV or HBV, have been transferred by the inhalation route (Tokars *et al.*, 1992; Petersen, 1980). A question not addressed by these studies is the viability of HIV in inhaled HIV-associated aerosols produced by surgical procedures. To ascertain the significance of our results, further studies are required to assess the amount and viability of pathogens associated with these blood-associated aerosols.

I. INTRODUCTION

In many types of surgery, especially orthopedic procedures, power tools such as saws and drills are used. These tools can impart considerable energy in disrupting tissue and may produce aerosolized blood and other biological material from bone and soft tissues. Surgical lasers and electrocautery tools can also produce aerosols when tissues are vaporized and condensed. Studies have been reported in the literature concerning production of aerosols during surgery, and some of these aerosols may contain infectious material. Garden *et al.* (1988) reported the presence of papilloma virus DNA in the fumes produced from laser surgery, but the infectivity of the aerosol was not assessed. Moon and Nininger (1989) measured the size distribution and production rate of emissions from laser surgery and found that particles were generally less than 0.5 μm diameter. More recently there has been concern expressed over the production of aerosolized blood during surgical procedures that require power tools. In an *in vitro* study, Johnson and Robinson (1991) reported the production of an aerosol containing the human immunodeficiency virus (HIV) when power tools were used to cut tissues with blood infected with HIV. Heinsohn *et al.* (1989) measured the size distribution of blood aerosols produced by surgical power tools and found blood-containing particles in a number of size ranges.

Health care workers are anxious and concerned about whether surgically produced aerosols are inspirable and can contain viable pathogens such as HIV. This concern also extends to other pathogens such as hepatitis B virus (HBV). Because of these concerns, the National Institute for Occupational Safety and Health (NIOSH) funded a project at the Inhalation Toxicology Research Institute (ITRI) to assess the extent of aerosolization of blood and other tissues during surgical procedures. This document reports details of the experimental and sampling approach, methods, analyses, and results on potential production of blood-associated aerosols from surgical procedures in the laboratory and in the hospital surgical suite.

This project focused on measuring the physical and biological properties of aerosols produced during surgery. The parameters of interest are the particle size distribution of the

aerosols produced by various surgical tools, the aerosol mass concentration, and whether these aerosols are blood-associated. From these information, the potential inhalation hazard that they may present can then be assessed.

II. LITERATURE REVIEW

An extensive literature review was conducted during the course of this project, using computerized databases and other library resources. Over 500 articles were identified as potentially of interest. Of these, the majority were related to the transmission of HIV by means other than aerosols (primarily needlesticks, cuts, etc.). A total of 113 papers were reviewed in detail. Each article reviewed is summarized briefly in Appendix A. The following paragraphs summarize the literature reviewed:

The literature available through April 1, 1993, has indicated that health care workers are increasingly concerned about the occupational hazard of HIV infection from patients. These concerns, at times, have created stress and fear among health care workers and related professionals (Bachner, 1990; Taylor *et al.*, 1990; Burgess *et al.*, 1992). Such concerns are justified, in part, from the morbidity and mortality associated with HIV infection and the resulting acquired immunodeficiency syndrome (AIDS). The transmission of HIV from an AIDS patient to a health care worker by accidental needlesticks, wounds with sharp instruments, and contamination of mucous membranes or broken skin with contaminated blood from a HIV-infected patient has been well documented (Weiss *et al.*, 1985; Tulis, 1987; Piaazza *et al.*, 1989; Bailey, 1990; Heald and Ransohoff, 1990; Vaughn *et al.*, 1990; Klatt and Noguchi, 1990; Beekmann *et al.*, 1990; Speller *et al.*, 1990; Beck and Martin, 1990; Rhame, 1992). The volume of blood and number of cells transferred by a needlestick with a needle contaminated with HIV-positive blood were quantitated by Shirazian *et al.* (1992). In tests of needles ranging from 20 to 27 gauge, it was found that 300 to 400 nL of blood were transferred by a needlestick, and at least one viable lymphomononuclear cell was transferred 68% to 96% of the time.

The risk of the transmission of HIV from infected patients to the health care worker, for accidental exposure by needlesticks, wounds, and contamination with blood, is generally accepted to be about 1 per 340 to 1 per 250 (0.29% to 0.4%). Others have placed the risk at 1 in every 8 years working with high-risk patients and 1 in 80 years of working with low-risk patients (Gazzard and Wastell, 1990), or 0.001 per month of work for surgeons and 0.00008 per month for physicians (Puro *et al.*, 1990). Although HIV has been isolated from numerous body fluids, blood appears to be the primary vehicle for accidental transmission (Hughes *et al.*, 1988; NIOSH, 1989).

The risk of HIV infection is of the same order of magnitude that people are willing to accept in other areas of their lives (Rhame, 1992). Nurses working full time in an AIDS ward have an HIV acquisition rate of 30 transmission per 100,000 person-years which can be compared with the 200 deaths per 100,000 person-years in the oil industry, 40 deaths per 100,000 person-years in the construction industry, and one on-the-job homicide per 100,000 person-years. Owens and Nease (1992) have expressed the risk of HIV infection in terms of loss of (quality-adjusted) life expectancy. Loss-of-life expectancy for a 30-year-old female nurse from a needlestick was 39 days (range: 17-93), and the quality-adjusted loss-of-live expectancy was 45 days (range: 20-108). This was compared with a loss-of-life expectancy of 1 day for a cross-country auto trip. The 45-day quality-adjusted loss-of-life for HIV infection was similar to that resulting from the gain in loss-of-life from 10 years of annual screening for breast cancer. Capiluto *et al.* (1992) used a deterministic model to calculate the cumulative annual risk of seroconversion of dentists working with HIV-positive patients as 0.006%, with a cumulative lifetime risk of 0.078% per 100 patients treated.

Recent concerns over the potential for the transmission of the HIV from infected patients to the health care worker via aerosol inhalation, particularly during orthopedic surgery, have added to the concerns about the hazards of working with HIV-positive patients in the medical profession (Day, 1988; Goldman, 1988; Anonymous, 1989; Jewett, 1990; Johnson and Robinson, 1991).

Heinsohn *et al.* (1991) have demonstrated in an *in vitro* laboratory study that respirable aerosols can be generated by power tools used in orthopedic surgery. In related work, Baggish *et al.* (1991) demonstrated the presence of proviral DNA in the smoke of laser-treated tissue culture pellets containing HIV. A possible case of a surgeon acquiring human papilloma virus from the plume created by laser therapy was recently reported (Hallmo and Naess, 1991). Important data on the concentration of HIV in blood and blood cells essential for the eventual development of risks from aerosols during surgery have been reported by Ho *et al.* (1989). Steps to minimize the creation of aerosols in the autopsy room, such as the use of wet towels next to the cutting area and covering of work area with plastic sheets, have been recommended by Geller (1990). It has also been demonstrated *in vitro* that respirable aerosols can be created by instruments commonly used in orthopedic surgery and, if HIV viremia is present, the virus may be recovered from the aerosols created (Jewett, 1990; Johnson and Robinson, 1991; Jewett *et al.*, 1992).

Evidence supporting the potential for the transmission of viral diseases from infected patients to health care workers via the inhalation of aerosols has been well documented (Wentzell *et al.*, 1989; Heinsohn, 1990). Surgical masks have not proven useful in the prevention of the inhalation of respirable aerosols by health care workers (Pippin *et al.*, 1987; Reingold *et al.*, 1988; Jewett, 1990). It has also been well documented that accidental transmission to health care workers can occur with other viruses not known normally to be transmitted by the aerosol route. This is particularly true for human HBV (Petersen, 1980), papillomavirus (Garden *et al.*, 1988; Ferenczy *et al.*, 1990; Lobraico *et al.*, 1989; Sawchut *et al.*, 1989; Abramson *et al.*, 1990), and has been reported to occur in the rabies virus (Giachino *et al.*, 1988). It also has been noted that both pathologists (Green and Yoshida, 1990) and morticians (Rhame, 1985) may also be at risk from occupationally acquired HIV infection.

Even in light of the information on the potential transmission of HIV by aerosols, Meech (1991) believes that more efforts should be directed at the major causes of the accidental transmission of HIV (needlesticks, etc.) than on exotic or theoretical modes of transmission.

The viability of the HIV in the laboratory environment is known to persist for some time, suggesting that this agent may remain infectious in aerosols that could be deposited in the human respiratory tract. When plasma contaminated with HIV is allowed to dry at room temperature, virus viability was retained for at least 3 days with a decreasing rate of viability of about 1 $\log_{10}$ tissue culture infectious dose ($TCID_{50}$) per 9 hours (Resnick *et al.*, 1986).

The risk of the transmission of HIV from dental patients to dentists appears to be low, even though aerosols or splashes of fluids containing blood may be created during dental procedures (Morris and Turgut, 1990; Scully and Porter, 1991). Blood splashes are considered by Brearly and Buist (1989) to be an underestimated hazard to surgeons. Data on the risk of exposures to needlesticks, etc., are numerous and well-known (Gergerding, 1989; Howard, 1990; Lamm, 1990).

Assigning numerical values to the potential risk of health care workers receiving HIV via inhalation is difficult, at best, without accurate information on the particle size distribution, composition, and concentration of the contaminated aerosols generated during surgery. It is important that these parameters be more clearly defined so that the potential risks involved can be more accurately estimated.

The use of universal precautions (based on the assumption that all patients are potentially infected with HIV) remains controversial although adherence to these procedures would reduce the risk of the accidental transmission of HIV (Gergerding, 1989; Lamm *et al.*, 1991; Murphy, 1991; Panlilio *et al.*, 1991; WHO, 1991). Hester and Nelson (1991) consider the use of isolators and high-volume laminar flow systems as important additions to the universal precautions procedures. Adherence to universal precautions and other recommended procedures has been included in the Occupational Safety and Health Administration (OSHA) guidelines on compliance with Instructions CPL 2-2.44B relative to the enforcement of precautions to be taken with HIV-positive patients. In contrast, Stock *et al.* (1990) have demonstrated that adherence to the universal precautions concept is not cost-effective. Although the universal precautions appear to be prudent procedures to follow, it has been recognized that frequently they are not followed in the workplace (Hammond *et al.*, 1990).

On March 6, 1992, 29 CFR Part 1910.1030 of the "Occupational Exposure to Bloodborne Pathogens" became effective to eliminate or to minimize occupational exposure to HBV, HIV, and other blood-borne pathogens (Federal Register, 1991). A 29-page overview of the standard is available from OSHA (1992). Organizations, such as the American Academy of Orthopaedic Surgeons (AAOS) and others, have also recommended procedures to minimize the accidental transmission of HIV (AAOS, 1989; Royle, 1992).

Although these guidelines exist, it appears that they are not being adhered to as closely as one would expect (Freeman and Chambers, 1992). These authors and others (Rhame, 1992; Shah *et al.*, 1992) have noted that education on following the recommended procedures is still needed in caring for HIV-infected patients in order to minimize the risks of accidental infection with the virus.

Aside from the risk of accidental transmission of HIV, the resultant AIDS syndrome, and its tragic consequences, financial losses to a business or hospital can be tremendous. It has been reported that $5.4 million has been awarded for pain and suffering in a case of accidental transmission of HIV (Anonymous, 1992).

III. GOALS AND APPROACH

From the currently available data, it is clear that HIV may potentially be transmitted from infected surgical patients to health care workers via the inhalation of aerosols created during surgery. However, assigning numerical values to this risk is difficult without accurate information on the particle size distribution, composition, concentration, and the viability of the contaminated aerosols generated during surgery. It is important that these parameters be more clearly defined so that the potential risks involved can be more accurately estimated.

This study was designed (1) to obtain more quantitative data than are currently available on the characteristics of the aerosols generated during orthopedic surgical procedures, and (2) to quantify the potential aerosolization of blood-associated particles during various surgical procedures in hospitals. Such data will facilitate a more accurate estimation of the risk of accidental HIV infection in health care workers from infected

surgical patients.

Our approach to the study was as follows:

1. We conducted an extensive literature search to identify the power tools used in surgery and to review the current knowledge on the aerosols produced from various surgical procedures, emphasizing blood-associated aerosols and potential HIV infection by inhalation.
2. We measured and characterized aerosols at a hospital during orthopedic surgery for size distribution and concentration and estimated blood-associated aerosols by the quantitation of hemoglobin.
3. We used the dog as an animal model to confirm and quantify blood-associated aerosols produced during orthopedic surgeries, using radioactive labeling technique.

Measuring aerosol size distributions that cover the whole range of inhalable sizes, i.e., all sizes less than about 100 μm, would be ideal. However, in practice, it is difficult to measure the size distribution of particles greater than about 20 μm since this is outside the range of most particle measuring and sampling instruments. Therefore, measuring respirable aerosol (generally less than 10 μm) was emphasized.

IV. SITE VISITS

The literature on the power tools and lasers used in surgery was examined to identify the tools commonly used with various tissues. Along with this review, site visits to operating rooms and consultation with practicing orthopedic surgeons were also done to obtain background information concerning the most commonly used surgical procedures and instruments. R. K. Jones, M.D., and B. A. Muggenburg, D.V.M., Ph.D., conducted three visits; two visits to the Lovelace Medical Center (LMC), consulting with R. S. Turner, M.D., head of Orthopedic Surgery, and one visit to the University of New Mexico Hospital, consulting with Dr. M. Moneim, the acting head of the Department of Orthopedic Surgery. In addition, several investigators observed total knee replacement and total hip replacement

surgeries, performed by Dr. Turner. As a result of these interactions, the total hip replacement surgery was chosen as the principal laboratory procedure, and the dog was chosen as the animal model. This decision was based on the common use of this orthopedic procedure in humans, its use in all areas of the United States, and because the instruments used in this surgery include saws, drills, electrocautery, and irrigation/suction. The dog was selected because the tissue mass at the hip is relatively large, permitting the use of human surgical instruments. These included the pneumatic saw and drill (3M Company), irrigation and suction equipment (Davol and Baxter), electrocautery (Valleylab), and various surgical hand instruments.

Dr. Turner agreed to participate in our studies as a co-investigator, without cost, and to help in developing the hip surgery procedure for dogs in order to replicate the standard procedure in humans. He also agreed to allow sampling of aerosols in the surgery suites at LMC for this project. This was very important because the study did not have to rely solely on the animal model, and the more needed data from an actual hospital setting could be obtained. Furthermore, from these site visits and discussions, needed aerosol sampling instruments were identified. These included a PC-2 Air Particle Analyzer (sometimes also called Quartz Crystal Microbalance cascade impactor (QCM)), (California Instruments, Inc., Sierra Madre, CA), several 8-stage Marple Personal Cascade Impactors (MPC) (Andersen Instruments, Inc., Atlanta, GA, Lovelace Multi-jet (LMJ) Cascade Impactors, filter samplers, and a point-to-plane electrostatic precipitator (ESP).

V. PILOT STUDY

The purpose of the pilot study was to develop the procedures for the characterization of aerosols produced during surgery. This involved: (1) replicating the total human hip replacement surgery in dogs, (2) facilitating the aerosol sampling during the surgery, including placement of aerosol sampling instruments, timing, and changing of samples, and (3) developing and evaluating methods for detecting blood in the aerosols.

A. Use of Laboratory Animals

The use of live laboratory animals was essential to the objectives of this experiment. The primary purpose of this experiment was to replicate, in animals, surgical procedures that are used in humans. Such factors as blood flow, tissue consistency, and fluid content are critical to these studies and cannot be obtained other than in the living animal. The dog was selected for use in this experiment because its size permitted the orthopedic surgical procedures to be done in the same manner as those in humans. Another factor is that the total hip replacement surgery is a developed procedure in the dog, and prostheses are available.

B. Experimental Protocol

1. Dog Selection and Care

This pilot study used three adult Beagle dogs (10-13 Kg body weight). Until the day before the surgery, the dogs were housed in kennel buildings and fed 350 g of dry kibble dog food (Wayne Mini Lab Dog Diet). Water was available at all times. The dog was moved into the veterinary hospital the day before the surgery, and food was withheld the morning of the procedure. Because the surgical procedure was nonsurvival, post-surgical care of the dogs was not required. No pre-study work-up was done on the dogs because the data collected were from the aerosols and not the dogs themselves. The health status of the dogs was not important to this pilot study.

2. Surgical Procedure

Although the surgery was nonsurvival, the correct atmosphere in the surgical suite was created to mimic orthopedic procedures at hospitals; sterile techniques were followed. These included the use of sterile drapes, surgical masks, gloves, and sterile gowns. Pre-operative preparation of the dogs included:

- no food the morning of the procedure,
- atropine, 0.045 mg/kg subcutaneously, 20 min before anesthesia,

- acepromazine, 1.0 mg/kg, intramuscularly, 20 min before anesthesia.

Anesthesia was induced with 5% halothane gas via a face mask. Once the dog was under light surgical anesthesia, an endotracheal tube was placed down the trachea and the amount of halothane gas adjusted to maintain a deep level of anesthesia. This level of anesthesia was maintained throughout the surgical procedure and euthanasia.

The surgical procedure was roughly divided into four segments according to the instruments used:

Part a. - The skin over the hip was opened and undermined enough to see the muscles of interest. The facial planes and muscles insertions were identified, dissected, and cut or moved. The primary instrument used during this part of the surgery was electrocautery (Force 2 Electrosurgical Generator, Valleylab). This part of the procedure ended with the exposure of the head of the femur and acetabulum.

Part b. - The head of the femur was cut off, and the acetabulum was enlarged and fitted with the acetabular prosthesis. The shaft of the femur was opened with a reamer and the trial prosthesis fitted. The instruments of particular interest were power saws, drills, and an acetabular reamer.

Part c. - The surgical site was cleaned, and the prosthetic devices were installed. Some hammering and drilling were done to seat the acetabular and femoral prosthesis; however, the device most likely to create aerosols was the irrigation/suction. The wound was then closed, and the surgical procedure per se was completed.

Part d. - Aerosols were collected during the initial clean up of the room at the end of the surgery. The logic for this was that considerable blood and tissue fragments were present on the surgical drapes and equipment, and the movement of drapes and equipment that occurs in the room increased significantly. Because the surgery was finished, concern over possible hazards appeared to

decrease considerably. The aerosol sampling continued until the dog (patient) and the instruments were removed from the surgical room and the waste, i.e., drapes and disposable materials, were packaged and removed.

3. Euthanasia Procedures

At the end of the surgical procedure, the dog still in deep surgical anesthesia was euthanized by an overdose of pentobarbital given intravenously.

4. Aerosol Collection and Characterization

An array of aerosol instruments was used to collect the produced aerosols and to characterize aerosol size distribution and average aerosol concentration over a given time period for a given surgical instrument used. The sampling devices used were: (1) a QCM, (2) MPC impactors, (3) filter samples, (4) ESP samples, and (5) a LMJ Cascade Impactor. The QCM is a sophisticated aerosol instrument for measuring aerosol size distribution. The flow rates of both the QCM and MPC impactors were calibrated using a Gilian Bubble meter. Furthermore, the jet sizes of the MPC impactor stages were checked with an optical comparator. The filter samples were used to estimate the aerosol concentration or rate of aerosol produced, and to identify the nature (e.g., hemoglobin associated) of the aerosols. Table 1 summarizes the purpose of the aerosol sampling and measurement instruments used. Figure 1 shows a schematic diagram of the room in which the surgery was performed on the dog and locations of various sampling instruments. All personnel wore MPC impactors in the chest area to collect breathing zone samples for determination of time-integrated size distribution and concentration during the entire surgery. A QCM probe was held by AS1, about 10-20 cm from the potential source of aerosol generation (surgery cite), to obtain a filter sample and a real-time size distribution for a given surgical instrument used. Figure 2 shows the arrangement of the sampling probe, the small aerosol chamber and their connection to the filter sampler, the ESP, and the QCM. In addition, two to

three area filter samplers, and an overhead LMJ (on the light fixture) were used to obtain information of the possible spread of the aerosols throughout the room. The flow rates were 2 L/min for the MPC impactor, 0.24 L/min for the QCM (and later upgrade to 2.0 L/min in PILOT_3 study), 14 L/min for the LMJ, and 20 and 2 L/min for two types of filter samplers.

Table 1 The Aerosol Sampling and Measurement Instruments Used and the Purpose of Each One

Instrument Type	Purpose
Marple personal cascade impactors	Time-integrated aerosol size distribution and concentration
Quartz crystal microbalance cascade impactor system	Real-time assessment of aerosol size distribution produced from different tools/processes
Filters	Aerosol mass concentration
Electrostatic precipitator	Samples for electron microscopy
Area filters & Lovelace Multi-Jet cascade impactor	Detect aerosol spreading within the surgical room

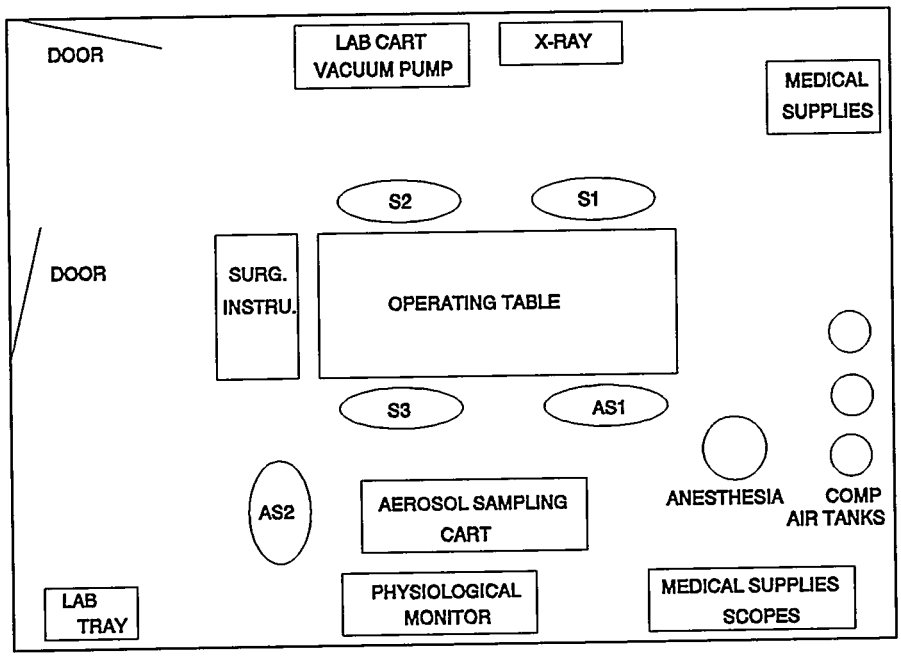

Figure 1 Schematic diagram of the dog surgical room. (S1, S2, and S3 are surgeons, and AS1 and AS2 are aerosol personnel)

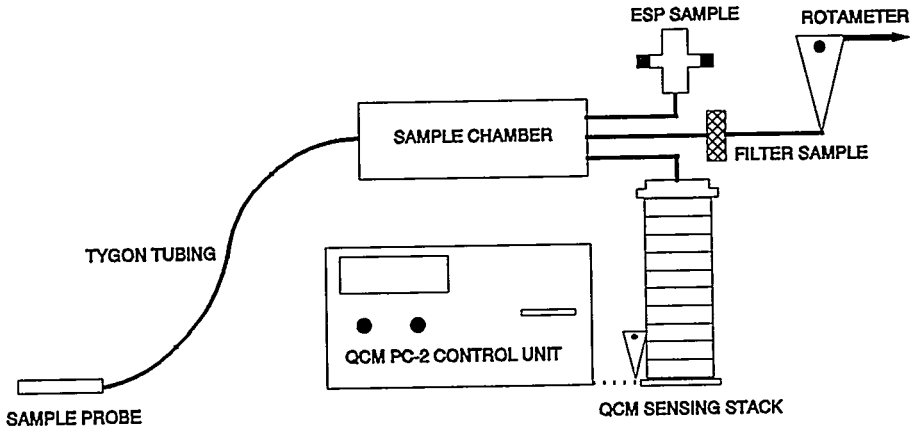

Figure 2 A schematic diagram showing the arrangement of the sampling probe, an aerosol chamber, and their connection to the filter sampler and the QCM (PC-2 Aerosol Particle Analyzer)

5. Estimation of Blood Content Collected on the Samples

After the aerosol collection filters were weighed, selected filters were washed and the hemoglobin content quantified. Three methods were examined: analysis by Chemstrip 9 (Boehringer Mannheim Diagnostics, Indianapolis, IN), by IL Monarch 1000 Clinical Chemistry analyzer, and by ELISA assay. It was determined that the IL Monarch 1000 Clinical Chemistry analyzer and the ELISA assay did not have the adequate sensitivity required for hemoglobin content determination, based on the samples obtained. When the amount of distilled water was reduced from 1.0 mL to 20 μL, Chemstrip 9 was adequately sensitive for determining hemoglobin content. Therefore, it was decided to use Chemstrip 9 in order to estimate the blood content in the samples in the main studies of this project.

6. Results and Discussion of the Pilot Study

The main purpose of the pilot study was to develop methods to be used in this project. Therefore, the amount of data was limited, and the information was primarily descriptive and only intended for limited use. Details of the data and data analyses are included in Appendix B. Results can be summarized as follows:

a. Among the MPC impactor samples, only those impactors worn by the principal surgeon and/or assistant surgeon showed measurable amounts of aerosols, showing multi-mode particle size distributions and indicating (1) high variability among personnel, depending on their

locations relative to the surgical site and their orientation, and (2) that each mode of distribution might be attributed to different tools used.

b. QCM (PC-2 Air Particle Analyzer) data obtained during the electrocautery procedure were very compatible in size distributions among runs (Fig. 3).

c. The aerosol size distributions changed with time, with higher mass concentrations during the electrocautery procedure.

d. The bulk of aerosols were respirable ($< 10\ \mu m$).

e. The three area filter samples, in all runs, showed negligible aerosol mass concentrations as compared to samples obtained from the surgical site, indicating that the spread of aerosol within the room was minimal.

f. These pilot experiments suggested that the distilled water used with Chemstrip 9 analyses should reduced from 1.0 mL (PILOT_1 and PILOT_2 runs) to 20 μL (PILOT_3), to achieve adequate sensitivity for hemoglobin content determination. This was indicated by the Chemstrip 9 analyses of 30 samples (including four filter samples, samples of impactors substrates from one LMJ, one personal impactor, and QCM stages) from PILOT_3 run where 23 samples had positive results as compared with only one sample showing a positive response among samples from PILOT_1 and PILOT_2.

g. PILOT_1 and PILOT_2 runs suggested that the aerosol concentration might be too low for the standard QCM (PC-2, sampling flow rate =

240 mL/min). A converting kit to higher sampling flow rates (PC-2H, 2.0 L/min) was installed.

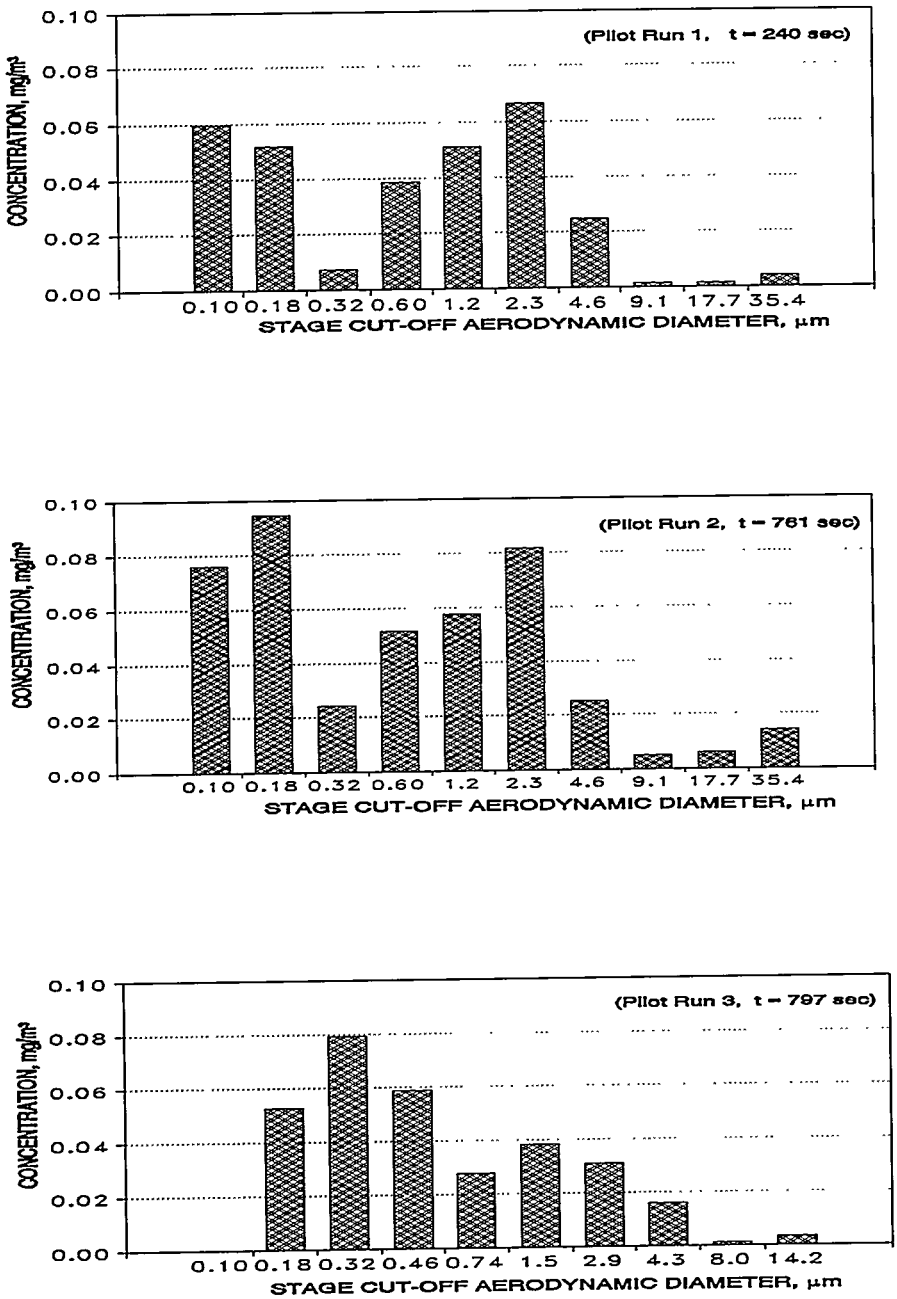

Figure 3 Comparison of size bar graphs of the concentration observed by QCM during electrocautery among runs (t = sampling time). Note the changes of stage cut-off size (x-axis) in Pilot Run 3, due to modification of standard QCM to higher flow rate QCM.

VI. CLINICAL STUDIES: CHARACTERIZATION OF AEROSOLS PRODUCED BY ORTHOPEDIC SURGICAL PROCEDURES IN THE HOSPITAL OPERATING ROOM

These experiments were conducted to collect and characterize aerosols produced during orthopedic surgery, especially the total hip replacement surgery, in human surgical procedures. The major focus of the overall project was to determine the potential for the transmission of viral diseases to operating room personnel via aerosols produced during surgical procedures on patients having HIV or other viral infections. The main surgical procedure was the total hip replacement which was selected because it requires a variety of high-energy surgical instruments; however, some other surgical procedures were also studied for comparison. Major emphases of this study were to determine if these surgical procedures produced respirable aerosols, what size distributions and concentrations were associated with these aerosols, and if these aerosols contained red blood cell (RBC) constituents.

Several techniques, similar to those used in the pilot study, were used to collect aerosols in the breathing zones of the surgical team. Personal monitors were placed on selected individuals of the team to obtain particle size information. Collection filters were used in three locations in the operating room to obtain information on the dispersion of the aerosols throughout the room. An aerosol collection probe was also used to collect aerosols at different times during the surgery to determine if aerosols of concern are more likely during the use of specific instruments.

A. Pre-field Sampling Visits and Arrangements

This study involved field sampling in a surgery room at the LMC. Pre-field

sampling visits to the hospital site were arranged to set up sampling instrumentation, define the sterilization procedures for the aerosol sampling equipment, determine the types of utilities available, and to become familiar with other precautionary procedures required for working in the operating rooms. Several visits were made prior to actual field sampling. These visits were coordinated through Dr. Robert Turner.

B. Field Sampling at the LMC Surgical Room

1. Sampling Site

The aerosol sampling site was the surgical suite at the LMC. Dr. Robert S. Turner, Head of the Department of Orthopedic Surgery, agreed to allow air sampling during some surgical procedures. Usually, the procedure was the total hip replacement surgery; however, some other procedures were also studied. Surgical Room No. 5, which is a room with laminar flow, was the site studied. The aerosol collection team visited this room several times before the actual sampling in order to develop an approach to sampling during the surgery. A diagram of the room and its equipment during the surgery is shown in Figure 4. The characteristics of this room, according to our measurements, are shown in Table 2.

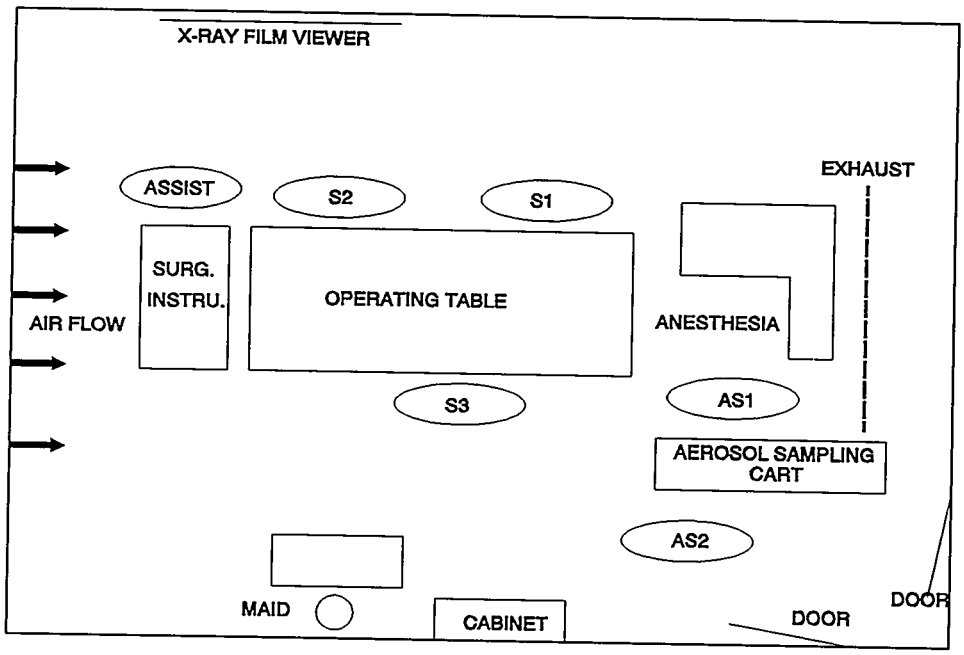

Figure 4 Schematic diagram of the operating room No.5 at LMC. (S1, S2, and S3 are surgeons; AS1 and AS2 are aerosol science personnel)

Table 2 Characteristics of Operating Room No. 5

- SIZE: 6.96 m (L) x 6.48 m (W) x 2.90 m (H) = 130.8 m^3
- AREA OF FACE OF FILTER BANK = 11.8 m^2
- AVERAGE AIR VELOCITY AT FACE OF FILTER BANK = 34.8 cm/sec
- AVERAGE AIR VELOCITY WITHIN THE ROOM = 22.0 cm/sec
- AVERAGE AIR VELOCITY AT OPERATING TABLE = 24.7 cm/sec
- VENTILATION RATE = 113.6 ROOM VOL./HR

2. Sterilization Procedures

Careful sterilization procedures for the aerosol sampling equipment were followed. The MPC impactors, including the attachment belts and hoses, and the aerosol probe with the associated tubing were sterilized with ethylene oxide by hospital personnel at LMC. These instruments were opened and attached to the surgery personnel by a nurse, assisted by an aerosol technician. To estimate the effect of the sterilization process on the uncertainty of weighing the impactor stage substrates and backup filter, several Marple personal impactors were sterilized, and the impactors' substrates were weighed before and after sterilization. Results indicated that the uncertainty in weighing were 0.003 $\pm$ 0.004 mg (mean $\pm$ S.D.) for the stainless steel stage substrate (n = 32) and 0.017 $\pm$ 0.009 mg for the backup filter (n = 4). This can be compared to the controlled (unsterilized) values of 0.001 $\pm$ 0.002 mg for the stainless steel substrate (n = 31) and 0.014 $\pm$ 0.018 mg for the backup filter (n = 4).

3. Surgical Procedures

The surgical procedures were performed by Dr. Turner and his team. For the purpose of aerosol collection, the surgical procedures were divided into four segments related to the surgical instruments used, similar to those described previously in the section "PILOT STUDY." Table 3 lists the four main segments involved in a hip replacement surgery and the associated primary surgical tools used in each segment. In reality, it was extremely difficult to take

samples according to these four segments because of the dynamic nature of the surgery and the different equipment and procedures used back and forth. For example, the irrigation and suction are used throughout the whole surgical procedure to clean the surgical site for better visibility by the surgeons.

Table 3 The Surgical Segments of a Total Hip Replacement and the Tools Used During Each Segment

Surgical Segment	Tools Used
Skin incision and exposure of hip joint	Scalpel, electrocautery, irrigation/suction
Femur cutting, acetabulum forming	Bone drill, saw, acetabular reamer, irrigation/suction
Cleaning, installation of prosthesis, and closure of site	Reamers, hammer, pulse irrigation/suction
Room cleanup	Spray, vacuum

C. Aerosol Collection and Characterization

Various aerosol instruments, similar to those used in the pilot study, except the LMJ which was not allowed to hang on the light fixture above the surgical table, were used to collect and characterize the aerosol size distribution and average aerosol concentration over a given time period. The sampling devices consisted of: (1) a QCM, (2) MPC impactors, (3) filter samples, and (4) a point-to-plane ESP. These instruments were cleaned and/or sterilized for each experimental run as outlined previously.

Unlike the pilot study where the sampling probe was held by an aerosol staff member at a distance of about 10 - 20 cm from and above the surgical site, the

sterilized aerosol probe was placed on top of the patient at a distance of about 40 - 60 cm from the surgical site and at an angle only slightly above the surgical site. Although nonideal, this probe location was used due to the requirement to maintain the sterilized field around the patient. Thus, the data obtained from filter samples and size distributions determined by the QCM may not be representative, because these samples were taken through the probe. These data should be considered as a relative indication of aerosol concentrations and the dynamic changes of size distribution during the surgery. The MPC impactors worn by the surgeons should better represent what these personnel would be exposed to.

D. Data Analyses and Estimation of Blood Content Collected on the Samples

At the conclusion of the surgical procedures and clean up, all aerosol samples, including personal samplers and filters, were placed in bags and transported to ITRI for analysis. The MPC impactors and filters were disassembled. Impactor substrates and filters were removed and placed in pre-labeled containers. The samples were weighed using a Cahn balance for estimating the aerosol concentration and determining the aerosol size distributions. After weighing, these samples were washed and the hemoglobin content quantified by using the Chemstrip 9. The crystal stages of the QCM were also washed and subjected to Chemstrip 9 analysis for the blood content. The ESP samples (grids) were examined for any abnormality in particle morphology, using the transmission electron microscope and scanning electron microscope.

E. Results and Discussion of the Field Study at LMC

Aerosol samples were taken during 10 surgical procedures including: five total hip replacements, one back vertebral fusion, three total knee replacements, and one hip reconstruction. Due to the nature of surgery, the dynamics of aerosol mass concentration and size distribution varied widely from procedure to procedure and from time to time during the same procedure. Complete data and results are included in Appendix C. Figure 5a shows a bar graph of particle size vs. concentration during the early part of a total hip replacement as determined by the QCM. After standardization with respect to interval size (Raabe, 1971), data in Figure 5a can be expressed as a concentration size distribution as shown in Figure 5b. Figures 5a and 5b indicate that there were two modes in size distribution during the first 6 minutes of the surgery where the primary tools used were electrocautery accompanied by occasional use of irrigation/suction. We think that the smaller mode (< 0.3 μm) was generated by electrocautery, whereas the larger mode (peak around 3 μm) was produced by irrigation/suction when a water jet was injected into the surgical site. To demonstrate the dynamic changes of particle size distributions during the whole surgical procedure, a sequence of measurements by the QCM is shown in Figures 6a to 6j. Figure 6a shows the background air concentration before the surgery, indicating very clean air within the surgical room. As shown in Figures 6b to 6i, the aerosol concentration was highest during the early part of the surgery when the surgical site was opened and the primary tools used were electrocautery and irrigation/suction. The aerosol concentration decreased rapidly as the surgery

proceeded when other tools were used, such as the saw, drill, and reamer. Figure 6j shows the measurement during the post-surgery room cleanup. The aerosol produced during this phase was negligible, with the concentration very close to the background aerosol concentration measured before the start of the surgery.

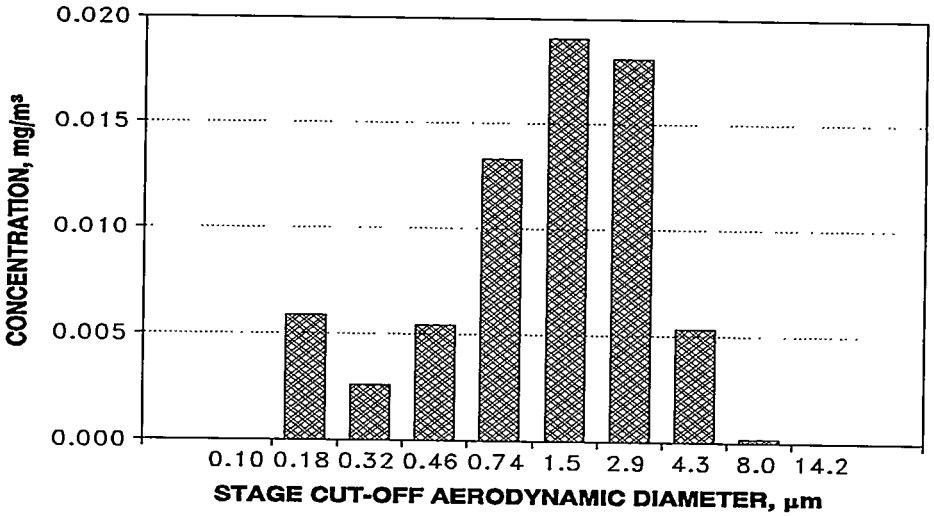

Figure 5a Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: electrocautery, irrigation-suction; sampling time = 480 sec)

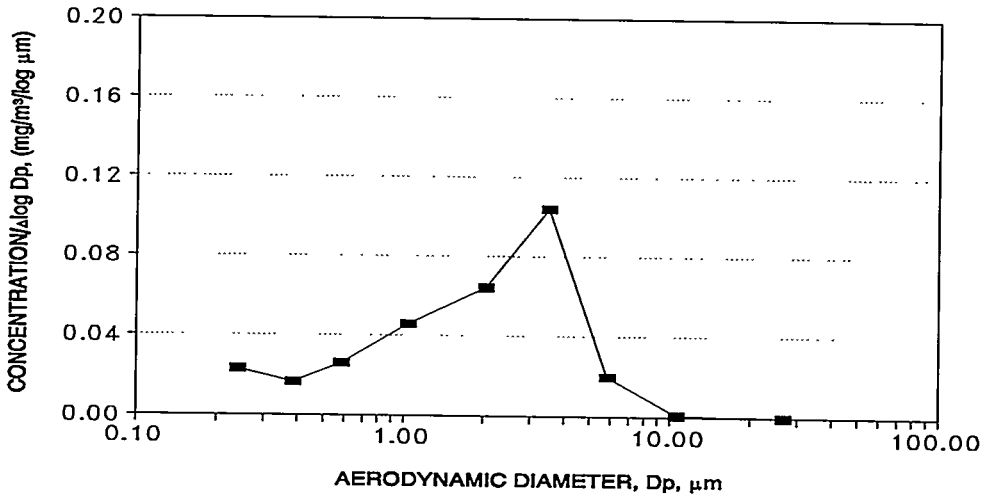

Figure 5b Aerosol size distribution as determined by the QCM, after standardization with respect to interval size.

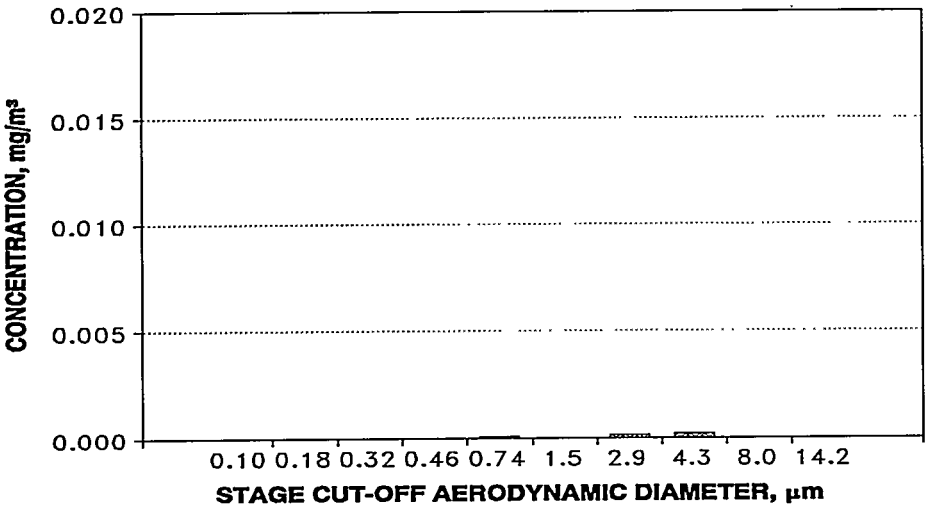

Figure 6a Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: surgical room background; sampling time = 300 sec)

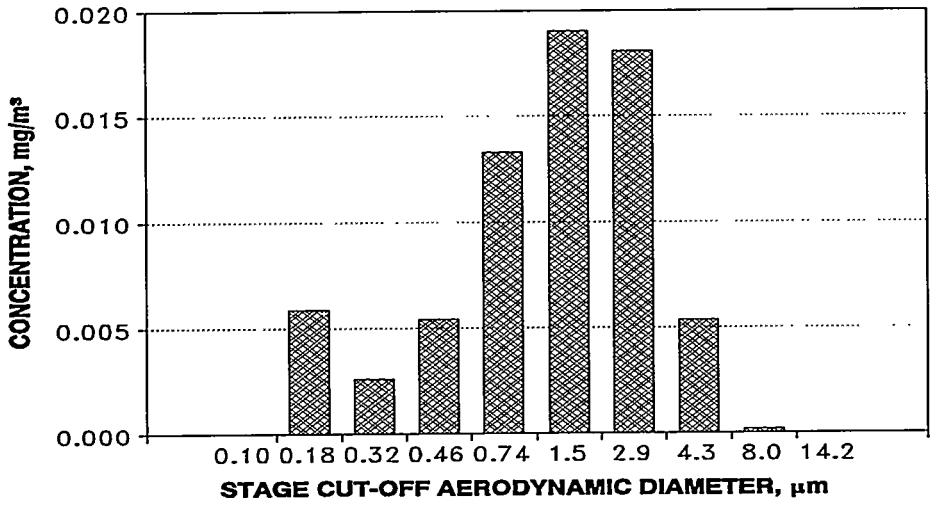

Figure 6b Bar Graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: electrocautery, irrigation-suction; sampling time = 480 sec)

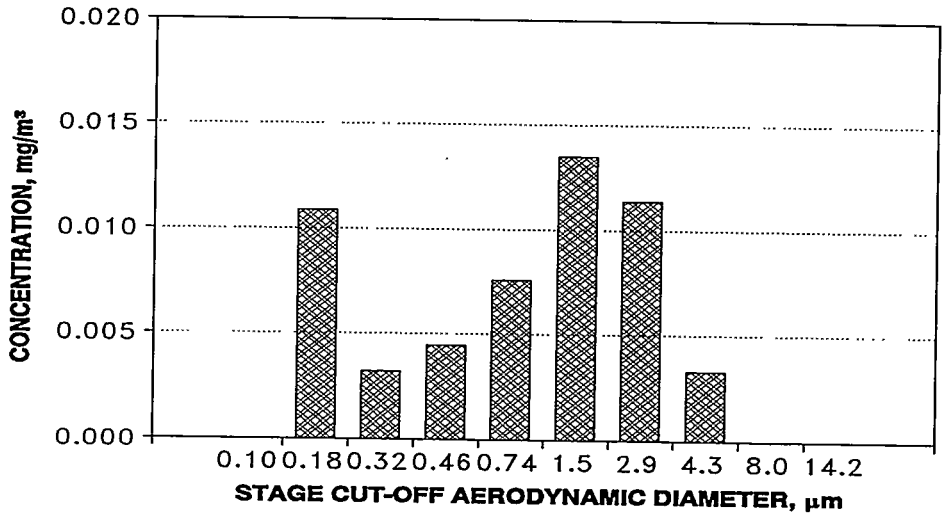

Figure 6c Bar Graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: electrocautery, irrigation-suction; sampling time = 120 sec)

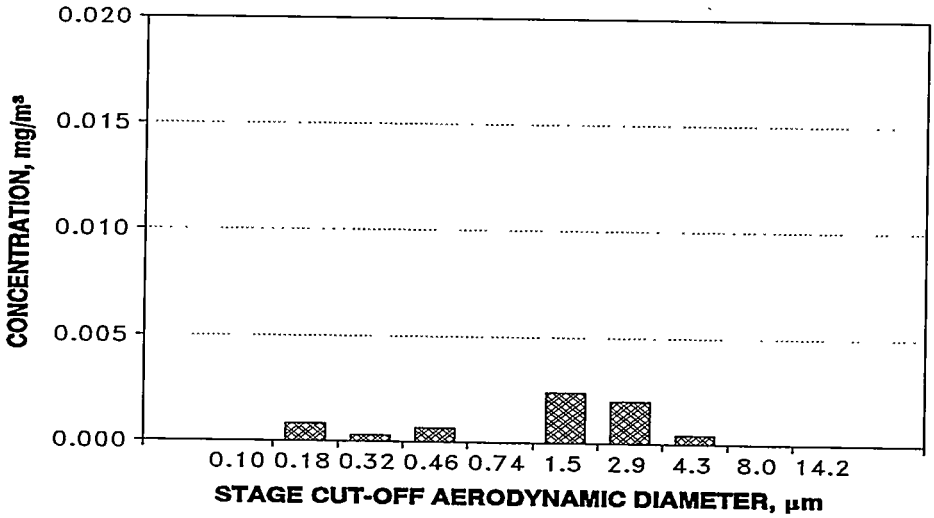

Figure 6d Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: saw off femur, electrocautery, irrigation-suction; sampling time = 400 sec)

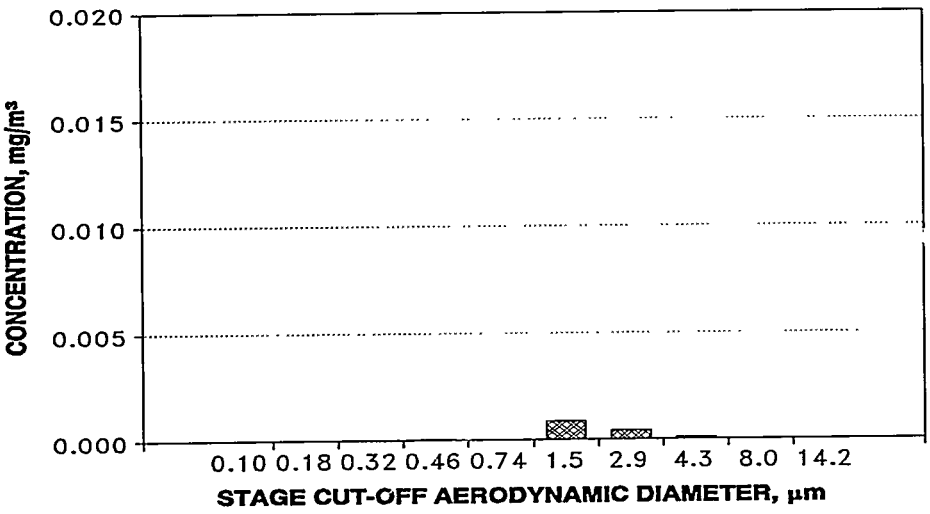

Figure 6e Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: reamer, electrocautery, irrigation-suction; sampling time = 900 sec; probe inlet angle twisted and partially block for a few minutes)

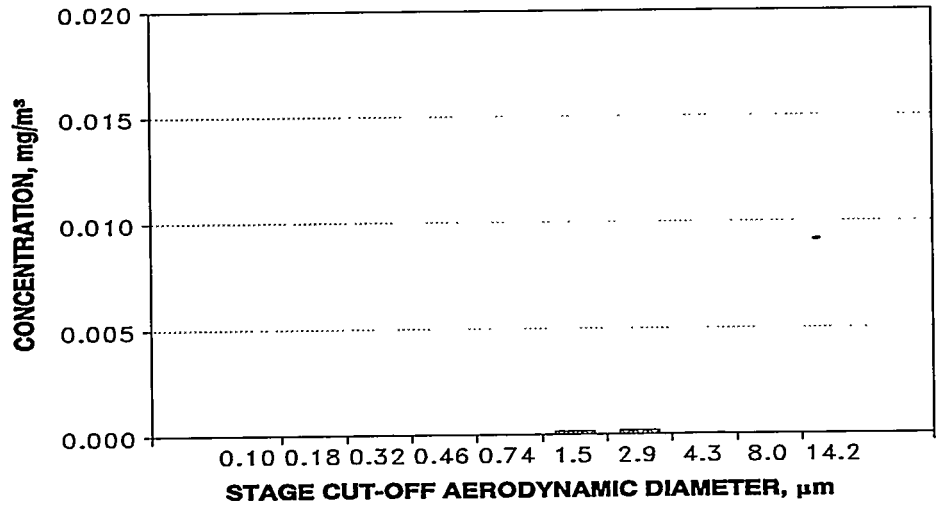

Figure 6f Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: hammer, irrigation-suction, drill; sampling time = 900 sec)

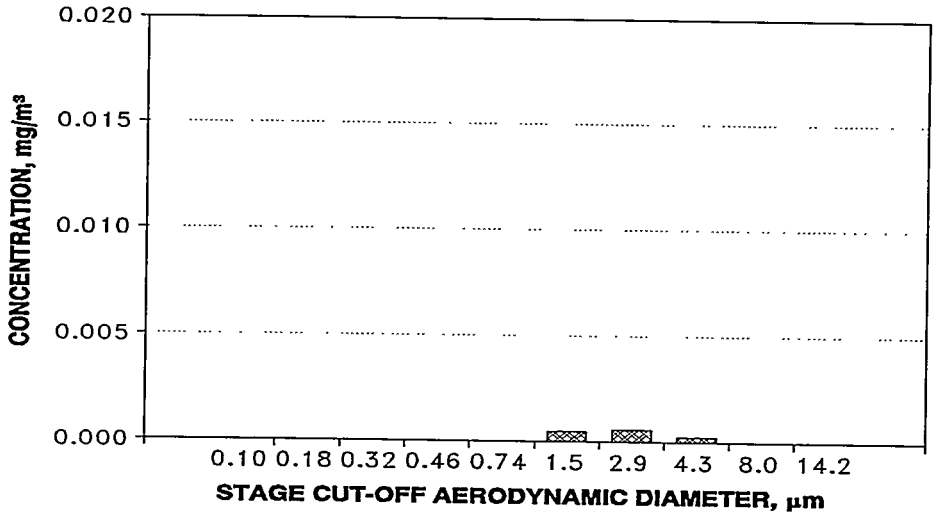

Figure 6g Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: fit prosthesis, chisel, grinding; sampling time = 900 sec)

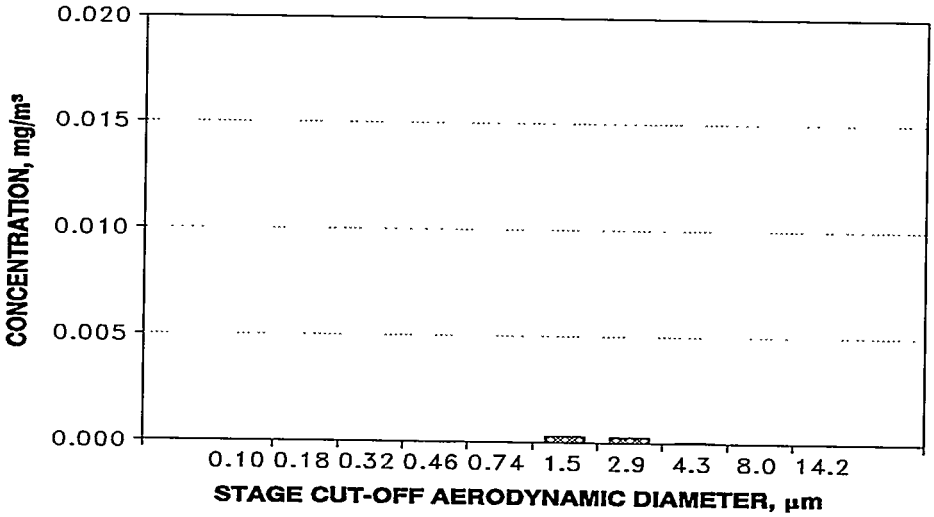

Figure 6h Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: cement, install prosthesis; sampling time = 900 sec)

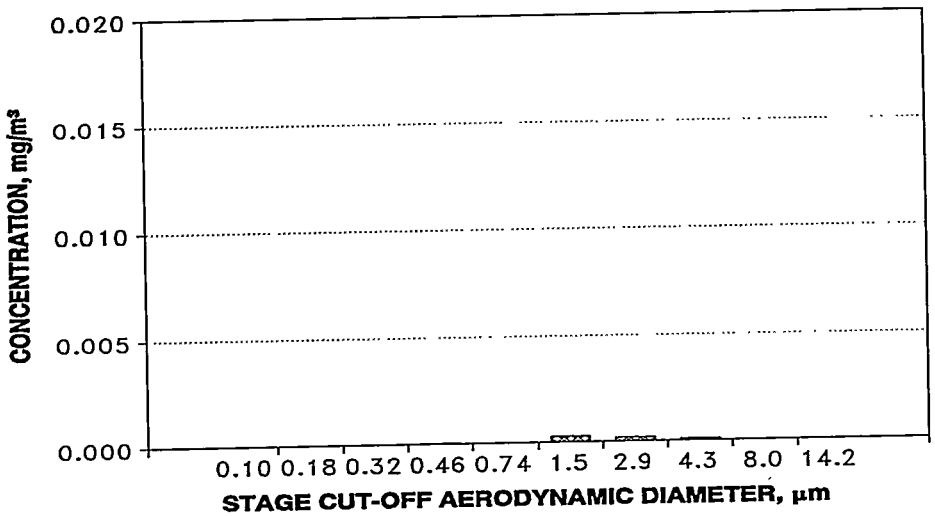

Figure 6i Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: suture, irrigation-suction; sampling time = 900 sec)

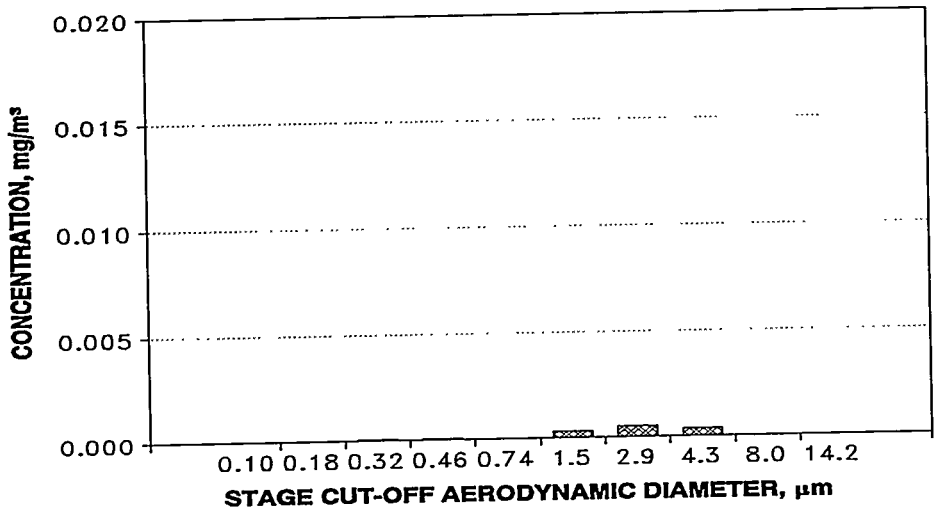

Figure 6j Bar graph of the aerosol concentration observed in each size interval. (LMC Run #5 Total Hip: room clean up; sampling time = 650 sec)

Figures 7a and 7b show a typical result obtained from a MPC Impactor worn by the chief surgeon. This impactor data showed the time-averaged size distribution over the entire surgical procedure, which usually lasted 1 to 2 hours. Similar results were obtained for other surgeons (see Appendix C). Also shown in Figure 7a are the results analyzed by Chemstrip 9 on each stage for quantifying blood content. Since these personal impactors were sterilized before use, the increased uncertainty in gravimetric (weighing) determination, as discussed previously, should be considered in interpreting these data. Therefore, the data discussed here should be considered as more qualitative than quantitative. In general, the size distribution obtained by MPC impactors showed two or three modes with peaks at < 0.3 μm, around 3.0 μm, and > 10 μm in aerodynamic diameter (see Appendix C). The contributions to each individual mode may be from evaporation-condensation (electrocautery), irrigation-suction with power tools, and those primarily from power tools, respectively, for the small, medium, and large mode. As shown in Figure 7b, the middle mode was missing, indicating most aerosols in this size range were liquid droplets and eventually evaporated before weighing. However, Chemstrip 9 analyses indicated that almost all stages tested had positive responses (even with unmeasurable net weights on stages 5-8) with the higher responses (3+ or 2+) on the first four to five stages (corresponding to an aerodynamic particle size of 3.5 μm to 21.3 μm). This is because the Chemstrip 9 analysis is much more sensitive than a gravimetric measurement of the impactor stage. Table 4 shows the qualitative response of Chemstrip 9. With 20 μL of distilled water used per sample, Chemstrip 9 can detect

a blood sample as small as 3.0×10^{-3} μg when compared to a few micrograms of sample required in the case of an impactor stage.

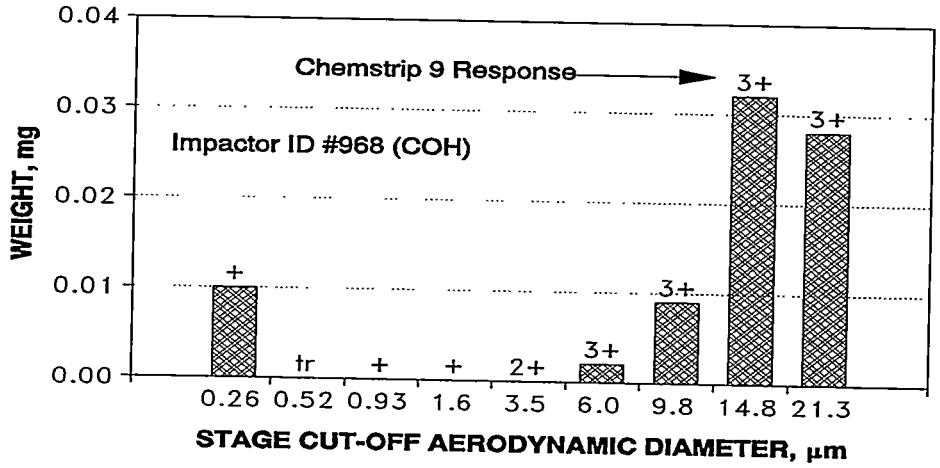

Figure 7a Bar graph of the mass in each size interval as determined by Marple Personal Cascade Impactor. (LMC Run #5: Total Hip: worn by the chief surgeon)

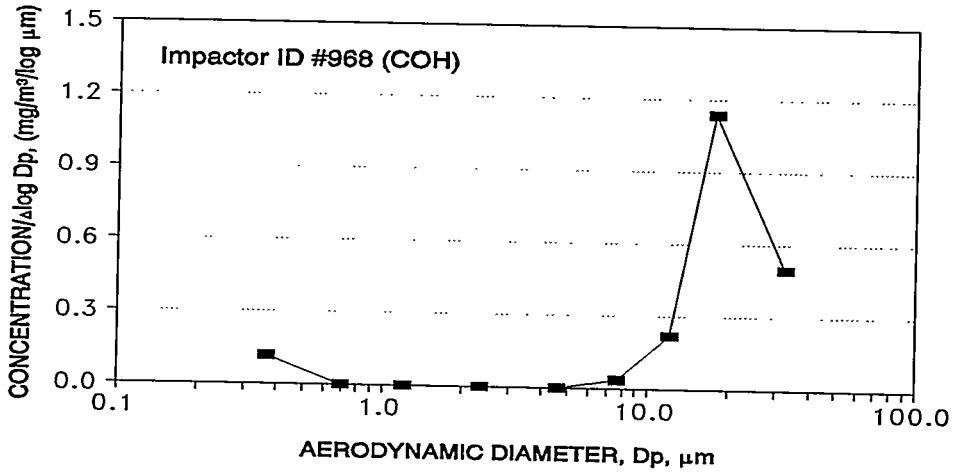

Figure 7b Size distribution as determined by Marple Personal Cascade Impactor, after standardization with respect to interval size.

Table 4 The Qualitative Responses of Chemstrip 9 to Human Blood as Provided by the Manufacturer (Boehringer Mannheim Diagnostics, Indianapolis, IN).

Degree of Positive Responses	Number of erythrocytes/μL	Hemoglobin concentration (μg/μL)	Hemoglobin concentration (μg/20 μL)
Negative	0	---	---
Trace	about 5	$\approx 1.5 \times 10^{-4}$	$\approx 3.0 \times 10^{-3}$
1+	about 10	$\approx 3.0 \times 10^{-4}$	$\approx 6.0 \times 10^{-3}$
2+	about 50	$\approx 1.5 \times 10^{-3}$	$\approx 3.0 \times 10^{-2}$
3+	about 250	$\approx 7.5 \times 10^{-3}$	$\approx 1.5 \times 10^{-1}$

To summarize the results from this phase of the study, some general observations can be made as follows: (1) the aerosol concentration (mass) was higher during the total hip replacement procedures than during the total knee replacement procedures; (2) among those wearing the MPC impactor, the three surgeons had measurable amounts of aerosol, although the amounts were low (on the order of 10 μg or less). Analysis by Chemstrip 9 consistently indicated positive results (3+, 2+, and 1+) for the first four to five MPC impactor stages which correspond to aerodynamic particle sizes of 3.5 μm to over 21.3 μm (Fig. 7a); (3) because a tourniquet was applied during most of the total knee replacement procedure, very little or no blood was observed in the aerosol samples. Filter samples obtained during the time period when a tourniquet was applied were either negative or showed a trace for hemoglobin by Chemstrip 9 analyses, while the filter sample obtained after the release of the tourniquet, followed by irrigation/suction, showed 1+ or higher responses, similar to

observations during the total hip replacement procedure. From these observations, we conclude that a) the bloodier the procedure the higher the probability of generating blood-containing aerosols, and b) most of the blood-associated aerosols might be produced during the irrigation/suction procedure; (4) QCM data indicated that the aerosol mass concentration was highest (although the absolute values were low) during the earliest stage of surgery, i.e., opening the surgical site when an electrocautery, and occasional irrigation and suction were used. The other surgical procedures produced a much lower mass concentration of aerosols; (5) occasionally, area filter samples and one or two stages of Marple impactor samples from personnel other than surgeons showed positive responses from Chemstrip 9 (either trace or 1+). This was probably due to splashing during the irrigation/suction procedure; and (6) room clean-up did not resuspend any blood-associated aerosols (negative results from Chemstrip 9 analysis). More detailed data are in Appendix C.

VII. LABORATORY STUDIES: CHARACTERIZATION OF AEROSOLS PRODUCED BY TOTAL HIP REPLACEMENT IN THE DOG LABELED WITH ^{51}CR

In the design of this project, one goal was to use an animal model to replicate surgical procedures done in humans so that a more controlled environment could be established for aerosol characterization. Furthermore, some experiments that can provide valuable information, such as using radioactive material as a tracer, cannot be performed on humans. The rationale of using the dog as the animal model has been discussed previously. The

limited data from the pilot study and extensive field sampling efforts at the LMC during the orthopedic surgeries suggested that blood-associated aerosols were produced from these surgical procedures. In these studies, the identification of blood-associated aerosols primarily relied upon the Chemstrip 9 analysis of the samples obtained. However, Chemstrip 9 will respond to either the hemoglobin or myoglobin but will not differentiate between the two. Myoglobin is distributed in smooth muscle, skeletal muscle, and myocardium. On the average, muscle in an adult male contains about 700 mg myoglobin per 100 grams wet weight (Mountcastle, 1968). HIV is primary carried through the lymphocytes in the blood, and myoglobin in muscle is probably not a good candidate vector for transmission of viral disease. During surgery using various power tools, the aerosol produced might contain muscle in addition to blood. Therefore, the positive response on Chemstrip 9 might be due to myoglobin, and its presence would bias the risk estimates toward overestimation. Additionally, the results from Chemstrip 9 are only qualitative, because the responses are classified into four discrete ranges of response (see Table 4).

This phase of study was designed to quantify the blood-associated aerosols that might be produced during the orthopedic surgical procedures. To achieve this goal, the blood was labeled with radioactive ^{51}Cr for subsequent radioactivity counting of aerosol samples using standard gamma-counting methods.

A. Radionuclide Labeling of Blood and Administration to Dogs

The most relevant biological elements that could be labeled would be the white blood cells (WBCs) that normally carry the HIV virus. However, because of the

relatively small number of circulating WBCs, such labeling did not appear to provide sufficient detection sensitivity for measurement of blood-containing aerosols in the microgram mass range based on known WBC labels. Therefore, a better strategy was to radiolabel RBCs, for which the RBC to WBC ratio is around 10^3. The method used in this study was the standard method of ^{51}Cr labeling (Owen, 1959).

Hexavalent sodium chromate readily penetrates the RBC membrane and establishes a stable bond with the intracellular hemoglobin. Reduced trivalent ^{51}Cr does not penetrate the RBCs. The labeling was achieved by incubating $^{51}Cr(VI)$ with fresh or refrigerated whole blood, and removing the reduced Cr(III) by washing and centrifugation. Labeling efficiencies were about 90%. Following radiolabeling and purification, the blood was transported to the surgical suite and intravenously infused into the anesthetized dog.

The ^{51}Cr 310 keV gamma rays were quantified using the Beckman 8000 automated gamma counter. The required amount of label radioactivity was initially estimated based on: (1) the minimum detectable true activity (Altshuler and Pasternack, 1963) required for a 100-minute count at a 5% confidence level, (2) assuming a desired mass limit of detection of 1 μg, (3) assuming that 7% of the mass of a 10-kg dog is blood, and (4) assuming a 90% binding efficiency for the radiolabeling procedure. The resulting calculated amount of ^{51}Cr was 25 mCi (9.3×10^8 Bq). However, results obtained from an experimental aerosol sampling during a total hip replacement surgery of a dog whose blood was

labeled with 25 mCi ^{51}Cr indicated that the specific activity of the labeled RBC was inadequate to quantitate the amount of blood-containing aerosol produced during the procedure. Therefore, the radioactivity was increased to 500 mCi(19 GBq) per experiment in the subsequent runs.

Because of the relatively large amount of ^{51}Cr to be added to the RBCs, all attempts were made to maintain the concentration of stable Cr below the level of 5 μg/mL RBC by purchasing the highest specific activity ^{51}Cr available. This level of Cr concentration (5 μg/mL RBC) has been shown to result in toxicity to the RBCs (Owen, 1959). To maximize the ^{51}Cr concentration in blood, the volume of blood to be labeled was increased from the original design of 60 mL to 300 mL. By increasing the blood volume labeled, a higher percentage labelled blood could be achieved without incurring a disproportionate increase in the ^{51}Cr activity per RBC. This reduces the probability of producing stable Cr toxicity within the RBCs.

The 300 mL of canine blood required for the ^{51}Cr labeling was obtained from a combination of blood taken from the subject dog supplemented with blood obtained from other donor dogs that were bled at or near the same time as the subject dog. This supplementation was required because over 40% (300 mL) of the blood volume cannot be removed without inducing hypovolemic shock. Small samples of blood from potential donor dogs and from the subject dog that were obtained prior to the surgical procedure, and were mixed and evaluated microscopically for evidence of agglutination. Donors in which such cross-

reactivity with the blood of the subject dog was absent were used in the study.

B. Surgical Procedure

The surgical procedure was similar to that used in the dog pilot study (Section V), so a description will not be repeated here. Adequate room exhaust in the surgery suite was verified before the procedure began. The surgery table was covered with labsoak and oilcloth beneath the sterile drapes to minimize contamination and to help collect spilled blood. Because of the significant increase in the amount of radioactivity used, special precautions were taken to reduce the potential radiation doses to the operating room personnel. Jumpsuits, disposable coveralls, shoe covers, and eye protection were worn. Disposable gloves were worn when handling animals or radioactive materials. A respirator was worn when the dog was injected with ^{51}Cr-labelled blood and during the entire surgical procedure. Radiation dosimeters and a β/γ survey meter were used to monitor exposure of the personnel involved. During the surgical procedure, a ¼" thick lead sheet was placed over the torso of the dog so that as much of the dog was shielded as possible, without interfering with the surgery. This reduced the external radiation dose to the surgeons by about a factor of four. At the end of the surgical procedure, with the dog still in deep surgical anesthesia, the dog was euthanized by exsanguination by cardiac puncture.

Following the surgery, the instruments and surgical surfaces were decontaminated with Radiac Wash, and the contaminated towels and other wastes

were placed in bags, labeled, and disposed of as low-level radioactive waste. Blood-soaked absorbent materials were considered radioactive, but collected separately from the nonbiological radioactive wastes. These absorbent materials were held until the ^{51}Cr decayed sufficiently before disposal as biological wastes. Following decontamination, the surgery suite was monitored to verify that no residual contamination was present. All ^{51}Cr-contaminated nonbiological materials were collected and consolidated as low-level, solid radioactive waste. Leftover radiochromium was solidified and stored to allow decay to acceptable levels as determined by the health physics personnel before disposal as low-level waste.

C. Aerosol Collection and Characterization

Because of the relatively large amount of radioactivity used in this phase of study, the following factors were considered when choosing the instruments for aerosol sample collection and characterization: (1) the instruments would not be used in the hospital study, (2) they were easy to decontaminate and could be used in the next experiment without the need to wait for radioactive decay (half-life for ^{51}Cr is 27.8 day), and (3) they provided the needed information to achieve the planned objective of the study. Based on these considerations, the following instruments were chosen: (1) an MPC impactor (to be worn by the chief surgeon), (2) two LMJ cascade impactors, (3) filter samples, and (4) a point-to-plane ESP. These instruments were cleaned and decontaminated for

each experimental run.

In the dog pilot study, the sampling probe was held by an aerosol science staff member at a distance of about 10-20 cm from and above the surgical site. To mimic those configurations used in the field sampling at LMC and to reduce potential radiation dose to the personnel performing the experiment, the aerosol sampling probe was attached to the top of the lead shield that covered the torso of the dog. The distance of the probe from the surgical site was about 15-25 cm. One LMJ cascade impactor was also placed next to the probe on top of the lead shield.

Five dogs were each radiolabeled with 500 mCi $^{51}Cr(VI)$. After the radiolabeling, aerosol measurements were taken during total hip replacement procedures in the dog surgical suite at ITRI. Aerosol samples, including one MPC impactor (worn by the chief surgeon), two LMJ cascade impactors (one placed near the surgical site, and the other one sampling through an aerosol chamber), and two consecutive filter samples taken from the aerosol chamber were obtained during each experiment. Figure 8 shows the arrangement of samples taken from the sampling chamber.

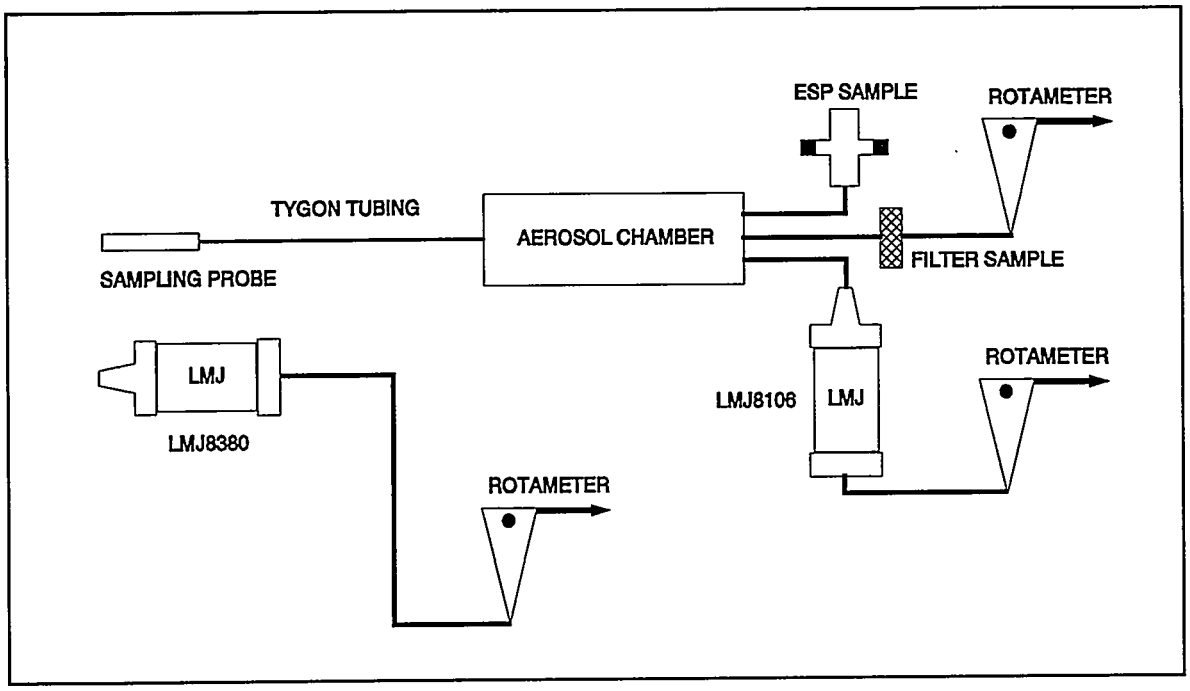

Figure 8 Schematic diagram showing the arrangement of two LMJ impactors (one placed near the surgical site, parallel to the sampling probe, and the other one sampling through an aerosol chamber), a sampling probe, an aerosol chamber, and the filter sampler.

D. Data Analyses and Estimation of Blood Content Collected on the Samples

At the conclusion of the surgical procedures and clean up, all samples, including personal samplers, filters, and LMJ impactors, were double-bagged and transported to a fume hood. The personal impactor, LMJ cascade impactors, and filters were disassembled. The impactor substrates and filters were removed and placed in pre-labeled containers. The samples were weighed using a Cahn balance. After weighing, each sample (filters, substrates from impactors' stages, and blood samples) was assayed for ^{51}Cr activity using the Beckman 8000 automated gamma counter. Because of the low activity in the

samples (although 500 mCi was used to label the blood), a 500-minute counting time was used per sample, except for a few samples with higher activities (such as blood samples). More than 30 samples (including background and standard samples) were counted per experiment. These counting data represent aerosolized RBC samples. Each blood sample, taken from the labeled subject dog for each experiment, was used as the counting standard for that experiment. This standard was also used to establish the converting factor between "count" and "number of RBCs" by activity counting and RBC counting, so that the number of RBCs collected on each impactor substrate could be estimated from the counting data of labeled ^{51}Cr activity. Thus, the number of RBCs associated with different particle sizes can be estimated. After counting, these filter and impactor substrate samples were washed and the hemoglobin content quantified by using Chemstrip 9. The ESP samples (grids) were examined using either the transmission electron microscope or scanning electron microscope for particle morphology observation and evaluation.

E. Results and Discussion of the ^{51}Cr-Labeled Dog Study

Because of the nature of the instruments used in this series of experiments, the aerosol size distribution data obtained represented the time-averaged information throughout the surgical procedures. Similar to those cases of surgeries at LMC, the aerosol size distributions varied from experiment to experiment due to the dynamic nature of the surgery. However, the results were similar among the

five dogs. Figures 9a and 9b show the results obtained from the MPC Impactor worn by the chief surgeon. Figure 9a shows a bar graph of the collected mass and estimated number of RBCs vs. particle size. Also included are the results analyzed by Chemstrip 9 on each stage substrate for quantifying blood content. The estimated number of RBCs was obtained from the radioactivity of ^{51}Cr; therefore, the estimated number of RBCs is proportional to the radioactivity within a given experimental run. Figure 9b shows the mass size distribution and activity size distribution (or RBCs) after standardization with respect to interval size (Raabe, 1971). In general, the size distributions obtained by weight and by radioactivity correlated very well. Considering the qualitative nature and also somewhat subjective nature of reading the color change in the strip, the Chemstrip 9 results correlated with the radioactivity (and thus to the estimated number of RBCs) fairly well. Figures 10a and 10b compare the results from two LMJ impactors, one placed near the surgical site (LMJ8380), parallel to the aerosol sampling probe, and the other sampling through the aerosol chamber (LMJ8106) (Fig. 8). Although the size distributions determined by the two LMJs are very similar, the total aerosol mass concentration measured by LMJ8380 was about twice that of the LMJ8106 (0.383 mg/m^3 vs. 0.197 mg/m^3). This may suggest some losses in the sampling line for the LMJ8106 (sampled through aerosol chamber). It may also suggest spatial nonuniformity of the aerosol concentration around the surgical area and within the surgical room. Again, the correlations between the Chemstrip 9 results and the estimated

numbers of RBCs from radioactivity labeling were quite good. Similar results were obtained for the other four experimental runs. Details of those data are included in Appendix D.

The good correlation between the Chemstrip 9 response and the estimated number of RBCs (or radioactivity of ^{51}Cr) indicated that the Chemstrip 9 response obtained was primarily from blood-associated (hemoglobin) aerosols rather than from myoglobin, because only hemoglobin was labeled with ^{51}Cr. Again, the MPC impactor data were similar to those obtained during experiments with unlabeled dogs and those derived from the orthopedic surgeries at LMC. Nearly all samples from stages of the MPC impactor worn by the chief surgeon (and other surgeons) showed aerosols that contained elements of blood. This finding suggests that blood-associated, inspirable aerosols were produced during the total hip replacements and other orthopedic surgical procedures.

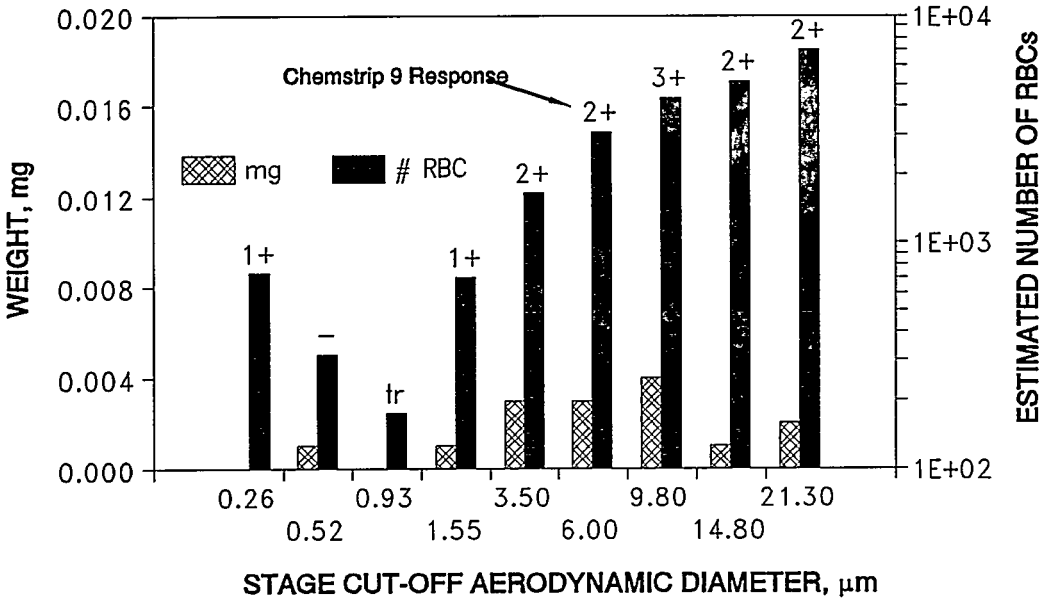

Figure 9a Bar graph of the mass and estimated number of RBCs observed in each size interval of a MPC impactor. (^{51}Cr-labeled dog: Run #1)

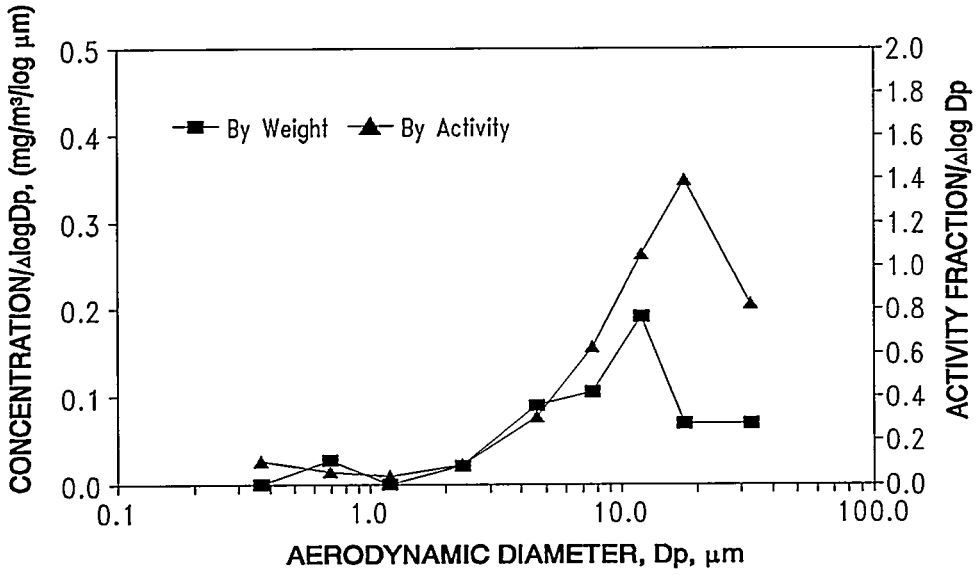

Figure 9b Size distribution and activity distribution as determined by a MPC impactor, after standardization with respect to interval size.

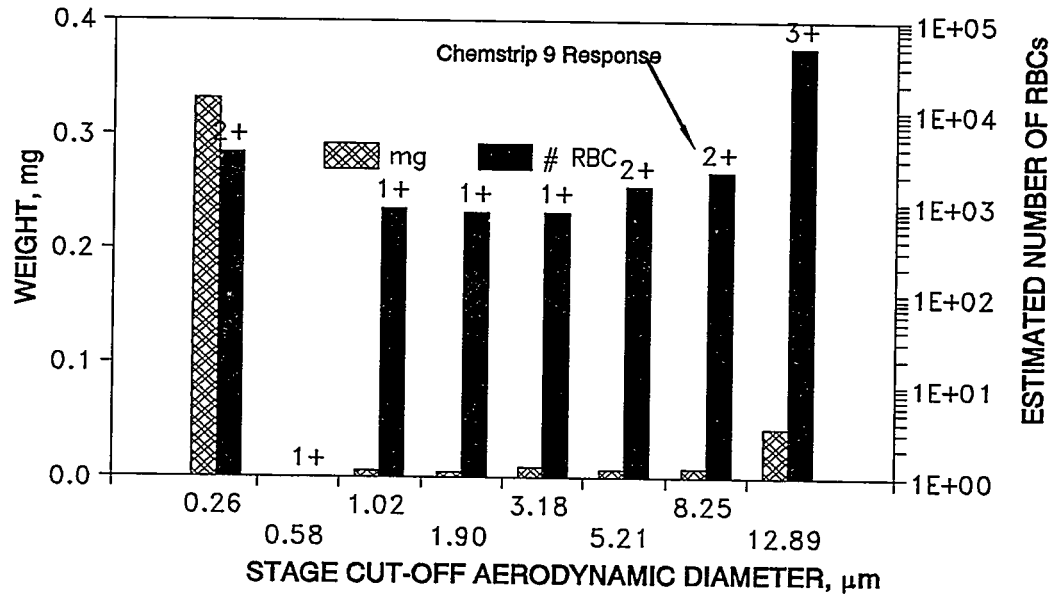

Figure 10a Bar graph of the mass and estimated number of RBCs observed in each size interval of a LMJ cascade impactor. (LMJ I.D. LMJ8380, ^{51}Cr-labeled dog: Run #1)

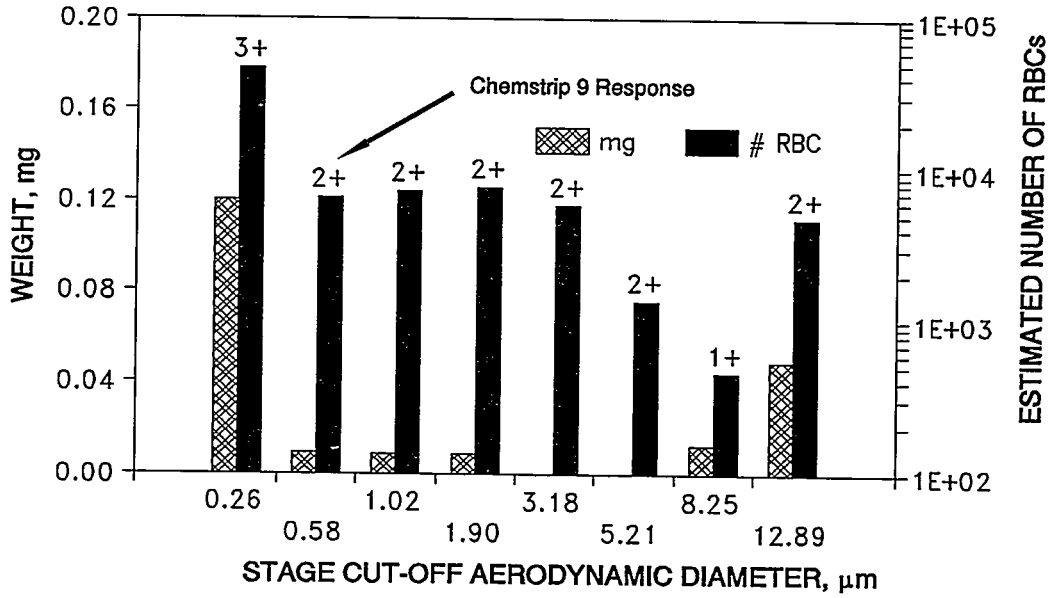

Figure 10b Bar graph of the mass and estimated number of RBCs observed in each size interval of a LMJ cascade impactor. (LMJ I.D. LMJ8106, ^{51}Cr-labeled dog: Run #1)

VIII. OVERALL SUMMARY, DISCUSSION AND CONCLUSIONS

Recent information on the potential for transmission of HIV from infected patients to health care workers via aerosol inhalation, particularly during orthopedic surgery, has added to the concerns about the hazards of working with HIV-positive patients in the medical profession (Jewett, 1990; Johnson and Robinsion, 1991). In order to adequately assess this risk, additional information on the aerosols, such as the particle size distribution, aerosol mass concentration, and whether these aerosols are blood-associated, is required. However, only very limited studies have been reported concerning the characteristics or concentration of aerosols produced during surgeries. Heinsohn *et al.* (1991) and Jewett *et al.* (1992) have demonstrated that respirable aerosols can be generated by power tools (such as the bone saw, Hall drill, Shea drill, and Bovie electrocautery) used in orthopedic surgery, under laboratory conditions using bovine tissue and blood. Johnson and Robinson (1991), in their T-cell culture infectivity study, demonstrated that HIV-1 can remain viable and may be recovered from the aerosol created by operating the power tools, such as a router or a Stryker bone saw, while contacting HIV-infected blood (no tissue involved). In a recent study to assess the amount of blood in aerosols inhaled by surgeons during 15 operations, Jewett and Heinsohn (1992) reported that a mean concentration of 1.5 μg of hemoglobin per cubic meter of air was detected. Although these studies suggested that blood-associated aerosols may be produced by power tools used in the surgery, the detection of blood-associated aerosols in these studies were based on Hemastix analysis which may be biased because the Hemastix can respond to both the hemoglobin and myoglobin. Also, data from measurements taken during surgeries in hospitals are very limited. Only one study, reporting 26 samples obtained from 15 operations with surgical procedures ranging across orthopedics, urology, vascular, pediatric cardiac, and obstetrics, has been documented (Jewett and Heinsohn, 1992). Therefore, more data are urgently required.

In our study, we concentrated on orthopedic surgical procedures. Our approach was two-fold: clinical studies at a hospital and a laboratory study using an animal model. The clinical study provided valuable human data in an actual surgical setting, and the laboratory

study using the animal model confirmed that the aerosols produced were indeed blood-associated. The laboratory study also provided a method for estimating how much of those surgically produced aerosols were blood-associated. Furthermore, we used an array of aerosol instruments to characterize the aerosols; therefore, not only the size information was obtained, but also the dynamic changes of the aerosol size were also available throughout the surgical procedures.

As presented in Section VI, 10 surgical procedures were sampled at the LMC. These orthopedic surgical procedures included the following: five total hip replacements, one back fusion, three total knee replacements, and one hip reconstruction. During each procedure, a minimum of five MPC impactors were worn by personnel within the surgical room, including the three surgeons, in order to measure aerosols in the breathing zone of each individual. To study the dynamic changes of the aerosols with time, periodic QCM measurements and sequential filter samples were taken through an aerosol sampling probe placed close to the surgical site. In addition, three area filter samples were taken for detecting potential spreading of aerosols from the source to the rest of the room. All of these samples were also subjected to Chemstrip 9 analyses for determining whether these aerosols were blood-associated. As discussed previously, our results from the aerosol sampling and characterization at LMC indicated that respirable, blood-associated aerosols were produced from power tools used in the orthopedic surgical procedures. In general, the higher blood content was associated with particles larger than 3.5 μm in aerodynamic diameter, as observed from the first five stages of the MPC impactors worn by the surgeons. Very little of the blood-associated aerosols spread to the rest of the room, as observed by three area filter samples and MPC impactors worn by nonsurgeons located away from surgical table in each operation. This may be due to the use of a laminar flow room where the aerosols were quickly diluted and exhausted. For surgical rooms without laminar flow ventilation, the aerosol characteristics may be different; the spread of the aerosols may depend on room ventilation design and require further study. The aerosol mass concentration varied with different surgical procedures, and even with the same surgical procedure from

case to case. However, in general, the aerosol concentration was highest during the early part of the surgery when the site was opened using electrocautery. The aerosol concentration dropped quickly to a relatively low level as other power tools were used. The time-averaged aerosol concentration over the entire surgical procedure was higher during the total hip replacement than among other procedures such as the total knee replacement, as observed from the filter samples. Table 5 lists the mean time-averaged aerosol concentration observed for the different surgical procedures, from filter samples taken near the surgical site (probe distance from the site was $\approx$ 40-60 cm). The background aerosol concentration for this laminar flow surgical room was less than 0.002 mg/m^3 as measured using QCM. For comparison, the aerosol concentration for typical indoor air is on the order of 0.03 mg/m^3.

Table 5 Time-averaged Aerosol Concentration as Measured by Filter Samples

Type of Surgery (number of cases)	Mean Aerosol Concentration $\pm$ S.D. mg/m^3
Total Hip Replacement (5)	0.064 $\pm$ 0.045
Hip Reconstruction (1)	0.041
Total Knee Replacement (3)	0.031 $\pm$0.010
Back Fusion (1)	0.057

One potentially interesting observation was that, for the knee surgery, the aerosol samples obtained by a filter when a tourniquet was applied showed nondetectable or very low blood content. However, all filter samples obtained after the release of the tourniquet, when the only tools used were irrigation-suction and suture, showed a $\geq$ 1+ response by Chemstrip 9. This observation suggested that the use of irrigation-suction during the surgery was one of the key processes for producing blood-associated aerosols.

Chemstrip 9 (or Hemastix), a product commonly used to detect hemoglobin in urine,

was used in this study and other studies (Heinsohn *et al.*, 1991; Jewett *et al.*, 1992) to assess the blood-associated aerosol particles. However, the aerosols produced from surgical procedures using power tools may also contain muscle. Chemstrip 9 will respond to either the hemoglobin or myoglobin but cannot differentiate between the two. This causes no problem in analyzing urine (their primary use) on samples where no muscle is involved. However, analyzing the aerosols produced from surgery by power tools imposes the uncertainty in positively identifying that the aerosols produced from orthopedic surgical procedure are indeed blood-associated. We approached this problem by using an animal model where only the blood was labeled with a radionuclide, ^{51}Cr. Five dogs had their blood labeled with ^{51}Cr prior to surgery, and aerosol samples were taken during a total hip replacement surgery. As discussed in Section VII.E, the results were very comparable to those obtained in human total hip replacement surgery at LMC.

The labeled dog study (1) confirmed that blood-associated aerosols were produced during the orthopedic surgery using power tools; (2) the degree of Chemstrip 9 response on samples correlated to radioactivity reasonably well, with the higher Chemstrip 9 response corresponding to the higher radioactivity; and (3) the number of RBCs associated with each size range could be estimated, as well as the total number of RBCs potentially inhaled. The MPC impactor data are summarized in Table 6, and the average data are plotted in Figure 11. The total average sample weight collected by the MPC impactor was 0.038 ± 0.021 mg (mean $\pm$ S.D.; $n = 5$), and the total estimated number of RBCs was $2.9 \times 10^4 \pm 1.5 \times 10^4$. A relatively large standard deviation indicated large variability between surgeries.

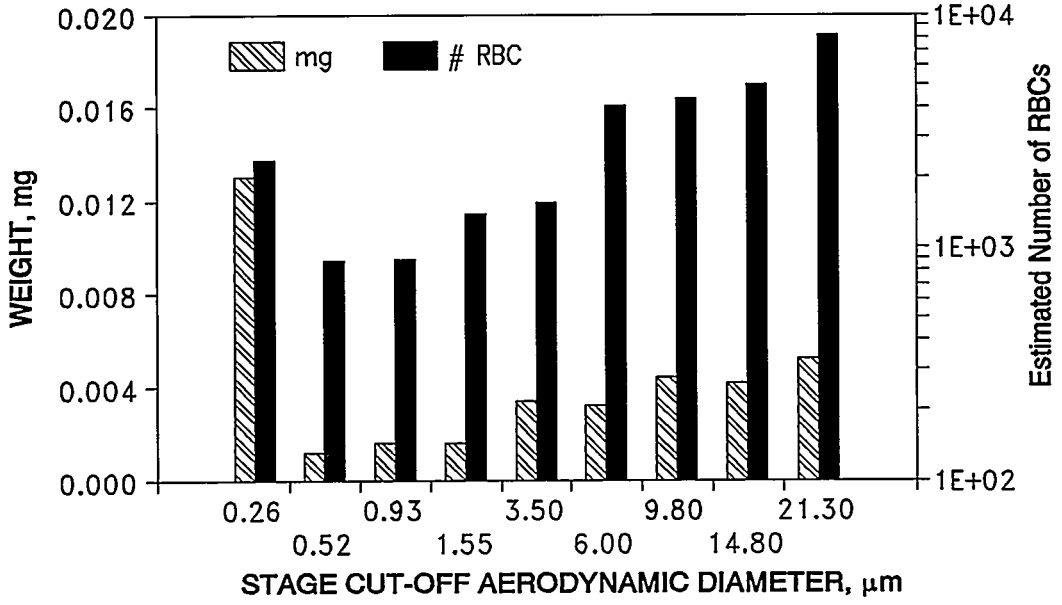

Figure 11 Bar graph of the mass and estimated number of red blood cells in each size interval of a Marple personal cascade impactor. (average of 5 ^{51}Cr-labeled dog experiments, mean and S.D. are listed in Table 6)

Table 6 ^{51}Cr-Labeled Dog Experiments: Marple Personal Cascade Impactor Data

		Run 1	Run 2	Run 3	Run 4	Run 5	Mean	S.D.	Max.	Min.
Stage	ECD,μm	ΔWt,mg	ΔWt,mg	ΔWt,mg	ΔWt,mg	ΔWt,mg	ΔWt,mg	mg	mg	mg
F	0.26	0.000	0.011	0.009	0.000	0.045	0.013	0.017	0.045	0.000
8	0.52	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.002	0.001
7	0.93	0.000	0.000	0.001	0.001	0.006	0.002	0.002	0.006	0.000
6	1.55	0.001	0.000	0.002	0.002	0.003	0.002	0.001	0.003	0.000
5	3.50	0.003	0.000	0.004	0.005	0.005	0.003	0.002	0.005	0.000
4	6.00	0.003	0.000	0.004	0.005	0.004	0.003	0.002	0.005	0.000
3	9.80	0.004	0.002	0.005	0.007	0.004	0.004	0.002	0.007	0.002
2	14.80	0.001	0.005	0.003	0.008	0.004	0.004	0.002	0.008	0.001
1	21.30	0.002	0.005	0.011	0.005	0.003	0.005	0.003	0.011	0.002
	50.00									
Sum		0.015	0.024	0.040	0.035	0.075	0.038	0.021	0.075	0.015
Stage	ECD,μm	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC
F	0.26	7.24E2	4.47E3	9.73E2	2.42E3	3.19E3	2.36E3	1.40E3	4.47E3	7.24E2
8	0.52	3.18E2	2.14E3	2.92E2	9.38E2	6.61E2	8.69E2	6.77E2	2.14E3	2.92E2
7	0.93	1.75E2	2.00E3	0.00E0	1.49E3	7.65E2	8.86E2	7.62E2	2.00E3	0.00E0
6	1.55	6.95E2	2.58E3	2.53E2	1.92E3	1.50E3	1.39E3	8.34E2	2.58E3	2.53E2
5	3.50	1.65E3	0.00E0	9.44E2	3.37E3	1.80E3	1.55E3	1.11E3	3.37E3	0.00E0
4	6.00	3.06E3	7.94E3	1.36E3	5.17E3	2.79E3	4.06E3	2.29E3	7.94E3	1.36E3
3	9.80	4.35E3	5.78E3	2.57E3	8.61E3	2.01E2	4.30E3	2.85E3	8.61E3	2.01E2
2	14.80	5.09E3	8.72E3	2.54E3	8.45E3	7.40E1	4.97E3	3.35E3	8.72E3	7.40E1
1	21.30	7.03E3	1.26E4	7.59E3	1.37E4	2.00E1	8.19E3	4.87E3	1.37E4	2.00E1
	50.00									
Sum		2.31E4	4.62E4	1.65E4	4.61E4	1.10E4	2.86E4	1.48E4	4.62E4	1.10E4

As mentioned previously, the results of the human study at LMC and the labeled dog study were similar, especially the magnitude of the responses from Chemstrip 9 among MPC impactors worn by the surgeons. To estimate the number of RBCs that might be associated with the aerosols produced during orthopedic surgery and inhaled by surgeons, we assumed that the magnitude of the RBCs estimated from the labeled dog study was applicable to those studies at LMC. Further, we assumed that the surgeon's respiratory minute volume was 20 L/min (corresponding to light exercise or moderate work conditions), which was 10 times the flow rate of MPC impactor (2.0 L/min). Under these assumptions, the estimated total number of RBCs that might be inhaled by a surgeon would be $\approx 2.9 \times 10^5$ (or ≈ 8.7 μg of RBCs). However, the primary vehicle for carrying HIV is through the lymphocytes, not through the RBCs. The ratio between the RBC and lymphocytes is about 2200:1 for humans (Wintrobe *et al.*, 1981). Therefore, the estimated number of lymphocytes that might be inhaled by a surgeon would be $\approx$ 135 during the course of an orthopedic surgical procedure. Further, not all inhaled particles will deposit in the respiratory tract, and the surgical mask will trap some of the aerosol particles. The collection efficiency of a properly worn surgical mask was reported to range from a few percent to 50% for the submicrometer-sized particles and from 20% to near 100% for micrometer-sized particles, depending on the type of surgical mask, flow rate, and particle size (Chen and Willeke, 1992; Tuomi, 1985). It was also reported that face-seal leakage, even for a properly worn surgical mask, of up to 10% to 20% were common (NIOSH, 1992). After an aerosol is inhaled, the deposition efficiency within the respiratory tract is dependent on particle size and breathing pattern (breathing frequency and tidal volume). Figure 12 shows the predicted deposition efficiency of inhaled particles, based on a mathematical deposition model (Yeh *et al.*, 1991). Furthermore, close examination of Table 6 indicates that about 60% of RBCs were associated with particles larger than 10 μm, and about 8% of RBCs were associated with particles less than 0.5 μm. Most particles larger than 10 μm will be filtered out by the surgical mask (except those that pass through the face seals), and most of those that pass through the mask will then be deposited in the nasal region, especially in the anterior region. Whether particles deposited in this region can be transported into blood stream is unknown. The majority of particles less than 0.5 μm probably originate from the use of electrocautery. Johnson and Robinson (1991) reported that no

infectious HIV-1 was detected in aerosols generated by electrocautery. In addition, the probability of lymphocytes carrying HIV also needs to take into account when assessing the potential inhalation hazard. From all of these considerations, the potential inhalation risk from aerosols produced during orthopedic surgery seems very low. One should note that the existing literature does not provide evidence that blood-borne pathogens, such as HIV or HBV, have been transferred by the inhalation route (Tokars *et al.*, 1992; Petersen, 1980). A question not addressed by these studies is the viability of HIV in inhaled HIV-associated aerosols produced by surgical procedures. To ascertain the significance of our results, further studies are required to assess the amount and viability of pathogens associated with these blood-associated aerosols.

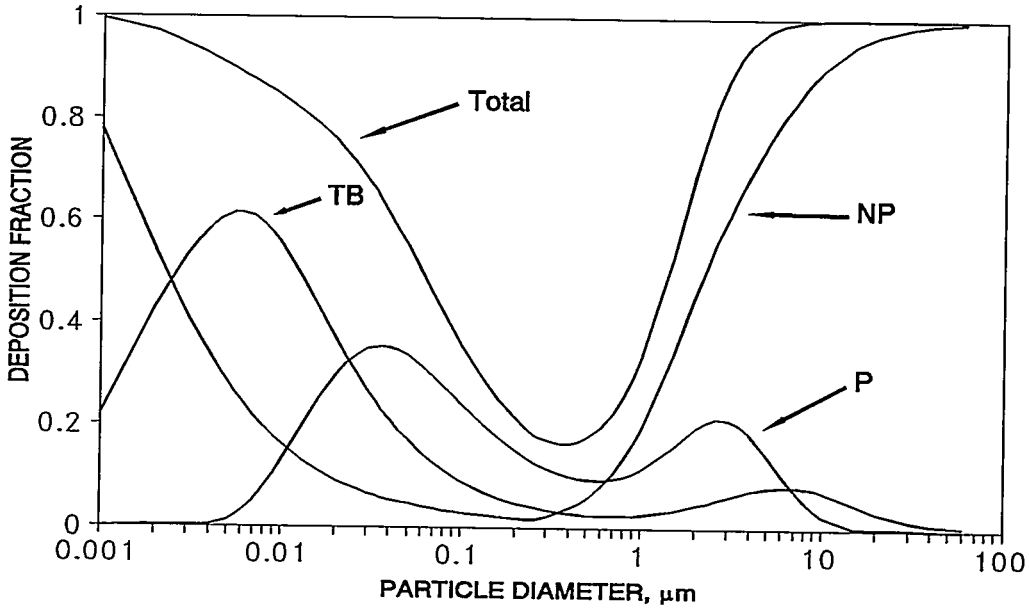

Figure 12 Calculated regional deposition of spherical particles of density 1 g/cm^3, with 100% nose breathing, 15 breaths/min, and tidal volume = 750 cm^3 (NP = nasopharyngeal; TB = tracheobronchial; P = pulmonary)

Therefore, based on this study, the potential risk of HIV transmission from patient to surgeons or other personnel in the surgical room by inhalation of blood-associated aerosols during an orthopedic surgical procedure appears to be small. However, one should note that the current study was carried out in a laminar flow surgical room. Without laminar flow capability or with

different flow characteristics within the surgical room, the results might be different, and further study is required. Other concerns of health care workers that need to be addressed include: (1) aerosol characterization in a trauma treatment center (Emergency Rooms), (2) the viability of HIV or other pathogens in aerosols generated during surgical procedures, and (3) characterization of aerosols produced by dental procedures.

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APPENDIX A: LITERATURE REVIEW

REVIEW OF LITERATURE RELATIVE TO THE OCCUPATIONAL RISK AND ACCIDENTAL INFECTION OF HUMAN IMMUNODEFICIENCY VIRUS WITH EMPHASIS ON AEROSOL TRANSMISSION

TABLE OF CONTENTS

I. TRANSMISSION OF GENERAL INFECTIOUS DISEASES

Anonymous. *Federal Register 56*: No. 235; December 6, 1991. Department of Labor. Occupational Safety and Health Administration. 29 CFR Part 1910.1030. Occupational Exposure to Bloodborne Pathogens. **AGENCY:** OSHA. **ACTION:** Final Rule. pp. 64004-64182.

Purpose: Promulgates a standard under section 6(b) of the Occupational Safety and Health Act of 1970, 29 U.S.C.655 to eliminate or minimize occupational exposure to Hepatitis B Virus (HBV), Human Immunodeficiency Virus (HIV) and other bloodborne pathogens.

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Approach: OSHA has determined that employees face a significant health risk as a result of occupational exposure to blood and other potentially infectious materials.

Results: The Agency concludes that such exposures can be minimized or eliminated by using a combination of engineering and work practice controls, personal protective clothing and equipment, training, medical surveillance, Hepatitis B vaccination, signs, labels, and other provisions.

Significance: **This standard became effective March 6, 1992.** Extensive details are provided in this document.

Giachino, A. A., A. W. Profitt, and W. Taine. Expected contamination of the orthopedic surgeon's conjunctiva. *Canad. J. Surgery 31*: 51-52, 1988.

Purpose: Study undertaken to define the rate of likely macroscopic contamination of the conjunctiva by orthopedic surgeons during their work. Cited several references related to contamination leading to infection with hepatitis by minute quantities of blood entering the body through breaks in the skin, needle pricks or through the mucosal surfaces including the conjunctiva. A fatal case of rabies in a veterinary surgeon from blood splashed in the eyes while performing an autopsy is also referenced.

Approach: Prospective evaluation of 60 cases where polycarbonate glasses were worn during orthopedic surgery was conducted by visual inspection of the glasses, and the perceived cause of the spray and content of the spray was recorded.

Results: Thirty-seven of the 60 operations resulted in contamination of the protective glasses. Power tools, hammering, and the use of rongeurs were the main culprits in producing spray. In no case was contamination associated with a severed blood vessel which may occur during hip reduction.

Significance: Since orthopedic surgeons work in a high-risk environment, safety glasses are recommended to prevent contraction of viral diseases such as hepatitis B and acquired immune deficiency syndrome by way of the conjunctiva and physical damage with propelled bone and cement.

Green, F. H. Y., and K. Yoshida. Characteristics of aerosols generated during autopsy procedures and their potential role as carriers of infectious agents. *Appl. Occup. Environ. Hyg. 5*: 853-858, 1990.

Purpose: The purpose of this study was to characterize the aerosols produced by autopsy procedures involving the cutting of bone.

Approach: Some experiments were conducted in the laboratory using a test liquid under controlled conditions in order to gain information on the generation of droplets and their likely trajectories. This was followed by a series of measurements taken in the morgue to determine the concentrations and size characteristics of respirable bone dust particles in the breathing zone of a worker during actual autopsy conditions.

Results: Both clinical and laboratory data confirmed that the saw blade generated clouds of fine bone dust particles and droplets which could pose a serious inhalation hazard.

Significance: Current NIOSH standards for autopsies do not adequately address this problem. Recommended that workers wear mist-dust respirators instead of the conventional surgical mask as protection from respirable aerosols.

Heinsohn, P., D. L. Jewett, L. Baizer, C. H. Bennett, P. Seipel, and A. Rosen. Aerosols Created by Some Surgical Power Tools: Particle Size Distribution and Qualitative Hemoglobin Content. *Appl. Occup. Environ. Hyg. 6*: 773-776 (1991).

Purpose: Prompted by concerns about exposure to blood and other body substances, the possible generation of blood-containing aerosols in orthopaedic surgical practice was investigated.

Approach: Aerosols generated by cutting bovine bone and tendon with blood dripping on them from above with different surgical instruments were measured:

Instruments used for cutting bone:

Oscillating bone saw.

Hall drill.

Shea drill.

Instruments used for cutting and coagulating tendon:

Electrocautery.

Qualitative particle size determined by:

Sampling aerosols with impinger (flow rate $\geq$ 1 L/min) and testing for hemoglobin with Hemastix strip sensitive to detect 375 ng Hgb/5 ml of impinger fluid.

Particle size determined by sampling aerosol with a ten-stage, low-pressure cascade impactor that measured real-time particle mass over a particle size distribution between 0.07 μm and 14 μm, assuming a particle density of 1 g/cm^3.

Results: Blood (hemoglobin) was detected in some of the impinger samples. Respirable aerosols ($<$ 5 μm) were generated by all of the power tools tested.

Significance: Demonstrated that respirable aerosols can be generated by power tools used in orthopaedic surgery.

Hussain, S. A., A. B. A. Latif, and A. A. A. A. Choudhary. Risk to surgeons: a survey of accidental injuries during operations. *Br. J. Surg. 75*: 314-316, 1988.

Purpose: To determine the rate of accidents during surgery in a hospital in Saudi Arabia.

Approach: Questionnaire completed by surgeons participating in 2016 surgical procedures. Areas of the body where the injuries occurred and circumstances surrounding the injury were recorded.

Results: A total of 112 (5.6% of the procedures) injuries were reported:

107 (95.5%) were needle sticks,

4 (3.6%) were knife cuts, and

1 (0.9%) was a diathermy burn.

Significance: Indicates the risk of potential exposure to infectious agents from patients, including AIDS. Care, experience, and good surgical techniques can reduce accidental surgical injuries.

Jewett, D. L., P. Heinsohn, C. Bennett, A. Rosen and C. Neuilly. Blood containing aerosols generated by surgical techniques: A possible infectious hazard.

We have a preprint that is not to be quoted; the work has not been published as yet. Literature search for this article conducted 6-1-91.

From: Dept. of Orthopaedic Surgery, U. C. San Francisco.

Purpose.....:

Approach....:

Results.....:

Significance:

Morrow, P. E. Physics of airborne particles and their deposition in the lung. *Ann. N. Y. Acad. Science 353*: 71-80, 1980.

Purpose: Paper is a review of the topic of aerosol physics and particle deposition in the lungs, particularly as related to airborne transmission of an infectious agent. This is one of many articles, reviews, etc., on this topic.

Approach: Review article.

Results: Basic physical laws governing the deposition of particles in the lungs reviewed. Particles containing bacteria, fungi, viruses, etc., small enough to be deposited in the nasal passages or lungs, are readily created by coughing, sneezing, and speaking. The size of the particle transporting the infectious agent and governing its deposition is related in part to the medium in which the agent was suspended, i.e., water, serum, etc. The same would apply to aerosols created from body fluids during surgery.

Significance: Droplets containing infectious agents that will pass through surgical masks are readily created by coughing, sneezing, and speaking.

Nezhat, C., W. K. Winer, F. Nezhat, C. Nezhat, D. Forrest, and W. G. Reeves. Smoke from laser surgery: Is there a health hazard? *Lasers Surg. Med. 7*: 376-382, 1987.

Purpose: To evaluate the potential risk of smoke created from laser surgery.

Approach: Composition of smoke plume produced during CO_2 laser endoscopic treatment for endometriosis was examined to determine if it presented a hazard to the staff. Samples were collected from 32 plumes produced from 17 women during treatment.

Results: Particle size was 0.31 μm with a range of 0.10 - 0.08 μm.

Significance: Aerosol particle size excluded the possibility of the presence of whole cancer cells. Aerosol particles were too small to be filtered out of the air by available surgical masks.

Occupational Exposure to Bloodborne Pathogens. OSHA 3127. Occupational Safety and Health Administration, U.S. Dept. of Labor. 1992.

Purpose: This booklet provides an overview of OSHA's bloodborne pathogens standard (Part 1910.1030 of Title 29 of the Code of Federal Regulations. *Federal Register 56*: No. 235; December 6, 1991) and informs employees and employers of the risks of occupational exposure to bloodborne pathogens and how to reduce these risks.

Approach: N/A

Results: N/A

Significance: Provides a 29-page summary of the lengthy Federal Regulations meant for the employer and employee.

Pippin, D. J., R. A. Verderame, and K. K. Weber. Efficacy of face masks in preventing inhalation airborne contaminants. *J. Oral. Maxillofac. Surg. 45*: 319-323, 1987.

Purpose: Investigated the ability of tracer particles to circumvent the filtering capability of two types of surgical face masks by airflow around the mask periphery during inhalation.

Approach: A capitis moulage with a vacuum sampling system installed to collect air through the mouth was used in a plexiglas chamber to study the ability of the surgical masks to filter out bacterial spores. The spores passing through or around the surgical masks and collected in collection flask were quantitated with a Coulter counter.

Results: There were no significant differences in the effectiveness of the two types of surgical masks. Recovery of spores was very low; however, when the masks were placed on the moulage as normally worn, leakage occurred around the periphery of the masks.

Significance: The passage of air around the periphery of surgical face masks in an arrangement simulating inhalation circumvented the masks ability to screen out airborne contaminates. Such masks will not provide complete protection from aerosols containing infectious agents for the surgeon.

Wentzell, J. M., J. K. Robinson, J. M. Wentzell, Jr., D. E. Schwartz, and S. E. Carlson. Physical properties of aerosols produced by dermabrasion. *Arch. Dermatol. 125*: 1637-1643, 1989.

Purpose: To analyze the physical properties of airborne particles produced by dermabrasion, with emphasis on the analysis or particulates in respirable size ranges.

Approach: Using standard dermabrasion procedures (2.0 cm X 0.5 cm wire wheel turning at 20,000 rpm), a 200 cm^3 area of the skin of a minipig was dermabraded to the level of the midreticular dermis. Air samples with filters were used to sample the aerosols generated. The aerosol particle size was determined by both TEM and SEM.

Results: Particulates produced by dermabrasion (majority ranged between about 0.8 to 5 or 6 μm) are sufficiently small in size to allow inspiration and pulmonary retention. Such particles could conceivably present the hazard of infectivity if they harbored viable microorganisms of viral particles.

Significance: This procedure has the potential for the transmission of infectious agents from infected patients to the health care provider. Recommended safety precautions should be used to minimize the potential transmission of infectious diseases by dermabrasion procedures.

II. TRANSMISSION OF SPECIFIC INFECTIOUS DISEASES

A. Human Immunodeficiency Virus (HIV):

American Academy of Orthopaedic Surgeons Task Force on AIDS and Orthopaedic Surgery. Recommendations for the prevention of Human Immunodeficiency Virus (HIV) Transmission in the Practice of Orthopaedic Surgery. American Academy of Orthopaedic Surgeons, Park Ridge, IL, 1989.

Purpose: Summarize the recommendations of the Task Force for the prevention of the transmission of HIV in orthopaedic surgery.

Approach: Review the history, prevalence, blood transfusions, risk to health care workers, "Universal Precautions," and serological tests for HIV.

Results: Support the standard "Universal Precaution" recommended by the CDC, AHA, and AAOS.

Significance: Provide strategies to minimize the risk of HIV transmission based on the best available data.

Anonymous. Update: Human immunodeficiency virus infections in health-care workers exposed to blood of infected patients. *J. Am. Med. Assoc. 257*: 3032-3033, 3039, 1987.

Purpose: Update from *Morbidity and Mortality Weekly Report* (*Vol 36/No. 16*: 19, 1987).

Approach: N/A.

Results: Six persons who provided health care to patients with 1.HIV infection and who denied other risk factors have previously been reported to have HIV infections. Four cases followed needle-stick exposures to blood from the infected patients. Neither of the remaining two sustained needle-sticks injuries and neither observed routinely recommended barrier precautions. CDC received reports of HIV infection in three other health care workers following non-needle-stick exposures to blood from infected patients.

Significance: Although the latter three cases represent rare events, they re-emphasize control recommendations for minimizing exposure to blood and body fluids of all patients.

Anonymous. Healthcare workers with AIDS. *Federal Register 54*: 23060, 1989.

Purpose: Provided further evidence of occupational transmission of healthcare workers who have AIDS, but have identifiable risk factors.

Approach: Briefly summarized recent findings (no reference for the source of the information, assume it was from CDC).

Results: Investigations of many cases still in progress. Many infections related to injuries such as needle sticks contaminated with the blood or other body fluids of AIDS patients.

Significance: State that is reasonable to assume that at least some of the infections being investigated resulted from occupational exposure.

Arnow, P. M., L. A. Pottenger, C. B. Stocking, M. Siegler, and H. W. DeLeeuw. Orthopedic surgeons' attitudes and practices concerning treatment of patients with HIV infection. *Public Health Report 104*: 121-129, 1989.

Purpose: To determine the attitudes of orthopedic surgeons regarding the occupational risk of acquiring HIV infection and how it may influence the surgeons' willingness to operate.

Approach: Questionnaire survey of all orthopedists in five cites with the most cases of AIDS was conducted to assess attitudes and practices.

Results: Questionnaires completed and returned by 325 of 510 orthopedists contacted. A total of 43% had examined or operated on HIV-infected patients during the previous year. At least 90% of those who had an opportunity to operate on AIDS patients did so. Although the orthopedists feel that they ethically have the right to refuse to treat AIDS patients, they almost always treat these patients. Most orthopedists take at least some measure of increased protection when operating on patients with AIDS, such as wearing a second pair of gloves, eye protection, etc.

Significance: Although a majority of the orthopedists perceive HIV to have a higher rate of transmissibility by needlestick than it actually is, at least 90% of the orthopedists were willing to operate on AIDS patients. Other factors, such as peer pressure, a desire to maintain referral networks, and the ethical obligation to operate, were given reasons why surgeons chose to operate on AIDS patients.

Bachner, P. The epidemiology of fear. Scientific, social, and political responses to the occupational risk or blood-borne infection. *Arch. Pathol. Lab. Med. 114*: 319-323, 1990.

Purpose: To review proposed professional and regulatory solutions in the context of widespread public and professional fear concerning occupational transmission of HIV and HBV infections.

Approach: Commentary and review article.

Results: Inadequate knowledge about the modes of transmission of HIV has lead to what appears to be an exaggerated fear of occupational transmission of AIDS that has produced stress responses among some health care workers. Concerns have been voiced by certain groups, orthopedists and cardiac surgeons, who face repeated and massive exposures. The October 19, 1987, OSHA-mandated compliance with the Centers for Disease Control guidelines for the prevention of HIV transmission in health-care settings has imposed a burden on the health care system. Proposed guidelines for occupational exposure to blood-borne pathogens, based on the CDC guidelines, were published by OSHA on May 30, 1989, in the *Federal Register* (*No. 102*: 23042-23139). The general provisions for these rules for employers are to:

1. Provide a workplace free of hazards.
2. Provide education and training.
3. Evaluate all procedures in regard to potential infectious agent exposures.
4. Identify all workers with potential hazardous exposures.
5. Implement signage and labeling.
6. Implement universal precautions.
7. Make available personal protective equipment.
8. Make hepatitis B vaccine available.

The author notes that some of these rules could be a source of confusion, controversy, and expense.

Significance: The author concludes that it will be the difficult task of pathologists to respond in a calm manner to the proposed rules.

Baggish, M. S., B. J. Poiesz, D. Joret, P. Williamson, and A. Refal. Presence of Human Immunodeficiency Virus DNA in Laser Smoke. *Lasers Surg. Med. 11*: 197-203, 1991.

Purpose: To determine if laser treatment on cells containing HIV produced smoke by-products that contained the virus or its DNA.

Approach: Concentrated tissue culture pellets containing 1 X 10^7 HIV infected cells/mL were vaporized with a CO_2 laser. Vapors produced were bubbled through cell culture medium and tested for viable HIV, HIV antigen, and HIV DNA.

Results: No HIV DNA was detected in the culture medium. Tissue cultures of the medium revealed p24 HIV gag antigen. HIV proviral DNA was detected in cell cultures exposed to the vapor samples, but no sustained infection in the cell was observed by the 28th day. However, polymerase chain reaction analysis was positive for HIV DNA in both immediately sampled and cultured media.

Significance: This study demonstrated that proviral DNA was present in the laser smoke and care must be taken to avoid the exposure of health care workers to potentially contaminated laser smoke.

Beck, J. M., and B. E. Martin. HIV infection in health care workers. What are the risks? *J. Arkansas Med. Soc. 86*: 379-381, 1990.

Purpose: To summarize what is known about the risks of accidental HIV transmission from AIDS patients to health care workers and to put that risk into perspective among other risks.

Approach: Review type of article but no references were cited.

Results: Current estimates of HIV infection from needlesticks, the most common occupationally related injury, is about 0.4% or about 1 in 250. It was concluded that health care workers have been less likely to report identified risk behavior than the general population, thus, apparently providing a bias in favor of occupationally acquired HIV infection. Concluded that there is a small, but measurable risk of HIV infection in the health care setting, and this risk is not excessive compared to other risks to health care workers. Prophylactic AZT is recommended in the case of significant exposures.

Significance: Health care workers should be tested serologically after a suspected exposure. Recommend that universal precautions for prevention of the transmission of infectious diseases be followed with special precautions to include "**respirator industrial masks**" **and** "**full face shields**" for procedures that are likely to splash to generate bone chips.

Beekmann, S. E., B. J. Fahey, J. L. Gerberding, and D. K. Henderson. Risky business: Using necessarily imprecise casualty counts to estimate occupation risks for HIV-1 infection. *Infect. Control Hosp. Epidemiol. 11*: 371-379, 1990.

Purpose: Attempted to answer the following questions: What types of data on HIV-1 infection in health care workers are available? What are the strengths and limitations of these data? What is the impact of changing the definition of occupational exposure in the casualty count? How relevant is knowing the precise number of occupational infections? Can this number be known with any precision? What data will best assist the health care worker in keeping occupational risks in appropriate perspective?

Approach: Review of medical literature.

Results: Authors found the literature to be quite confusing because of variabilities in the numbers of individuals in various categories of health care workers. A majority of seroconversions (22 of 27) reported in health care workers were related to percutaneous exposure, and five of the 27 were related to mucous membrane or cutaneous exposure. Several cases of seroconversion have not been reported until recently, thus, causing some confusion on the risks involved. Infection rate among exposed health care workers has remained relatively constant at about 0.4% or one out of every 250 percutaneous exposures.

Significance: Authors consider the data questionable because of the relatively limited number of cases involved and the variability in the severity of the injuries that occurred when individuals were exposed. Although health care worker anxiety has continued to increase, study indicates that work habits have not changed for the better. Encouraged that well- designed clinical studies by conducted and that appropriate precautions should be used by health care workers. No note on the risk of surgical room aerosol exposure and its risk.

Brearly, S. and L. J. Buist. Blood Splashes: and Underestimated Hazard to Surgeons. *Br. Med. J. 299*: 1315, 1989.

Purpose: At the time of this work, it was not known how often surgeons were splashed with blood. The authors attempted to determine the frequency of such splashes, especially to the face and eyes. In the UK few surgeons wear eye protection during surgery.

Approach: Over a 3-month interval, the authors recorded the frequency that blood was splashed onto their glasses and the procedures used.

Results: Though the surgeons were generally unaware of the splashes in all but three instances, they found 1 to 40 splashes of blood on their glasses after 64 (25%) of 257 operations that varied in type and duration. Several of the blood splashes on the glasses were on the inside the lenses examined.

Significance: The authors feel that eye protection should be a standard procedure during surgery.

Burgess, A. W., B. S. Jackson, T. Baker, J. B. Thompson, and C. Grant. Workplace Fear of Acquired Immunodeficiency Syndrome. *J. Emerg. Nurs. 18*: 233-238, 1992.

Purpose: This study compares the differences with regard to fear of exposure to HIV in the workplace among six work groups with varying degrees of physical contact with patients and clients.

Approach: Distributed 1000 questionnaires to individuals in the six work groups. A total of 614 (61.4%) were returned.

Results: Fear of becoming HIV seropositive was measured by work group and sex.

1. The level of fear varied significantly among the work groups. In descending order of the fear level reported were:

   Emergency Nurses..... 5.6 on the scale used.
   Law-Enforcement Officers..... 5.2 "
   Emergency Physicians..... 4.9 "
   Corrections Officers..... 2.9 "
   Social Workers..... 2.4 "
   Rape-Crisis Workers..... 2.2 "

2. Among the ER personnel there was no correlation between the fear level and years of experience, i.e., the level of fear did not decrease with increased experience on the job.
3. Men reported more fear than women.

Significance: AIDS has replaced cancer and blindness as the most feared diseases. Continuing education of safety precautions stressed for experienced and inexperienced workers at all levels was recommended.

Burtis, R. E. and J. T. Evangelisti. 'Will Universal Precautions Protect Me?' A Look at Staff Nurses' Attitudes. *Nursing Outlook 40*: 133-138, 1992.

Purpose: To determine nurse's attitudes toward the use of Universal Precautions before and after training in the revised procedures.

Approach: Developed a survey to determine if there was a change in attitudes of nurses concerning the care of AIDS patients after Universal Precautions had been established. A total of 181 individuals responded.

Results:

1. Health care workers have a right to know if the patients had AIDS or HBV.
2. There was a decrease in the number of nurses willing to volunteer to care for AIDS patients after Universal Precautions were implemented.
3. A greater number of nurses would accept being assigned to care for AIDS or HBV patients after Universal Precautions were implemented than before.
4. There was a surprising lack of knowledge about the risks of HBV.
5. After Universal Precautions were initiated, there were positive trends concerning self-protection when providing direct care to patients.

Significance: Care of patients with AIDS or HBV infection requires an ongoing commitment by educators, administrators, and health care workers alike.

Capiluto, E. I., M. C. Weinstein, D. Hemenway, and D. Cotton. What Is the Dentist's Occupational Risk of Becoming Infected with Hepatitis B or the Human Immunodeficiency Virus? *Am. J. Pub. Health 82*: 587-589, 1992.

Purpose: To determine the risk of seroconversion from HIV relative to that for HBV in dentists treating patients.

Approach: Estimates of the dentist's risk of infection made using the following deterministic model:

$$\text{Cumulative Risk} = 1-[p(1-ib)^n + (1-p)]^m,$$

in which the parameters derived from a variety of secondary sources that affect risk are:

- p = probability that any individual patient will be infected,
- i = probability that the dentist will sustain a percutaneous injury while delivering therapy to an individual patient,
- b = probability of viral transmission given a percutaneous injury,
- n = number of visits by each patient, and
- m = number of different patients treated.

Results: Cumulative annual risk:

HIV (%) = 0.006

HBV (%) = 0.34

Cumulative risk (abbreviated example):

No. of Infected Patients Treated	Cumulative Risk (%) HIV	HBV
10	0.008	0.30
1000	0.78	26.8

Significance:

1. Annual cumulative risk of infection from routine treatment of patients whose seropositivity is unknown is 57 times greater for HBV than HIV.
2. Risk of dying from HBV is 1.7 times greater than the risk of HIV infection, for which mortality is almost certain.

Castro, K. G., A. R. Lifson, C. R. White, T. J. Bush, M. E. Chamberland, A. M. Lekatsas, and H. W. Jaffe. Investigations of AIDS patients with no previously identified risk factors. *JAMA 259*: 1338-1342, 1988.

Purpose: Classification of risk factors for AIDS patients.

Approach: Through Sept. 30, 1987, 20,059 patients with AIDS and no recognized risk factors (as determined by standard procedures) were reported to CDC. Follow-up investigations (questionnaires, interviews, etc.) were conducted in a more concerted effort to identify risk factors.

Results: Additional investigations indicated that risk factors did exist for many of those not initially considered to be at risk to AIDS virus.

Significance: Work indicates that the modes of transmission of AIDS virus have remained stable.

Cello, G. P. AIDS and the gastroenterologist. *Scand. J. Gastroenterol. Suppl. 175*: 146-158, 1990.

Purpose: To evaluate the risk of the transmission of HIV from patients to gastroenterologists. Gastrointestinal disorder associated with AIDS reviewed.

Approach: Reviews procedures in use and provides recommendations. Author cited 34 references.

Results: Universal safety precautions recommended. No mention of aerosol transmission.

Significance: Precaution recommended even though the risk of accidental HIV infection among gastroenterologists is much less than that for orthopedic surgeons.

CDC. Update: Transmission of HIV infection during an invasive dental procedure - Florida. *MMWR 40*: 21-27,33, 1991.

Purpose: Follow-up to a previous *MMWR* report (*39*: 489-493, 1990).

Approach: Reported additional and more detailed findings from the investigation of the suspected transmission of HIV.

Results: Study strongly suggests that three patients of a dentist who had AIDS became infected with the HIV during invasive dental procedures. This was concluded from: 1) The three patients had no other known risk factors; 2) the three had invasive procedures performed by the same dentist; and 3) DNA sequences of HIV from the patients and dentist were similar and unlike those present in the general community at that time. Transmission probably occurred via blood from the dentist resulting from minor cuts, needle-sticks, etc., and contamination of the surgical wounds of the patients. The dental office did not have or adhere to accepted safety precautions to minimize the possibility of disease transmission, nor did they have standard procedures for the sterilization of instruments, the washing of hands, etc., that were constantly adhered to. Transmission by aerosol from the dentist to the patients was not a consideration.

Significance: Demonstrates the need for all health care providers to adhere to the recommended standards of disease prevention when dealing with HIV infected patients as with other infectious diseases. Has led to the convening of a public hearing February 21-22, 1991, on the risks of transmission of bloodborne pathogens to patients during invasive procedures (*Federal Register 56*: 2527, 1991).

CDC. Estimates of the risk of endemic transmission of hepatitis B virus and human immunodeficiency virus to patients by the percutaneous route during invasive surgical and dental procedures. *Draft*. January, 30, 1991. CDC, Public Health Service, U. S. Department of Health and Human Services, Atlanta, GA.

Purpose: Draft of background material supplied for the public hearings noted in *Federal Register 56*: 2527, 1991, as cited above. An estimation of the number of patients who may have been infected from infected surgeons and dentists (a review).

Approach: Reviewed available data on the transmission of HIV and HBV to health care workers and from health care workers (where data is very limited) to patients. Using these known and assumed rates, and the known rates of injuries to health care workers where blood could be transferred to the patient improved estimations of the risk to patients from infected health care workers.

Results: No mention made of aerosol transmission. Transfer of virus by blood via wounds was the only method of transmission considered here. Actual confirmed data on the transmission of HIV from health care workers to patients is very limited; so several assumptions were made.

Range	Risk to Single Patient from Infected Surgeons	Risk to Single Patient from Infected Dentists
High	0.000024	0.0000038
Low	0.0000024	0.00000038

Significance: Risk model indicates that the risk to patients is very low.

Freeman, S. W., C. V. Chambers. Compliance with Universal Precautions in a medical practice with a high rate of HIV infection. *JABFP 5*: 313-318, 1992.

Purpose: To determine to what extent the recommended Universal Precautions are be adhered to by health care workers.

Approach: A total of 195 procedures among health care workers were evaluated using a before-and-after design. Health care workers with various levels of training were included.

Results:

1. No improvement in adherence to recommended procedures after education for either use of latex gloves or hand washing.
2. Faculty had the lowest level of compliance with "Universal Precautions."
3. While knowledge of precautions was high, staff at all levels overestimated their compliance with the recommendations.

Significance: Basic compliance with standard "Universal Precautions" are not being routinely followed. Current training does not appear to be sufficient to result in compliance with the recommendations. Faculty must become more aware of their own compliance with the recommendations to better be able to instruct others.

Gartner, S., P. Markovits, D. M. Markovitz, M. H. Kaplan, R. C. Gallo, and M. Popovic. The role of mononuclear phagocytes in HTLV-III/LAV infection. *Science 233*: 215-219, 1986.

Purpose: To evaluate the infectivities of the AIDS virus in mononuclear phagocytic cells.

Approach: Mononuclear phagocytes isolated from the brain and lung tissue of patients with AIDS have been found to harbor HTLV-III/LAV. Cells with properties characteristic of mononuclear phagocytes isolated from a variety of tissue were evaluated for infectivity with different isolates of the AIDS virus, HTLV-III/LAV *in vitro*.

Results: High concentrations of virus were produced by mononuclear phagocytes *in vitro*.

Significance: Results suggest that mononuclear phagocytes may serve as primary targets for infection and aid in the dissemination of the virus and that these cells may have a role in the pathogenesis of the disease.

Gazzard, B. G., and C. Wastell. HIV and surgeons. The risks are small. *British Med. J. 301*: 1003-1004, 1990.

Purpose: To put into perspective the risk of accidental transmission of HIV infection from patients to surgeons. The Royal College of Surgeons of England has delayed a decision on requiring patients to be tested for HIV antibodies with their consent in elective surgery and without their consent in emergencies.

Approach: Review article with 13 references cited.

Results: Surgeons contaminate themselves with blood in about 8.7% of cases and have a penetrating injury in about 1.7% of their cases. The risk to the surgeon of becoming infected with HIV through injury with sharp objects is small and was calculated to be one in every 8 years in areas of high HIV prevalence and as small as one infection in 80 years in low-prevalence areas. There also is a theoretical risk of HIV infection via aerosols that reach the conjunctiva.

Significance: Universal precautions may not lower the risk of accidental HIV infection. Recommend double gloving and eye protection.

Geller, S. A. The Autopsy in Acquired Immunodeficiency Syndrome. *Arch. Pathol. Lab. Med. 114*: 324-329, 1990.

Purpose: The author addresses the issue as to whether or not autopsies should be performed on patients who have died of AIDS.

Approach: The article discusses some aspects of the AIDS virus that pertain to the issue of performing an autopsy on patients who have died of AIDS and reviews the evidence concerning risk to the pathologist and ancillary staff in performing such autopsies.

Results: There is no documented case of the transmission of HIV from a patient to a pathologist or autopsy room assistant or of the seroconversion of the autopsy staff, although other health care workers have acquired the HIV infection from patients. In contrast, there is a significant risk to the autopsy room staff from patients who have died with HBV. Increasing numbers of hospital staff are questioning the need for an autopsy in the case of a death from AIDS. The reasons for the medical value of the autopsy are discussed.

The author recommends that the use of an oscillating saw (Stryker) should be kept to a minimum, and when used steps should be taken to minimize the creation and release of an aerosol. Many methods have been recommended for control of aerosols during bone cutting, including: 1) the use of a vacuum line near the saw, 2) keeping wet towels next to the blade, and 3) covering the work area with a large plastic bag. More recently a number of devices have become available to be fitted to the autopsy table. These devices will do far better at controlling any aerosol generated.

Significance: The hospital pathologist can safely examine the patient who has died of AIDS by using the well-established techniques for performance of the autopsy.

Gerberding, L., C. E. Bryant-LeBlanc, K. Nelson, A. R. Moss, D. Osmond, H. F. Chambers, J. R. Carlson, W. L. Drew, J. A. Levy, and M. A. Sande. Risk of transmitting the human immunodeficiency virus, cytomegalovirus, and hepatitis B virus to health care workers exposed to patients with AIDS-related conditions. *J. Infect. Dis. 156*: 1-8, 1987.

Purpose: This study was undertaken to prospectively evaluate a cohort of health care workers with frequent and intensive exposure to patients infected with HIV to determine their risk of occupational transmission of HIV, HBV, and CMV.

Approach: Blood samples and questionnaires were obtained from workers in high risk areas with special attention to those having experienced needle-stick injuries. More than 2400 workers enrolled in this and other studies; more than 800 had experienced accidental parenteral or mucous membrane exposures to HIV, HBV, of CMV.

Results: In a follow-up study 10 months after initial enrollment of health care workers, results indicate that health care workers are at minimal risk for HIV, CMV, and HBV infection from occupational exposure to patients with AIDS or ARC, even though intensively exposed for prolonged periods of time.

Significance: The study indicates that it would be prudent to implement and enforce standard infection-control guidelines designed to prevent occupational transmission of HIV even though not required. A possible problem not discussed in the paper is the latent period for serum antibodies to develop after exposure.

Gergerding, J. L. Occupational HIV Infection: Risk Assessment. In: *AIDS Clinical Review*. Chapter 2. pp. 19-27, 1989.

Purpose: Review of occupational HIV infections.

Approach: Literature review (15 references).

Results: Surveillance of AIDS cases in Health Care Workers:

Of 55,315 cases of AIDS reported by CDC through March 1988, 2586 cases were seen in health care personnel. Of these, 2451 cases were attributed to established risk behaviors. Follow-up detailed investigations of 121 cases identified established risk behaviors in 80 workers. Of the remaining 41 cases of AIDS in health care workers, epidemiological evidence did not support occupational related work as the source of the infections.

Anecdotal case reports of occupational HIV infection: A total of 23 definite or possible cases of HIV transmission has been reported since 1981. Ten cases could be attributed to needlesticks, and two cases occurred in laboratory personnel working with high concentrations of HIV. Three other cases were due to exposure to blood of individuals with breaks in the skin. Mode of transmission for two others was unknown, but they did have repeated and extensive exposures to blood and body fluids without using appropriate infection-control precautions. The six remaining cases could not be adequately related to occupational transmission.

Prospective cohort studies: The importance of determining the rate of infection must be prospectively measured. The rate of infection from needlestick exposure to infected blood is about 0.5% (5 infections/1200 needlesticks: 95% C.I. = 0-0.8%). Risk of infection via mucous membranes and cutaneous exposure of unbroken tissue to infected blood is even lower (0 infections/2525 exposures: 95% C.I.=0-0.1%).

Significance: Health care workers are at a low but measurable risk for HIV infection. The use of universal precautions is emphasized.

Hammond, J. S., J. M. Eckes, G. A. Gomez, and D. N. Cunningham. HIV Trauma, and Infection Control: Universal Precautions Are Universally Ignored. *J. Trauma 30*: 555-561, 1990.

Purpose: Because of the lack of a detailed comprehensive study of the adherence to universal precautions in the literature, this study was undertaken.

Approach: Adherence to universal precautions in the emergency surgical area of the University of Miami Medical Center was observed on a random basis for a period of 6 months by trauma nurse coordinators.

Results: There was only a 16% compliance with the recommended universal precautions, even though the issue had been addressed in meetings, memos, etc., for 2 months before the survey was taken.

Significance: Compliance with universal precautions is difficult to maintain, even under the best circumstances. It can- not be assumed that passive measures will assure adherence to the recommended procedures.

Hanson, P. J. V. AIDS: practicing safe endoscopy. *Bailliere's Clinical Gastroenterol. 4*: 477-4, 1990.

Purpose: Reappraised infection control practices in endoscopy.

Approach: Review article of HIV transmission in endoscopy. A total of 82 references cited.

Results: Universal precautions recommended and provided specific requirements for specific pieces of equipment. Accidental injury by needlesticks is considered the single greatest hazard for the transmission of the AIDS virus. Risk is estimated to be about 1 in 200 accidents where health care workers have been exposed to blood from AIDS patients. Aerosols of saliva from HIV-infected patients have not been known to be a source of transmission of the virus. Low incidence of HIV infection among dentists supports this conclusion.

Significance: Summary of recommendations for minimizing the potential for the accidental transmission of the HIV in endoscopy.

Heald, A. E., and D. F. Ransohoff. Needlestick injuries among resident physicians. *J. Gen. Intern. Med. 5*: 389-393, 1990.

Purpose: To assess the frequency and causes of needlestick injuries in medical and surgical staffs.

Approach: A retrospective study conducted by questionnaire sent to 386 housestaff members.

Results: Of 221 respondents to the survey, 26% reported never having had a needlestick, while 74% reported at least one needlestick injury. Average frequencies of the injuries were 0.63 per resident-year among 149 non-surgical residents and 3.8 per resident-year among 72 surgical residents. Among residents in internal medicine, 12 of 78 needlesticks were sustained from patients known to be HIV-positive. Suturing accounted for 57% of the needlesticks, while recapping needles accounted for 38%. Only 19% of the injuries were reported soon after they occurred.

Significance: Needlestick injuries are common, and greater care must be exercised to minimize them.

Hester, R. A. and C. L. Nelson. Current Concepts Review. Methods to Reduce Intraoperative Transmission of Blood-Borne Disease. *J. Bone Joint Surg. 73*: 1108-1111, 1991.

Purpose: The purpose of this review is to provide information that can aid the surgeon in preventing the transmission of blood-borne diseases at the time of an operation.

Approach: Literature review - 47 references.

Results: Surgeons are becoming more aware of the precautions that need to be exercised in the operating room to minimize the risk of accidental transmission of HIV. The prevalence of HBV seropositive individuals is 3 to 10 times greater among surgeons than among the general population, suggesting that there is a risk from blood-borne infectious agents. Precaution for the protection from sharp instruments is discussed. Injuries with sharps represent the single greatest hazard to the operating room staff. Contamination with blood during orthopaedic surgery has been reported by 90% of the surgeons surveyed. A high percentage of these contaminations were of areas of the face resulting from the use of power tools.

It was noted that the role of aerosols from cautery or high-speed instruments has not been defined and that there is currently no available commercial filter system which is certified for filtration of viral particles.

Significance: The authors conclude that there are no perfect preventive solutions. The use of operative isolators and high-volume laminar flow filtered air systems are recommended as are increased precautions and better education, such as that provided by The American Academy of Orthopaedic Surgeons Task Force on AIDS and Orthopaedic Surgery

Ho, D. D., T. Moudgil, and M. Alam. Quantitation of Human Immunodeficiency Virus Type I in the Blood of Infected Persons. *N. Eng. J. Med. 321*: 1621-1625, 1989.

Purpose: To determine the concentration of HIV in peripheral-blood monocytes (PBMC) and plasma of seropositive individuals.

Approach: Used end-point-dilution cultures to measure the level of HIV-1 in PBMC and plasma from 54 HIV-1 infected patients who were not receiving chemotherapy.

Results: HIV-1 was recovered from every seropositive patient but from none of 22 seronegative patients. Mean titers of the tissue infective doses (TCID) of HIV-1 ranged from 30 to 3500 per mL of plasma depending on the status of the patients. The TCID titers in PBMC ranged from 20 to 2700 per 10^6 PBMC depending on the status of the patients. These values indicate that 1 in every 400 PBMCs from symptomatic patients harbored HIV-1.

Significance: Concluded that the levels of HIV-1 in plasma and PBMC were much higher than previous estimates. These data are critical for those wishing to quantitate the actual exposure of health care workers to HIV in blood from HIV-positive patients.

Howard, R. J. Human Immunodeficiency Virus Testing and the Risk to the Surgeon of Acquiring HIV. *Surg. Gynecol. 171*: 22-26, 1990.

Purpose: A mathematical model is used for predicting the risk of acquiring HIV from patients in a given hospital and the total number of needle-stick injuries. Surgeons are more concerned with the lifetime risk of infection with HIV than with the risks from single incidence.

Approach: Minimal likely HIV seroprevalence of patients in any given hospital can be used in the model. To estimate the lifetime probability of HIV infection in surgeons, the following formula was used:

$$p = (p_1p_2) + (1-p_1p_2)^1(p_1p_2) + (1-p_1p_2)^2(p_1p_2) + \ldots(1-p_1p_2)^{n-1}(p_1p_2),$$

where: p_1 = probability of becoming infected if one sustains a needle-stick injury with the blood from an HIV-infected patient (CDC data $p_1=0.005$).

p_2 = the probability that the blood will be from an HIV-infected patient (may vary from 15 to 50%, depending on the hospital).

n = number of percutaneous exposures from needle sticks, etc., for any given period (not the number per year).

Results: The model predicts that at least 47 of the approximately 18,000 Fellows of the American College of Surgeons will become infected with HIV.

Significance: It was suggested that a routine procedure be established to test patients voluntarily for HIV.

Hughes, J. M., J. S. Garner, R. Marcus, and H. W. Jaffe. AIDS: Epidemiological lessons from the health-care setting. *J. Hospital Infect. 11* (Supplement A): 209-217, 1988.

Purpose: To provide a brief overview of the epidemiology of AIDS in the United States and to summarize current CDC recommendations for the prevention and control of HIV transmission in the health care setting.

Approach: Review article.

Results: Although HIV has been isolated from a number of body fluids, only blood, semen, vaginal secretions, and possibly breast milk have been implicated in the transmission of HIV in the community. Only blood has been implicated in the transmission of HIV from patients to health care workers. The 'bottom line' of the CDC recommendations involves the one-tiered approach that blood and body fluids from all patients are potentially infective. Recommendations continue to evolve and to be consolidated. In general, the main goal for most all recommendations is to prevent the health care worker from contact with potentially infective blood or other body fluids. It has been reported that about 56% of the health care workers surveyed do not use sufficient procedures to meet the recommended precautions when caring for AIDS patients.

Significance: The risk of HIV infection following a needlestick contaminated with infected blood is less than 1%. The risk of transmission of the HIV in the absence of a needlestick injury rarely occurs. There is no evidence of casual transmission of HIV in the health care setting. Also, it is not known if "extraordinary" precautions beyond the CDC universal recommendations will further reduce the risk of infection. There was no mention of the potential risk of infection from aerosols created during orthopedic surgery.

Hughes, J. M. Universal precautions: CDC perspective. *Occup. Med. 4*: 13-20, 1989.

Purpose: Review of the literature through about December 1988 on accidental transmission of HIV in health care workers.

Approach: Review focused on two issues:

1. Risk to Health-Care Workers.
2. Recommendations for Prevention of HIV Transmission in the Health-Care Setting.

Results: We know that blood is the primary concern and that the risk following a needle-stick injury or a cut involving exposure to blood from an HIV-infected individual is approximately 0.5%. And, we know that transmission can occur without such injuries (mode of transmission in cases that could not be attributable to needle-sticks or cuts was unknown: However, investigations are continuing in these cases - many have been reclassified, the individual has died, has refused to cooperate, etc.), but that the risk of such transmission is lower than after a needle-stick or cut. It is known that many exposures are preventable and that new strategies and technologies are needed. This review contains references to similar studies in progress elsewhere.

Significance: We need to know the risk of infection in groups of health-care workers with extensive blood exposures, whether alterations in the design of devices and procedures can reduce the risk of needle-stick and other injuries, and the optimal strategies for ensuring compliance with recommendations.

Jewett, D. L., P. Heison, C. Bennett, A. Rosen, and C. Nevilly. Blood-containing aerosols generated by surgical techniques: A possible infectious hazard. **Cited** in the preceding article (Johnson, G. K. and W. S. Robinson. *J. Med. Virol. 33*: 47-50, 1991) as a submitted paper. From our literature searches, it appears that this articles has not yet been published.

Purpose:

Approach:

Results: Submicron and micron sized particles were collected from simulated surgical room aerosols with quartz-crystal PC-2H cascade impactors (From information in the preceding reference in Section II).

Significance:

Jewett, D. L., P. Heinsohn, C. Bennett, A. Rosen and C. Neuilly. Blood containing aerosols generated by surgical techniques: A possible infectious hazard. *Am. Ind. Hyg. Assoc. J. 53*: 228-231, 1992.

Purpose: This study was conducted to characterize simulated surgical room aerosols, produced by surgical power tools, by their hemoglobin content and particle size.

Approach: Two protocols were used:

A. Protocol 1: Simulated operating room aerosols created by cutting bone or tendon while 10 mL of citrated blood was dripped onto the surface of bovine bone or tendon. The power tools tested were: 1) an oscillating bone saw (Stryker), 2) cast saw with a fine blade, 3) a Hall high-speed air-driven drill, 4) a Shea high-speed irrigation drill, 5) a Bovie electrocautery used in both the cutting and coagulation mode.

B. Protocol 2: Duplication of the "Stanford" aerosols (Johnson & Robinson. *J. Med. Virol. 33*: 47-50, 1991) that used HIV-infected blood and 1) an Valleylab electrocautery operated in both the cutting and coagulation mode, 2) a Stryker bone saw, 3) a manual irrigation syringe, and 4) router. Infected blood was not used in this duplicate study.

C. Aerosol sampled with a 10-stage, low-pressure cascade impactor. Mass (microbalance) and hemoglobin (Hemastix) content were determined per sampling stage.

Results:

A. Protocol 1:

1. Shea Drill: a. Modal size was 14 μm.
   b. Hemoglobin in 0.14 μm and larger particles.
2. Hall Drill: a. Bimodal particle size distribution.
   b. Hemoglobin in 0.28 μm and larger particles.
3. Bone Saw: a. Most particles 4.2 μm or smaller.

b. Most particle size fractions positive for hemoglobin.

4. Bovie Electrocautery:

a. Both operating modes produced aerosols of 0.42 μm or smaller.

b. Most were positive for hemoglobin.

B. Protocol 2:

1. Valleylab Electrocautery:

a. Like in Protocol 1, most particle size fractions of the aerosol contained hemoglobin.

2. Bone Saw: a. Similar to the aerosol produced by the bone saw in Protocol 1.

3. Manual Irrigation Syringe:

a. Aerosol produced was similar to that created by the Shea drill.

4. Router: a. Produced a unique aerosol size distribution.

b. Minimum quantity of aerosol in the 14 μm size range and greater percentages in the 0.28 to 2.8 μm range.

Significance: This work suggests that individuals in an operating room where these tools are used could be exposed to respirable, blood-containing aerosols created by these tools.

Johnson, G. K. and W. S. Robinson. Human immunodeficiency virus-1 (HIV-1) in the vapors of surgical power instruments. *J. Med. Virol. 33*: 47-50, 1991.

Purpose: To determine if infectious HIV-1 could be isolated from aerosols generated from human blood containing HIV-1 by common orthopedic and surgical procedures known to cause aerosols.

Approach: Cell culture adapted strain of HIV-1 (HTLV III) was mixed with human banked O packed RBC known to be negative for CMV and HIV antibodies. Mixtures were individually subjected to treatment with electrocautery in the coagulation of the cutting mode, a high speed bone cutting router, an oscillating bone saw, and a wound irrigation syringe jet as follows: 1) electrocautery of thawed fresh frozen human skin and muscle samples on sterile filter paper while HIV-1 containing blood was pipetted over the surface, 2) a router spinning at 30,000 RPM while HIV-1 containing blood was slowly pipetted on to it, 3) a Stryker bone saw was used to generate an aerosol while HIV-1 containing blood was slowly pipetted over the oscillating blade, and 4) an attempt to generate an aerosol with a Uromatic irrigator from which HIV-1 containing blood was ejected (no viable aerosol was noted). Aerosols were collected in tissue culture media to which MT-2 or human mononuclear cells were added. The cells were cultured for 4 weeks and tested for P-24 HIV-1 core antigen by ELISA.

Results: Positive cultures were obtained from the aerosols generated by the effects of the high speed router tip and the oscillating bone saw on HIV-1 containing blood mixture.

Significance: Demonstrated that HIV-1 can remain viable in cool aerosols generated by certain surgical power tools, and this raises the possibility of HIV-1 transmission to medical personnel exposed to aerosols similarly generated during the care of HIV infected patients.

Klatt, E. C., and T. T. Noguchi. AIDS and infection control in forensic investigation. *Am. J. Forensic Med. Path. 11*: 44-49, 1990.

Purpose: Review article; 26 references cited.

Approach: Discusses the nature, modes of transmission, and infectivity of important infectious agents likely to be encountered in the course of forensic medicine.

Results: Non-sexual transmission of HIV outside of the health care work place is extremely rare. Most common non-sexual mode of transmission is via the use of contaminated needles by IV drug abusers. HIV infection via transfusion is also rare; about 1 in 64,000. Unless HIV-infected people die of other causes, they will eventually die of AIDS. Workers in professions, including forensic specialists, who come into contact with body fluids of HIV-infected individuals are at risk of infection themselves. Fewer than 0.5% of those exposed to HIV in a work-related injury involving a penetrating wound, usually via an accidental needlestick, ever develop an HIV infection. Documentation of possible exposures to HIV is essential. Testing of those exposed to HIV is the most practical course of action to evaluate past and future HIV infection. Risk of HBV infection also discussed.

Significance: Provide principles and guidelines to be followed in a program of infection control. Support the use of the CDC universal precautions for infectious disease control for health care workers in the area of forensic medicine. Commented on the OSHA standards being developed. No specific mention of aerosols in this article, other than provision for protection from splashes of body fluids or potentially contaminated fluids.

Klein, R. S., J. A. Phelan, K. Freeman, C. Schable, G. H. Friedland, N. Trieger, and N. H. Steigbigel. Low occupational risk of human immunodeficiency virus infection among dental professionals. *N. Engl. J. Med. 318*: 86-90, 1988.

Purpose: Since hepatitis B and HIV have several similarities in their modes of transmission, this study was undertaken to determine the occupational risk of HIV infection among dentists.

Approach: Mailed questionnaires to 1309 dental professionals; including dentists, hygienists, and assistants without behavior risk factors for AIDS.

Results: Fifty-one percent of the professionals worked in areas where "many cases" of AIDS had been reported. Seventy-two percent treated patients who had AIDS. Ninety-four percent reported accidental puncturing of the skin with instruments. Adherence to recommended infection-control procedures were infrequent. Twenty-one percent of unvaccinated professional had antibodies to hepatitis B. Only one dentist had antibodies to HIV. Note that dental professionals are exposed to splashes and aerosols containing blood and saliva and that these persons should be followed as a sentinel population to indicate what is happening in the general population.

Significance: Even with the above risk factors, dental professional are at a low risk for HIV infection.

Lamm, A. H. Epidemiology of AIDS: An Overview of AIDS Epidemiology and Major Modes of Transmission. *Am. Ind. Hyg. Assoc. 51*: A742-A746, 1990.

Purpose: Review the major modes of transmission of HIV.

Approach: Literature review - 39 references.

Results: Risk of transmission by needlesticks (the only mode of accidental transmission in the work place mentioned) is considered to be low. The risk of HIV infection by parenteral exposure to blood is about 0.5% compared with 6-30% for accidental transmission of HBV. Transmission of HIV by blood from infected persons coming in contact with mucous membranes or nonintact skin has been reported (no estimate of the risk of such exposures given in this review).

Significance: As the number of HIV infections has increased, so has the knowledge of the transmission of HIV. Needlesticks with contaminated blood (cuts, etc., with sharps not mentioned) and exposure of mucous membranes or nonintact skin to contaminated blood are the only recognized means of the accidental transmission of HIV in the work place mentioned.

Lamm, S. H., T. F.Brewer, and J. M. Crutcher. AIDS in the Workplace: A Summary of Risks and Responses. *Am. Ind. Hyg. Assoc. J. 52*: A112-A115, 1991.

Purpose: Summarize the risks of AIDS in the work place.

Approach: Literature review - 14 references.

Results: Health Care Workers experience a high rate of exposure to HIV but a low rate of accidental infection. Needlestick injuries are the most common cause of occupational exposure to HIV. Less that 0.5% of needlesticks result in the transmission of HIV. About 40% of the accidental transmissions of HIV are readily preventable by strict adherence to universal precautions. AIDS (HIV) transmission in the work place does not occur if there is not direct introduction of contaminated blood under the skin (such as IV drug use), sexual contact (primarily anal intercourse), or perinatal contact (from mother to unborn child).

Significance: HIV infection is a major health concern in the work place in the U.S. and world wide.

Meech, R. J. AIDS and Surgeons. *New Zealand Med. J. 104*: 159-160, 1991.

Purpose: Reviews the status of knowledge of AIDS and risks to surgeons.

Approach: Literature review - 8 references.

Results: There has been one reported case of occupational HIV infection of a surgeon who sustained a blood splash in the eye (*Hosp. Infect. Control March*: 34; 1989). In regard to possible aerosol transmission of HIV, the author makes the point that one must differentiate between splashes and actual aerosol generation. There has been no documented case of the transmission of HIV by aerosols created in the operating room, nor has the virus been demonstrated to be present in the aerosols generated during surgical procedure involving infected patients. The author considers the technology used to generate HIV-containing aerosols in the laboratory to be flawed since high titers of virus were used in the studies compared with the relatively low virus titers found in the HIV-positive patient.

Significance: The author suggests that instead of focusing on exotic and theoretical ways of transmitting HIV, health care workers should address the known routes of accidental transmission of HIV, e.g., transfer of contaminated blood via needlesticks, sharps, etc.

Morris, R. E., and E. Turgut. Human Immunodeficiency Virus: Quantifying the Risk of Transmission of HIV to Dental Health Care Workers. *Community Dent. Oral Epidemiol. 18*: 294-298, 1990.

Purpose: Develop estimates of the occupational risks of accidental transmission of HIV.

Approach: Literature review - 20 references.

Results: Based on an estimated prevalence of 400-600 HIV carriers per 100,000 in the U.S. population:

Expected incidence per 100,000 dental health care workers with a 0.5% transmission risk and a 0.6% prevalence of HIV = approximately 30.

Expected incidence per 100,000 dental health care workers with a 1% transmission risk and a 0.6% prevalence of HIV = approximately 60.

Prevalence in Central Africa is 30 to 50 times that in the U.S.

Significance: The cumulative, long-term risk of accidental HIV transmission to workers in the dental health care area is similar to that of homosexuals in areas where there is a high prevalence of HIV infection, such as in Central Africa. Recommend adherence to universal precautions to minimize the transmission of HIV in the work place.

Murphey, S. A. HIV and Safety: Universal Precautions. *Clin. Dermatol. 9*: 31-38, 1991.

Purpose: Review the status of knowledge on the transmission and prevention of HIV in the health care setting.

Approach: Literature review - 45 references.

Results: The importance of universal precautions is reviewed. Proper care of instruments, disinfection procedures, and biohazardous waste management are reviewed. If accidental exposure to HIV does occur, most seroconversions of workers exposed in the work place will occur within 6 months. Follow-up testing after an accidental exposure should be done at 6 weeks, and 3, 6, and 12 months. Risk from a needlestick with contaminated blood was considered to be about 0.4%. It is difficult to estimate the risks from other types of exposure, such as from splashes of blood and other body fluids, because of the lack of data and the underreporting of accidental exposures.

Significance: Strict adherence to the concept of universal precautions recommenced.

NIOSH. *Guidelines for Prevention of Transmission of Human Immunodeficiency Virus and Hepatitis B Virus to Health-Care and Public-Safety Workers*. A Response to P.L. 100-607. The Health Omnibus Programs Extension Act of 1988. DHHS (NIOSH) Publication No. 89-107. U.S. Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, Atlanta, GA, 1989.

Purpose: Document prepared in response to Public Law 100-607, The Health Omnibus Programs Extension Act of 1988, Title II, Programs with Respect to Acquired Immune Deficiency Syndrome. Subtitle E, General Provisions, Section 253(a) of Title II specifies that "the Secretary of Health and Human Services, acting through the Director of the Centers for Disease Control, shall develop, issue, and disseminate guidelines to all health workers, public safety workers in the US concerning:

1. Methods for reducing risk of infection with the AIDS virus in the workplace.
2. Circumstances under which exposure to the AIDS virus occurs.

The purpose of this document is to provide an overview of the modes of transmission of the AIDS virus in the workplace. Information on hepatitis is also presented because:

1. Modes of transmission for HBV are similar to those of HIV.
2. Potential for HBV transmission in the workplace is greater than that for HIV.
3. There is a large body of information on the transmission of the HBV in the workplace.
4. General practices to prevent the transmission of HBV are similar to those that also will minimize the transmission of HIV.

Approach: A review of modes of transmission relative to the workplace. This document was developed primarily to provide guidelines for fire-service personnel, emergency medical technicians, paramedics, law-enforcement officers, and correctional-facility personnel. Updates of previously issued guidelines for laboratory, clinic, and hospital health care workers are reprinted

in the appendices of this report. **No specific recommendations were made for protection from aerosolized, potentially infectious material beyond protection with surgical masks and face shield recommended for protection from splashes.**

Results: Blood is the single most important source of HIV and HBV in the workplace. Risk of infection from a single needlestick, the most common cause for the accidental transmission of these viruses, are about 0.5% for HIV and 6 to 30% in individuals not immunized against HBV. Guidelines may be summarized as follows:

1. Standard general infectious disease control should be followed.
2. All patients should be assumed to be infected with HIV or other blood-borne pathogens.
3. All body fluids should be treated as if potentially hazardous if differentiation of fluid types is not readily identifiable.
4. Training and procedures should be provided to all workers.
5. If a potential exposure has occurred, appropriate diagnostic and medical follow-up should be provided.
6. All potential exposures should be documented in the medical records of those involved.
7. Disinfection, decontamination, and disposal procedures are discussed. In all cases, local regulations should be consulted and followed prior to disposal of potentially infective waste.

Tables of: 1) Hypothetical risks from a needlestick and 2) List of HIV-infected health-care workers with no reported nonoccupational risk factors that have been reported in the literature (seroconversion has been reported in 7 of these workers).

Significance: Details for most all conceivable situations for workers in these groups are discussed relative to each specific work area. This information is also presented in tabular form. **No specific recommendations for protection from aerosols of potentially infective material are presented** beyond that recommenced for protection from splashes of blood or other body fluids, such as the wearing of a surgical mask, a protective apron, etc.

Owens, D. K. and R. F. Nease. Occupational Exposure to Human Immunodeficiency Virus and Hepatitis B Virus: A Comparative Analysis of Risk. *Am. J. Med.* *92*: 503-512, 1992.

Purpose: To estimate the occupational risk from infection with HIV in terms of loss of (quality-adjusted) life expectancy, and to compare that risk to those posed by other hazards faced by health care workers.

Approach: Authors used a decision-analytic model.

Results:

1. A 30-yr-old female has a loss-of-life expectancy from a needlestick from a symptomatic HIV-positive patient of 39 (range: 17-93) days compared with 17 to 38 days from a needlestick from a HBV positive patient.
2. When morbidity is included the risk increases.
3. The quality-adjusted loss-of-life expectancy due to such needlesticks is 45 days (range: 20-108) for HIV and 48 to 109 days for HBV.
4. For comparison, a cross-country auto trip is associated with a loss-of-life expectancy of about 1 day. The 45- to 50-day loss of quality-adjusted life expectancy from percutaneous exposure to HIV and HBV is similar to the gain in life expectancy from 10 yrs of annual screening for breast cancer.

Significance: Attempts to put the risk of HIV infection into perspective relative to other risks.

Panlilio, A. L., D. R. Foy, J. R. Edwards, D. M. Bell, B. A. Welch, C. M. Parrish, D. H. Culver, P. W. Lowry, W. R. Jarvis, and C. A. Perlino. Blood Contacts During Surgical Procedures. *JAMA 265*: 1533-1537, 1991.

Purpose: Describe and quantify the types of blood exposures that occur during surgical procedures and assess the risks of the exposures.

Approach: Pilot study. Trained personnel observed 206 operations (including 45 orthopedic operations) over 6 months and recorded the frequency and types of exposures to blood.

Results: Of 1828 operating room person-procedures (including 101 orthopedic procedures) observed, 5.3% had blood contacts. Of these, 90% were skin contacts, 7% were percutaneous injury, and 3% were eye splashes. Important factors in blood contacts were: 1) trauma, burn, and orthopedic emergency procedures, 2) blood loss of more than 250 mL, and 3) remaining in the operating room longer than 1 hr. Seventy-four percent of the blood contacts were preventable. No mention was made of aerosol generation or protection from aerosols.

Significance: Re-evaluation of surgical room procedures, use of appropriate barrier precautions, and development of puncture-resistant gloves are indicated. No risks of HIV infection were calculated from the data presented.

Pate, J. W. Risks of blood exposure to the cardiac surgical team. *Ann. Thorac. Surg. 50*: 248-250, 1990.

Purpose: To evaluate the potential risk of accidental HIV transmission from an HIV-positive patient to the cardiac surgical team.

Approach: Review of literature relative to the risk of HIV transmission in cardiac surgery. Ten references cited.

Results: Open heart operation carries a high risk of skin puncture and splashes to the operating team; thus, a significant risk of working with HIV-positive patients is created.

Significance: Recommended the development of better surgical gloves and better procedures to lower risk. Surgical teams should remain on guard for skin or mucous membrane contamination or injury.

Piaazza, M., A. Chirianni, L. Picciotto, F. Guadagnino, R. Orlando, and P. T. Cataldo. Passionate kissing and microlesions of the oral mucosa: Possible role in AIDS transmission. *JAMA 261*: 244-245, 1989.

Purpose: Study examined the potential for microlesions in the oral mucosa to have a role in the transmission of the AIDS virus.

Approach: Blood in saliva was used as an indication of the presence of microlesions in the oral mucosa before and after a meal, brushing teeth, and passionate kissing by the measurement of the hemoglobin content of saliva.

Results: There was a significant increase in the concentration of blood in saliva after all three of the activities tested. Brushing the teeth produce the greatest effect, followed by kissing and eating a meal. In the tests, most couples brushed their teeth before kissing, thus increasing the possibility of viral transmission if one of the couple were infected with the AIDS virus.

Significance: The authors conclude that passionate kissing cannot be considered protective sex for the transmission of the AIDS virus. The virus could be transmitted directly from one person to another via blood and the microlesions in the oral mucosa.

Puro, V., M. Ranchino, and F. Profili. Occupational exposures to blood and risk of HIV transmission in a general hospital (1986-88). *European J. Epidemiol. 6*: 67-70, 1990.

Purpose: To study occupational exposure to blood in a 1500-bed general hospital to assess the risk of HIV transmission.

Approach: Survey conducted between 1986 and 1988.

Results: Five hundred and forty eight cases of accidental exposure to blood were reported. The personnel category, type of injury if any, and the circumstances of each accident were investigated. All injuries were classified as needlesticks, wounds with other sharp objects, or mucous membrane contamination. Highest observed HIV at-risk exposure per month of work was surgeons (0.001), and the lowest was among physicians (0.00008). No mention of the risk of aerosol transmission of HIV infection.

Significance: Careful adherence to W.H.O. and C.D.C. universal precautions recommended.

Resnick, L., D. Vernen, S. Z. Salahuddin, S. Tondreau, and P. D. Markham. Stability and inactivation of HTLV-III/LAV under clinical and laboratory environments. *JAMA 255*: 1887-1891, 1986.

Purpose: To determine the stability of human T-cell lymphotropic virus type III/lymphadenopathy-associated virus (HTLV-III/LAV) under environmental conditions encountered in a clinical or laboratory setting and its inactivation by commonly used chemical disinfectants were investigated.

Approach: Testing started with high concentration of virus: 10^7 tissue culture infectious dose ($TCID_{50}$) per ml in 50% human plasma.

Results:

Aqueous environment: Recoverable for more than a week at 23-27° or at 36-37°C. Viability decreased as a rate of ~ 1 $\log_{10}TCID_{50}$ per 20 min at 54-56°C.

Dried at room temp.: Retained infectivity for more than 3 days with a decrease in viability of ~ 1 $\log_{10}TCID_{50}$ per 9 hours.

Disinfection.....: Rapid loss of viability within 1 min in 0.5% NaOH, 70% alcohol or 0.5% nonidet-P40, and with 10 min with 0.08% Rocal or a 1:1 mixture of acetone-alcohol.

Significance: Results help to provide a rational basis to prevent the accidental spread of HTLV-III/LAV in the laboratory or clinical setting.

Rhame, F. S. Prevention of in-hospital transmission of the acquired immune deficiency syndrome virus (HTLV III): current USA policy. *J. Hospital Infection 6(Supplement C)*: 53-66, 1985.

Purpose: Article reviews standard US and UK guidelines on the prevention of AIDS virus transmission in health care facilities.

Approach: Where there were differences in guidelines between the US and the UK or where no guidelines have been formulated, procedures in use at the University of Minnesota Hospital were also discussed.

Results: There were very few differences in the guidelines discussed. Specific recommendations were made for dental care workers and morticians by the authors. The advisability of using mechanical saws in performing autopsies had not been previously addressed. Heightened precautions for those performing an autopsy indicate that this procedure is more hazardous than providing patient care. It is also mentioned that the apparatus causing the most spatter is the air/water flusher. The greatest hazard seems to be the transmission of contaminated body fluids (mostly blood) via needle sticks and other such injuries as accidental cuts, etc., inflicted by the healthcare worker.There was no mention of orthopedic surgical procedures in this article. Because of the "paucity of AIDS patients who convincingly lack known risk factors makes true airborne spread of the AIDS virus extraordinarily unlikely." Biological safety Level 2 should be used for routine diagnostic work, while Level 3 should be used for work with high concentrations of virus. AIDS virus infected health care workers can continue to provide health care to patients.

Significance: There are not great differences in the guidelines reviewed.

Rhame, F. S. Preventing HIV Transmission: Strategies to Protect Clinicians and Patients. *Postgrad. Med. 91*: 141-144, 1992.

Purpose: The author discusses the new recommendations, the medical community's challenges and responsibilities, and the likely outcome of the current situation.

Approach: Commentary.

Results:

1. In the mid-1980s the fear of the transmission of HIV lessened as it was found that health care workers working with HIV-positive patients did not become infected themselves. However, it was soon recognized that infections did occur when there were injuries, such as needlesticks, involving contact with infected blood or blood-contaminated body fluids. Recent reviews have documented 18 known instances of the accidental transmission of HIV. The route of the transmission of the HIV in all but four of these 18 cases was related to percutaneous exposure to sharp instruments.
2. In a prospective study of needlestick injuries, 6 transmissions occurred in 2,042 exposures for a transmission rate of 0.29% or 1 per 340.
3. Six convincing HIV transmissions have occurred without percutaneous injury. Each involved skin or mucous membrane contact with "warm blood".
4. No transmissions have occurred in more than 5,000 accidental splashes of blood or body fluids containing blood.
5. HIV Risk In Context:
    a. Nurses working full time on an AIDS ward have a risk of HIV infection of 0.1 per needlestick per year. Such individuals have an HIV acquisition rate of 30 transmissions per 100,000 person-years.
    b. This can be related to:
        1) 40 deaths per 100,000 person-years in the construction

industry,

2) 200 deaths per 100,000 person-years in the oil industry, and

3) 1 on-the-job homicide per 100,000 person-years.

6. Adherence to "Universal Precautions" is recommended along with care in handling sharps.

7. OSHA rule on dealing with bloodborne pathogens were reviewed.

Significance:

1. The risk of HIV is of the same magnitude which people accept in other areas of their life.

2. Adherence to appropriate guidelines and rules will reduce the risk of accidental transmission of HIV.

Salahuddin, S. Z., R. M. Rose, J. E. Groopman, P. D. Markham, and R. C. Gallo. Human T lymphotropic virus Type III infection of human alveolar macrophages. *Blood 68*: 281-284, 1986.

Purpose: Study was conducted to determine if human T lymphotropic virus Type III would infect human alveolar macrophages and, if so, what would be the role of the alveolar macrophages in *in vivo* infection?.

Approach: Cultured pulmonary alveolar macrophages from patients with AIDS and from volunteers. Inoculated some in culture with HTLV-III and quantitated the cultures for the production of virus. Also determined that the virus from the alveolar macrophages could infect peripheral mononuclear leukocytes.

Results: Though more resistant to the cytopathic effects of the virus that T4 Lymphocytes, the virus reproduced in alveolar macrophages, but at lower concentrations than in the lymphocytes. Virus could be transferred from the macrophages to peripheral blood mononuclear leukocytes. The virus was also produced spontaneously in pulmonary alveolar macrophages from two of four patients with AIDS.

Significance: HTLV-III infection of macrophages may be one mechanism for the establishment of viral persistence in infected hosts.

Scully, C., and S. Porter. The ···el of R . of Transmission of Human Immunodeficiency Viru 3etween Patients and Dental Staff. *Br. Dental J. 170*: 97-100, 1991.

Purpose: Review the data on the transmission of HIV to health care workers.

Approach: Literature review - 82 references.

Results: Worldwide there are no reported proven cases of occupational transmission of HIV to dental staff.

Significance: It was concluded that the risk of accidental transmission of HIV from patient to health care worker is extremely low.

Shah, S. S., J. C. Roxburgh, C. Loveday, P. Goldstraw, and M. H. Yacoub. HIV-1 infection and cardiothoracic surgery: The difference in attitudes between consultants and junior surgeons in the United Kingdom. *Eur. J. Cardio-thorac. Surg. 6*: 279-283, 1992.

Purpose: To assess the attitudes of cardiothoracic surgeons in the UK to HIV infection and to determine if there was a difference in the clinical practices of consultants and junior surgeons.

Approach: Postal survey: 199 questionnaires mailed and 144 (72.4%) returned.

Results:

1. Surgeons were more likely to operate on someone who was HIV seropositive than someone with AIDS.
2. Routine preoperative screening of patients was advocated for patients from the traditionally high risk groups.
3. There were no significant differences in the responses of "juniors" and "consultants" to the scenarios presented.
4. However, a greater number of junior surgeons admitted to having modified their surgical procedures in light of the increasing incidence of HIV-1 infection.

Significance: This survey emphasizes the concern among cardiothoracic surgeons about HIV-1 infection and the need for both education and clear policy guidelines to deal with this issue.

Shirazian, D., B. C. Herzlich, F. Mokhtarian, G. Spatoliatore, and D. Gorb. Needlestick injury: Blood, mononuclear cells, and acquired immunodeficiency syndrome. *Am. J. Infect. Cont. 20*: 133-137, 1992.

Purpose: Determine the volume of blood and number of cells transferred by accidental needlesticks using different sized needles.

Approach:

1. 20 to 27 gauge needles filled with HIV positive blood and used to pierce human skin, parafilm, or no barrier into saline, Drabkin's, or culture media for 1 second.
2. Volume of blood measured by both modified Drabkin's method (UV adsorption at 410 nm) and ^{51}Cr-labeled red blood cells.
3. Cells transferred measured by culture in media containing feeder cells.

Results:

1. Volume of blood transferred:
   a. Varied from 312 $\pm$ 69 nL from a 20-gauge needle to 14 $\pm$ 4 nL for a 27-gauge needle measured by the Drabkin method.
   b. Varied from 404 $\pm$ 80 nL from a 20-gauge needle to 12 $\pm$ 3.1 nL for a 27-gauge needle measured by the ^{51}Cr method.
   c. Volume transferred through parafilm was twice that transferred through skin.
2. Transfer of mononuclear cells.
   a. Passage of needle through human skin reduced the probability of transmission of at least one viable lymphomononuclear cell from 99% to 68%, compared with needle not passed through a barrier.
   b. Passage of a needle through parafilm was much less effective than human skin.

Significance:

1. Risk of health care workers for acquiring HIV infection from

needlesticks is about 0.4%. But the risk of AIDS once seroconversion has occurred may be 100%.

2. Quantitation of the volume of blood and number of cells transferred by needlesticks was determined. The larger the needle the greater the volume of blood and number of cells transferred.

3. A better risk assessment model for accidental HIV transmission should include the volume of blood transferred, the number of cells transferred, the virus titer in the blood or stage of HIV infection in the patient, and the duration of antiretroviral therapy.

Speller, D. C. E., D. C. Shanson, G. A. J. Ayliffe, and E. M. Cooke. Acquired immune deficiency syndrome: Recommendations of a Working Party of the Hospital Infection Society. *J. Hospital Infec. 15*: 7-34, 1990.

Purpose: Occupational safety procedures for health care workers recommended by a Working Party of the Hospital Infection Society in the UK.

Approach: Health care procedures recommended by a Working Party established in 1985. A total of 52 references cited.

Results: In the discussion of the transmission of the HIV, it was noted that there is no evidence of the transmission by the respiratory route among health care workers. Of 1036 health care workers with definite incidents of percutaneous or mucous membrane exposure to material from HIV-positive patients, only three have had seroconversions. A revised estimate of the incidence of HIV infection in accidentally exposed health care workers was 0.4%.

Significance: Essentially, this group recommends safety precautions similar to the CDC universal precautions. Explicit details of all recommendations included in the article. No special respiratory protection procedures were mentioned.

Stock, S. R., A. Gafni, and R. F. Bloch. Universal Precautions to Prevent HIV Transmission to Health Care Workers: an Economic Analysis. *Can. Med. Assoc. J. 142*: 937-946, 1990.

Purpose: To determine if the recommended universal precautions for the minimize potential patient to health care worker transmission of blood-borne infections such as HIV.

Approach: Reviewed the evidence on the risk of HIV transmission to hospital workers and the effectiveness of the universal precautions.

Results: Estimated that 0.038 cases of HIV seroconversion would be prevented by strict adherence to universal precautions by health care workers in a 450-bed Canadian hospital. It was estimated that adherence to universal precautions would cost the hospital about $350,000 per year or over $8,000,000 per case of HIV seroconversion prevented. When less conservative, more probable assumptions were applied to the best estimate of implementation, the cost was $128,862,000 per case of HIV seroconversion prevented.

Significance: The authors concluded that the use of universal precautions is not cost-effective. Preventive measures recommended on the basis of demonstrated efficacy and aimed at routes of exposure that represent true risk are needed.

Taylor, K. M., J. M. Eakin, H. A. Skinner, M. Kelner, and M. Shapiro. Physician's perception of personal risk of HIV infection and AIDS through occupational exposure. *Can. Med. Assoc. J. 143*: 493-500, 1990.

Purpose: The purpose of this study was to gain a better understanding of the sometimes irrational and "unfounded" fear of AIDS in the health care environment. These fears frequently are inconsistent with documented evidence of seroconversion rate among health care workers after accidental exposure.

Approach: A survey of 268 physicians with different specialties in three geographic regions of North America was conducted.

Results: More than half of the respondents feared AIDS more than any other disease and had changed the way they interacted with their patients. Physicians perceived the risk to be far greater than published data would indicate. A contradiction was found in that physicians with more AIDS patients to care for had a lower perception of the risk of accidental transmission of HIV than did the physicians with fewer AIDS patients. Also, physicians that perceived themselves to be at a higher risk were more likely than others to report that physicians had the right to refuse to treat AIDS patients.

Significance: Physician's perception of the risk involved with working with HIV-infected patients is seriously compromising initiatives designed to facilitate physician's participation in AIDS care.

Tulis, J. J. AIDS prevention and control in the laboratory and healthcare setting. *No. Carol. Med. J. 48*: 365-367, 1987. (No references).

Purpose: Brief article for general information and presented as part of panel discussion at the 15th Annual Alumni Conference of the University of North Carolina School of Public Health, Chapel Hill, April 1987.

Approach: NA.

Results: Comment on transmission: "Considering the classic routes of most viral infections -- namely, aerogenic, by ingestion, contact, percutaneous penetration, and vectors -- HIV does not appear to pose a hazard except through intimate contact (sexual relations) and mucosa and skin penetration." Accidental transmission of HIV from AIDS patients to the healthcare workers most likely occurs by the transfer of body fluids to the broken skin of the healthcare worker. Exposure through inhalation of aerosolized HIV has probably occurred, as documented at several reagent laboratories in 1985, but no evidence of infection was detected.

Significance: Because of the potential for the transmission of the AIDS virus by aerosols in the laboratory, the use of level 3 biosafety cabinets for work with this virus is recommended.

U.S. Department of Labor, Occupational Safety and Health Administration. *Compliance Assistance Guideline for the February 27, 1990 OSHA Instruction CPL 2-2.44B Enforcement Procedure for Occupational Exposure to Hepatitis B Virus and Human Immunodeficiency Virus*. 1991.

Purpose: Guideline offers employers assistance in understanding the OSHA requirements for preventing occupational exposure to HBV and HIV

Approach: N/A.

Results: Control methods covered:

A. Universal Precautions are to be used.

B. Engineering Controls:

Available technology and devices to isolate or remove hazards from the worker are to be used.

C. Work Practice Controls:

Alter the tasks to minimize the exposure of workers.

D. Personal Protective Equipment:

Specialized clothing and/or equipment are to be used to protect the worker from blood or other potentially infectious material.

Guidelines are also provided for post-exposure evaluation and follow-up, infectious waste disposal, including use of tags, labels, and bags, housekeeping practices, training and education, and record keeping.

Significance: Compliance with the requirements is being enforced by OSHA and will reduce the risk of the transmission of HIV from patients to health care workers.

Vaughn, R. Y., J. L. Lesher, and D. K. Chalker. HIV and the dermatologic surgeon. *J. Dermatol. Surg. Oncol. 16*: 1107-1110, 1990.

Purpose: To discuss the risks of and precautions for minimizing risk of HIV infection among dermatologists.

Approach: Review paper; 39 references cited.

Results: The spread of AIDS has increased the risk of accidental infection with HIV to the dermatologic surgeon. Known modes of the transmission of HIV are 1) sexual contact, 2) exposure to infected blood or blood products, and 3) perinatal transmission from infected mother to child. Exposure of the health care worker to blood occurs most commonly from accidental needlesticks. Risk of accidental transmission of HIV is about 0.5% following needlestick exposure involving AIDS patients and about 25% involving hepatitis-B patients. Transmission via mucous membrane of non-intact skin has also been implicated. Potential transmission via contaminated aerosols created during various surgical procedures is a definite possibility that must be considered.

Significance: Universal precautions for the prevention of accidental transmission of HIV infection from the patient to the surgical staff are recommended.

Weiss, S. H., W. C. Saxinger, D. Rechtman, M. H. Grieco, J. Nadler, S. Holman, H. M. Ginzburg, J. E. Groopman, J. J. Goedert, P. D. Markham, R. C. Gallo, W. A. Blattner, and S. Landesman. HTLV-III infection among health care workers: Association with needle-stick injuries. *JAMA 254*: 2089-2093, 1985.

Purpose: Detailed review of 361 health care workers in institutions in communities where there were high to moderate levels of HTLV-III infection among high-risk group members was conducted to evaluate routes of exposure and seropositive for HTLV-III.

Approach: Volunteers from the various institutions were surveyed for HTLV-III and serological status.

Results: Most all cases of infection among health care workers could be attributed primarily to needle-sticks or other wounds involving injury with items contaminated with blood from infected patients. One case of transmission was noted with a needle used on an infected patient. Such injuries appear to be the primary means of spreading the infection to health care workers.

Significance: In light of apparent occasional HTLV-III transmission from such parenteral exposures, vigorous implementation of institutional policies to minimize the risks of such exposures appears warranted.

Weiss, S. H., J. J. Goedert, S. Gartner, M. Popovic, D. Waters, P. Markham, F. M. Veronese, M. H. Gail, W. E. Barkelyu, J. Gibbons, F. A. Gill, M. Leuther, G. M. Shaw, R. C. Galo, and W. A. Blatiner. Risk of human immunodeficiency virus (HIV-1) infection among laboratory workers. *Science 239*: 68-71, 1988.

Purpose: A prospective cohort study of 265 laboratory and affiliated workers was conducted to assess laboratory risk of HIV infection.

Approach: Invitations to participate in the study sent to workers in 15 laboratories in six states where there was a possible risk of exposure to HIV-1. Sera samples were analyzed for antibody to HIV-1 and HTLV-1 with ELISA. Follow-up sera samples were tested 8 to 12 months later. All ELISA seropositive samples were then evaluated by immunoblots with disrupted HIV-1 and HTLV-1 by radioimmune precipitation assays.

Results: One individual without any recognized risk factors for HIV-1 was found to be seropositive. Molecular analyses indicated that viruses isolated by two different laboratories from this worker were indistinguishable from the HIV-1 that the individual had been working with. Exposure to the virus probably occurred during work with concentrated virus or culture fluids from virus-producing cell lines although no specific incidence could be identified as leading to this infection. Work had been conducted under standard Biosafety Level 3 containment.

Significance: Demonstrated that prolonged laboratory exposure to HIV-1 is associated with a risk of infection similar to that reported for exposure by accidental needlesticks. The use of strict Biosafety Level 3 containment and practices should be followed when working with concentrated HIV-1 preparations.

WHO (World Health Organization). Global Programme on AIDS. *Weekly Epidemiological Record. No. 26*: June 28, 1991.

See comments on section VII NEWS ITEMS:

WHO Reports on HIV and HBV Transmission in the Health Care Setting. *Bull. Pan. Am. Health Orgn. 25*: 291-292, 1991.

B. Human Hepatitis B Virus (HBV):

Petersen, N. J. An assessment of the airborne route in hepatitis B transmission. *Ann. N. Y. Acad. Science 353*: 157-166, 1980.

Purpose: Evaluate the literature to assess the potential for the transmission of HBV by the aerosol route.

Approach: Review article.

Results: Transmission of HBV by body fluids from infected patients can occur when the contaminated fluids, primarily blood, come in contact with mucosa surfaces of another person without the mucosa surface being injured and by contact with contaminated inanimate environmental surfaces. Transmission of HBV can also occur by accidental injury with sharp contaminated objects, such as needle and knife blades as well as transfusions and the injection of blood products. Because infection can result from contaminated body fluids coming into contact with mucus membranes it is conceivable that HBV in aerosols will also result in the initiation of an infection. However, epidemiologic evidence available at the time of this review was inconclusive about the airborne transmission of HBV. Extensive sampling for airborne HBV during renal dialysis was consistently negative, even when the virus could be recovered from wipes of surface areas in the same location where the aerosol samplers were placed. Air samples were also collected near patients during dental procedures. Again, the HBV could not be detected in the samples collected.

Significance: From the inconclusive epidemiological data on the airborne transmission of HBV and the consistently negative findings for the HBV in dialysis centers, laboratories, and dental operations, the author concludes that airborne transmission of this virus does not have a major role in this infectious disease and that airborne transmission is probably a very rare occurrence.

Reingold, A. L., M. A. Kane, A. W. Hightower. Failure of gloves and other protective devices to prevent transmission of hepatitis B virus to oral surgeons. *JAMA 259*: 2558-2560, 1988.

Purpose: Survey was conducted to determine if the routine use of gloves, surgical masks, and eye protection reduced the risk of exposure to HBV.

Approach: Survey conducted at the 63rd annual meeting of the American Association of Oral and Maxillofacial Surgeons between Sept. 18-22, 1981, in Washington, DC.

Results: Found that the routine use of gloves, surgical masks, or eye protection did not reduce the risk of exposure to HBV.

Significance: Use of gloves, surgical masks, or eye protection does not offer protection from HBV infection. Recommended that because of these findings, all oral surgeons should receive HBV vaccine.

C. Human Infectious Papillomavirus (HIP):

Abramson, A. L., T. P. DiLorenzo, and B. M. Steinberg. Is papillomavirus detectable in the plume of laser-treated laryngeal papilloma? *Arch. Otolaryngol. Head Neck Surg. 116*: 604-607, 1990.

Purpose: This study was to investigate whether HPV DNA can be detected in the smoke plume that results from the carbon dioxide laser therapy of laryngeal papilloma.

Approach: Plumes were collected with a suction tip and trapped in phosphate-buffered saline. Aspirates were also collected from the surface of the lesions. Cytospins of samples were examined for cells and supernatants tested for papillomavirus DNA by Southern blot hybridization.

Results: Human papillomavirus DNA was not detected in the smoke plume from vaporization of laryngeal papillomas unless direct suction contact was made with the papilloma tissue during surgery. Laryngeal papillomas usually have an average of only 1 to 50 copies of the papillomavirus DNA per cell in contrast with the extremely high number of copies found in cutaneous bovine warts and human plantar warts studied by others.

Significance: Transmission of this papillomavirus in the smoke plume appears to be very unlikely. The laryngeal type viruses infect only mucus membranes and genital tissues and have never been associated with cutaneous warts. All material contacting the tissues during surgery should be considered as potentially contaminated and treated accordingly.

Anonymous. Intact viruses in CO_2 laser plumes spur safety concern. *Clinical Laser Monthly 5*: 101-103, 1987.

Purpose: Commentary on the research reported by J. M. Garden, *et al.* (*JAMA 259*: 1199-1202, 1988), on the detection of HIP viral DNA in smoke plumes from laser surgery.

Approach: NA.

Results: There is increasing awareness and concern about recent reports of the detection of HIP virus DNA in laser smoke plumes and the potential lack of the ability for standard surgical masks to filter out the small sized particles created by laser surgery.

Significance: Acknowledges existence of the transmission of the HIP virus, and possibly others (including HIV), by inhalation. It is recognized that the standard surgical mask will only remove a small percentage of the viral DNA from the smoke plume.

Ferenczy, A., C. Bergeron and R. M. Richart. Human papillomavirus DNA in CO_2 laser-generated plume of smoke and its consequences to the surgeon. *Obstet. Gynecol. 75*: 114-118, 1990.

Purpose: This article explores, with the aid of molecular hybridization techniques, whether laser treatment of HPV-containing genital infections is associated with viral dispersion.

Approach: Smoke plumes created by the CO_2 laser treatment of 110 patients with histologically diagnosed HPV infections of the lower genital tract were sampled by swabbing the inner surface of the distal end of the disposable vacuum tube (patients in group A) and by swabbing the pre-filter canister used for the exhaust of the plume (group B). Body surfaces of the laser operator were also swabbed. Filter hybridization was used to detect the HPV DNA.

Results: Of the two groups of treated patients, no HPV DNA was found in the smoke samples taken during the treatment of 45 patients nor from samples collected from the laser operator. One of five pre-filter canisters collected from the second group of 35 patients was positive.

Significance: Although HPV DNA may be released during laser vaporization of genital HPV infections, contamination of the operator is unlikely provided appropriate equipment for evacuating HPV DNA-positive smoke is used

Garden, J. M., M. K. O'Brian, L. S. Sheinitz, K. S. Pinski, A. D. Bakus, M. E. Reichmann, and J. P. Sundberg. Papillomarivus in the vapor of carbon dioxide laser-treated verrucae. *JAMA 259*: 1199-1202, 1988.

Purpose: Vapor produced by the carbon dioxide laser during the vaporization of papillomavirus-infected verrucae was analyzed for viral DNA content.

Approach: Two models used:

1) Four *in vitro* cutaneous bovine fibropapillomas tested. Vapor collected in a chamber with a vacuum system.
2) Laser vapor from seven patients undergoing carbon dioxide laser therapy for plantar or mosaic verrucae was collected.

Results: Results from the two models:

1) Hybridization with papillomavirus DNA probes detected viral DNA in vapor from all of the bovine fibropapillomas tested.
2) Hybridization with human papillomavirus (HPV-2a) DNA probe indicated intact DNA was present in the vapor from two of the seven patients treated.

Significance: Studies indicate that intact viral DNA is liberated into the air with the vapor of laser-treated verrucae. It would be prudent for all practitioners who use the laser in treating patients with viral infections or conditions associated with viruses to practice extreme care and safety procedures during laser treatments.

Hallmo, P. and O. Naess. Laryngeal Papillomatosis with Human Papillomavirus DNA Contracted by a Laser Surgeon. *Eur. Arch. Otorhinolaryngol. 248*: 425-427, 1991.

Purpose: Presents a case report of a 44-yr-old laser surgeon who developed laryngeal papillomatosis that may have been transmitted by a laser plume..

Approach: *In situ* DNA hybridization of tissue used to characterize the virus type.

Results: Human papillomavirus DNA types 6 and 11 were present. Past history revealed that the surgeon had given laser therapy to patients with anogenital condylomas, which are known to harbor the same viral types.

Significance: Findings suggest that the papillomas in the patient (the surgeon) may have been caused by inhaled virus particles present in the laser plume.

Lobraico, R. V., M. J. Schifano, and K. R. Brader. Acquired HPV lesions compared in laser and nonlaser users. *J. Gynecol. Surgery 5*: 77-85, 1989.

Purpose: A comparative study conducted to determine the incidence of human papilloma virus (HPV) infections acquired by practitioners treating warts by both laser and nonlaser methods.

Approach: Survey conducted by questionnaires sent to 10,500 practitioners. Survey based on 1879 responses.

Results: Responses indicated that direct contact with the HPV lesion rather that the laser plume was responsible for acquiring a lesion.

Significance: Preventive methods suggested for control of viral transmission and control of the smoke plume during laser surgery.

Sawchuk, W. S., P. J. Weber, D. R. Lowy, and L. M. Dzubow. Infectious papillomavirus in the vapor of warts treated with carbon dioxide laser or electrocoagulation: Detection and protection. *J. Am. Acad. Dermatol. 21*: 41-49, 1989.

Purpose: To obtain additional information on the risk potential of wart therapy and to test whether a surgical mask could reduce exposure.

Approach: Treated one-half of individual human plantar warts (HPV) and infectious bovine papillomavirus warts (BPV) with both electrocoagulation and a carbon dioxide laser. Vapor samples collected with a dry filter vacuum apparatus. To test the effectiveness of surgical masks to remove papillomavirus from the vapors created, pieces of masks were placed in front of the filter collection devices. The presence of HPV DNA was determined by dot-blot analysis, and the presence of BPV by *in vitro* infectivity assay from samples of the surgical masks and filter material.

Results: Vapors from five of eight plantar warts treated with the laser HPV and four of seven treated with electrocoagulation were positive for HPV. Greater amounts of DNA were found on the filters from the laser produced vapor than from the electrocoagulation vapor. The surgical mask removed virtually all of the virus from the vapors.

Significance: Work suggests that surgical masks can protect operators from potential inhalation exposure to papillomavirus.

III. EDITORIALS ON HIV

Anonymous. AIDS: An occupational hazard for orthopaedic surgeons? A conversation with Lorraine J. Day, MD. *Orthopaedic Rev. 18*: 493-497, 1989.

Purpose: This interview summarizes Dr. Day's views on what is currently known about risk assessment and minimization for the practicing orthopaedic surgeon in the treatment of patients with AIDS.

Approach: Anonymous interview.

Results: Considers risk of AIDS transmission to be high among orthopaedic surgeons. Chances of infection 1 in 200 from a needle stick (CDC) considered to be low by some. Related to the strict control of exposures to carcinogens, including X rays. AIDS can be transmitted only by coming into contact with body fluids containing the virus. Suggests that aerosolized virus can be a source of infection for hepatitis B virus; inferring that HIV infection could be transmitted by the same means. Accidental injuries to surgeons are inevitable. The department at U.C.S.F. has money to investigate the problem of aerosols created during orthopedic surgery. Bone fragments and blood are aerosolized but the question remains; is viable HIV virus in the aerosols? No cases of AIDS-infected surgeons have been reported because of the long latent period for the infection. Favors screening of patients and surgeons for AIDS.

Significance: Heightened the concern about the transmission of AIDS from patients to surgeons.

Baker, J. L. What is the occupational risk to emergency care providers from the Human Immunodeficiency Virus? *Ann. Emerg. Med. 17*: 700-703, 1988.

Purpose: This report addresses the extent and nature of risk of HIV infection to emergency care providers and reviews the current management of significant exposures.

Approach: Commonly asked questions from emergency care providers are answered.

Results: One question is worthy of comment here:

> "Can the HIV virus be transmitted by mouth-to-mouth resuscitation?" Answer: "There have been several instances of persons providing mouth-to-mouth resuscitation to patients who were HIV infected, but there never have been any reported cases of transmission of the virus in this manner. Furthermore, attempts to infect animals through direct exposure to high concentrations of HIV to oral mucosa have not demonstrated infection through this mechanism. Because of the theoretical risk, however, either bag-valve-mask equipment or one-way valve pocket ventilation devices should be immediately available in areas where resuscitations are likely to be performed, as recommended by the CDC." However, no references were cited in support of this answer.

Significance: Serves as a means of educating and informing emergency care providers with information about the risks of accidental infection with HIV.

Cohen, L. J., P. M. Hurley, and E. P. McGriff. Meeting the challenge of AIDS: Caring for the providers. *Orthopaedic Nursing 7*: 33-36, 1988.

Purpose: This paper describes one attempt at addressing the issue of the need for nurses to know about the risks of working with patients with AIDS.

Approach:

1. NYU has received funds from the National Institute of Mental Health for the education of health care providers concerning the mental health aspects of caring for patients with AIDS.
2. The Health Resources and Services Administration has funded a project to establish a Regional AIDS Education and Training Center at NYU.
3. Using an interdisciplinary approach in these projects.
4. Effectiveness of training being evaluated through pre- and post-training testing.

Results: N/A; a commentary.

Significance: Such efforts will provide a better understanding of the disease and improve treatment and care of persons with AIDS.

D'Ambrosia, R. AIDS: Protecting both surgeon and patient. *Orthopedics 13*: 705, 1990.

Purpose: Editorial on the protection of both surgeons and patients.

Approach: N/A.

Results: Now recognized that orthopedic surgery is a high-risk profession due to the risk of accidental transmission of the AIDS virus during surgery. Routine voluntary testing of patients for HIV is recommended. Patients not voluntarily tested should be considered as seropositive. With the lack of routine testing for HIV, surgeons should assume that all patients are potentially infected with HIV and should be familiar with and follow the universal precautions. Precautions also need to be used to avoid patient-to-patient transmission of the AIDS virus via surgical procedures.

Significance: Orthopedic educators should provide appropriate training for residents to avoid exposure to HIV. The goal is to protect both the surgeon and the patient.

Goldman, B. Doctors divided: AIDS and the physicians at San Francisco General. *Can. Med. Assoc. J. 138*: 736-738, 1988.

Purpose: Determine how physicians view the risk of treating AIDS patients.

Approach: This journal sent Dr. Goldman (a contributing editor) to San Francisco to study the problem of AIDS in patients at San Francisco General Hospital.

Results: Nurse contacted AIDS from one accidental needle stick. S. F. General staff feels that hospital and CDC "experts" had soft-pedalled the risk of accidental AIDS infection. Orthopedic surgeons frequently receive wounds during surgery.

Significance: The controversy has lead to an increased awareness of the potential risk(s) involved in orthopedic surgery and AIDS patients and the ethics of operating or not operating on such patients.

Hamblen, D. and G. Newton. HIV and Surgeons. *Br. Med. J. 301*: 1216-1217, 1990.

The authors acknowledge that orthopaedic surgeons are at greater risk from infection with HIV than other surgeons because of the procedures and instruments used. They are appalled at the lack of extensive application of universal precautions and note that there are now legal requirements in the UK for the protection of health care workers from microbiological hazards and that these guidelines need to be enforced. The British Orthopaedic Association recommends that when operating on known HIV positive patients precautions beyond the universal precautions be used, including the use of ventilated space suits or helmets.

Mahaffey,P. AIDS and Dermabrasion. *Plas. Recon. Surg. 80*: 757, 1987.

The author comments on his concern about the creation of HIV- contaminated aerosols resulting from dermabrasion. He considers the safety guards provided by manufacture as inadequate. He is sure that only a closed breathing system or, more practically, an adequate vacuum clearance system next to the dermabrasion wheel will avoid the inevitable infection of a surgeon or one of his team with HIV in the next few years.

Newton, G. AIDS and the Orthopaedic Surgeon. *J. Bone Joint Surg. (Br.) 73-B*: 707-708, 1991.

Orthopaedic surgeons may feel that they are at greater risk from the hazards of injury by sharp bone fragments, wires, and power tools than other health care workers. Risk depends on three factors: 1) frequency of skin lacerations, 2) incidence of HIV in the population treated, and 3) proportion of infections from a single inoculation. The latter has been estimated to be about 0.5% or 1 in about 200 needlesticks. Because of the difficulties associated with identifying the HIV positive patient, universal precautions must be used to prevent injuries and accidental infections. These include the use of suitable masks and visors to protect the surgeon from blood splashes and spatter from power tools.

The most controversial aspect of contamination in the operating theater is whether or not aerosols can transmit HIV infection. **More information is urgently needed on the subject of the operating room environment.**

IV. LETTERS TO THE EDITOR ON HIV

Bailey, M. Occupational HIV infection risk. *Lancet 335*: 1104, 1990.

Purpose: Letter to editor commenting on needlestick injuries and the transmission of HIV.

Approach: Reviewed data on the risk of HIV infection after needlestick injuries.

Results: In this letter Dr. Bailey suggests that reports of injuries from needlesticks and sharp instruments used with HIV-infected patients should include information on how the items had been used. He states that a needlestick with a needle containing blood (hypodermic needle) would be of greater risk than one without (suture needle). This should be taken into consideration in risk calculations. The same is true of other accidental exposures to body fluids of HIV-infected patients. Also, exposure of mucous membranes to such body fluids should also be reported.

Significance: More detailed reporting of accidental exposures to body fluids from HIV-infected patients will lead to improved estimations of the risk involved.

Bygbjerg, I. C. AIDS in a Danish surgeon (Zaire, 1976). *Lancet* 1983;i:925.

Purpose: In questioning whether or not the AIDS/KS syndrome could be the result of an infectious viral agent, the author asked "was the patient in the following case the victim of such an agent?".

Approach: N/A.

Results: Described the case of possible AIDS in a woman surgeon who had worked in a primitive hospital in northern Zaire from 1972-1975. Was probably exposed frequently to blood and excretions in the primitive hospital where she worked and contracted the infection from her patients, at least one of whom had Kaposi's sarcoma. She had not been in the US or Haiti and did not abuse drugs.

Significance: Possible case of a surgeon acquiring AIDS from a patient.

Day, L. Perils of orthopedic surgery. *Can. Med. Assoc. J. 139*: 1035-1036, 1988. (Letter to Editor).

Purpose: Comment on the article by Goldman, B. Doctors divided: AIDS and the physicians at San Francisco General. *Can. Med. Assoc. J. 138*: 736-738, 1988.

Approach: N/A.

Results: Considers orthopedic surgery to be a "high risk" occupation. Has done surgery on many high risk and potentially violent patients. Not done for high pay but because work is interesting and challenging and the patients really need a doctor. If any thing, she considers the work as low paying and high risk.

Significance: N/A.

Purpose: Response to L. Day from B. Goldman:

Approach: N/A.

Results: Dr. Goldman's article was addressing the threat of HIV infection in physicians rather than possible actions of violent patients. Also states that the threat of HIV infection evolved with the recognition of the presence of the infectious disease.

Significance: N/A.

Duthie, G. S, Johnson, S. R., G. J. Packer, and I. G. Mackie. Eye protection, HIV, and orthopaedic surgery. *Lancet 1 (8583)*: 481-482, 1988.

Purpose: Trying to find out what procedures used in a trauma center are most likely to lead to contamination.

Approach: All of the staff in orthopedic and general surgery theatres were provided with "targets" (graph paper on a head band immediately above the eye) that were used to monitor contamination for each operation. After surgery, the "targets" were examined under 10X magnification for contamination with fluids and particles.

Results: Target strikes were determined during all 30 of the bone invasive procedures tested. No contamination noted from 24 soft tissue orthopedic and 40 general surgeries.

Significance: The conjunctiva of the eye offers a portal of entry for infection, and abrasive mixture of bone, marrow, and blood propelled by high speed power tools and reamers could damage any epithelial surface. Since emergency orthopedic surgery usually cannot be delayed until the patient is screened for antibody to HIV or other blood borne infectious agents, although low, there is a probability of an injured patient being HIV positive. HIV infection acquired occupationally by the surgical staff has not yet been reported, but it seems sensible for all scrubbed personnel to wear eye protection during procedures such as bone surgery.

Grouse, L. D. HTLV-III transmission. *JAMA 254*: 2130-2131, 1985.

Purpose: Few general comments on HTLV-III transmission and praise for paper by Weiss, *et al.* (*JAMA 254*: 2089-2093, 1985) in which transmission of HTLV-III has resulted from needle-stick injuries. Also comments on the ethics of a physicians' knowledge of the patients' HTLV-III status.

Approach: N/A.

Results: Comments that hospital acquired infections with HTLV-III transmission are not the result of airborne virus and that transmission is much like that of hepatitis B.

Significance: A balance must always be struck between public needs and personal freedom, but providing individuals, in circumstances under their own control, with the information that allows them to prevent the further spread of AIDS is most consistent with a free society.

Individual Letters to the Editor by: W. C. Wilson, J. B. Jagger, C. Sculy, and D. Martin. "Surgeons fear of AIDS in the air". *Lancet 169*: 148-149 and 230, 1990.

Purpose: Responses to an article in the *The Sunday Times* in the UK dated August 12, 1990, about the then-unpublished work of Drs. D. Jewett, G. Johnson, and W. Robinson.

Approach: N/A.

Results: Great concerns were expressed about how large the "real" risk of HIV transmission via aerosols was, especially relative to dental work. In Dr. D. Martin's response to one of these letters, he suggests that there is no real cause for alarm on the part of dental practitioners and suggests new procedures could greatly lessen the potential problem.

Significance: Points out how some individuals may "overreact" when only given a limited amount of information in the lay press.

Jessop, J. H. Hazards of Blood Splashes. *Br. Med. J. 300*: 49, 1990.

The author states that, in the light of the current knowledge of the risks of accidental HIV transmission to health care workers during surgery, it is scandalous that it is a case of everyone for themselves for appropriate protection. Notes that the quality of surgical gloves and protective clothing needs to be markedly improved.

Le F. Porteous, M. J. Hazards of Blood Splashes. *Br. Med. J. 300*: 466, 1990.

The author presents his observations of blood splashes on his glasses during orthopaedic surgery with (n=240 operations) and without (n=271 operations) the use of power tools. Joint arthroplasty seemed to be a particularly high risk procedure. Of 800 orthopaedic surgeons surveyed, 296 had had body fluids splashed into their eyes during the past month. Two documented cases of the transmission of AIDS through facial contamination are noted. The author warns that if orthopaedic surgeons do not take the necessary steps to protect themselves from such exposures, it is only a matter of time before surgically related transmission of AIDS occurs.

Michaelis, B. A. and J. A. Levy. Recovery of human immunodeficiency virus from serum. *JAMA 257*: 1327, 1987.

Purpose: Report of the isolation of HIV from sera.

Approach: Standard procedures.

Results: Laboratory has isolated HIV from cells and body fluids from hundreds of patients. Now report the isolation of this virus from 20 (25.6%) of 78 randomly selected serum samples from seropositive individuals.

Significance: Isolation of HIV from serum is not a common event and could explain the low incidence of HIV infections following needle-stick injuries reported elsewhere (Weiss, et al., *JAMA 254*: 2089-2093, 1985).

Royle, J. P. AIDS and the vascular surgeon. *J. Cardiovasc. Surg. 32*: 139-142, 1992.

Purpose: Vascular and cardiac surgeons are at a higher risk of percutaneous exposure to blood than any other surgical groups. How can the risks be reduced?

Approach: Re-examine the basic surgical techniques leading to the development of strategies for the handling of instruments to minimize the risks of accidental injury to operating room staff.

Results: Several suggestions on improved techniques mentioned. Most are just basic common sense. All cardiac and vascular surgeons must re-examine their surgical techniques. Trainees must be taught safe strategies.

Significance: Techniques, procedure, etc. need to be under constant review for improvements to reduce risk.

Sawchuk, W. S. Infectious potential of aerosolized particles. *Arch. Dermatol. 125*: 1689-1692, 1989.

Purpose: Given the increased awareness and concern among health care workers about the transmission of an infectious agent from patients to the health care provider, this editorial address the question: How much protection is adequate for operator safety?

Approach: Discussed several papers on patient to health care provider transmission of infectious disease and related topics relative to potential transmission by aerosols. No reason to suspect that aerosols from surgical debris would be any different than from other known sources of potential hazard, such as recognized in industry.

Results: Laser smoke alone contains mutagens for *Salmonella typhimurium* (Ames' test). Chronic exposure of rats to laser smoke (without infectious agents) has resulted in histological changes in the lung similar to long-term inhalation exposure to particulate matter. Although particles themselves pose some risk, concern about this hazard has diminished relative to the concern for disease transmission by aerosolized particles. Also, evidence that some particles potentially carrying HIV, HBV, or papilloma virus DNA may not be filtered from the breathing air by surgical masks has increased this concern. Hazard may be greater for HBV than HIV since the latter occurs at far lower concentrations in blood; about 10^9 particles per mL of serum for HBV and about 10 to 50 viral particles per mL for HIV. Epidemiological data suggest that the risk of transmission of HIV, HBV, and cytomegalovirus is present but minimal. There is a need for a better understanding of the barriers needed for health care worker's protection.

Significance: Evidence on the potential for disease transmission via aerosolized particles has lead to improved recommendations for health care worker protection.

Sim, A. J. W. and H. A. F. Dudley. Surgeons and HIV. *Br. Med. J. 296*: 80, 1988.

Purpose: Discussion of the hazards of HIV in surgeons.

Approach: N/A.

Results: Clear indication of the risk to surgeons is unknown. This topic was the subject of a 1987 international meeting coordinated from St. Mary's Medical Hospital. Because of the time involved in testing for seroconversion, this procedure is of questionable value. The subgroup of patients (homosexuals) was considered as "high risk" patients. Present precautions of unproven efficacy. As with other problems associated with this new infection, modified procedures are adopted because of surgeon's perceptions of the problem rather than its reality. Further consideration of improved surgical safety procedures are needed.

Significance: N/A.

Torre, D., C. Sampietro, G. Ferraro, C. Zeroli, and F. Speranza. Transmission of HIV-1 infection via sports injury. *Lancet 335*: 1105, 1990.

Purpose: Report of the transmission of one case of HIV-1 infection.

Approach: N/A.

Results: Reports the transmission of HIV-1 from an infected individual to an individual with no known risk of HIV-1 infection (and previously seronegative) as the result a severe injuries to two soccer players when they collided. There was a considerable amount of bleeding involved in the injuries to both players.

Significance: Adds to the lists of incidence of the transmission of HIV-1.

V. TESTIMONY AT HEARINGS

Heinsohn, P. Testimony at the Federal OSHA Hearing January 9, 1990, San Francisco, CA.

Purpose: Supplements part of Dr. D. L. Jewett's testimony on operating room personnel exposure to blood-containing aerosols.

Approach: Testimony intended to:

1. Explain the sampling methodology.
2. Explain sampling strategy.
3. Present the personal sampling results.
4. Interpret the exposure data.

Assumptions: 1) Exposure to blood constitutes exposure to blood-borne pathogens; 2) Exposure to blood came from data on μg of blood per cubic meter of air while a potential exposure to HIV (tissue culture infective doses) was calculated from these data using assumptions and published data on surgical mask leakage and aerosol deposition in the respiratory tract.

Surgical power tools have been shown to create respirable aerosols. Presence of blood in the samples collected was quantitated by analyzing samples for hemoglobin using Hemastix which provided the minimum concentration of hemoglobin present, but not the exact quantity. Therefore, the measurements taken were known to be underestimations of the actual exposures to blood. Monitored surgeons and first assistants by sampling air in the breathing zone during three primary total hip operations using Marple personal cascade impactors.

Results: Likely exposures the HIV varied with each procedure; samples probably due to slightly different procedures and durations of the surgery. Data indicated that operating room personnel are exposed by inhalation to blood-containing aerosols that could contain blood-borne pathogens..

Significance: Results indicate that a potential respiratory hazard exists for which control should be implemented, unless it is demonstrated that blood-containing aerosols do not pose a risk of infection in the operating room. Respiratory protection remains as the most viable control measure.

Jewett, D. L. Testimony at the Federal OSHA Hearing January 9, 1990, San Francisco, CA. Title: Summary of Scientific Evidence Suggesting Need for Respiratory Protection Against Blood-Containing Aerosols.

Purpose: Presented information in a clear and simplified manner to be understood by the non-scientist.

Approach: Provided a broad introduction and review of the potential for the transmission of the AIDS virus by the aerosol route.

Results: Forty-four references were cited. Included points relevant to the present literature (abbreviated subtitles from the testimony):

1. Blood-containing aerosols have been generated by surgical power tools.
2. Infectious aerosols are known to be generated liquids.
3. Hemoglobin (Hb) is a marker that can be used to estimate risks to aerosols containing blood.
4. Human hepatitis B virus (HBV) transmission in hospitals has been associated with aerosolized blood during surgery.
5. HIV remains infectious in aerosols generated by surgical power tools for sufficient duration to present a potential hazard in surgery.
6. Inhaled HIV is likely to be infectious.
7. Many disease agents are transmitted via aerosols.
8. Surgical masks are designed to protect the patient and are not respiratory protection devices.
9. Potential risk of infection via the respiratory route can be estimated from the concentration of the HIV in an aerosol, the particle size, and the duration of the exposure during surgery.
10. Possible mechanisms of infection can be established by experimental methods.
11. Concluded that it is better to assume that there is a significant risk of infection than to assume there is no risk until further evidence is presented.

Significance: A thorough review of the literature related to the aerosol transmission of HIV.

VI. NEWS ITEMS:

Anonymous. Blood aerosol hazard. *Occup. Health Saf. 58*: 10-11, 1989.

Purpose: Interviews with Dr. D. Jewett, professor of orthopedic surgery at U. of California and Steven Carlson, industrial hygienist with Boelter Assoc. Inc., Chicago, an environmental consulting firm.

Approach: N/A.

Results: Dr. Jewett stated that it has been demonstrated that power tools used in orthopedic surgery can create aerosols that can be inhaled and deposited in the lungs. Whether or not this presents a real danger has yet to be proven. He suggests that those concerned about the potential hazard wear a respirator, but doubts that there are any on the market of the type needed to remove potentially infected aerosols from the air. Mr. Carlson noted that there is a lack of evidence of accidental transmission of the HIV in the operating room.

Significance: Both Dr. Jewett and Mr. Carlson warned that additional work is needed to better define the risks involved.

Anbnymous. Antiviral trial conducted (news). *Occupational Health Safety 58*: 11-12, 1989.

Purpose: Determine the effectiveness of the prophylactic treatment of health care workers with RETROVIR-brand zidovudine after accidental exposure to AIDS virus. No references cited.

Approach: Request for volunteers to participate in a double blind, placebo-controlled trial has been initiated to evaluate the potential effectiveness of the prophylactically administered RETROVIR-brand zidovudine (formerly known as AZT) to health care worker exposed to AIDS virus. Exposure to the virus could come any of three ways: 1) Penetrating wounds from contaminated needles or other sharp instruments, 2) from splashes onto abraded skin, and 3) splashes onto mucous membranes.

Results: Notice of the initiation and request for volunteers in the study was published in the April 1989 issue of this journal.

Significance: NA at this time.

Anonymous. Tests show that the AIDS virus is capable of being transmitted as a mist during certain surgical operations. *Canadian Operating Room Nursing J. 7*: 27, 1989. Anonymous. Study shows AIDS virus can be transmitted as a mist. *Canadian J. Nursing Admin. 2*: 25, 1989.

Purpose: Both news items comment on a Canadian Press report from interviews with Dr. G. Johnson of Stanford University and Dr. L. Day of San Francisco General Hospital.

Approach: N/A.

Results: Dr. Johnson is quoted as saying that studies in the laboratory have shown that the HIV can travel 50 cm. and infect human cells. Dr. Day said that sometimes there is blood all over the floor, walls, and herself up to her knees when power tools are used in orthopedic surgery.

Significance: N/A.

Anonymous. AIDS risk to health care workers. *SAMJ 78*: 8, 1990.

Purpose: The Medial Association of South Africa (MASA) shares the growing concern about the increasing risk to health care workers of AIDS infection from patients.

Approach: Trying to provide better guidelines for the medical community.

Results: Because of hard-pressed health care budgets, provisions for protective equipment may be prohibitive at times.

Significance: The MASA still supports the philosophy that doctors have a long and honored tradition of caring for patients with infectious diseases with compassion and courage. This philosophy is supported by medial groups in the US, the UK, and the WHO. Health care workers should take appropriate precautions to prevent exposure.

Anonymous. Airborne aids. Page ?. *USA Today*. Friday, February 8, 1991.

Purpose: Brief paragraph reports that fears of the airborne transmission of HIV resulting from the use of high speed saws and drills has prompted NIOSH to initiate an investigation into this potential problem. Linda Martin of NIOSH is quoted as saying that since there is no evidence that the AIDS virus is transmitted by airborne particles no special recommendations are being made by NIOSH while the studies are in progress.

Approach: NA.

Results: NA.

Significance: NA.

Anonymous. AIDS-Infected Nurse to Get $5.4 Million. *Am. J. Nurs. 92*: 91, 1992.

Purpose: News report. New York state was ordered to pay $5.4 million to a nurse who contracted the disease during a struggle with a prisoner while guards stood by and did nothing to help.

Approach: N/A.

Results: N/A.

Significance: There can be significant dollars awarded for pain and suffering associated with the accidental infection with HIV.

Tofani, L. AIDS risk from airborne surgical particles studied. *Philadelphia Inquirer.* Page A01. Thursday, February 7, 1991.

Purpose: To provide a report of the current status of concerns about the potential of the transmission of the AIDS virus by aerosols created during orthopedic surgery.

Approach: NA.

Results: The CDC is funding a $300,000 investigation of the use of power tools and the creation of aerosols during orthopedic surgery. Although CDC has previously said that AIDS cannot be spread through the air, aerosols created during surgery that may impinge on the mucous membranes of members of surgical teams present an added complexity to the issue. The spattering of blood and accidents with needles and sharp instruments continue to be of major concern. It was assumed that HIV lost viability rapidly after aerosolization; however, recent work has shown that the virus can remain viable for much longer periods of time than initially assumed. Surgeon's masks will not filter out all aerosols containing the AIDS virus.

Work at Stanford (G. K. Johnson and W. S. Robinson) has demonstrated that when HIV infected blood is dropped on a rotating drill bit aerosols containing infective virus are created. Another study at the University of California, San Francisco, showed that aerosols containing AIDS-infected blood were produced during orthopedic surgery when bone cutting tools were used. Small amounts of these aerosols were shown to penetrate surgical masks (D. L. Jewett) when high concentrations of virus were used. These studies were conducted by the urging of Dr. L. J. Day who has since abandoned surgery because of fears of the possible transmission of AIDS by orthopedic surgical procedures. The article also notes that CDC has funded work on aerosols created during orthopedic surgery, and on the viability of the AIDS virus in such aerosols. This work was initiated at ITRI in November 1990.

To date, there has only been one confirmed case of the transmission of the AIDS virus by the airborne route. This occurred when a laboratory worker became infected as the result of an accident involving work with a large

volume of concentrated HIV. Changes in the recommended safety procedures will await the results of these studies.

Significance: This article provides a brief, accurate description of the current status of the concerns about the potential transmission of the AIDS virus by aerosols generated by orthopedic surgical procedures.

WHO Reports on HIV and HBV Transmission in the Health Care Setting. *Bull. Pan. Am. Health Orgn. 25*: 291-292, 1991.

The WHO Global Program on AIDS organized a consultation of international experts on HIV and HBV transmission in the health care setting in Geneva in April 11-12, 1991, at the request of several countries. The consultation report examined the risks of:

Patient to patient transmission (considered minimal risk),

Patient to health care worker transmission, and

Health care worker to patient transmission (rarest of all).

Transmission by any of these means is considered rare. The report rejects the mandatory testing of patients or health care workers for HIV as a means of minimizing potential transmission of HIV and highly recommends strict adherence to universal precautions concepts. Recommendations for health care institutions are provided in the report (copy of report requested from WHO).

APPENDIX B

DATA ON PILOT STUDY

Abbreviation or Acronyms

A, B, C, ...	column in the table
(B)/(E), etc.	column (B) divided by column (E) in the table
BAM	surgeon
C	mass concentration, mg/m^3
C.f.	correction factor for sampling efficiency and internal loss
D_{ae}	aerodynamic diameter, μm
D_p	particle diameter, μm
EC	electrocautery
ECD	effective cut-off diameter, μm
f	fraction
GMD	geometric mean diameter, μm
HCY	aerosol staff
IRR	irrigation/suction
LMJ	Lovelace Multi-Jet cascade impactor
m frac	mass fraction
MAB	surgeon
PL#	Pilot run #
RST	surgeon
SUC	suction/irrigation
TDH	aerosol staff
t	sampling time, sec.
WS	surgeon
δWt	$= \Delta Wt$ = delta weight

Pilot Study: Filter Sample Data

Exp ID	Filter ID	Chem.9	δt,min	δm,mg	C,mg/m3	Ave of FS C,mg/m3	Ave of PS C,mg/m3
PILOT_1*	FS1	neg*	11	0.216	0.982	0.318	
	FS2	neg*	2	0.018	0.450		
	FS3	neg*	19	0.061	0.161		
	FS4	neg*	10	0.028	0.140		
	FS5	neg*	14	0.033	0.118		
	PS1	--	56	0.004	0.036		0.027
	PS2	--	56	0.001	0.009		
	PS3	--	56	0.004	0.036		
PILOT_2*	FS1	--	13	0.580	2.231	0.799	
	FS2	1+*	7	0.150	1.071		
	FS3	--	17	0.068	0.200		
	FS4	--	15	0.033	0.110		
	PS1	--	64	0.001	0.008		0.003
	PS2	--	64	0.000	0.000		
	PS3	--	64	0.000	0.000		
PILOT_3**	FS1	3+	15	0.502	1.673	0.550	
	FS2	2+	6	0.023	0.192		
	FS3	2+	20	0.030	0.075		
	FS4	neg	11	0.017	0.077		
	PS1	--	58	0.002	0.017		0.029
	PS2	--	58	0.004	0.034		
	PS3	--	58	0.004	0.034		
Average						0.556	0.019
S.D.						0.196	0.012
Maximum						0.799	0.029
Minimum						0.318	0.003

* Chemstrip 9 analyzed in 1.0 mL of water

** Chemstrip 9 analyzed in 20 μL of water

Pilot Study: Chemstrip 9 Data on QCM Stages

Exp ID	Stage 1 35.4 μm	Stage 2 17.7 μm	Stage 3 9.09 μm	Stage 4 4.56 μm	Stage 5 2.30 μm	Stage 6 1.17 μm	Stage 7 0.60 μm	Stage 8 0.32 μm	Stage 9 0.18 μm	Stage 10 0.10 μm
PILOT_1	--	--	--	--	--	--	--	--	--	--
PILOT_2*	neg	neg	neg	neg	1+	neg	neg	neg	trace	neg

Exp ID	Stage 1 14.2 μm	Stage 2 7.96 μm	Stage 3 4.28 μm	Stage 4 2.87 μm	Stage 5 1.45 μm	Stage 6 0.74 μm	Stage 7 0.46μm	Stage 8 0.32 μm	Stage 9 0.18μm
PILOT_3**	trace	neg	trace	1+	1+	trace	trace	1+	1+

* Chemstrip 9 analyzed in 1.0 mL of water

** Chemstrip 9 analyzed in 20 μL of water

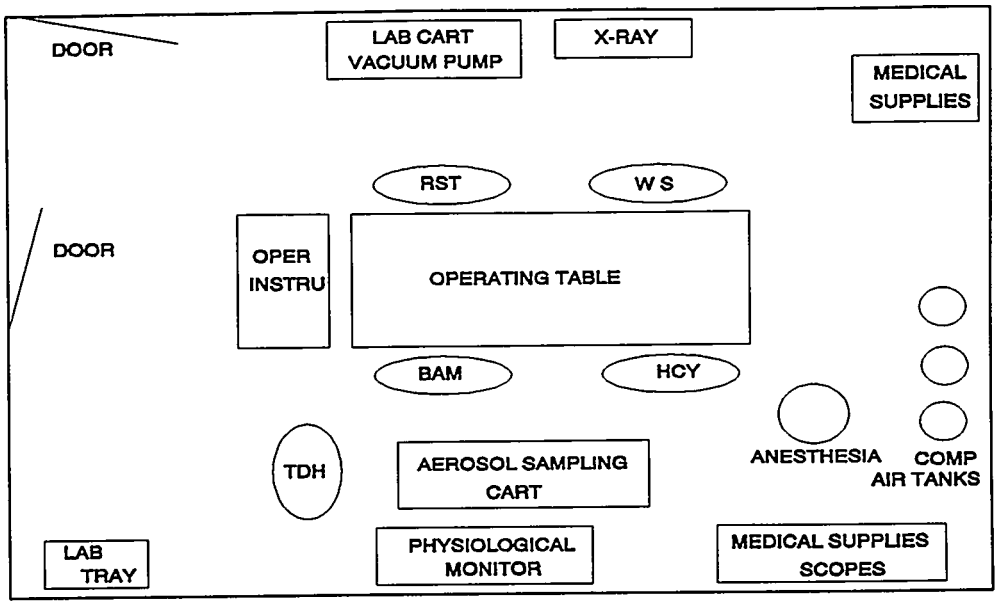
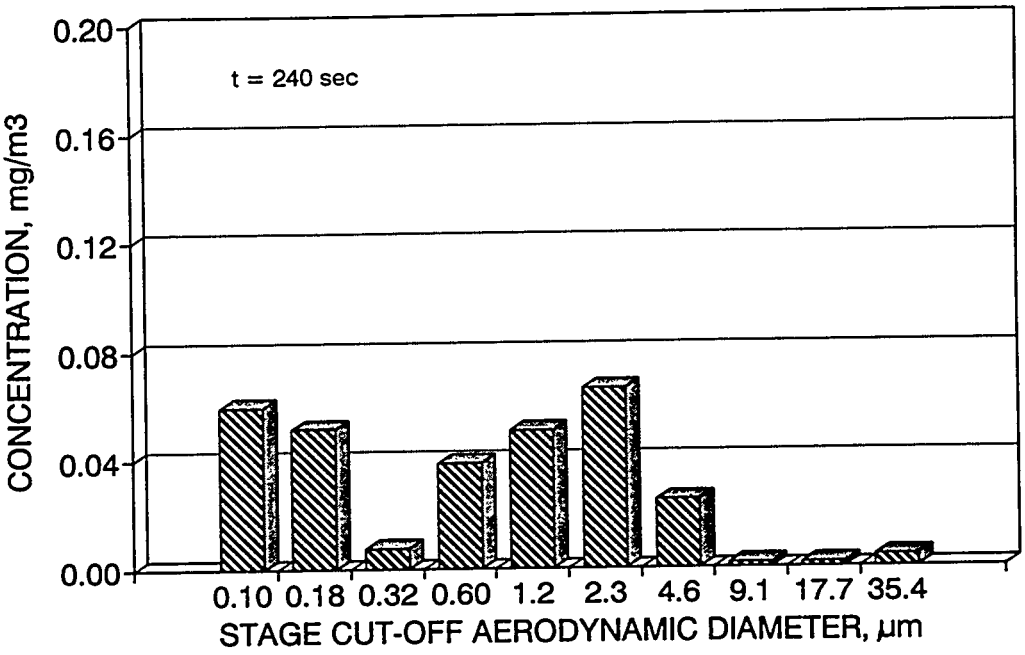


Figure B.1 Personnel locations during Pilot #1 experiment

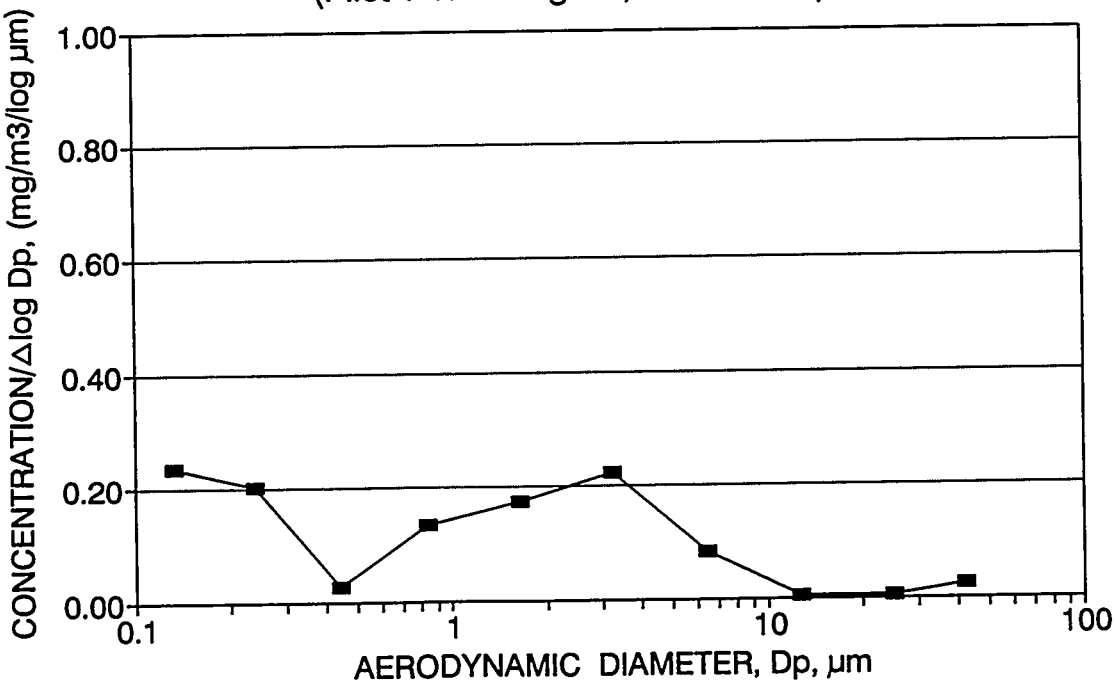
Pilot 1-1: During EC (t = 240 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.05967	0.10	-1.001	0.252	0.237	0.13	0.1946	0.000
0.10	0.05180	0.18	-0.749	0.257	0.201	0.24	0.1689	0.195
0.20	0.00725	0.32	-0.492	0.272	0.027	0.44	0.0236	0.363
0.40	0.03875	0.60	-0.220	0.287	0.135	0.84	0.1264	0.387
0.80	0.05115	1.17	0.067	0.294	0.174	1.64	0.1668	0.513
1.60	0.06640	2.30	0.362	0.298	0.223	3.24	0.2165	0.680
3.20	0.02497	4.56	0.659	0.299	0.083	6.44	0.0814	0.897
6.40	0.00142	9.09	0.959	0.290	0.005	12.69	0.0046	0.978
12.50	0.00142	17.72	1.248	0.301	0.005	25.04	0.0046	0.983
25.00	0.00385	35.40	1.549	0.150	0.026	42.07	0.0126	0.987
		50.00	1.699					1.000
Sum	0.30668						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-1: During EC)



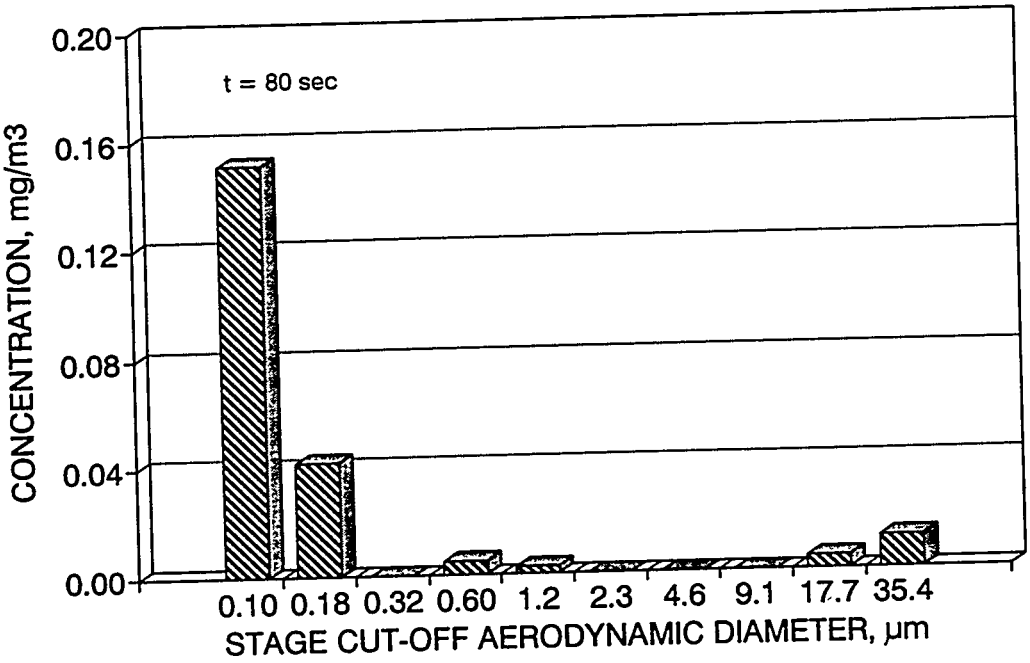
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-1: During EC, t = 240 sec)



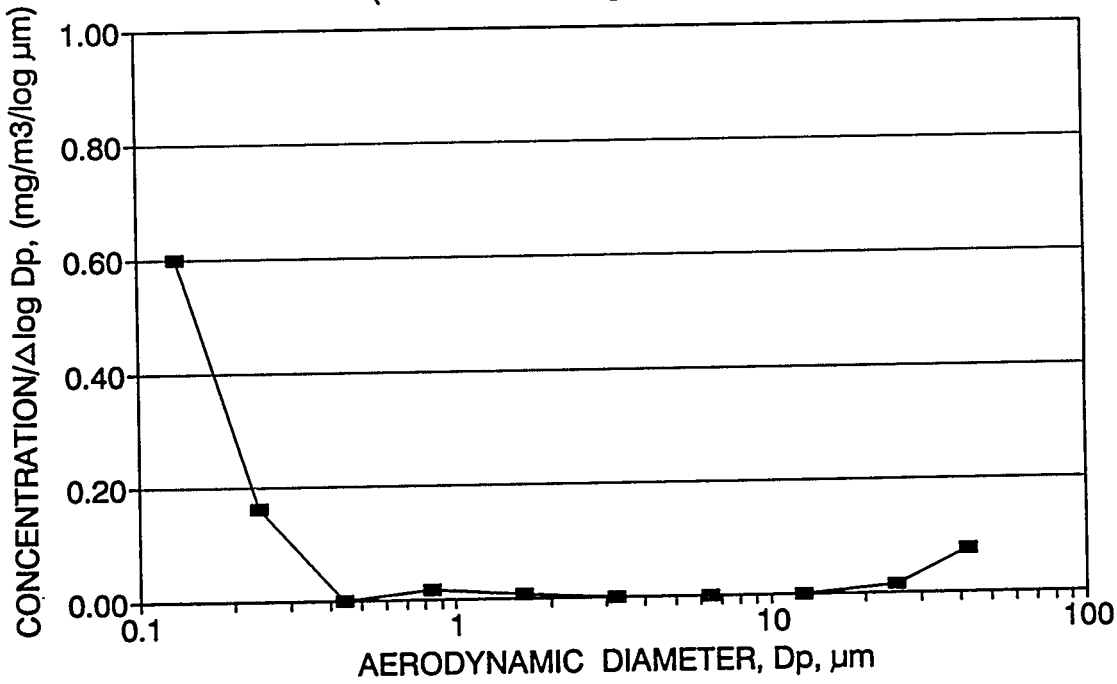
Pilot 1-2: During EC/SAW (t = 80 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.15112	0.10	-1.001	0.252	0.600	0.13	0.7012	0.000
0.10	0.04162	0.18	-0.749	0.257	0.162	0.24	0.1931	0.701
0.20	0.00000	0.32	-0.492	0.272	0.000	0.44	0.0000	0.894
0.40	0.00465	0.60	-0.220	0.287	0.016	0.84	0.0216	0.894
0.80	0.00232	1.17	0.067	0.294	0.008	1.64	0.0108	0.916
1.60	0.00000	2.30	0.362	0.298	0.000	3.24	0.0000	0.927
3.20	0.00000	4.56	0.659	0.299	0.000	6.44	0.0000	0.927
6.40	0.00000	9.09	0.959	0.290	0.000	12.69	0.0000	0.927
12.50	0.00427	17.72	1.248	0.301	0.014	25.04	0.0198	0.927
25.00	0.01155	35.40	1.549	0.150	0.077	42.07	0.0536	0.946
		50.00	1.699					1.000
Sum	0.21553						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-2: During EC/SAW)



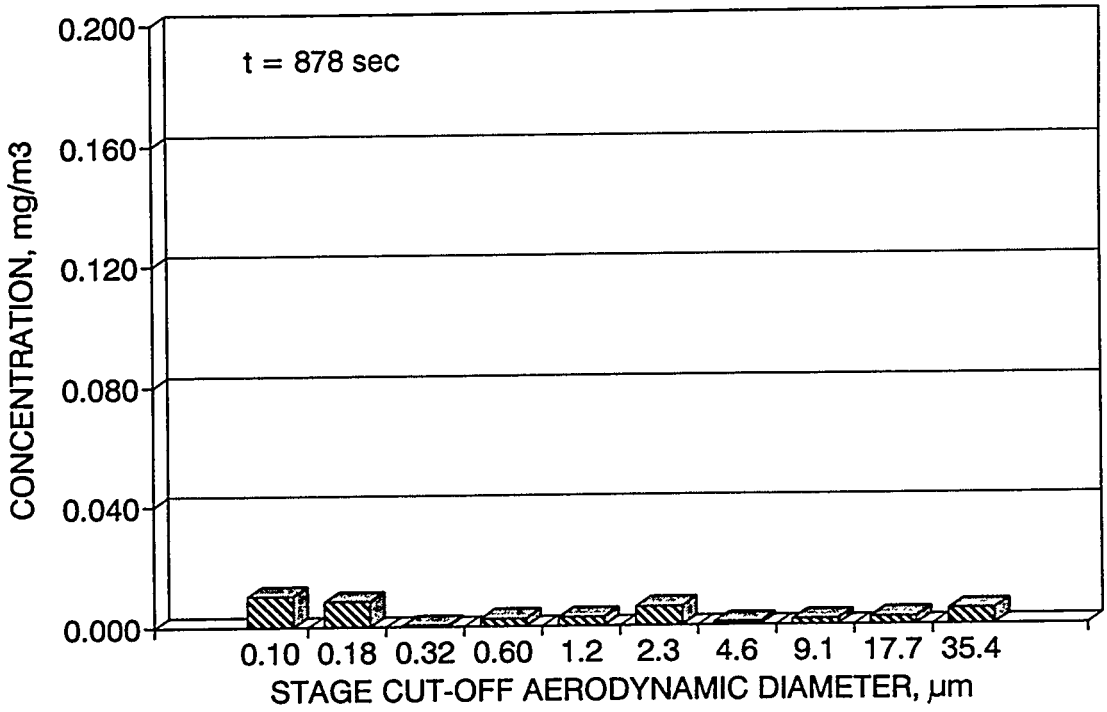
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-2: During EC/SAW)



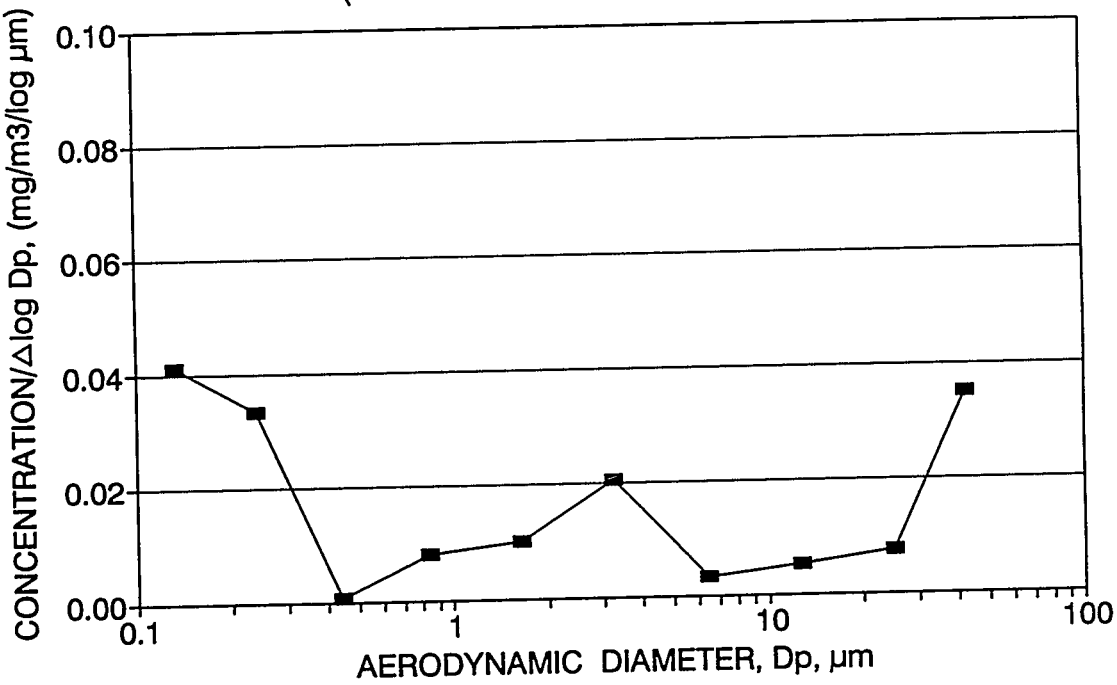
Pilot 1-3: During IRR/Hand Borer (t = 878 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.01038	0.10	-1.001	0.252	0.041	0.13	0.2549	0.000
0.10	0.00859	0.18	-0.749	0.257	0.033	0.24	0.2110	0.255
0.20	0.00019	0.32	-0.492	0.272	0.001	0.44	0.0047	0.466
0.40	0.00233	0.60	-0.220	0.287	0.008	0.84	0.0572	0.471
0.80	0.00296	1.17	0.067	0.294	0.010	1.64	0.0727	0.528
1.60	0.00612	2.30	0.362	0.298	0.021	3.24	0.1503	0.600
3.20	0.00101	4.56	0.659	0.299	0.003	6.44	0.0248	0.751
6.40	0.00155	9.09	0.959	0.290	0.005	12.69	0.0381	0.776
12.50	0.00233	17.72	1.248	0.301	0.008	25.04	0.0572	0.814
25.00	0.00526	35.40	1.549	0.150	0.035	42.07	0.1292	0.871
		50.00	1.699					1.000
Sum	0.04072						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-3: IRR./HAND BORER)



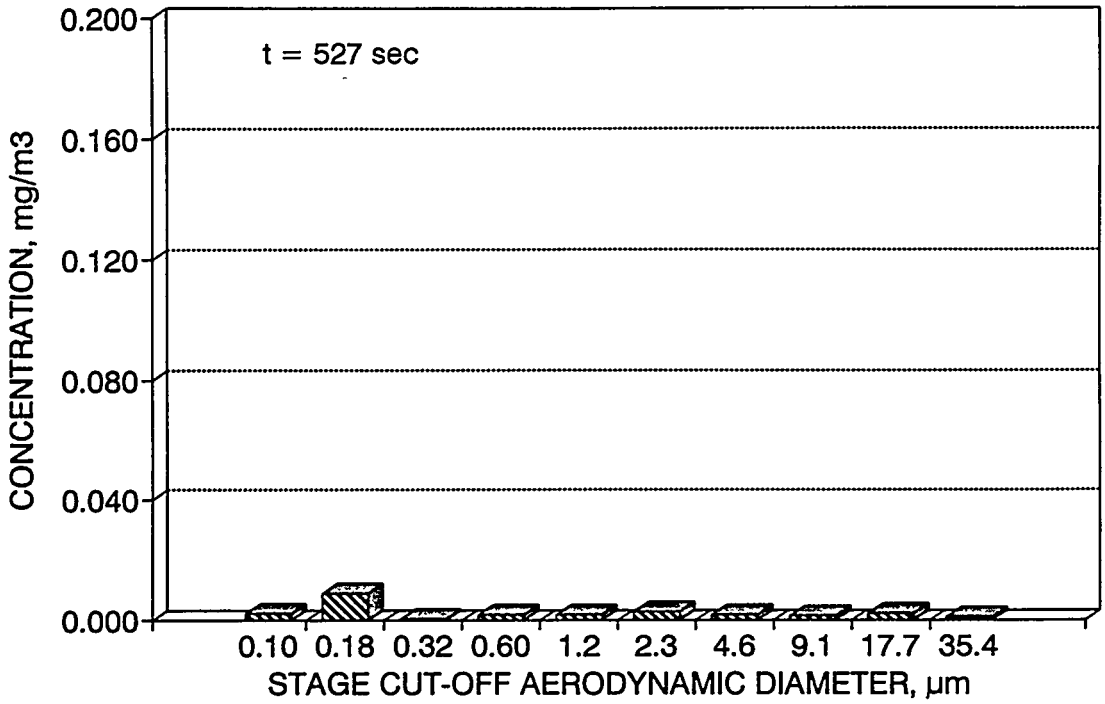
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-3: IRR./HAND BORER)



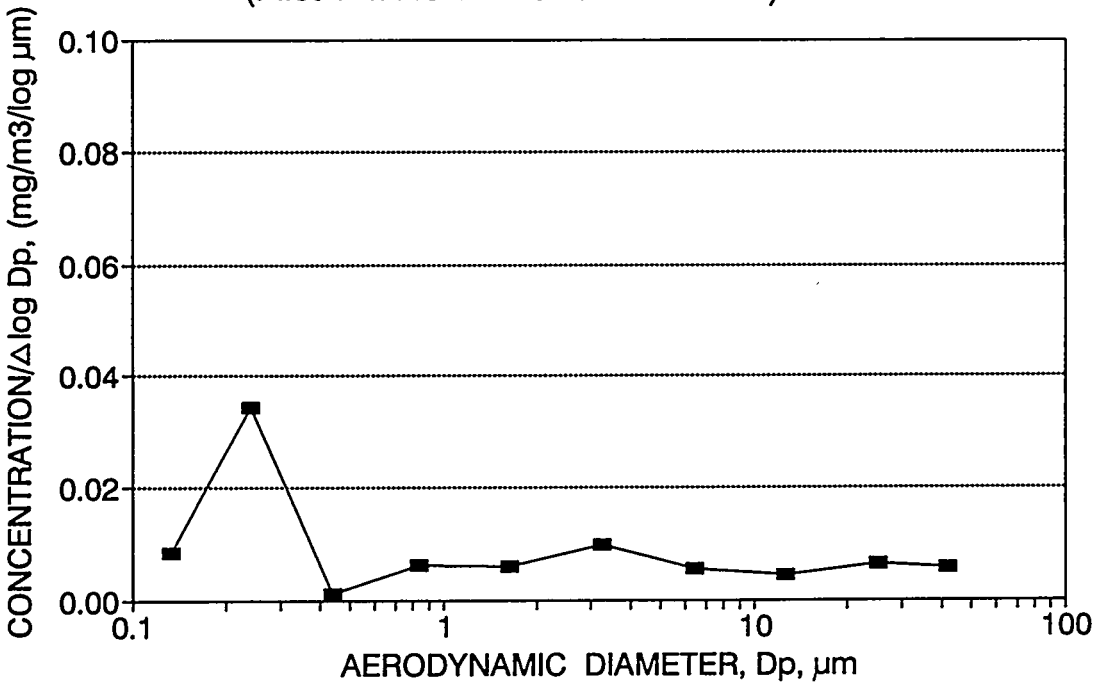
Pilot 1-4: During Acetabulum Reamer (t = 527 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.00211	0.10	-1.001	0.252	0.008	0.13	0.0898	0.000
0.10	0.00884	0.18	-0.749	0.257	0.034	0.24	0.3763	0.090
0.20	0.00033	0.32	-0.492	0.272	0.001	0.44	0.0140	0.466
0.40	0.00176	0.60	-0.220	0.287	0.006	0.84	0.0749	0.480
0.80	0.00176	1.17	0.067	0.294	0.006	1.64	0.0749	0.555
1.60	0.00291	2.30	0.362	0.298	0.010	3.24	0.1239	0.630
3.20	0.00168	4.56	0.659	0.299	0.006	6.44	0.0715	0.754
6.40	0.00129	9.09	0.959	0.290	0.004	12.69	0.0549	0.825
12.50	0.00194	17.72	1.248	0.301	0.006	25.04	0.0826	0.880
25.00	0.00087	35.40	1.549	0.150	0.006	42.07	0.0370	0.963
		50.00	1.699					1.000
Sum	0.02349						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-4: ACETABULUM REAMER)



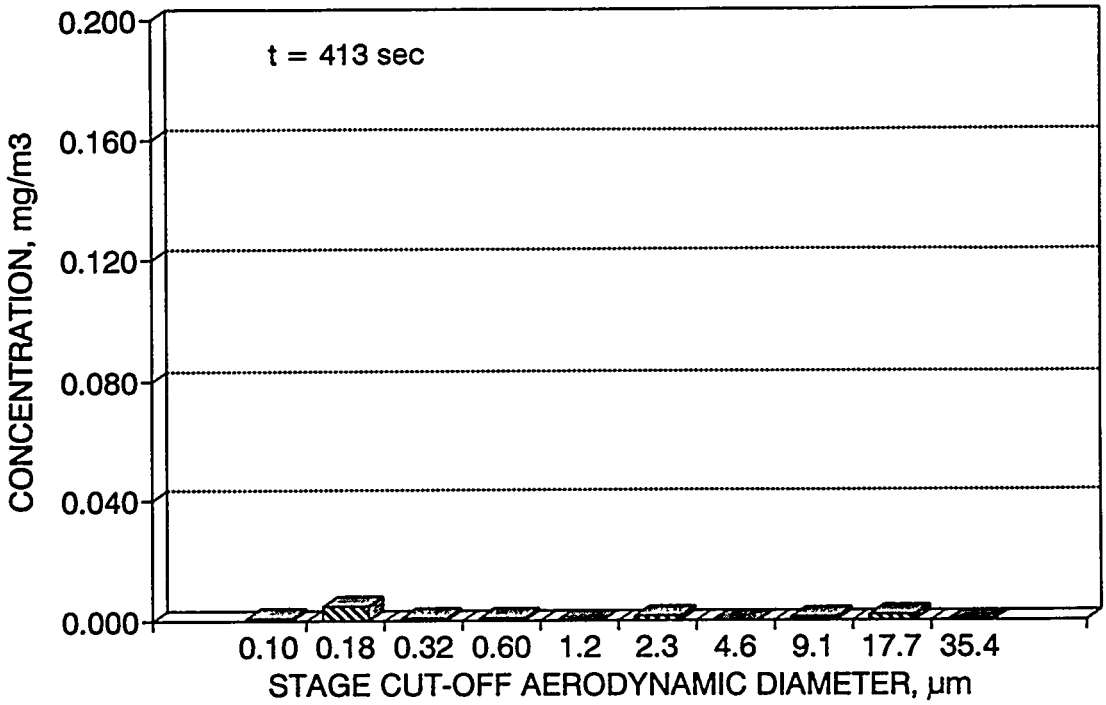
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-4: ACETABULUM REAMER)



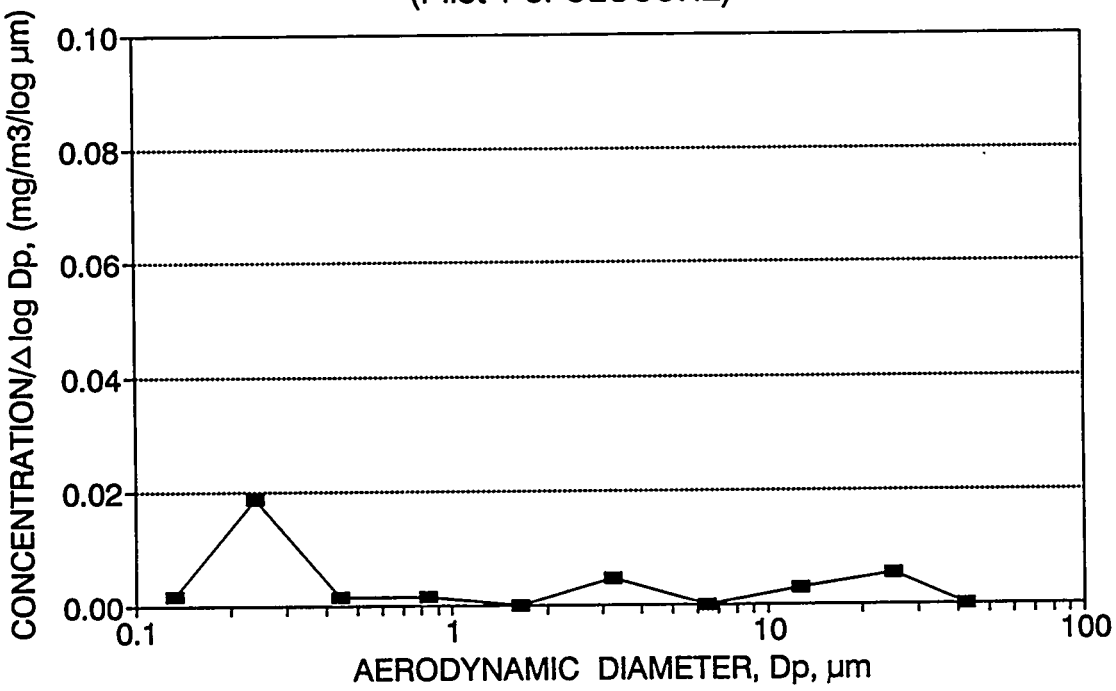
Pilot 1-5: Closure (t = 413 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.00045	0.10	-1.001	0.252	0.002	0.13	0.0450	0.000
0.10	0.00483	0.18	-0.749	0.257	0.019	0.24	0.4825	0.045
0.20	0.00042	0.32	-0.492	0.272	0.002	0.44	0.0420	0.527
0.40	0.00045	0.60	-0.220	0.287	0.002	0.84	0.0450	0.569
0.80	0.00000	1.17	0.067	0.294	0.000	1.64	0.0000	0.614
1.60	0.00139	2.30	0.362	0.298	0.005	3.24	0.1389	0.614
3.20	0.00000	4.56	0.659	0.299	0.000	6.44	0.0000	0.753
6.40	0.00082	9.09	0.959	0.290	0.003	12.69	0.0819	0.753
12.50	0.00165	17.72	1.248	0.301	0.005	25.04	0.1648	0.835
25.00	0.00000	35.40	1.549	0.150	0.000	42.07	0.0000	1.000
		50.00	1.699					1.000
Sum	0.01001						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-5: CLOSURE)



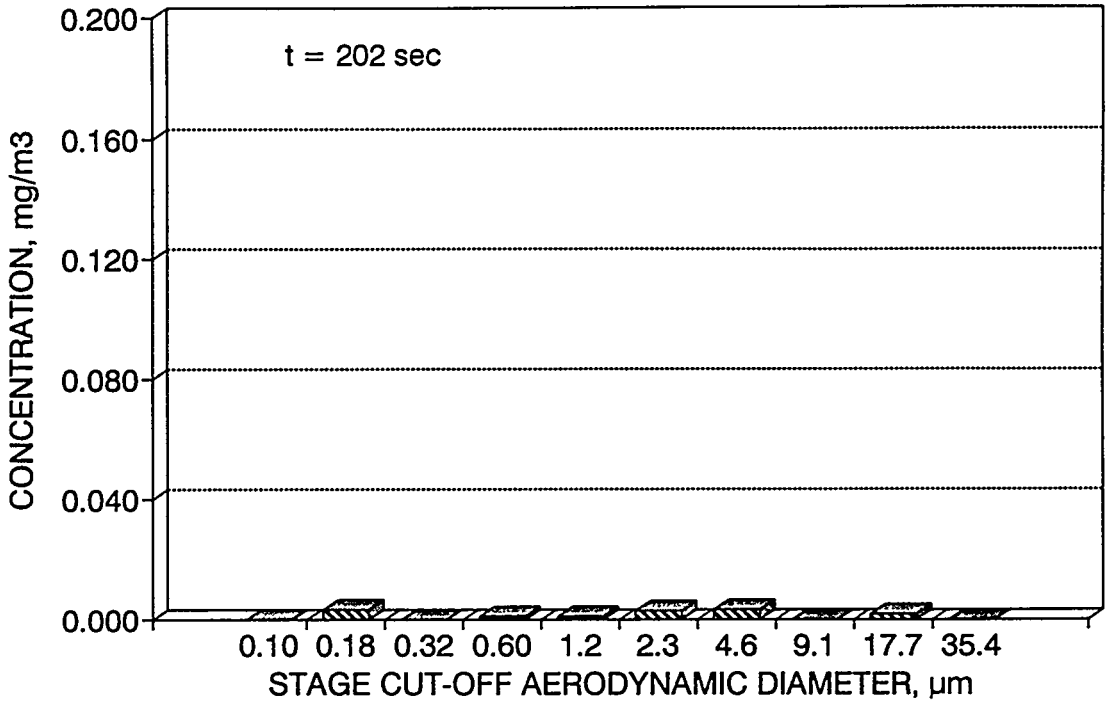
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-5: CLOSURE)



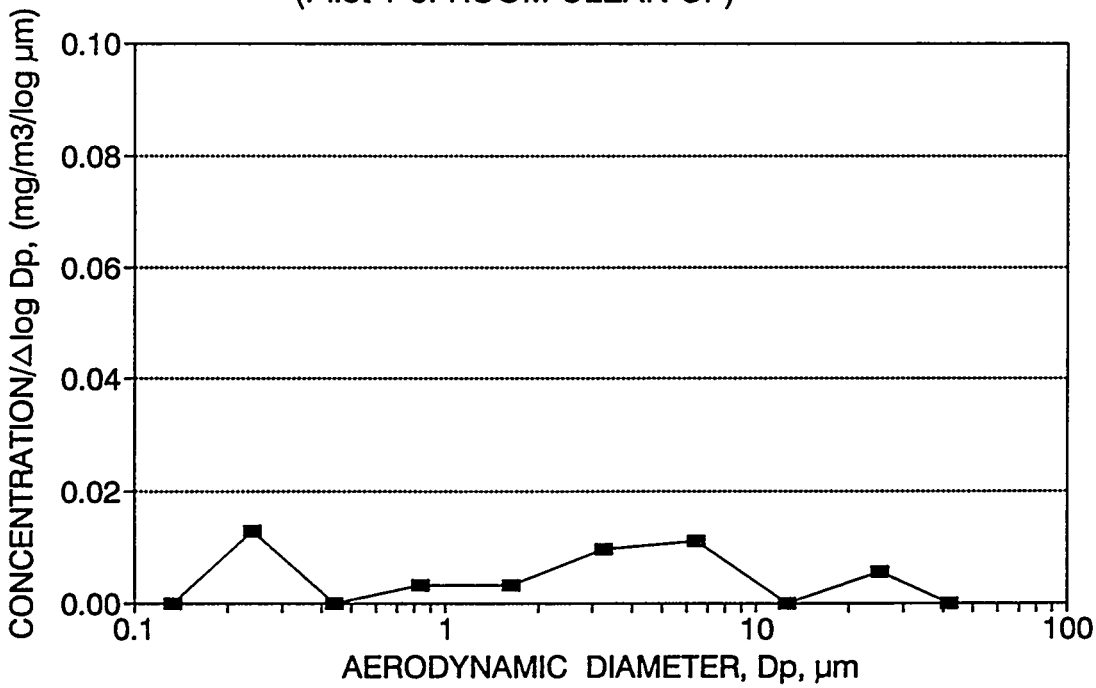
Pilot 1-6: Room Clean-up (t = 202 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.00000	0.10	-1.001	0.252	0.000	0.13	0.0000	0.000
0.10	0.00329	0.18	-0.749	0.257	0.013	0.24	0.2539	0.000
0.20	0.00000	0.32	-0.492	0.272	0.000	0.44	0.0000	0.254
0.40	0.00092	0.60	-0.220	0.287	0.003	0.84	0.0710	0.254
0.80	0.00092	1.17	0.067	0.294	0.003	1.64	0.0710	0.325
1.60	0.00285	2.30	0.362	0.298	0.010	3.24	0.2199	0.396
3.20	0.00329	4.56	0.659	0.299	0.011	6.44	0.2539	0.616
6.40	0.00000	9.09	0.959	0.290	0.000	12.69	0.0000	0.870
12.50	0.00169	17.72	1.248	0.301	0.006	25.04	0.1304	0.870
25.00	0.00000	35.40	1.549	0.150	0.000	42.07	0.0000	1.000
		50.00	1.699					1.000
Sum	0.01296						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 1-6: ROOM CLEAN UP)



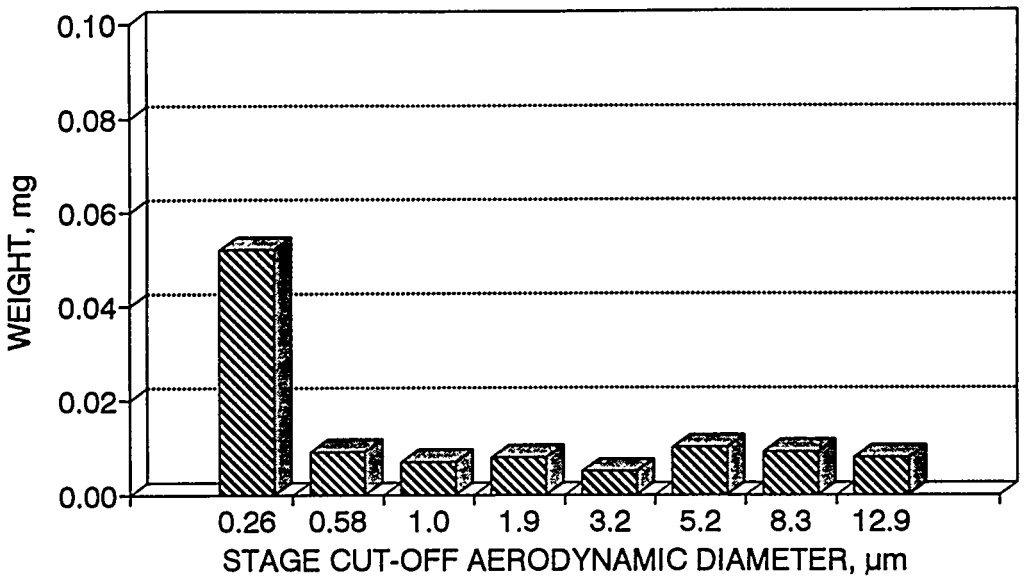
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 1-6: ROOM CLEAN UP)



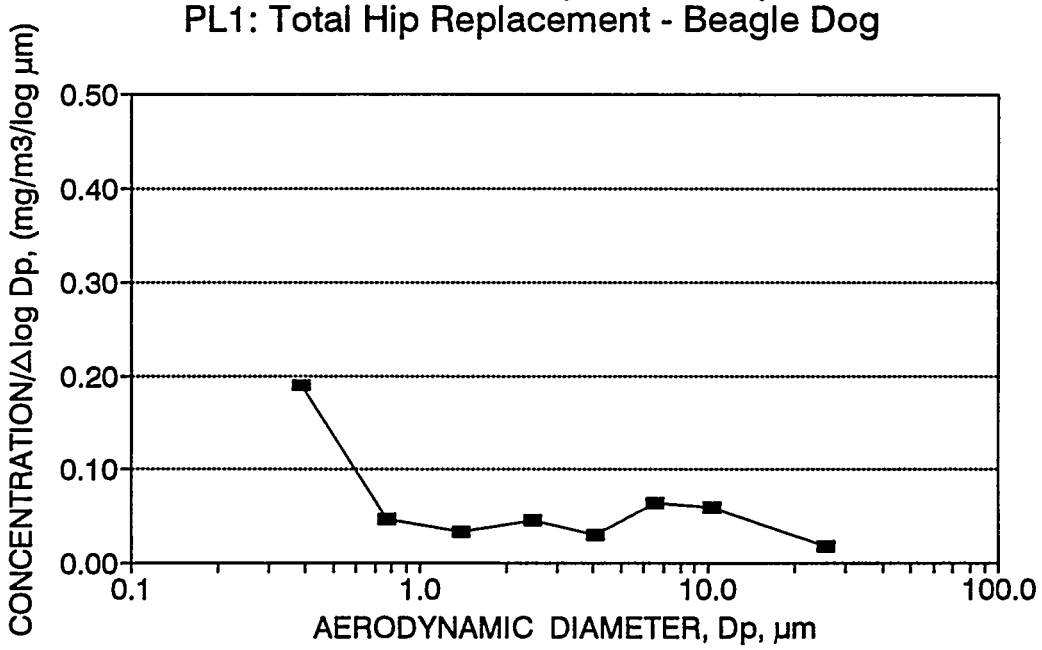
Pilot 1: LMJ Impactor Data

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.052	1	0.784	0.066	-0.585	0.348	0.190	0.39	0.481	0.000
7	0.58	0.009	1	0.784	0.011	-0.237	0.245	0.047	0.77	0.083	0.481
6	1.02	0.007	1	0.784	0.009	0.009	0.270	0.033	1.39	0.065	0.565
5	1.90	0.008	1	0.784	0.010	0.279	0.224	0.046	2.46	0.074	0.630
4	3.18	0.005	1	0.784	0.006	0.502	0.214	0.030	4.07	0.046	0.704
3	5.21	0.010	1	0.784	0.013	0.717	0.200	0.064	6.56	0.093	0.750
2	8.25	0.009	1	0.784	0.011	0.916	0.194	0.059	10.31	0.083	0.843
1	12.89	0.008	1	0.784	0.010	1.110	0.589	0.017	25.39	0.074	0.926
	50.00					1.699					
Sum		0.108			0.138					1.000	

Lovelace Multi-jet Impactor Data
PL1: Total Hip Replacement - Beagle Dog



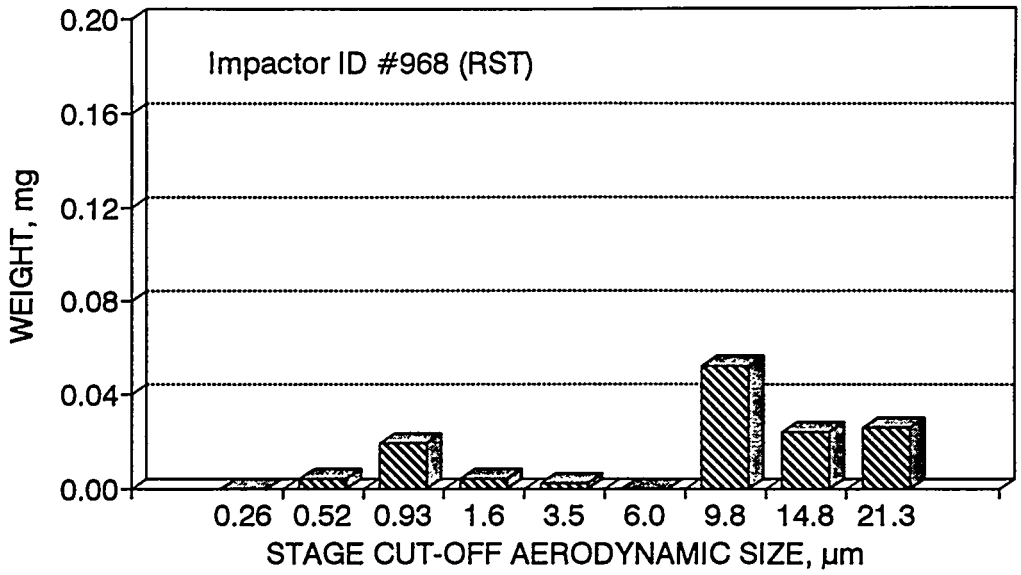
Size Distribution by LMJ Impactor
PL1: Total Hip Replacement - Beagle Dog



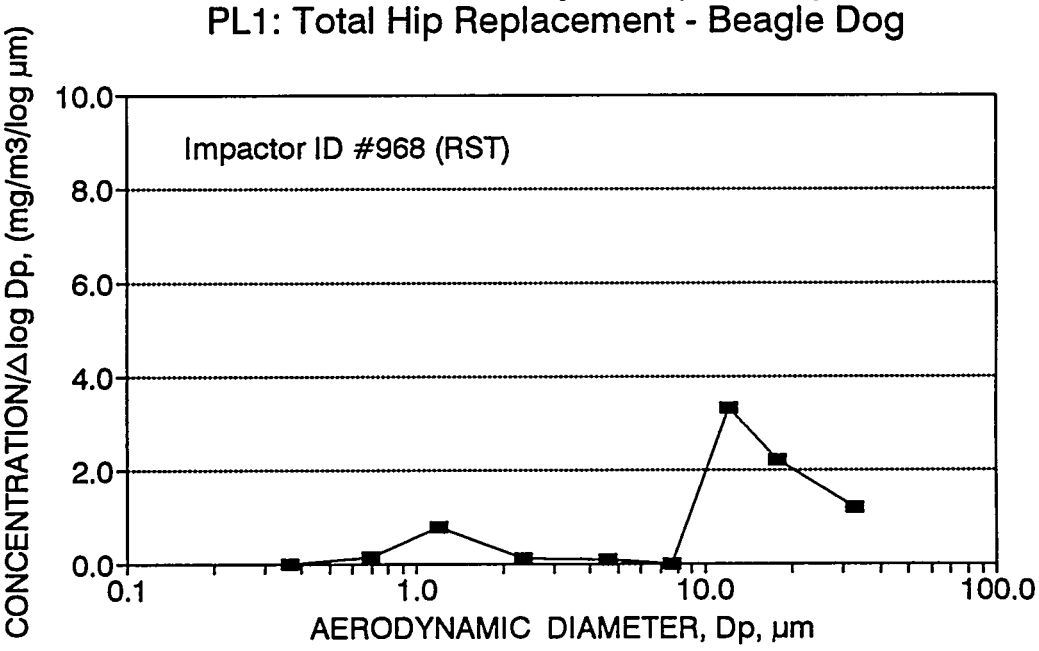
Pilot 1: Marple Personal Impactor Data (ID No. 968: RST)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.000	1	0.112	0.000	-0.585	0.301	0.000	0.37	0.000	0.000
8	0.52	0.004	0.99	0.112	0.036	-0.284	0.252	0.143	0.70	0.022	0.000
7	0.93	0.019	0.97	0.112	0.175	-0.032	0.222	0.788	1.20	0.105	0.022
6	1.55	0.004	0.96	0.112	0.037	0.190	0.354	0.105	2.33	0.022	0.127
5	3.50	0.002	0.95	0.112	0.019	0.544	0.234	0.080	4.58	0.011	0.150
4	6.00	0.000	0.89	0.112	0.000	0.778	0.213	0.000	7.67	0.000	0.161
3	9.80	0.052	0.78	0.112	0.595	0.991	0.179	3.325	12.04	0.359	0.161
2	14.80	0.024	0.61	0.112	0.351	1.170	0.158	2.222	17.75	0.212	0.519
1	21.30	0.026	0.52	0.112	0.446	1.328	0.371	1.205	32.63	0.269	0.731
	50.00					1.699					
Sum		0.131			1.660					1.000	

Marple Personal Impactor Data
PL1: Total Hip Replacement - Beagle Dog



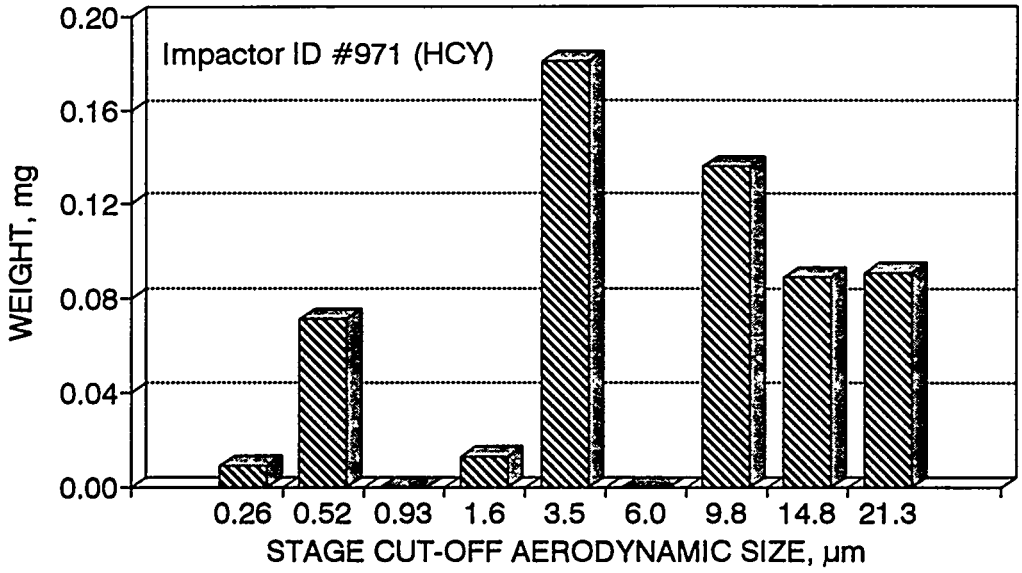
Size Distribution by Marple Impactor
PL1: Total Hip Replacement - Beagle Dog



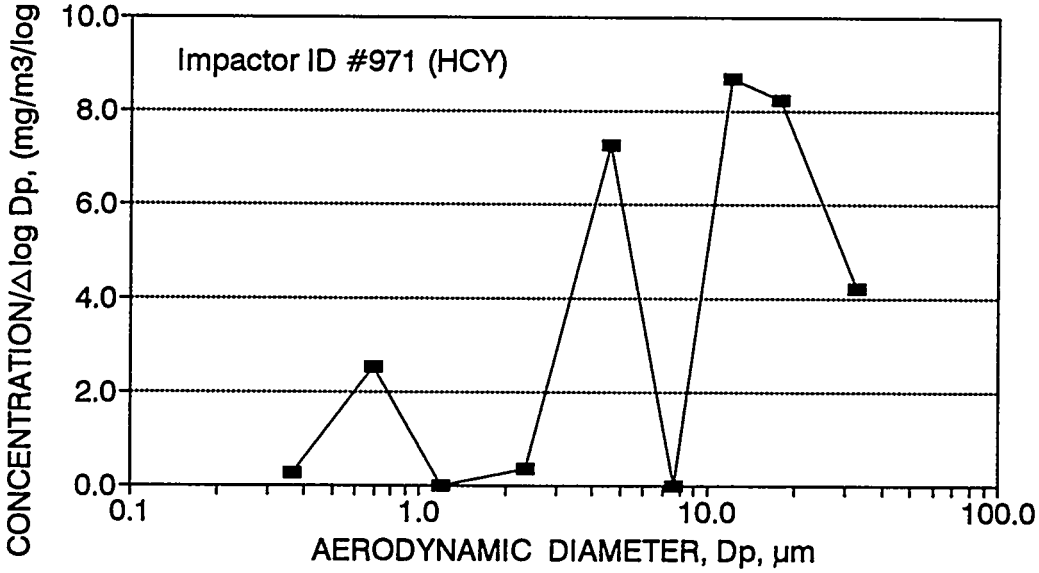
Pilot 1: Marple Personal Impactor Data (ID No. 971: HCY)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.009	1	0.112	0.080	-0.585	0.301	0.267	0.37	0.012	0.000
8	0.52	0.071	0.99	0.112	0.640	-0.284	0.252	2.536	0.70	0.092	0.012
7	0.93	0.000	0.97	0.112	0.000	-0.032	0.222	0.000	1.20	0.000	0.103
6	1.55	0.013	0.96	0.112	0.121	0.190	0.354	0.342	2.33	0.017	0.103
5	3.50	0.181	0.95	0.112	1.701	0.544	0.234	7.267	4.58	0.244	0.121
4	6.00	0.000	0.89	0.112	0.000	0.778	0.213	0.000	7.67	0.000	0.365
3	9.80	0.136	0.78	0.112	1.557	0.991	0.179	8.695	12.04	0.224	0.365
2	14.80	0.089	0.61	0.112	1.303	1.170	0.158	8.239	17.75	0.187	0.589
1	21.30	0.091	0.52	0.112	1.562	1.328	0.371	4.216	32.63	0.224	0.776
	50.00					1.699					
Sum		0.590			6.965					1.000	

Marple Personal Impactor Data
PL1: Total Hip Replacement - Beagle Dog



Size Distribution by Marple Impactor
PL1: Total Hip Replacement - Beagle Dog



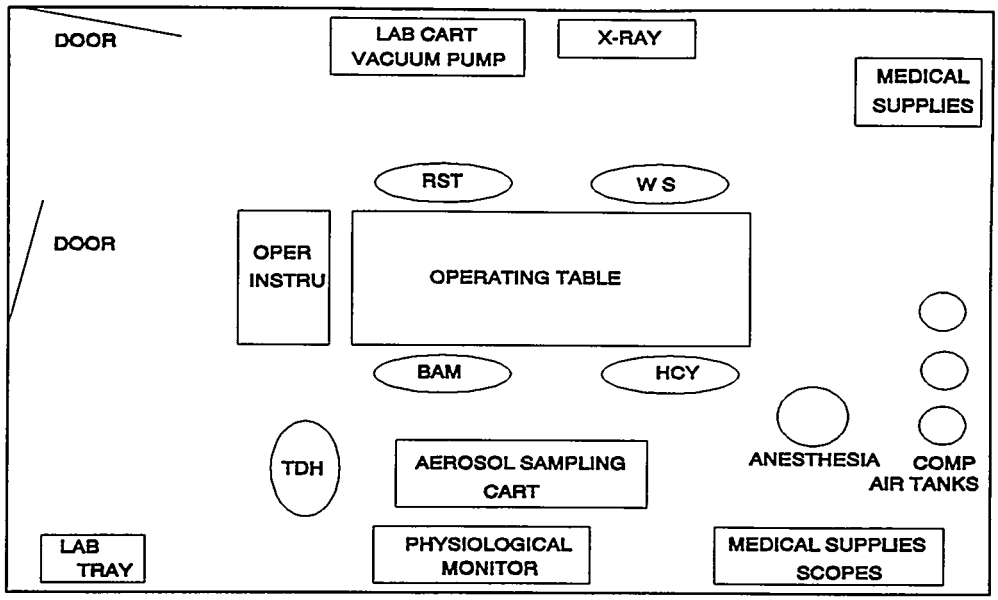
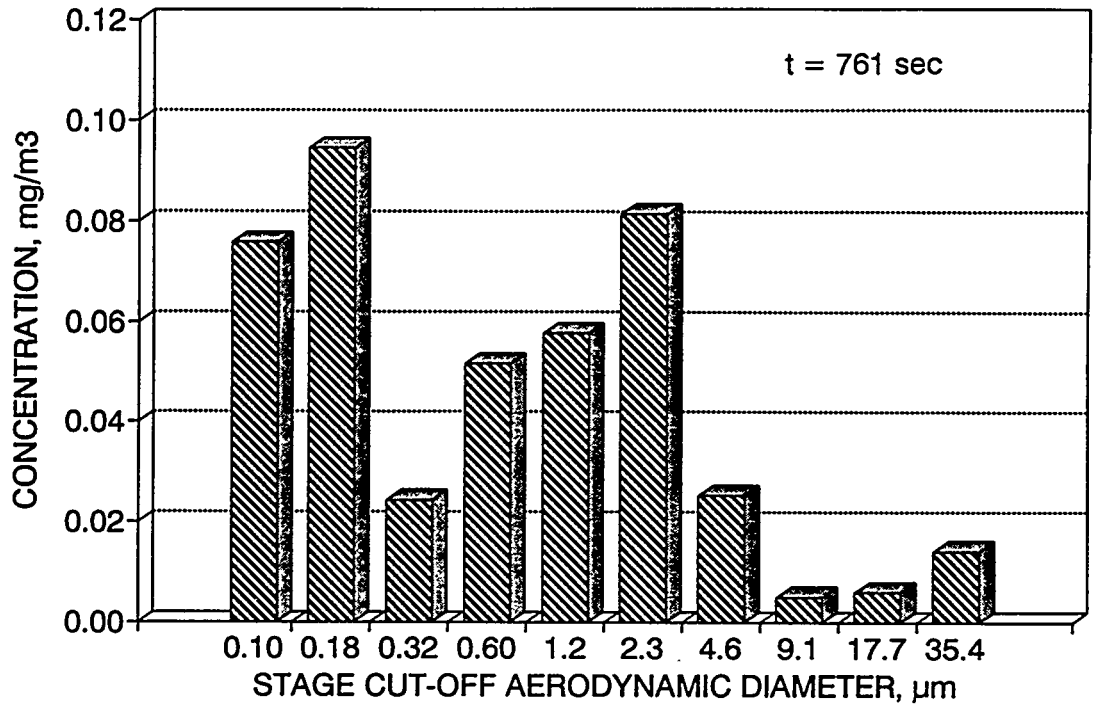


Figure B.2 Personnel locations during Pilot #2 experiment

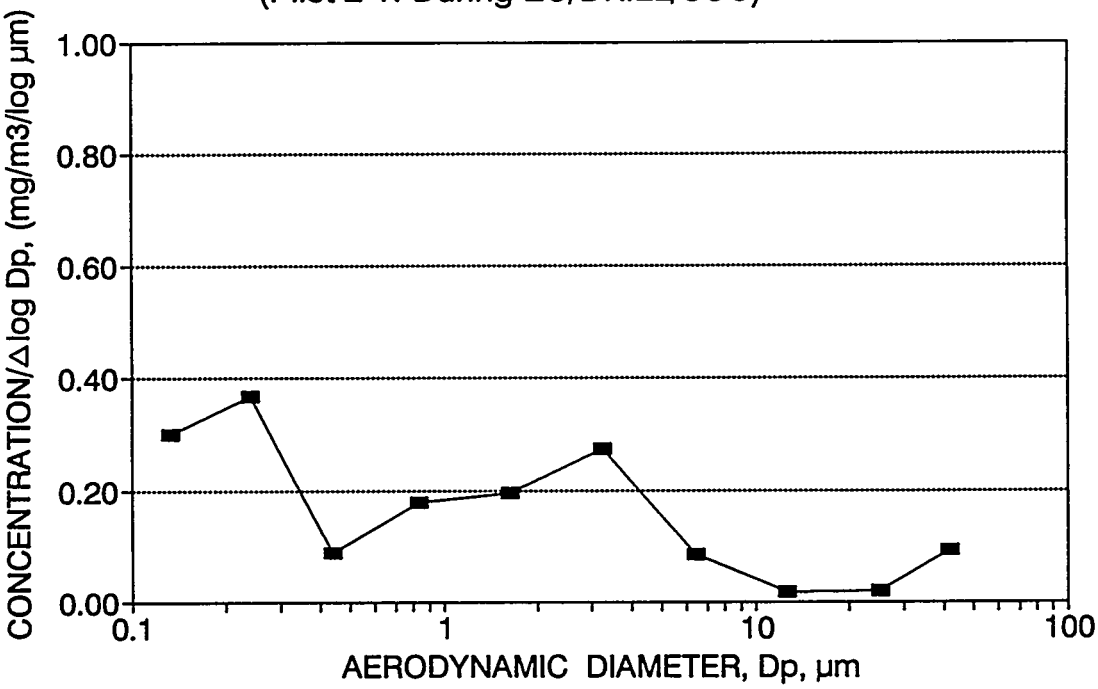
Pilot 2-1: During EC/DRILL/IRR (t = 761 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.07601	0.10	-1.001	0.252	0.302	0.13	0.1745	0.000
0.10	0.09451	0.18	-0.749	0.257	0.367	0.24	0.2170	0.175
0.20	0.02423	0.32	-0.492	0.272	0.089	0.44	0.0556	0.391
0.40	0.05157	0.60	-0.220	0.287	0.180	0.84	0.1184	0.447
0.80	0.05768	1.17	0.067	0.294	0.196	1.64	0.1324	0.566
1.60	0.08174	2.30	0.362	0.298	0.275	3.24	0.1877	0.698
3.20	0.02508	4.56	0.659	0.299	0.084	6.44	0.0576	0.886
6.40	0.00494	9.09	0.959	0.290	0.017	12.69	0.0113	0.943
12.50	0.00584	17.72	1.248	0.301	0.019	25.04	0.0134	0.955
25.00	0.01396	35.40	1.549	0.150	0.093	42.07	0.0321	0.968
		50.00	1.699					1.000
Sum	0.43556						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 2-1: During EC/DRILL/SUC)



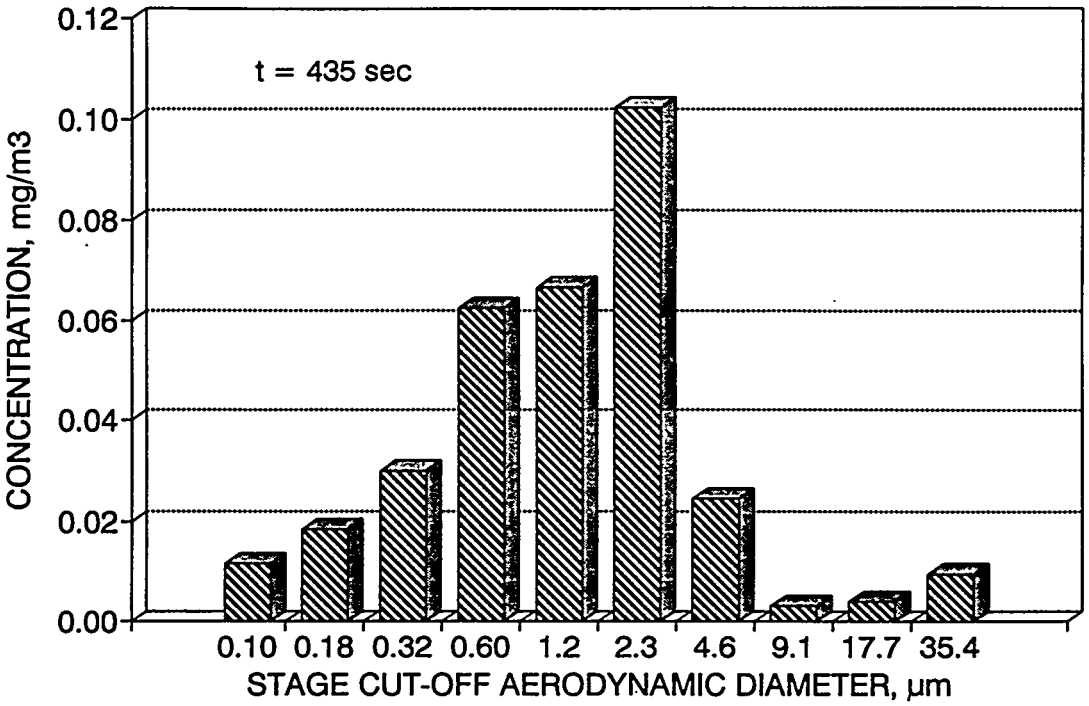
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 2-1: During EC/DRILL/SUC)



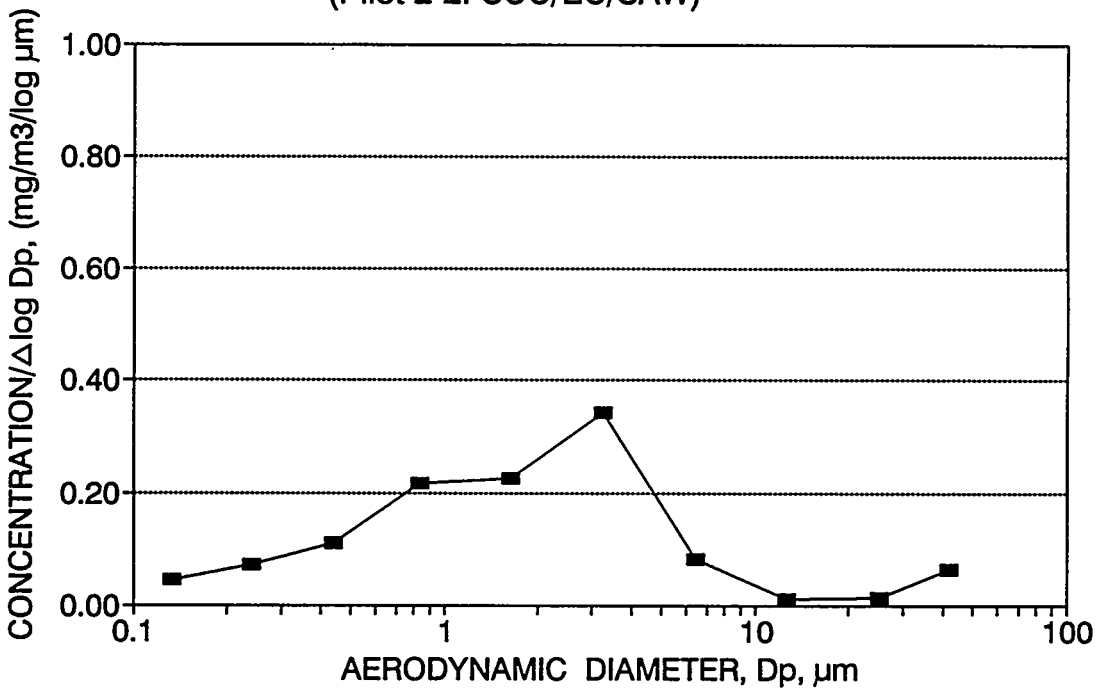
Pilot 2-2: IRR/EC/SAW (t = 435 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.01154	0.10	-1.001	0.252	0.046	0.13	0.0347	0.000
0.10	0.01837	0.18	-0.749	0.257	0.071	0.24	0.0552	0.035
0.20	0.03000	0.32	-0.492	0.272	0.110	0.44	0.0902	0.090
0.40	0.06242	0.60	-0.220	0.287	0.217	0.84	0.1877	0.180
0.80	0.06670	1.17	0.067	0.294	0.227	1.64	0.2006	0.368
1.60	0.10240	2.30	0.362	0.298	0.344	3.24	0.3079	0.568
3.20	0.02449	4.56	0.659	0.299	0.082	6.44	0.0736	0.876
6.40	0.00314	9.09	0.959	0.290	0.011	12.69	0.0094	0.950
12.50	0.00393	17.72	1.248	0.301	0.013	25.04	0.0118	0.959
25.00	0.00955	35.40	1.549	0.150	0.064	42.07	0.0287	0.971
		50.00	1.699					1.000
Sum	0.33254						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 2-2: SUC/EC/SAW)



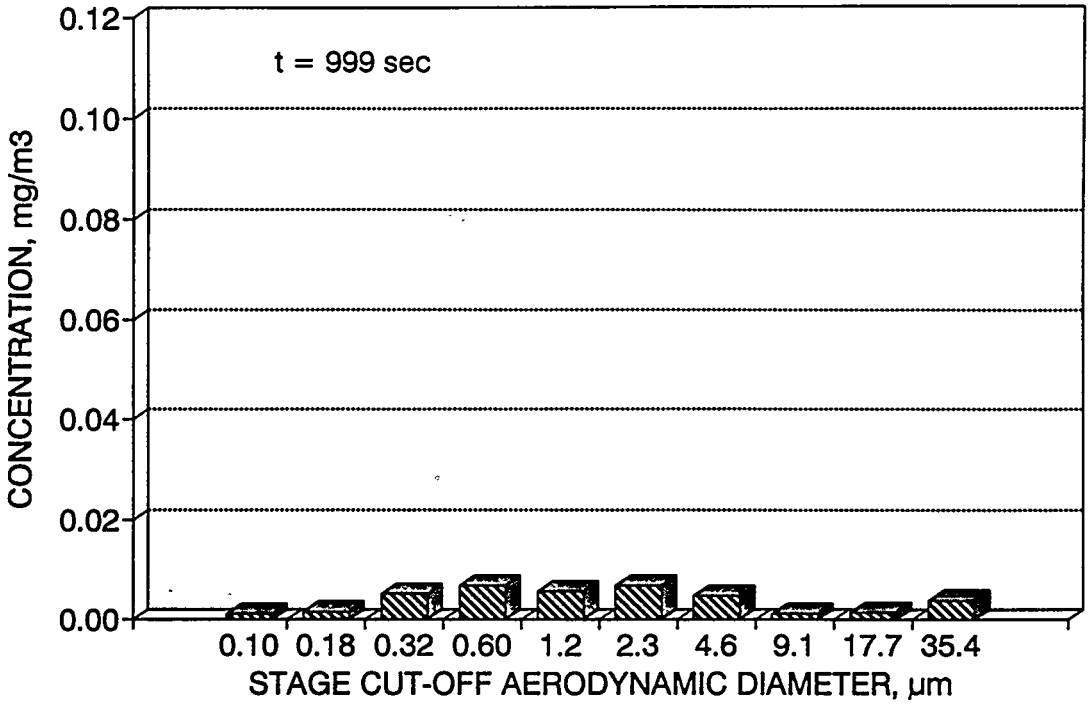
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 2-2: SUC/EC/SAW)



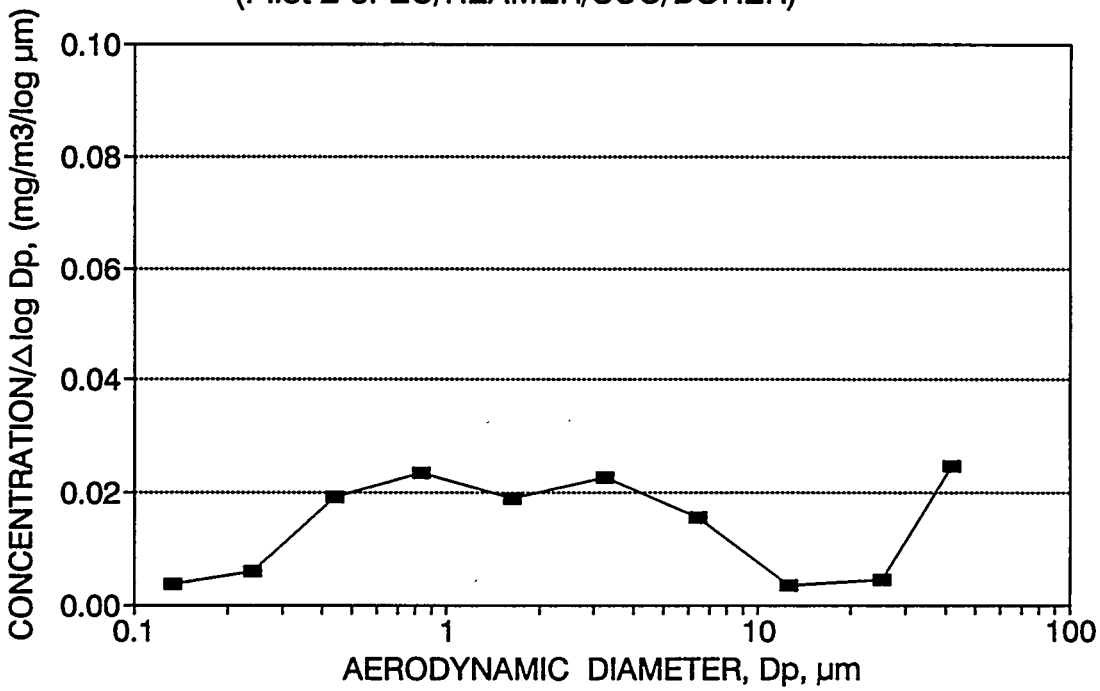
Pilot 2-3: EC/REAMER/IRR/BORER (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.00093	0.10	-1.001	0.252	0.004	0.13	0.0248	0.000
0.10	0.00155	0.18	-0.749	0.257	0.006	0.24	0.0414	0.025
0.20	0.00522	0.32	-0.492	0.272	0.019	0.44	0.1395	0.066
0.40	0.00670	0.60	-0.220	0.287	0.023	0.84	0.1790	0.206
0.80	0.00558	1.17	0.067	0.294	0.019	1.64	0.1491	0.385
1.60	0.00672	2.30	0.362	0.298	0.023	3.24	0.1795	0.534
3.20	0.00466	4.56	0.659	0.299	0.016	6.44	0.1245	0.713
6.40	0.00102	9.09	0.959	0.290	0.004	12.69	0.0273	0.838
12.50	0.00136	17.72	1.248	0.301	0.005	25.04	0.0363	0.865
25.00	0.00369	35.40	1.549	0.150	0.025	42.07	0.0986	0.901
		50.00	1.699					1.000
Sum	0.03743						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 2-3: EC/REAMER/SUC/BORER)



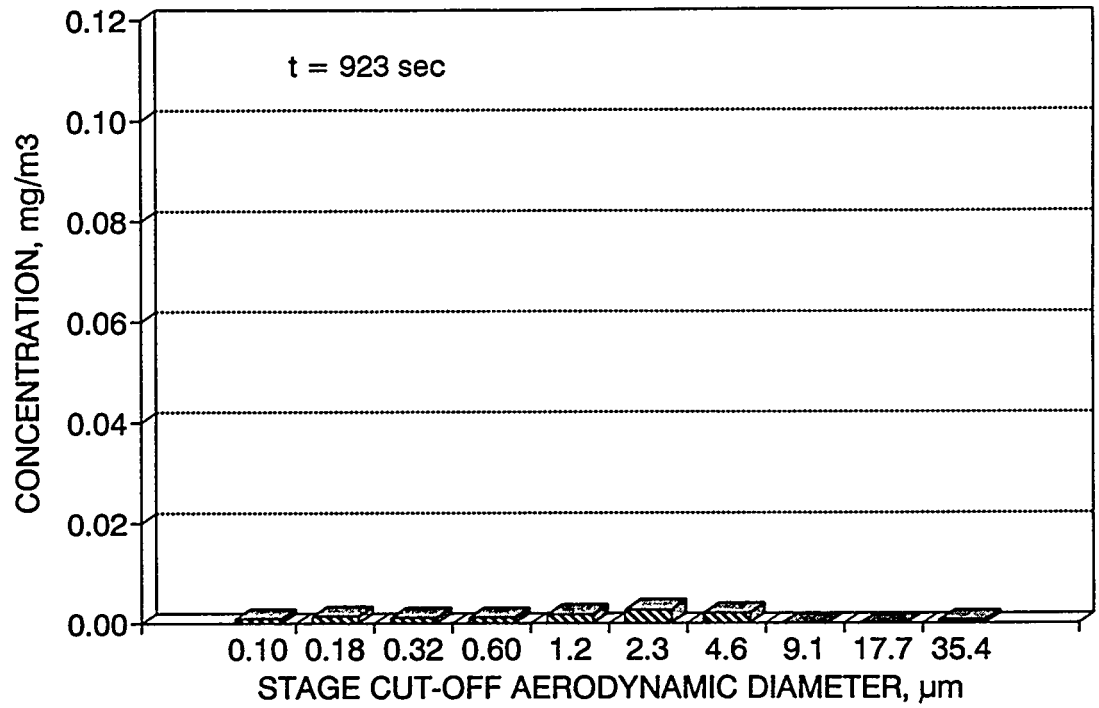
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 2-3: EC/REAMER/SUC/BORER)



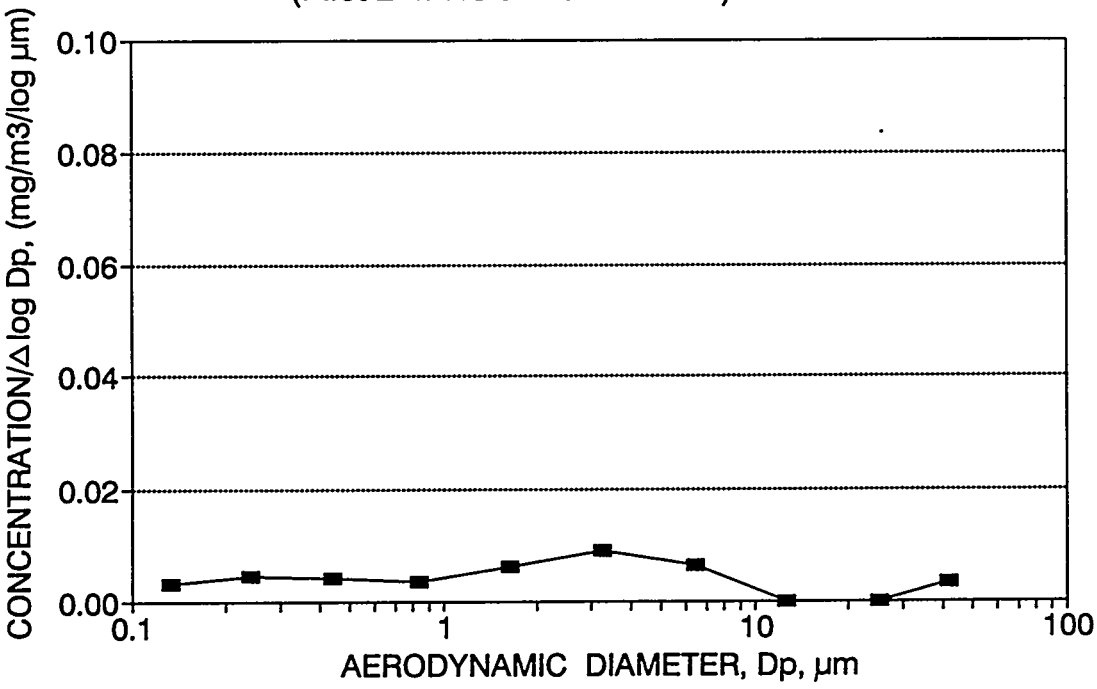
Pilot 2-4: ROOM CLEAN UP (t = 923 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.025		0.06	-1.222	0.221	0.000	0.08		
0.05	0.00080	0.10	-1.001	0.252	0.003	0.13	0.0723	0.000
0.10	0.00120	0.18	-0.749	0.257	0.005	0.24	0.1085	0.072
0.20	0.00113	0.32	-0.492	0.272	0.004	0.44	0.1022	0.181
0.40	0.00100	0.60	-0.220	0.287	0.003	0.84	0.0904	0.283
0.80	0.00181	1.17	0.067	0.294	0.006	1.64	0.1637	0.373
1.60	0.00270	2.30	0.362	0.298	0.009	3.24	0.2441	0.537
3.20	0.00192	4.56	0.659	0.299	0.006	6.44	0.1736	0.781
6.40	0.00000	9.09	0.959	0.290	0.000	12.69	0.0000	0.955
12.50	0.00000	17.72	1.248	0.301	0.000	25.04	0.0000	0.955
25.00	0.00050	35.40	1.549	0.150	0.003	42.07	0.0452	0.955
		50.00	1.699					1.000
Sum	0.01106						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 2-4: ROOM CLEAN UP)



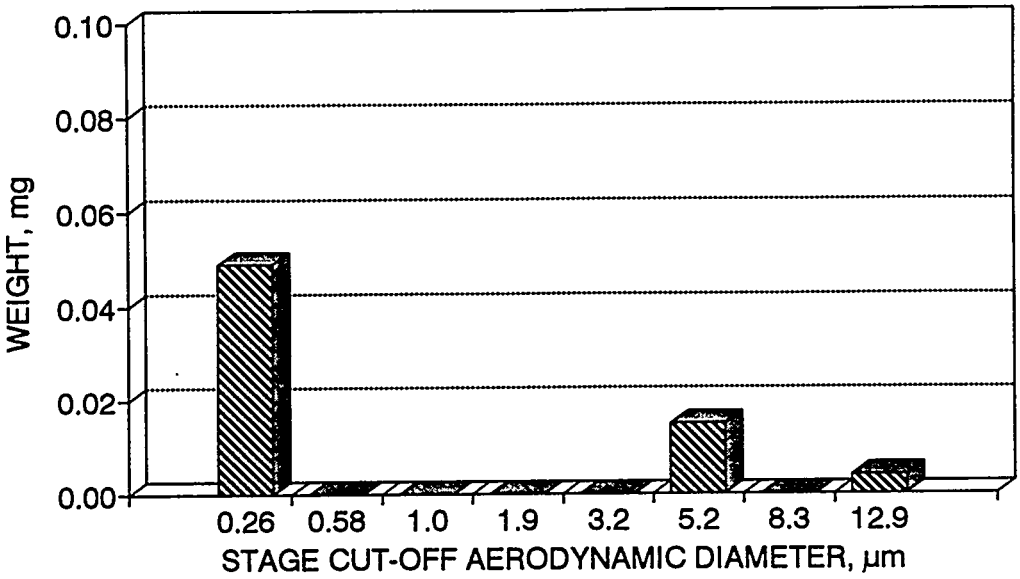
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 2-4: ROOM CLEAN UP)



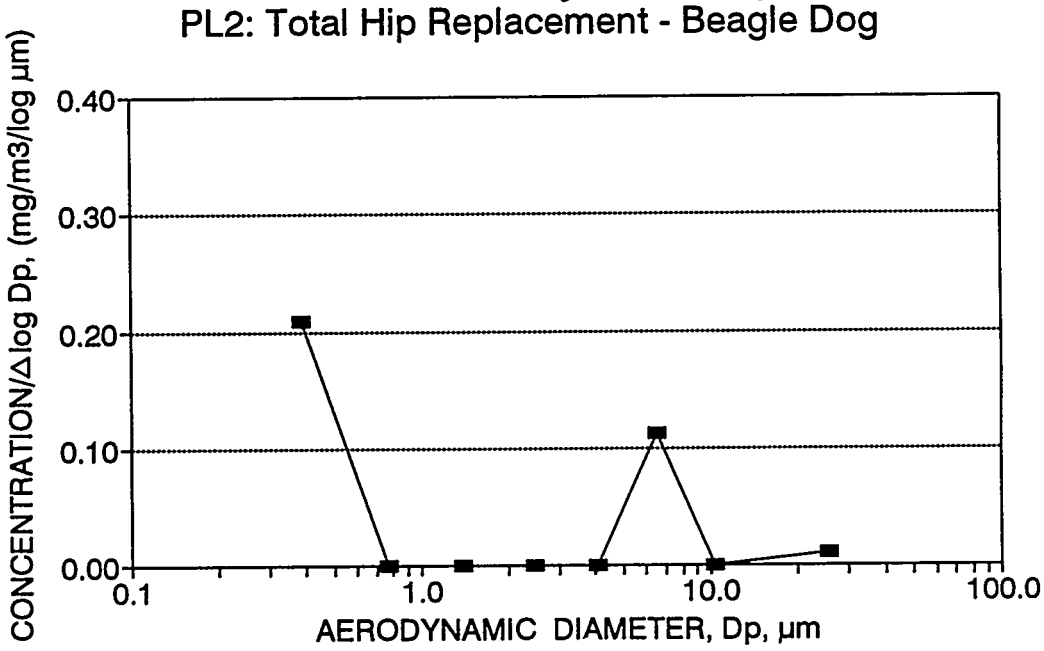
Pilot 2: LMJ Impactor Data

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.049	1	0.672	0.073	-0.585	0.348	0.209	0.39	0.721	0.000
7	0.58	0.000	1	0.672	0.000	-0.237	0.245	0.000	0.77	0.000	0.721
6	1.02	0.000	1	0.672	0.000	0.009	0.270	0.000	1.39	0.000	0.721
5	1.90	0.000	1	0.672	0.000	0.279	0.224	0.000	2.46	0.000	0.721
4	3.18	0.000	1	0.672	0.000	0.502	0.214	0.000	4.07	0.000	0.721
3	5.21	0.015	1	0.672	0.022	0.717	0.200	0.112	6.56	0.221	0.721
2	8.25	0.000	1	0.672	0.000	0.916	0.194	0.000	10.31	0.000	0.941
1	12.89	0.004	1	0.672	0.006	1.110	0.589	0.010	25.39	0.059	0.941
	50.00					1.699					
Sum		0.068			0.101					1.000	

Lovelace Multi-jet Impactor Data
PL2: Total Hip Replacement - Beagle Dog



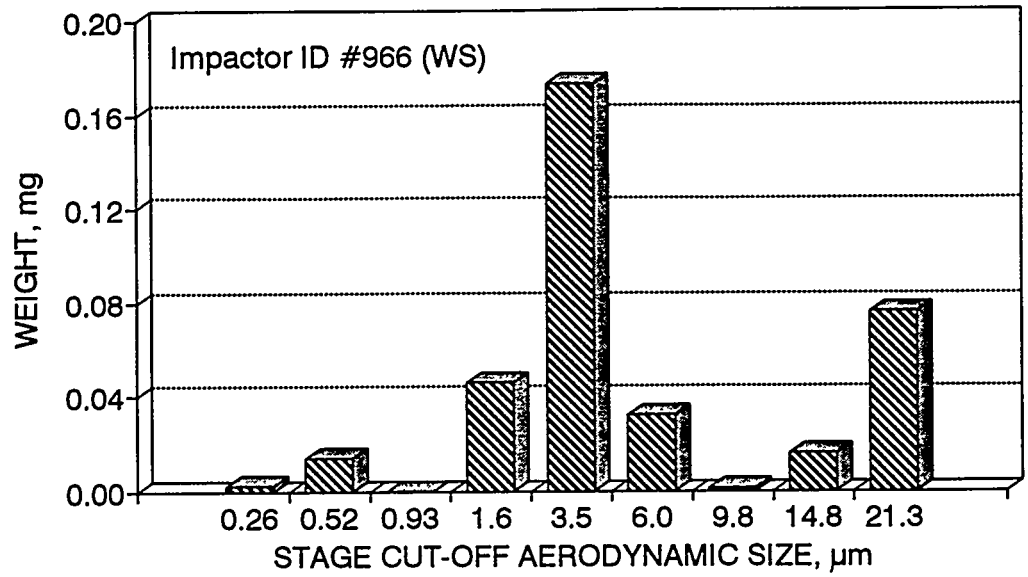
Size Distribution by LMJ Impactor
PL2: Total Hip Replacement - Beagle Dog



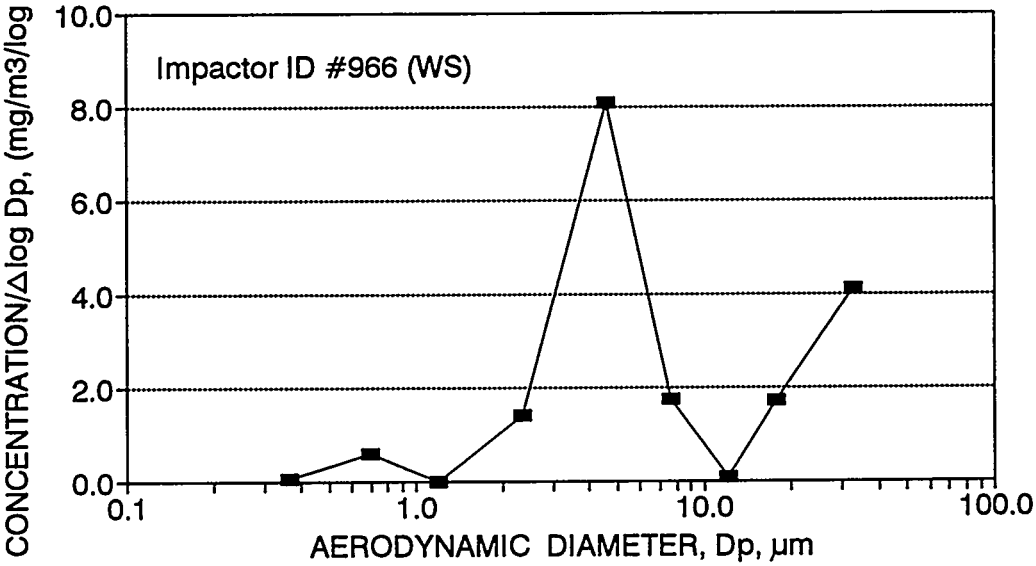
Pilot 2: Marple Personal Impactor Data (ID No. 966: WS)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.002	1	0.096	0.021	-0.585	0.301	0.069	0.37	0.004	0.000
8	0.52	0.014	0.99	0.096	0.147	-0.284	0.252	0.583	0.70	0.031	0.004
7	0.93	0.000	0.97	0.096	0.000	-0.032	0.222	0.000	1.20	0.000	0.035
6	1.55	0.046	0.96	0.096	0.499	0.190	0.354	1.411	2.33	0.105	0.035
5	3.50	0.173	0.95	0.096	1.897	0.544	0.234	8.104	4.58	0.400	0.141
4	6.00	0.032	0.89	0.096	0.375	0.778	0.213	1.758	7.67	0.079	0.540
3	9.80	0.001	0.78	0.096	0.013	0.991	0.179	0.075	12.04	0.003	0.619
2	14.80	0.016	0.61	0.096	0.273	1.170	0.158	1.728	17.75	0.058	0.622
1	21.30	0.076	0.52	0.096	1.522	1.328	0.371	4.108	32.63	0.321	0.679
	50.00					1.699					
Sum		0.360			4.748					1.000	

Marple Personal Impactor Data
PL2: Total Hip Replacement - Beagle Dog



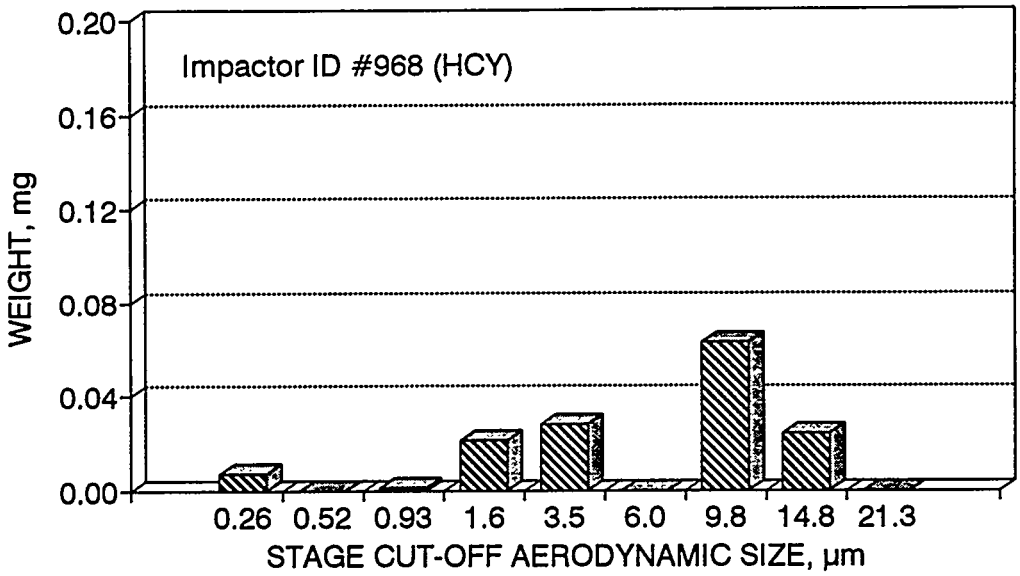
Size Distribution by Marple Impactor
PL2: Total Hip Replacement - Beagle Dog



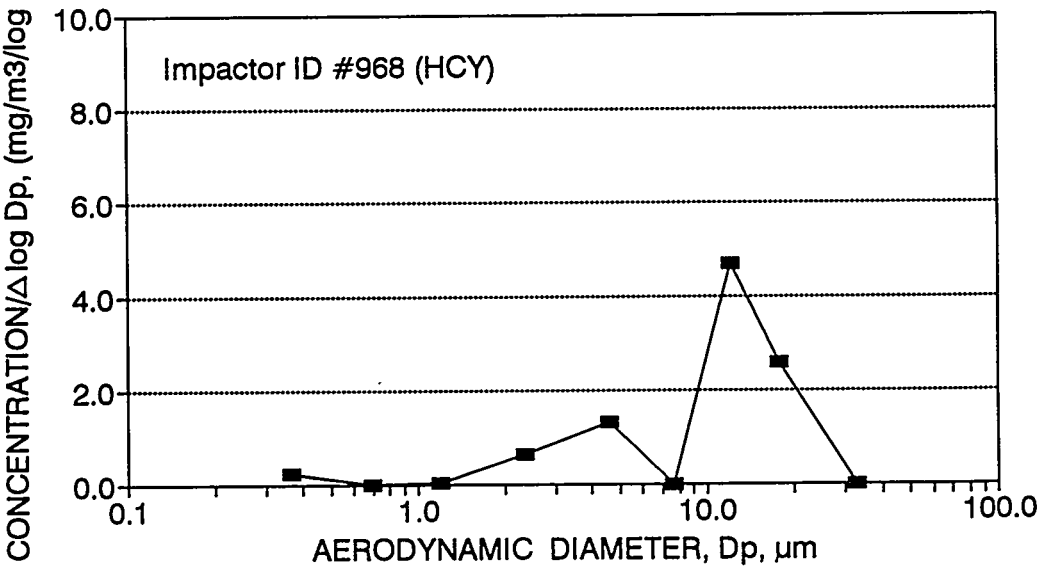
Pilot 2: Marple Personal Impactor Data (ID No. 968: HCY)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.007	1	0.096	0.073	-0.585	0.301	0.242	0.37	0.039	0.000
8	0.52	0.000	0.99	0.096	0.000	-0.284	0.252	0.000	0.70	0.000	0.039
7	0.93	0.001	0.97	0.096	0.011	-0.032	0.222	0.048	1.20	0.006	0.039
6	1.55	0.021	0.96	0.096	0.228	0.190	0.354	0.644	2.33	0.122	0.045
5	3.50	0.028	0.95	0.096	0.307	0.544	0.234	1.312	4.58	0.164	0.167
4	6.00	0.000	0.89	0.096	0.000	0.778	0.213	0.000	7.67	0.000	0.331
3	9.80	0.063	0.78	0.096	0.841	0.991	0.179	4.699	12.04	0.450	0.331
2	14.80	0.024	0.61	0.096	0.410	1.170	0.158	2.592	17.75	0.219	0.781
1	21.30	0.000	0.52	0.096	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		0.144			1.870					1.000	

Marple Personal Impactor Data
PL2: Total Hip Replacement - Beagle Dog



Size Distribution by Marple Impactor
PL2: Total Hip Replacement - Beagle Dog



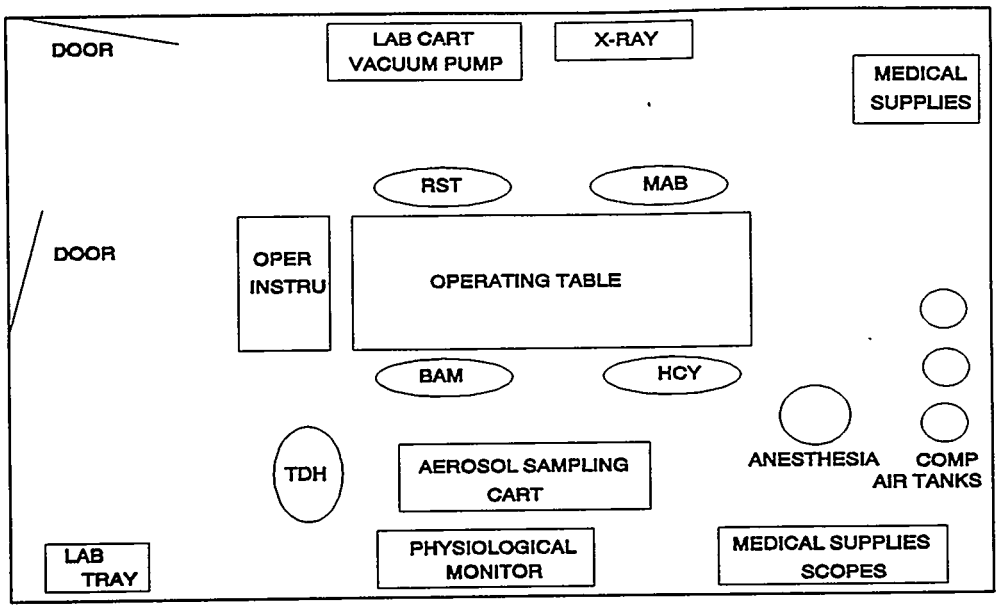
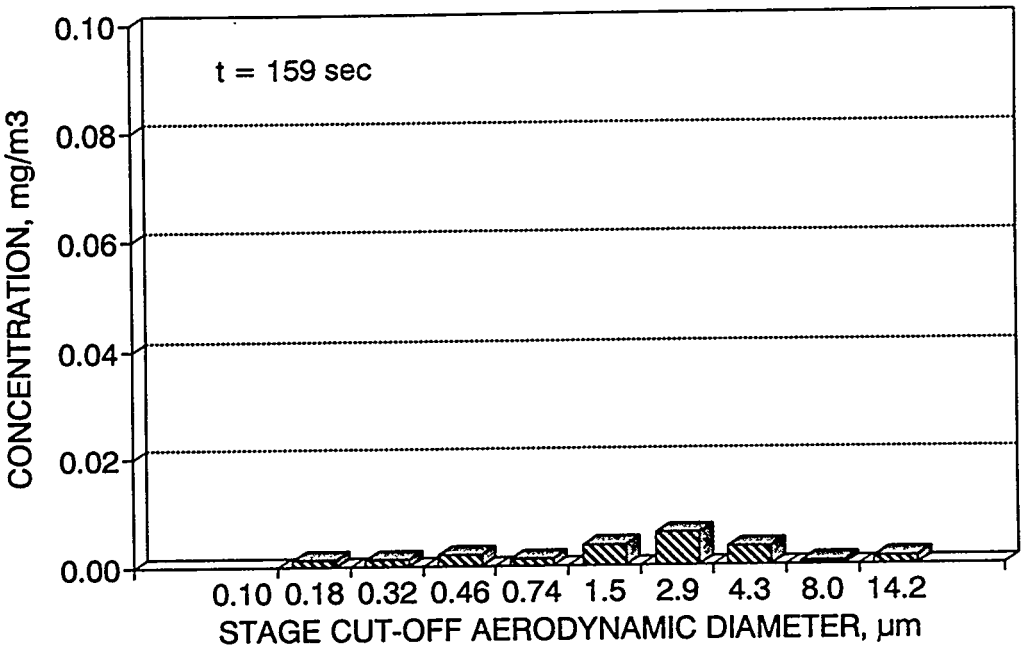


Figure B.3 Personnel locations during Pilot #3 experiment

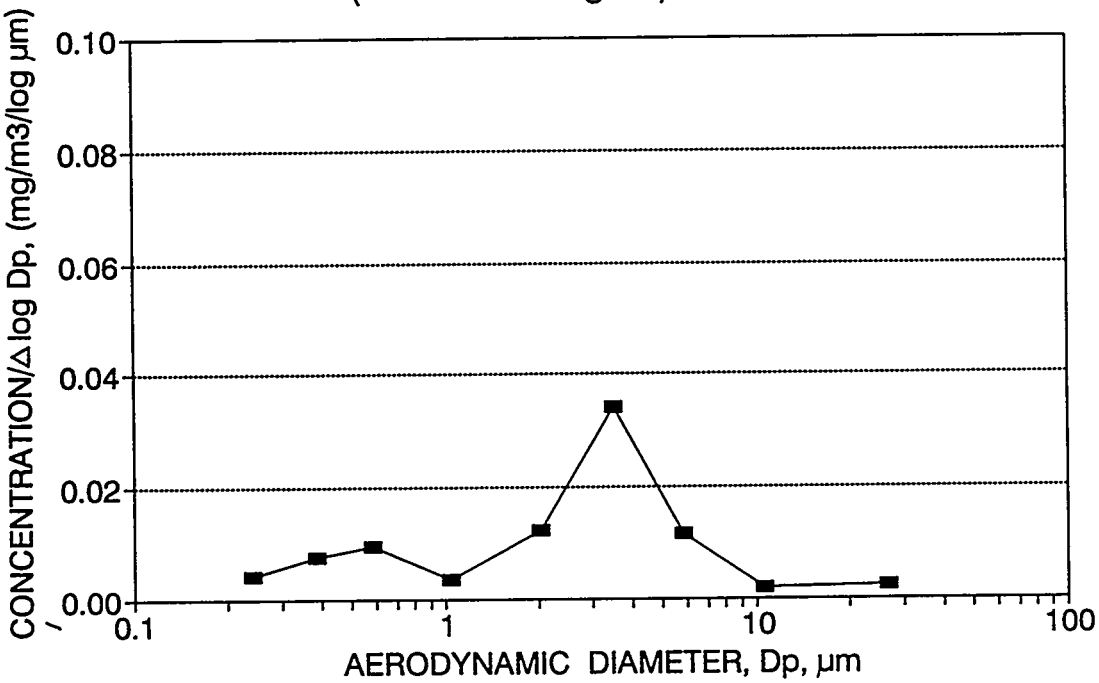
Pilot 3-1: During EC (first 159 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00108	0.18	-0.749	0.257	0.004	0.24	0.0545	0.000
0.20	0.00120	0.32	-0.492	0.157	0.008	0.39	0.0606	0.055
0.30	0.00193	0.46	-0.335	0.206	0.009	0.59	0.0974	0.115
0.50	0.00105	0.74	-0.128	0.290	0.004	1.04	0.0530	0.213
1.00	0.00361	1.45	0.162	0.296	0.012	2.04	0.1822	0.266
2.00	0.00597	2.87	0.457	0.174	0.034	3.50	0.3014	0.448
3.00	0.00315	4.28	0.632	0.269	0.012	5.84	0.1590	0.749
5.60	0.00050	7.96	0.901	0.251	0.002	10.62	0.0252	0.908
10.00	0.00132	14.18	1.152	0.547	0.002	26.63	0.0666	0.933
		50.00	1.699					1.000
Sum	0.01981						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 3-1: During EC)



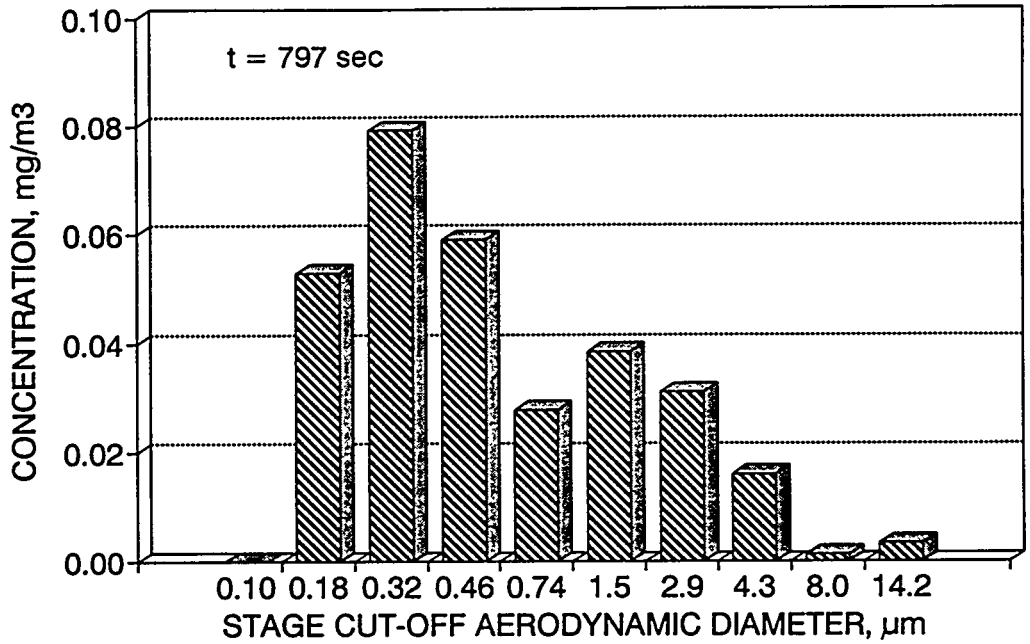
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 3-1: During EC)



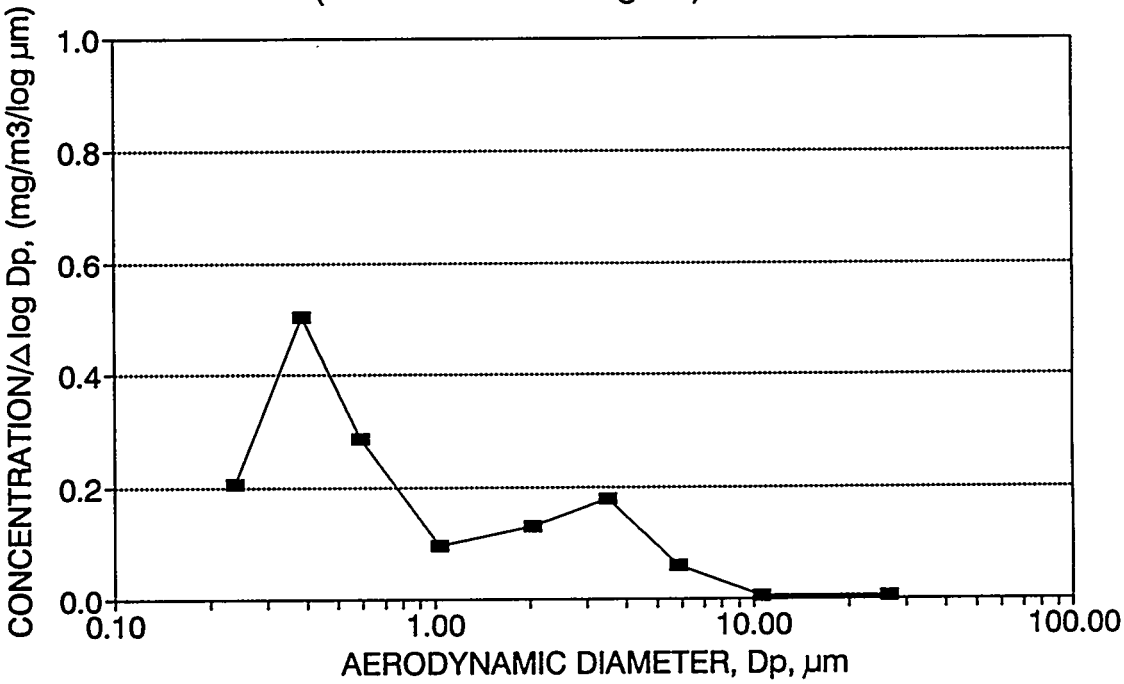
Pilot 3-2: During EC (t = 797 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05	0.00000	0.10				0.13		
0.10	0.05299	0.18	-0.749	0.257	0.206	0.24	0.1715	0.000
0.20	0.07923	0.32	-0.492	0.157	0.504	0.39	0.2565	0.172
0.30	0.05904	0.46	-0.335	0.206	0.286	0.59	0.1911	0.428
0.50	0.02769	0.74	-0.128	0.290	0.095	1.04	0.0896	0.619
1.00	0.03857	1.45	0.162	0.296	0.130	2.04	0.1249	0.709
2.00	0.03122	2.87	0.457	0.174	0.179	3.50	0.1011	0.834
3.00	0.01596	4.28	0.632	0.269	0.059	5.84	0.0517	0.935
5.60	0.00105	7.96	0.901	0.251	0.004	10.62	0.0034	0.986
10.00	0.00316	14.18	1.152	0.547	0.006	26.63	0.0102	0.990
		50.00	1.699					1.000
Sum	0.30891						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot Run 3-2: During EC-2)



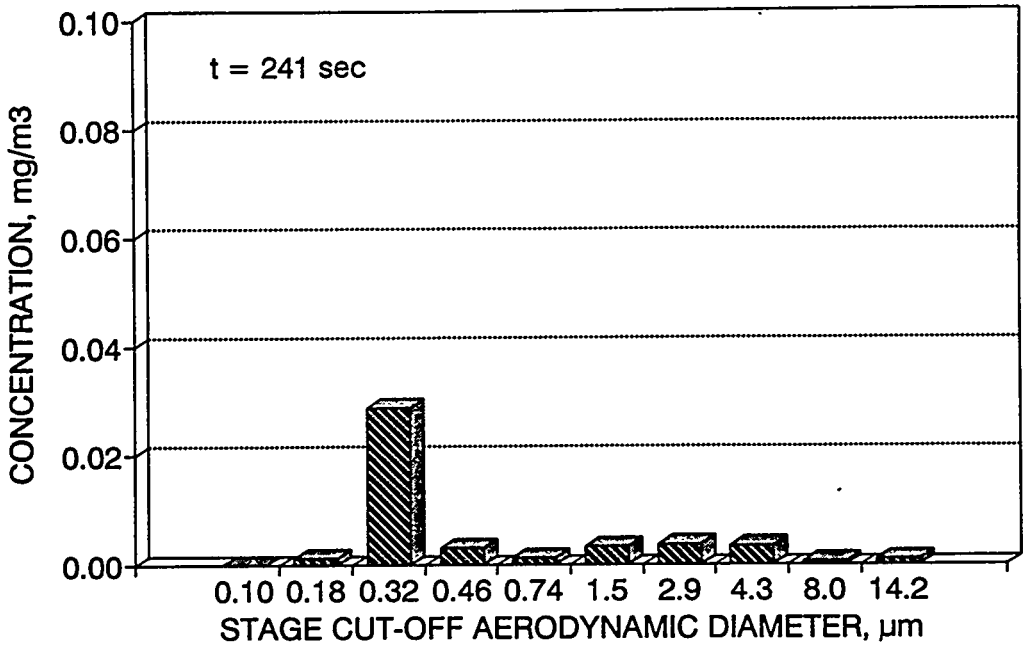
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot Run 3-2: During EC)



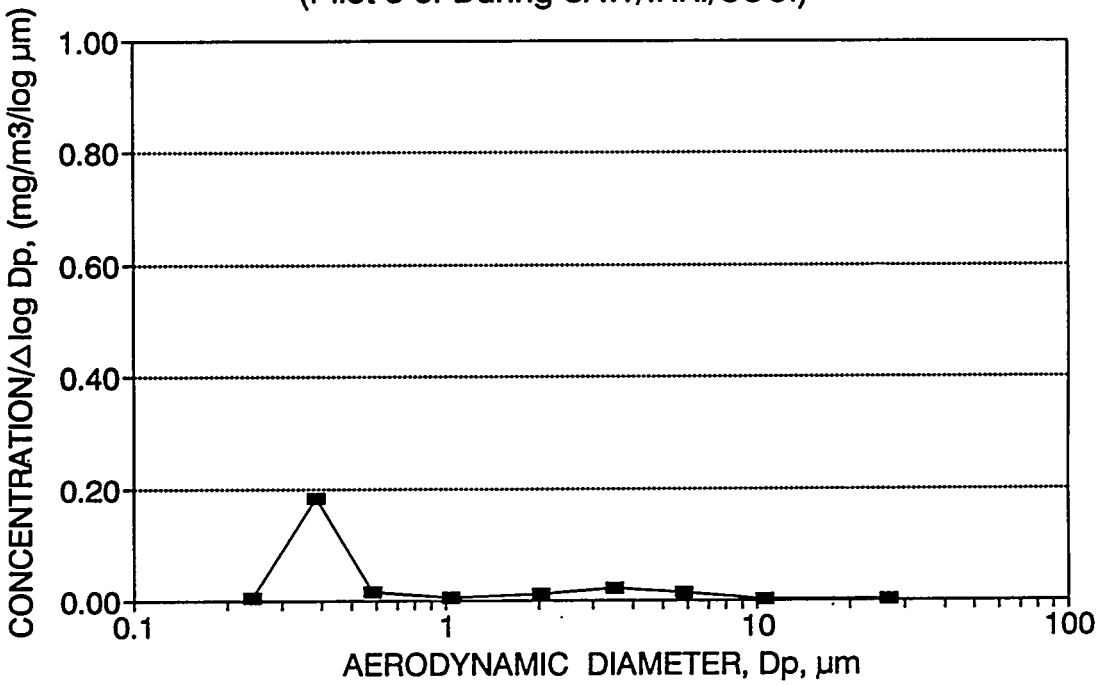
Pilot 3-3: During SAW/IRR (T = 241 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05	0.00000	0.10				0.13		
0.10	0.00119	0.18	-0.749	0.257	0.005	0.24	0.0258	0.000
0.20	0.02891	0.32	-0.492	0.157	0.184	0.39	0.6258	0.026
0.30	0.00302	0.46	-0.335	0.206	0.015	0.59	0.0654	0.652
0.50	0.00118	0.74	-0.128	0.290	0.004	1.04	0.0255	0.717
1.00	0.00317	1.45	0.162	0.296	0.011	2.04	0.0686	0.742
2.00	0.00369	2.87	0.457	0.174	0.021	3.50	0.0799	0.811
3.00	0.00350	4.28	0.632	0.269	0.013	5.84	0.0758	0.891
5.60	0.00050	7.96	0.901	0.251	0.002	10.62	0.0108	0.967
10.00	0.00104	14.18	1.152	0.547	0.002	26.63	0.0225	0.977
		50.00	1.699					1.000
Sum	0.0462						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 3-3: During SAW/IRR./SUC.)



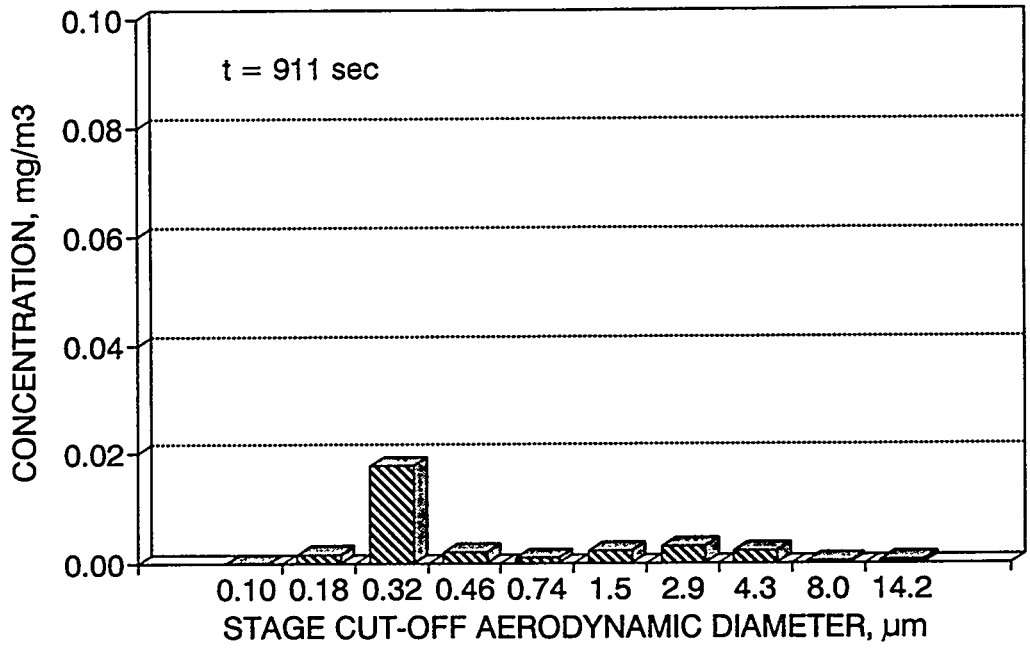
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 3-3: During SAW/IRR./SUC.)



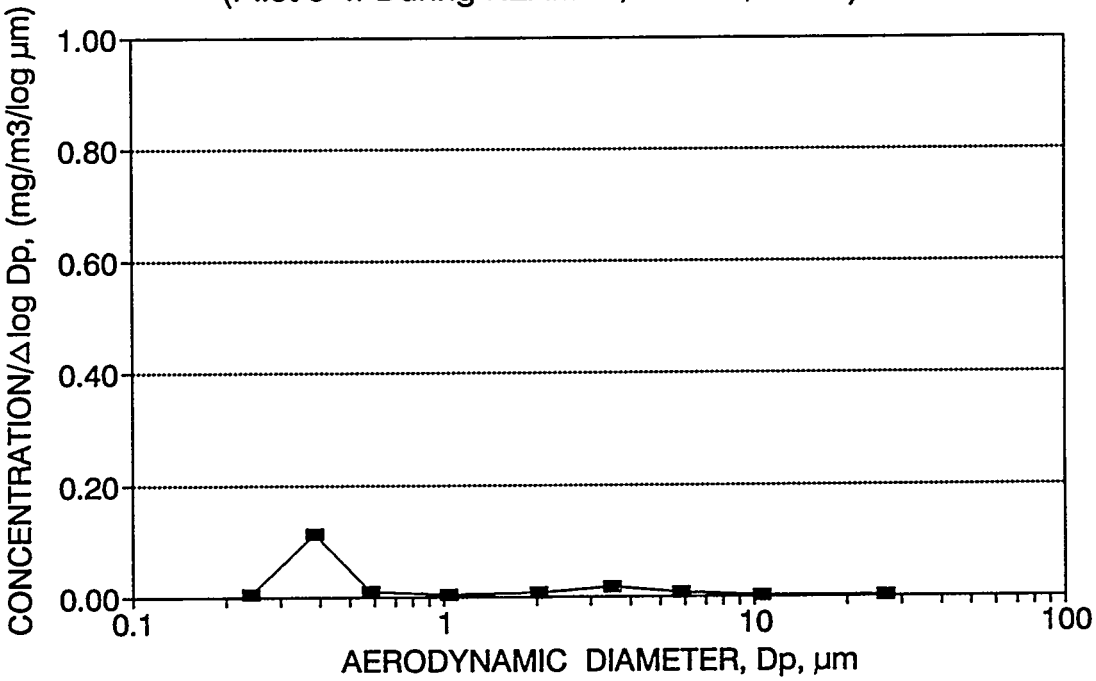
Pilot 3-4: During REAMER/BORER/DRILL (t = 911 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05	0.00000	0.10				0.13		
0.10	0.00149	0.18	-0.749	0.257	0.006	0.24	0.0493	0.000
0.20	0.0178	0.32	-0.492	0.157	0.113	0.39	0.5884	0.049
0.30	0.00193	0.46	-0.335	0.206	0.009	0.59	0.0638	0.638
0.50	0.00094	0.74	-0.128	0.290	0.003	1.04	0.0311	0.701
1.00	0.00219	1.45	0.162	0.296	0.007	2.04	0.0724	0.733
2.00	0.00295	2.87	0.457	0.174	0.017	3.50	0.0975	0.805
3.00	0.00214	4.28	0.632	0.269	0.008	5.84	0.0707	0.902
5.60	0.00022	7.96	0.901	0.251	0.001	10.62	0.0073	0.973
10.00	0.00059	14.18	1.152	0.547	0.001	26.63	0.0195	0.980
		50.00	1.699					1.000
Sum	0.03025						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 3-4: During REAMER/BORER/DRILL)



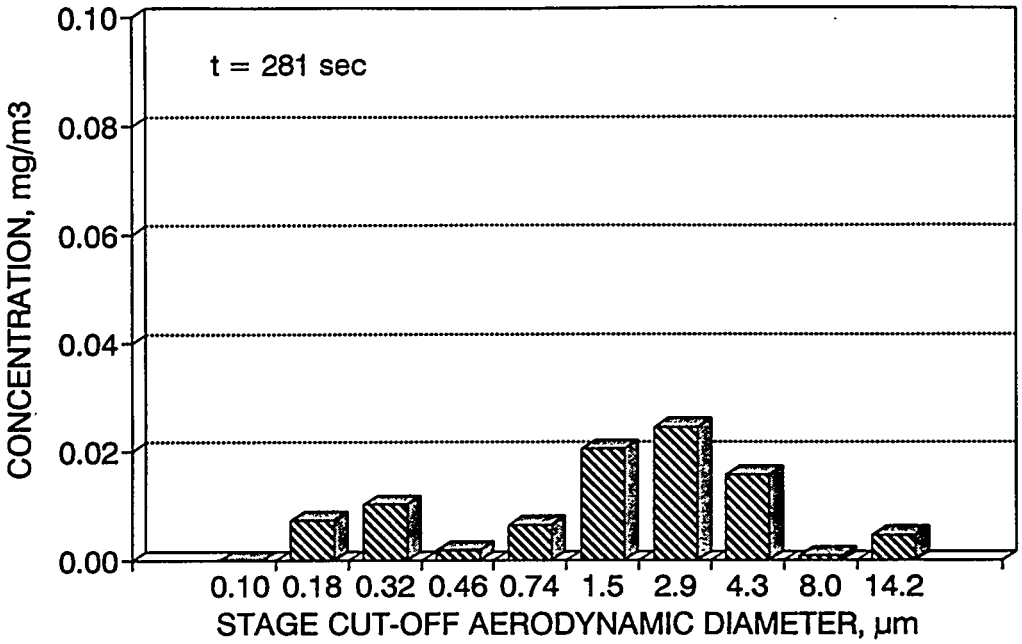
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 3-4: During REAMER/BORER/DRILL)



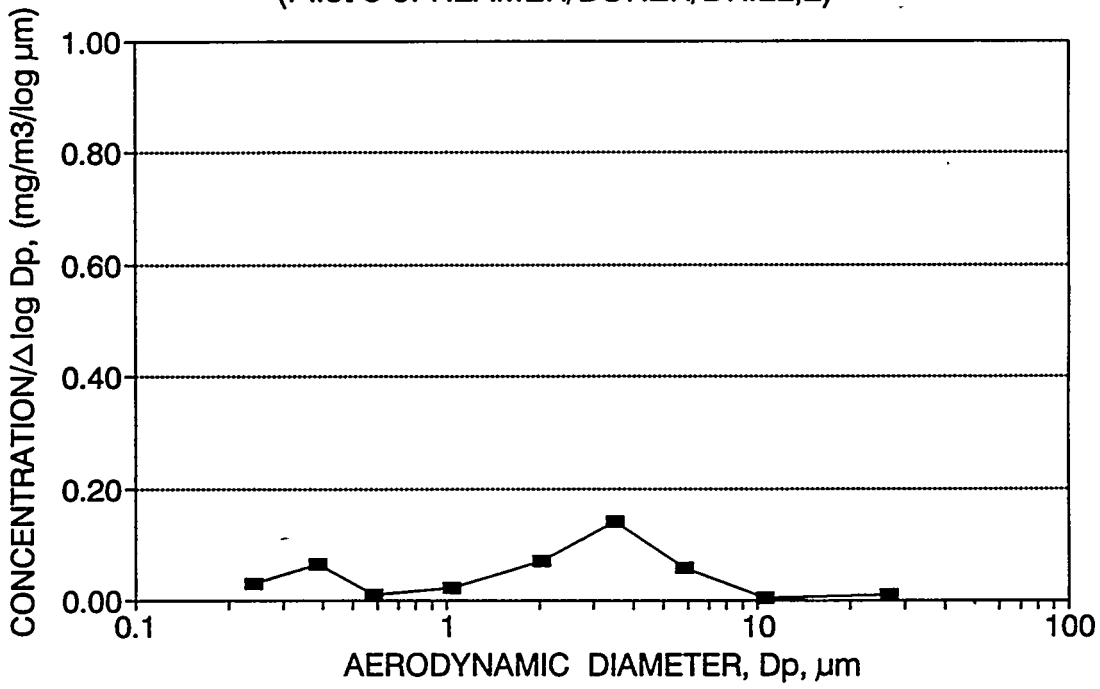
Pilot 3-5: REAMER/BORER/DRILL (t = 281 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05	0.00000	0.10				0.13		
0.10	0.00731	0.18	-0.749	0.257	0.028	0.24	0.0798	0.000
0.20	0.01018	0.32	-0.492	0.157	0.065	0.39	0.1111	0.080
0.30	0.00184	0.46	-0.335	0.206	0.009	0.59	0.0201	0.191
0.50	0.00645	0.74	-0.128	0.290	0.022	1.04	0.0704	0.211
1.00	0.02049	1.45	0.162	0.296	0.069	2.04	0.2237	0.281
2.00	0.02445	2.87	0.457	0.174	0.140	3.50	0.2669	0.505
3.00	0.01559	4.28	0.632	0.269	0.058	5.84	0.1702	0.772
5.60	0.00082	7.96	0.901	0.251	0.003	10.62	0.0090	0.942
10.00	0.00448	14.18	1.152	0.547	0.008	26.63	0.0489	0.951
		50.00	1.699					1.000
Sum	0.09161						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 3-5: REAMER/BORER/DRILL;2)



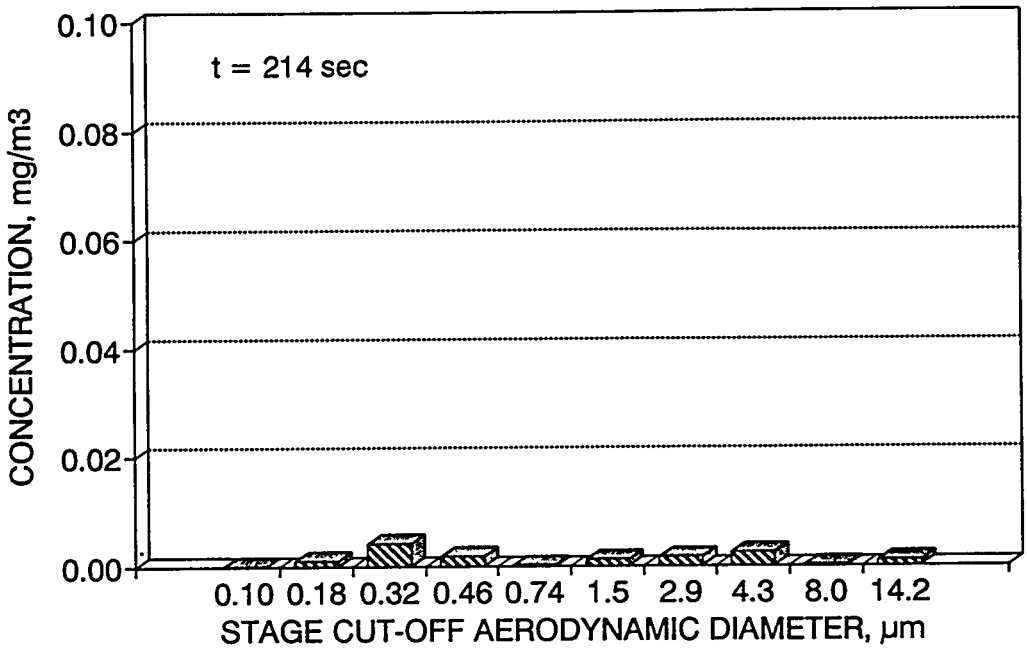
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 3-5: REAMER/BORER/DRILL;2)



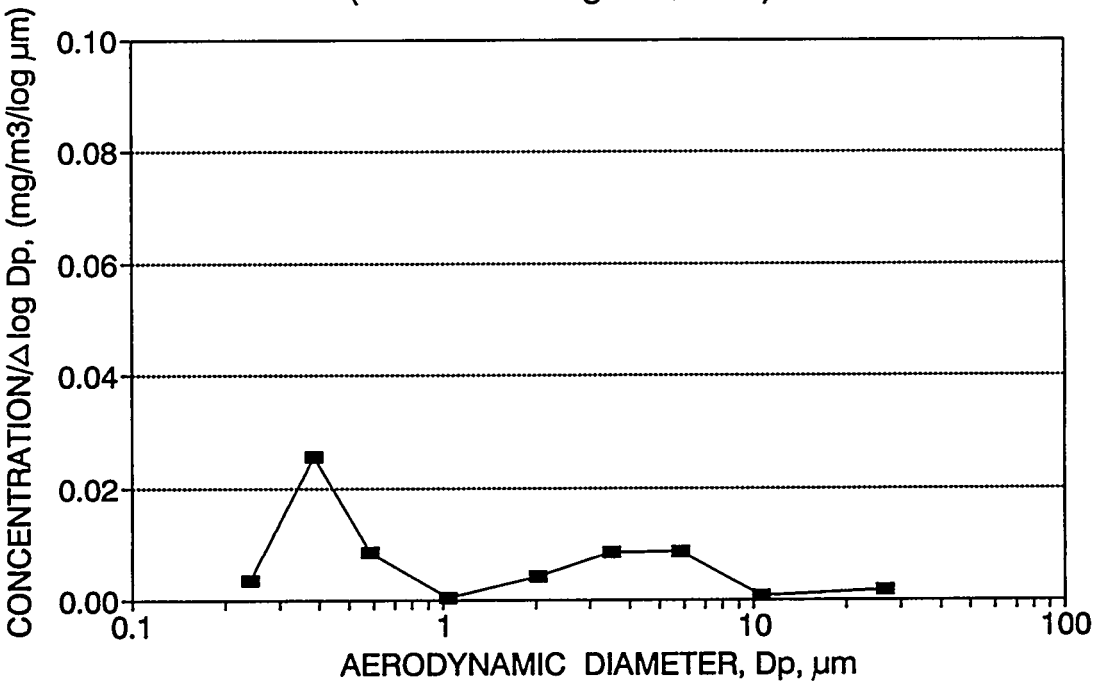
Pilot 3-6: During IRR (t = 214 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05	0.00000	0.10				0.13		
0.10	0.00089	0.18	-0.749	0.257	0.003	0.24	0.0689	0.000
0.20	0.00403	0.32	-0.492	0.157	0.026	0.39	0.3119	0.069
0.30	0.00174	0.46	-0.335	0.206	0.008	0.59	0.1347	0.381
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.0054	0.515
1.00	0.00121	1.45	0.162	0.296	0.004	2.04	0.0937	0.521
2.00	0.00148	2.87	0.457	0.174	0.008	3.50	0.1146	0.615
3.00	0.00234	4.28	0.632	0.269	0.009	5.84	0.1811	0.729
5.60	0.00018	7.96	0.901	0.251	0.001	10.62	0.0139	0.910
10.00	0.00098	14.18	1.152	0.547	0.002	26.63	0.0759	0.924
		50.00	1.699					1.000
Sum	0.01292						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(Pilot 3-6: During IRR./SUC.)



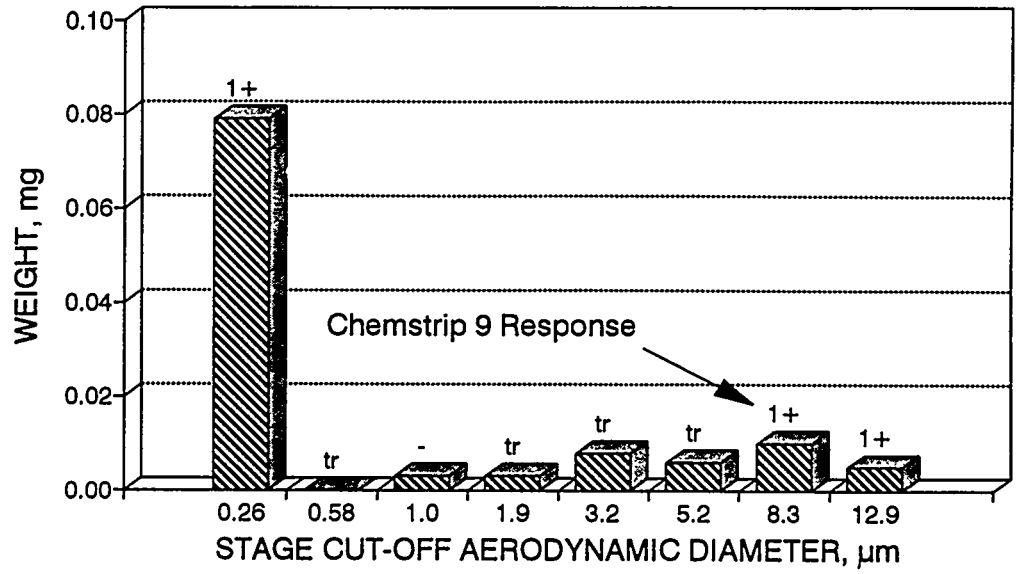
SIZE DISTRIBUTION AS DETERMINED BY QCM
(Pilot 3-6: During IRR./SUC.)



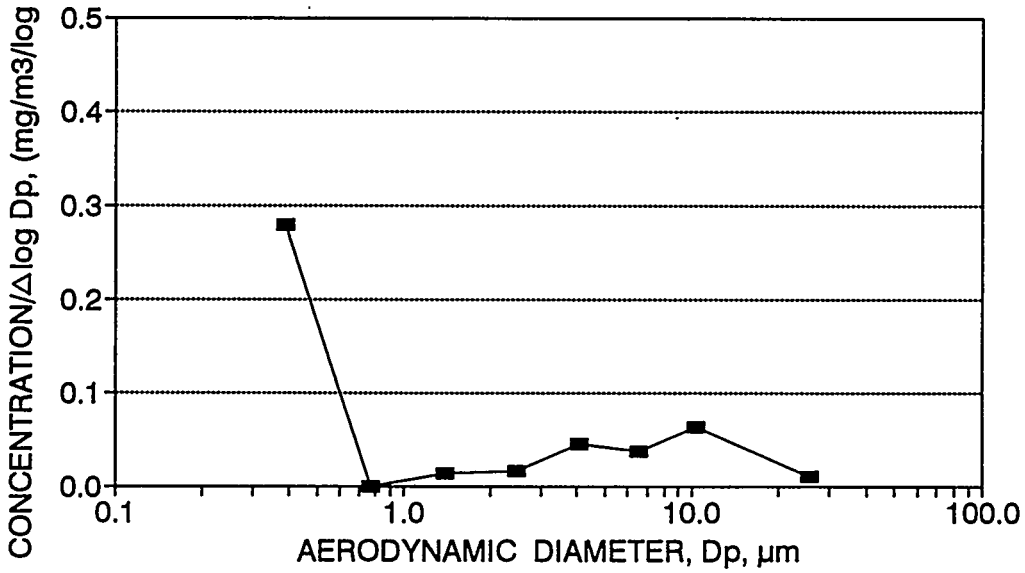
Pilot 3: LMJ Impactor Data

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.079	1	0.812	0.097	-0.585	0.348	0.279	0.39	0.693	0.000	1+
7	0.58	0.000	1	0.812	0.000	-0.237	0.245	0.000	0.77	0.000	0.693	tr
6	1.0	0.003	1	0.812	0.004	0.009	0.270	0.014	1.39	0.026	0.693	-
5	1.9	0.003	1	0.812	0.004	0.279	0.224	0.017	2.46	0.026	0.719	tr
4	3.2	0.008	1	0.812	0.010	0.502	0.214	0.046	4.07	0.070	0.746	tr
3	5.2	0.006	1	0.812	0.007	0.717	0.200	0.037	6.56	0.053	0.816	tr
2	8.3	0.010	1	0.812	0.012	0.916	0.194	0.064	10.31	0.088	0.868	1+
1	12.9	0.005	1	0.812	0.006	1.110	0.589	0.010	25.39	0.044	0.956	1+
	50.0					1.699						
Sum		0.114			0.140					1.000		

Lovelace Multi-jet Impactor Data
PL3: Total Hip Replacement - Beagle Dog



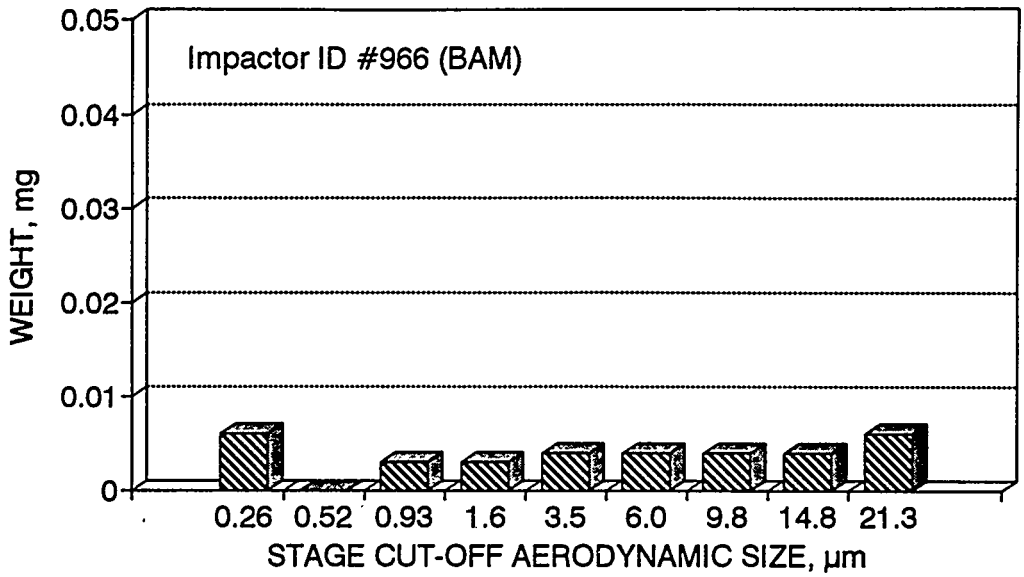
Size Distribution by LMJ Impactor
PL3: Total Hip Replacement - Beagle Dog



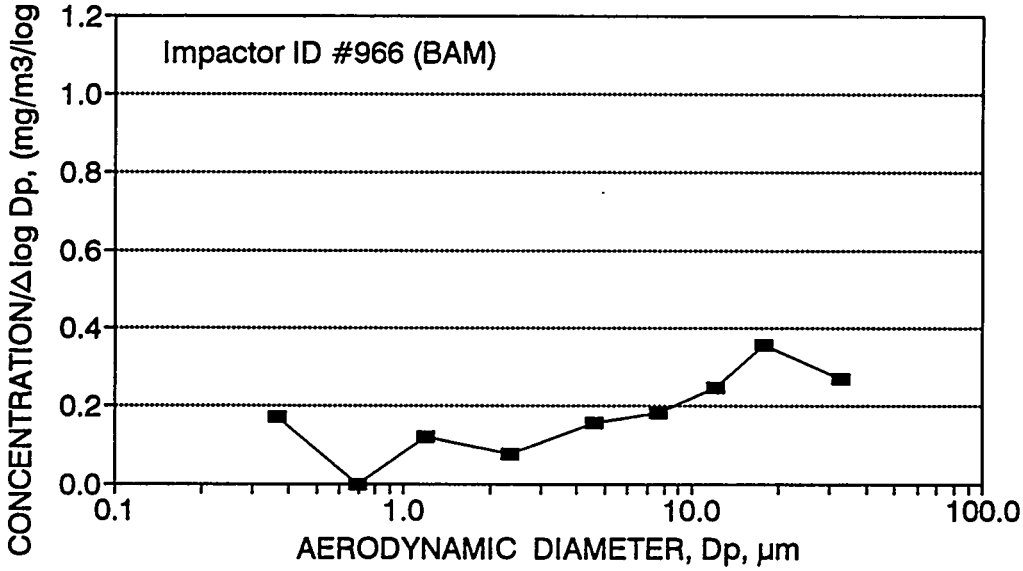
Pilot 3: Marple Personal Impactor Data (ID No. 966: BAM)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.006	1	0.116	0.052	-0.585	0.301	0.172	0.37	0.136	0.000
8	0.52	0.000	0.99	0.116	0.000	-0.284	0.252	0.000	0.70	0.000	0.136
7	0.93	0.003	0.97	0.116	0.027	-0.032	0.222	0.120	1.20	0.070	0.136
6	1.55	0.003	0.96	0.116	0.027	0.190	0.354	0.076	2.33	0.071	0.206
5	3.50	0.004	0.95	0.116	0.036	0.544	0.234	0.155	4.58	0.095	0.277
4	6.00	0.004	0.89	0.116	0.039	0.778	0.213	0.182	7.67	0.102	0.372
3	9.80	0.004	0.78	0.116	0.044	0.991	0.179	0.247	12.04	0.116	0.474
2	14.80	0.004	0.61	0.116	0.057	1.170	0.158	0.358	17.75	0.149	0.590
1	21.30	0.006	0.52	0.116	0.099	1.328	0.371	0.268	32.63	0.261	0.739
	50.00					1.699					
Sum		0.034			0.381					1.000	

Marple Personal Impactor Data
PL3: Total Hip Replacement - Beagle Dog



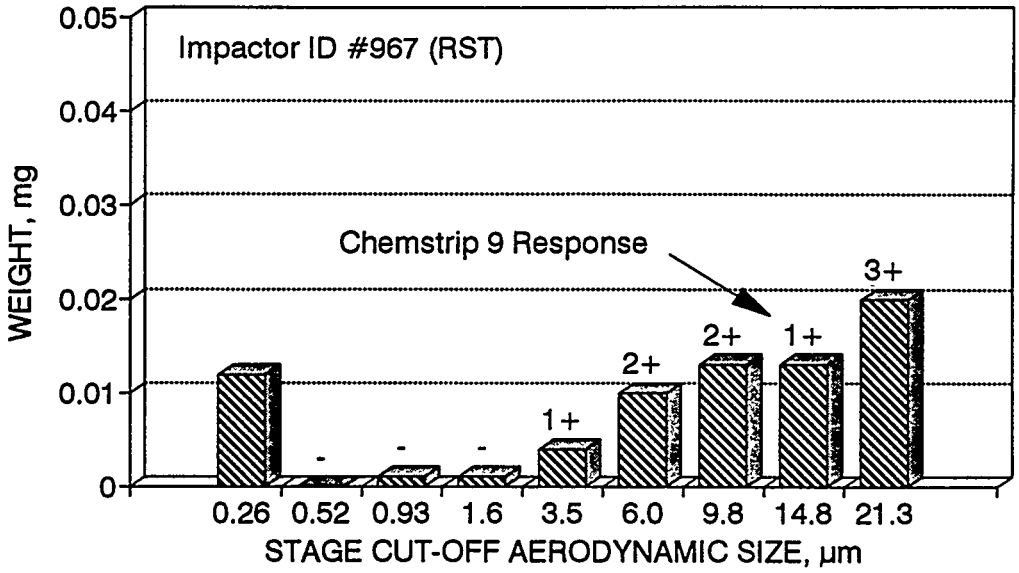
Size Distribution by Marple Impactor
PL3 Total Hip Replacement - Beagle Dog



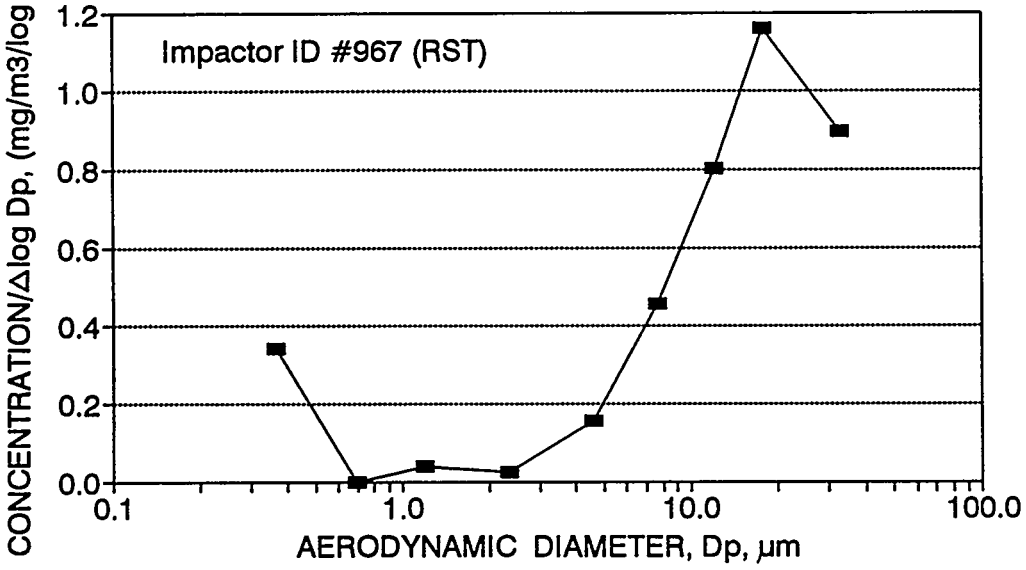
Pilot 3: Marple Personal Impactor Data (ID No. 967: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.012	1	0.116	0.103	-0.585	0.301	0.344	0.37	0.113	0.000	-
8	0.52	0.000	0.99	0.116	0.000	-0.284	0.252	0.000	0.70	0.000	0.113	-
7	0.93	0.001	0.97	0.116	0.009	-0.032	0.222	0.040	1.20	0.010	0.113	-
6	1.6	0.001	0.96	0.116	0.009	0.190	0.354	0.025	2.33	0.010	0.123	-
5	3.5	0.004	0.95	0.116	0.036	0.544	0.234	0.155	4.58	0.040	0.133	1+
4	6.0	0.010	0.89	0.116	0.097	0.778	0.213	0.455	7.67	0.106	0.173	2+
3	9.8	0.013	0.78	0.116	0.144	0.991	0.179	0.803	12.04	0.157	0.279	2+
2	14.8	0.013	0.61	0.116	0.184	1.170	0.158	1.162	17.75	0.201	0.436	1+
1	21.3	0.020	0.52	0.116	0.332	1.328	0.371	0.895	32.63	0.363	0.637	3+
	50.0					1.699						
sum		0.074			0.913					1.000		

Marple Personal Impactor Data
PL3: Total Hip Replacement - Beagle Dog



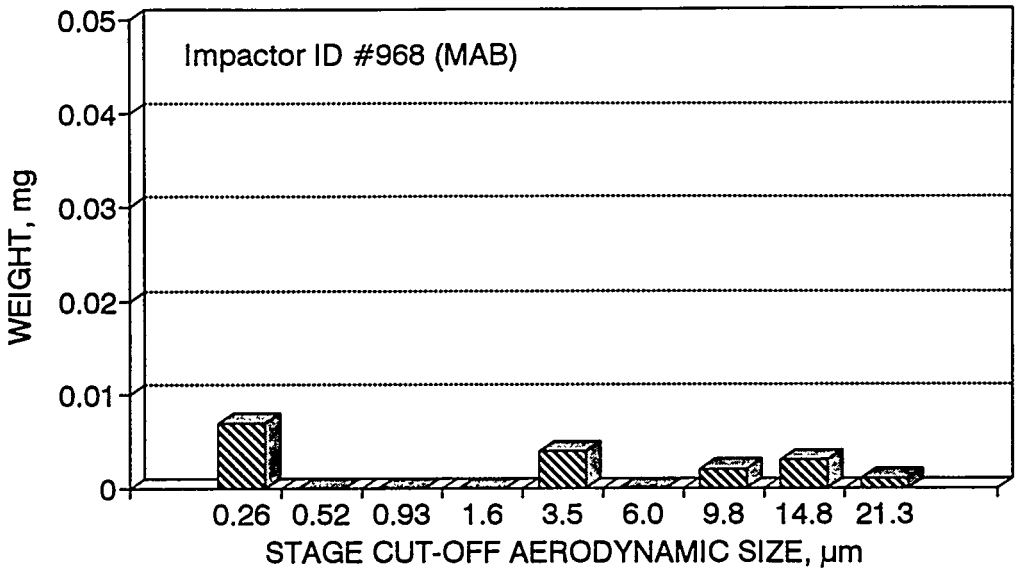
Size Distribution by Marple Impactor
Total Hip Replacement - Beagle Dog



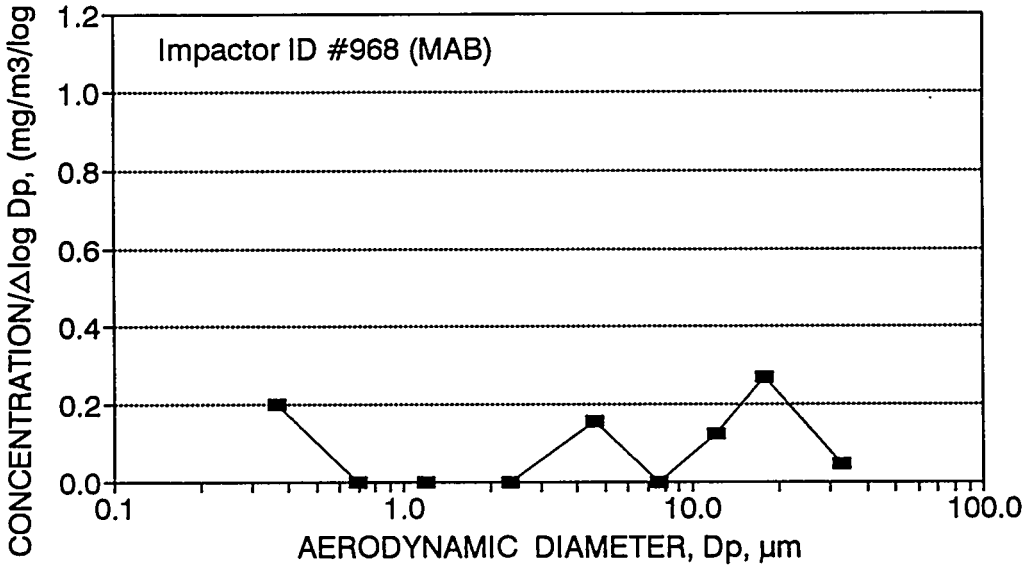
Pilot 3: Marple Personal Impactor Data (ID No. 968: MAB)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.007	1	0.116	0.060	-0.585	0.301	0.200	0.37	0.340	0.000
8	0.52	0.000	0.99	0.116	0.000	-0.284	0.252	0.000	0.70	0.000	0.340
7	0.93	0.000	0.97	0.116	0.000	-0.032	0.222	0.000	1.20	0.000	0.340
6	1.55	0.000	0.96	0.116	0.000	0.190	0.354	0.000	2.33	0.000	0.340
5	3.50	0.004	0.95	0.116	0.036	0.544	0.234	0.155	4.58	0.204	0.340
4	6.00	0.000	0.89	0.116	0.000	0.778	0.213	0.000	7.67	0.000	0.544
3	9.80	0.002	0.78	0.116	0.022	0.991	0.179	0.123	12.04	0.124	0.544
2	14.80	0.003	0.61	0.116	0.042	1.170	0.158	0.268	17.75	0.239	0.668
1	21.30	0.001	0.52	0.116	0.017	1.328	0.371	0.045	32.63	0.093	0.907
	50.00					1.699					
Sum		0.017			0.178					1.000	

Marple Personal Impactor Data
PL3: Total Hip Replacement - Beagle Dog



Size Distribution by Marple Impactor
Total Hip Replacement - Beagle Dog



APPENDIX C

DATA ON

Characterization of Aerosols

Produced by

Orthopedic Surgical Procedures in Hospital

Abbreviation or Acronyms

A, B, C, ...	column in the table
B Chip	bone chips
Bak	background
(B)/(E), etc.	column (B) divided by column (E) in the table
C	mass concentration, mg/m^3
C.f.	correction factor for sampling efficiency and internal loss
CAS	surgeon
CEM	cement
Chem.9	Chemstrip 9 response
CHI	chisel
COH	surgeon
COR	surgeon
D_{ae}	aerodynamic diameter, μm
D_p	particle diameter, μm
DR	drill
EC	electrocautery

ECD	effective cut-off diameter, μm
f	fraction
F Femoral	fitting femoral
F LINER	fitting liner
FEL	surgeon
FS1, FS2, FS3	filter samples during surgery
FS4	filter sample during surgical room clean-up
GHA	nurse
GLO	surgeon
GMD	geometric mean diameter, μm
GOU	surgeon
Grd	grinding
H FILE	hand file
HAM	hammer
HAN	(scrub) nurse
HCY	aerosol staff
INST	install prosthesis
IRR	irrigation/suction
LMJ	Lovelace Multi-Jet cascade impactor
m frac	mass fraction
MAR	nurse
NA	not available
OR5	operating room #5
PS1, PS2, PS3	area filter samples during surgery
REAM	reamer
ROG	nurse
RST	surgeon
S.D.	standard deviation
S.Vol	sampling volume, m^3
SHA	surgeon, assistant

SLO	nurse
SPR	surgeon
t	sampling time, sec.
TDH	aerosol staff
THO	assistant
WH	assistant
δWt	$= \Delta$Wt = delta weight

LMC Filter Sample Data

Exp ID	Filter ID	Chem.9	δt,min	δm,mg	C,mg/m3	Ave FS1-3 C,mg/m3	Clean-up,FS4 C,mg/m3	Ave PS1-3 C,mg/m3
LMC1	FS1	neg	20	0.022	0.055	0.043		
Total Hip	FS2	neg	28	0.068	0.121			
	FS3	2+	57	0.000	0.000			
	FS4	neg	23	0.000	0.000		0.000	
	PS1	neg	125	0.004	0.016			0.015
	PS2	neg	125	0.003	0.012			
	PS3	2+	125	0.004	0.016			
LMC2	FS1	2+	30	0.030	0.050	0.060		
Total Hip	FS2	1+	30	0.085	0.142			
	FS3	2+	55	0.024	0.022			
	FS4	neg	30	0.058	0.097		0.097	
	PS1	neg	150	0.004	0.013			0.011
	PS2	1+	150	0.004	0.013			
	PS3	neg	150	0.002	0.007			
LMC3	FS1	2+	30	0.071	0.118	0.057		
Back Fusion	FS2	1+	30	0.018	0.030			
	FS3	2+	42	0.028	0.033			
	FS4	neg	18	0.000	0.000		0.000	
	PS1	tr	125	0.004	0.016			0.012
	PS2	neg	125	0.005	0.020			
	PS3	neg	125	0.000	0.000			

LMC Filter Sample Data

Exp ID	Filter ID	Chem.9	δt,min	δm,mg	C,mg/m3	Ave FS1-3 C,mg/m3	Clean-up,FS4 C,mg/m3	Ave PS1-3 C,mg/m3
LMC4	FS1	neg	31	0.034	0.055	0.041		
Total Knee	FS2	neg	33	0.013	0.020			
	FS3	1+	46	0.044	0.048			
	FS4	---	---	---	---		---	
	PS1	neg	109	0.001	0.005			0.008
	PS2	neg	109	0.002	0.009			
	PS3	tr	109	0.002	0.009			
LMC5	FS1	2+	30	0.062	0.103	0.143		
Total Hip	FS2	1-2+	30	0.011	0.018			
	FS3	3+	88	0.349	0.198			
	FS4	neg	15	0.000	0.000		0.000	
	PS1	1-2+	144	0.004	0.014			0.013
	PS2	1-2+	144	0.002	0.007			
	PS3	neg	144	0.005	0.017			
LMC6	FS1	tr	25	0.017	0.034	0.031		
Total Knee	FS2	neg	25	0.016	0.032			
	FS3	1-2+	25	0.013	0.026			
	FS4	neg	18	0.024	0.067		0.067	
	PS1	neg	112	0.001	0.004			0.004
	PS2	neg	112	0.000	0.000			
	PS3	neg	112	0.002	0.009			

LMC Filter Sample Data

Exp ID	Filter ID	Chem.9	δt,min	δm,mg	C,mg/m3	Ave FS1-3 C,mg/m3	Clean-up,FS4 C,mg/m3	Ave PS1-3 C,mg/m3
LMC7	FS1	1+	35	0.046	0.066	0.034		
Total Hip	FS2	2+	30	0.000	0.000			
	FS3	2+	55	0.036	0.033			
	FS4	neg	20	0.010	0.025		0.025	
	PS1	1+	125	0.000	0.000			0.001
	PS2	neg	125	0.000	0.000			
	PS3	neg	125	0.001	0.004			
LMC8	FS1	2+	40	0.041	0.051	0.042		
Total Hip	FS2	2+	40	0.025	0.031			
	FS3	2+	36	0.031	0.043			
	FS4	neg	10	0.012	0.060		0.060	
	PS1	tr	120	0.000	0.000			0.013
	PS2	2+	120	0.005	0.021			
	PS3	tr	120	0.004	0.017			
LMC9	FS1	2+	40	0.052	0.065	0.041		
Hip Reconstruct	FS2	1-2+	35	0.009	0.013			
	FS3	neg	---	(0.007	ERR			
	FS4	neg	---	(0.002	---		---	
	PS1	1+	82	0.000	0.000			0.008
	PS2	neg	82	0.002	0.012			
	PS3	1-2+	82	0.002	0.012			

LMC Filter Sample Data

Exp ID	Filter ID	Chem.9	δt,min	δm,mg	C,mg/m3	Ave FS1-3 C,mg/m3	Clean-up,FS4 C,mg/m3	Ave PS1-3 C,mg/m3
LMC10	FS1	tr	30	0.010	0.017	0.021		
Total Knee	FS2	1+	40	0.016	0.020			
	FS3	1+	34	0.017	0.025			
	FS4	neg	13	0.000	0.000		0.000	
	PS1	neg	111	0.004	0.018			0.011
	PS2	1+	111	0.003	0.014			
	PS3	neg	111	0.000	0.000			
Average						0.051	0.025	0.010
S.D.						0.032	0.034	0.004
Maximum						0.143	0.097	0.015
Minimum						0.021	0.000	0.001

LMC Chemstrip 9 Data: QCM Stages

Exp ID	Procedure	Stage 1 14.2 μm	Stage 2 7.96 μm	Stage 3 4.28 μm	Stage 4 2.87 μm	Stage 5 1.45 μm	Stage 6 0.74 μm	Stage 7 0.46μm	Stage 8 0.32 μm	Stage 9 0.18μm	Probe (in 3mL)	Tube (in 3mL)
LMC_01	Total Hip	1+	neg	neg	neg	neg	neg	neg	neg	neg	NA	NA
LMC_02	Total Hip	neg	trace	neg	neg	neg	neg	neg	neg	neg	NA	NA
LMC_03	Back Fusion	1+	neg	trace	neg	neg	neg	neg	neg	neg	NA	NA
LMC_04	Total Knee	neg	neg	neg	neg	neg	neg	neg	neg	neg	NA	NA
LMC_05	Total Hip	2+	trace	trace	1+	trace	trace	neg	neg	trace	4+	NA
LMC_06	Total Knee	neg	neg	neg	neg	neg	neg	neg	neg	neg	2+	NA
LMC_07	Total Hip	neg	neg	neg	1+	1+	1+	neg	neg	neg	1+	2+
LMC_08	Total Hip	neg	neg	neg	neg	trace	neg	neg	neg	neg	1+	1-2+
LMC_09	Hip Reconst	neg	neg	trace	trace	trace	neg	neg	neg	neg	trace	1-2+
LMC_10	Total Knee	neg	neg	neg	neg	neg	neg	neg	neg	neg	neg	neg

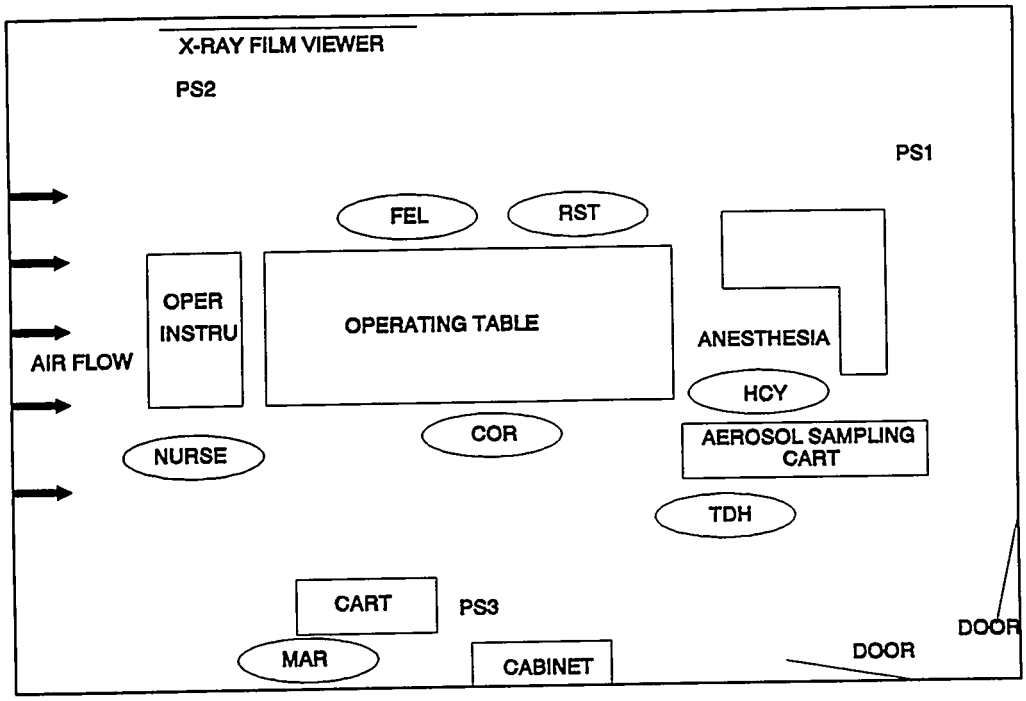
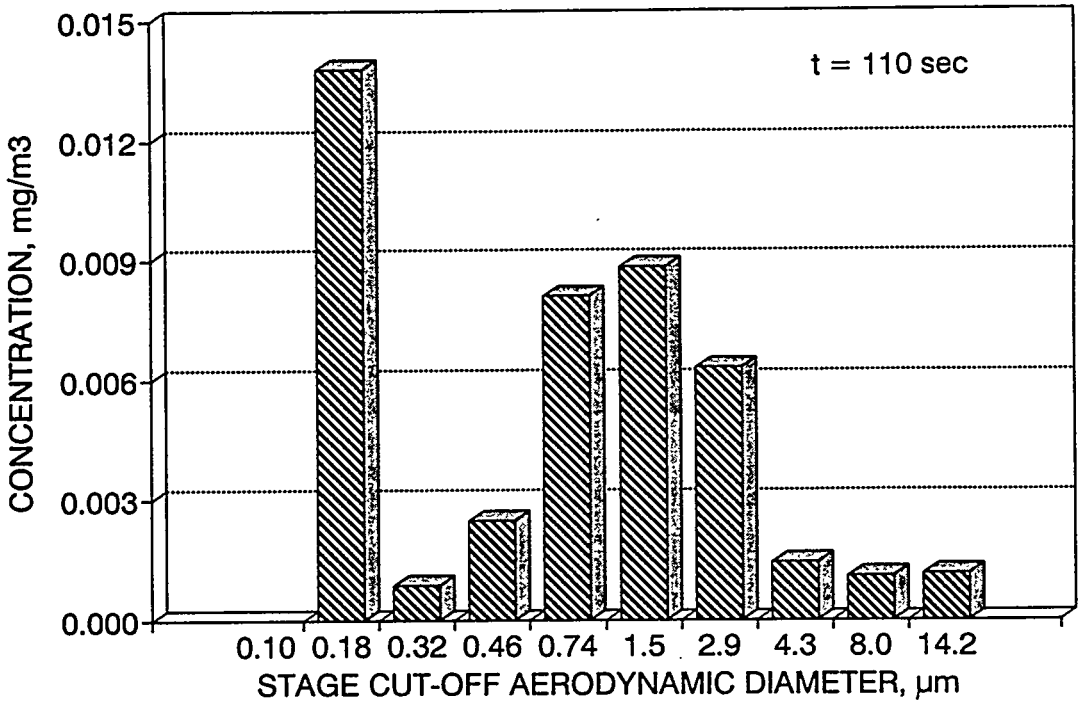


Figure C.1 Initial locations of personnel and area filters during LMC #1 measurement (total hip replacement).

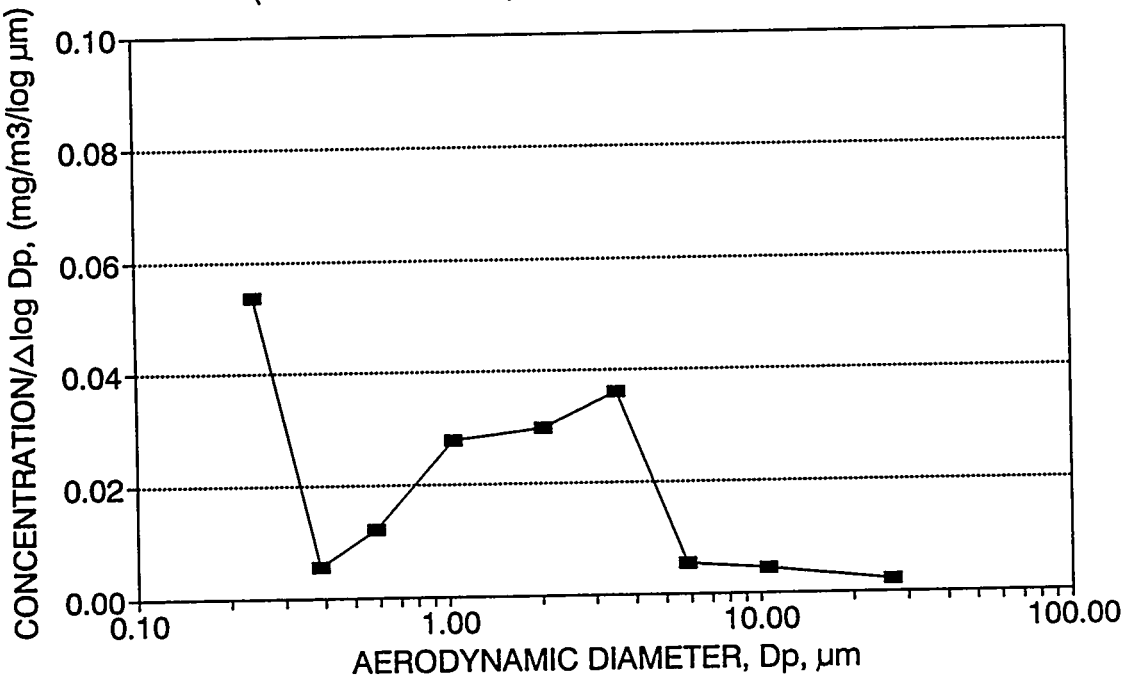
LMC1-1 Total Hip: During EC/IRR (t = 110 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.01378	0.18	-0.749	0.257	0.054	0.24	0.3128	0.000
0.20	0.00087	0.32	-0.492	0.157	0.006	0.39	0.0197	0.313
0.30	0.00250	0.46	-0.335	0.206	0.012	0.59	0.0567	0.333
0.50	0.00809	0.74	-0.128	0.290	0.028	1.04	0.1836	0.389
1.00	0.00885	1.45	0.162	0.296	0.030	2.04	0.2009	0.573
2.00	0.00630	2.87	0.457	0.174	0.036	3.50	0.1430	0.774
3.00	0.00144	4.28	0.632	0.269	0.005	5.84	0.0327	0.917
5.60	0.00109	7.96	0.901	0.251	0.004	10.62	0.0247	0.949
10.00	0.00114	14.18	1.152	0.547	0.002	26.63	0.0259	0.974
		50.00	1.699					1.000
Sum	0.04406						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-1 Total Hip: During EC/IRR)



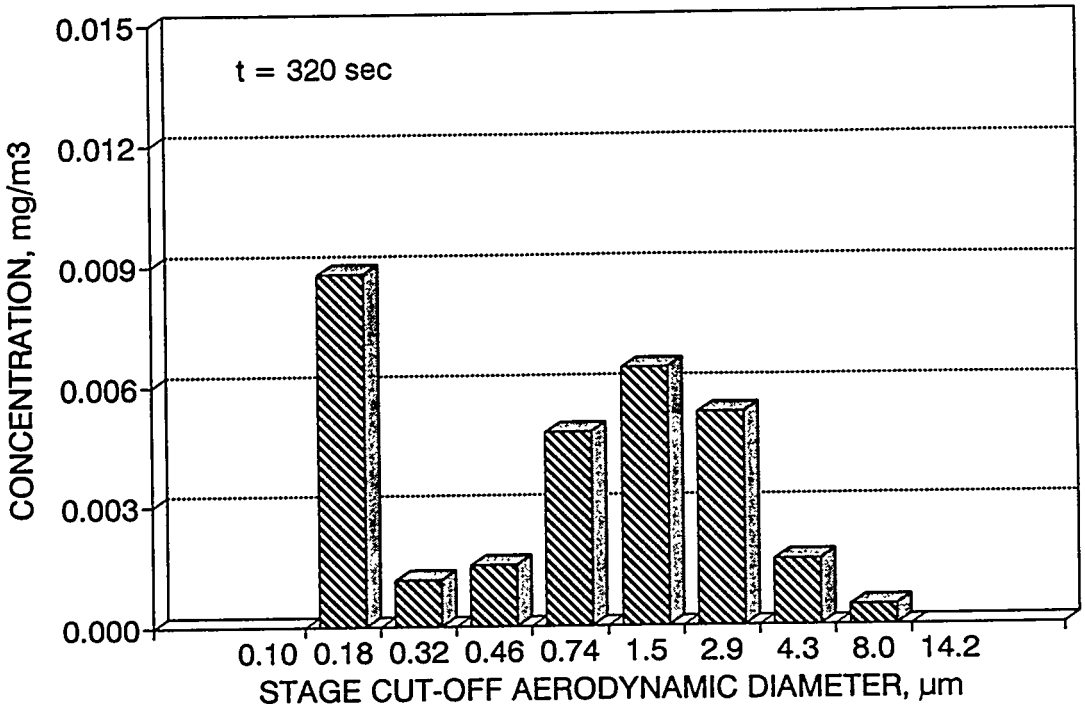
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-1 Total Hip: During EC/IRR)



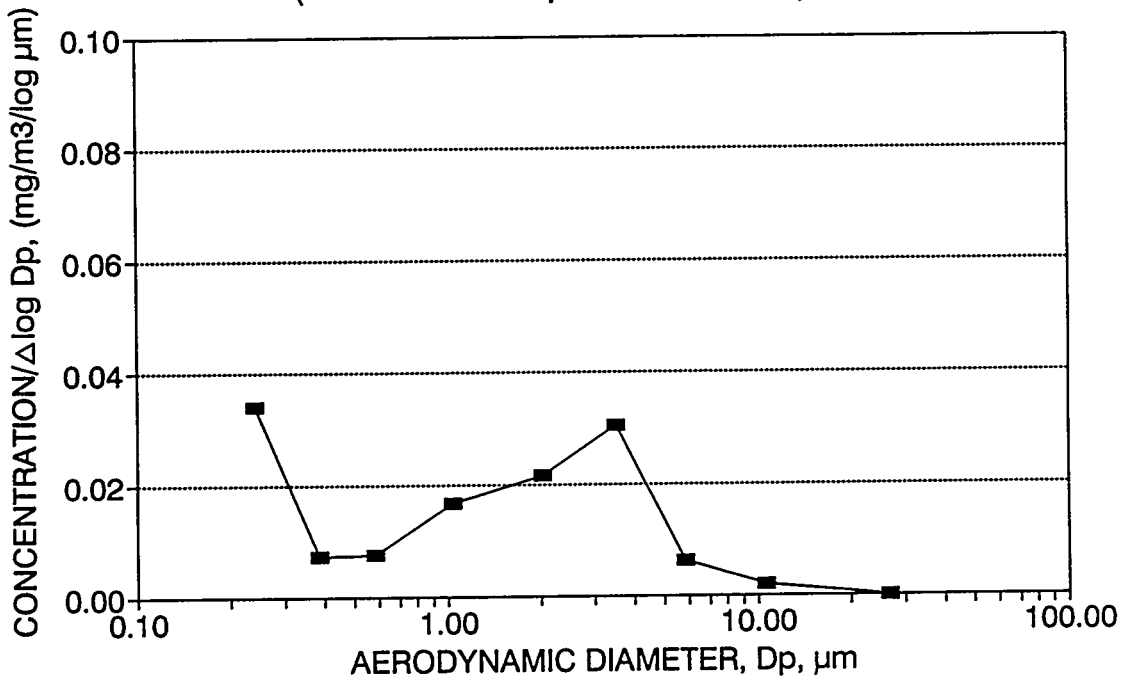
LMC1-2 Total Hip: EC/IRR/DRILL (t = 320 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00882	0.18	-0.749	0.257	0.034	0.24	0.2922	0.000
0.20	0.00114	0.32	-0.492	0.157	0.007	0.39	0.0378	0.292
0.30	0.00151	0.46	-0.335	0.206	0.007	0.59	0.0500	0.330
0.50	0.00483	0.74	-0.128	0.290	0.017	1.04	0.1600	0.380
1.00	0.00641	1.45	0.162	0.296	0.022	2.04	0.2124	0.540
2.00	0.00532	2.87	0.457	0.174	0.031	3.50	0.1763	0.752
3.00	0.00165	4.28	0.632	0.269	0.006	5.84	0.0547	0.929
5.60	0.00050	7.96	0.901	0.251	0.002	10.62	0.0166	0.983
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.03018						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-2 Total Hip: EC/IRR/DRILL)



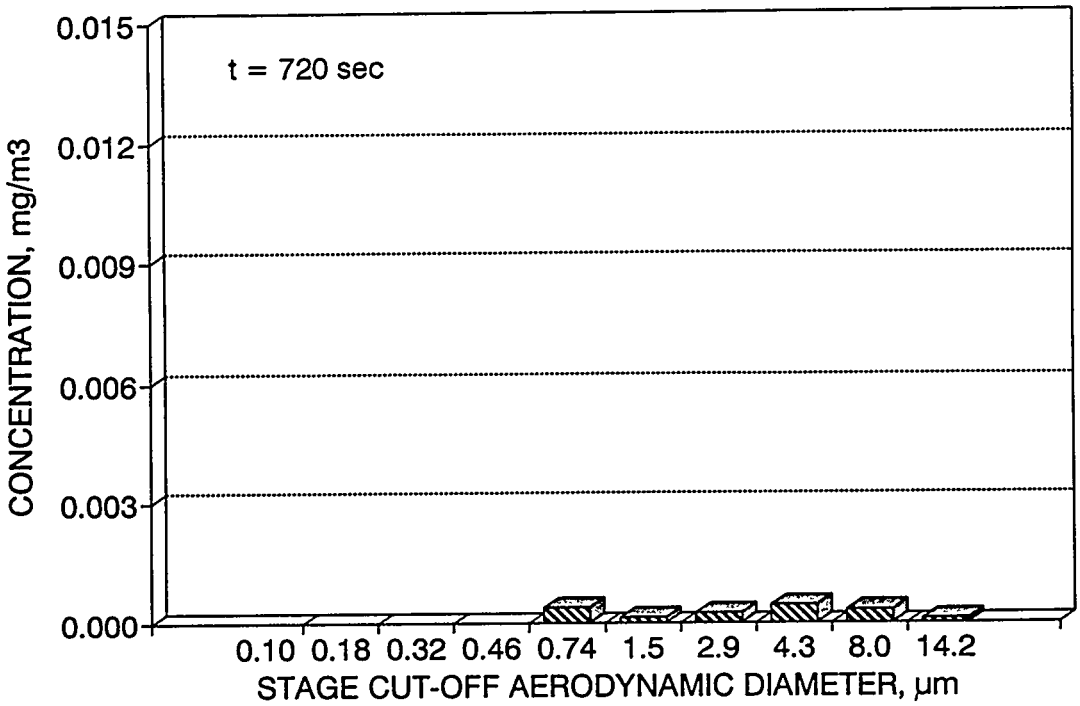
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-2 Total Hip: EC/IRR/DRILL)



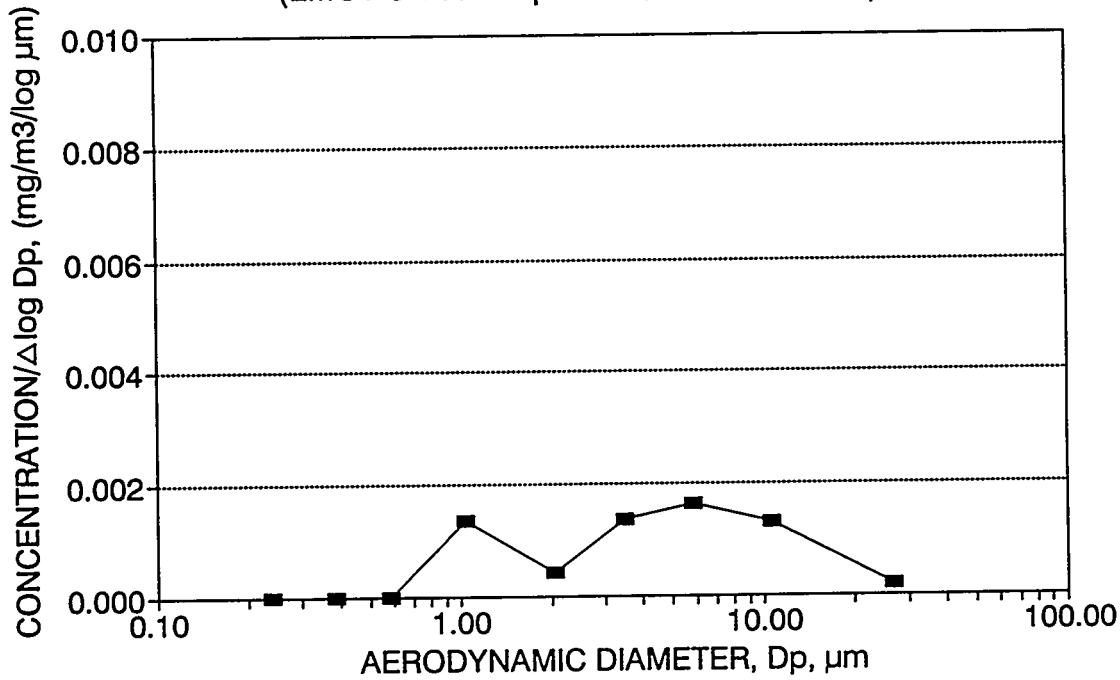
LMC1-3 Total Hip: SAW/REAM/EC/IRR (t = 720 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00039	0.74	-0.128	0.290	0.001	1.04	0.2393	0.000
1.00	0.00012	1.45	0.162	0.296	0.000	2.04	0.0736	0.239
2.00	0.00024	2.87	0.457	0.174	0.001	3.50	0.1472	0.313
3.00	0.00044	4.28	0.632	0.269	0.002	5.84	0.2699	0.460
5.60	0.00033	7.96	0.901	0.251	0.001	10.62	0.2025	0.730
10.00	0.00011	14.18	1.152	0.547	0.000	26.63	0.0675	0.933
		50.00	1.699					1.000
Sum	0.00163						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-3 Total Hip: SAW/REAM/EC/IRR)



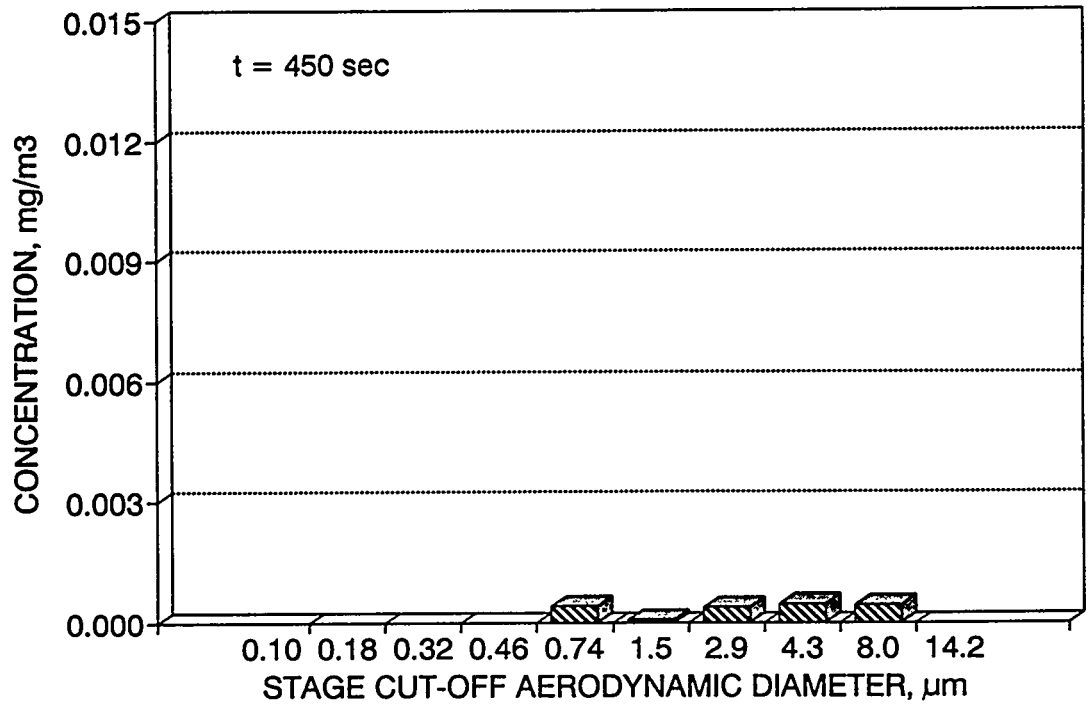
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-3 Total Hip: SAW/REAM/EC/IRR)



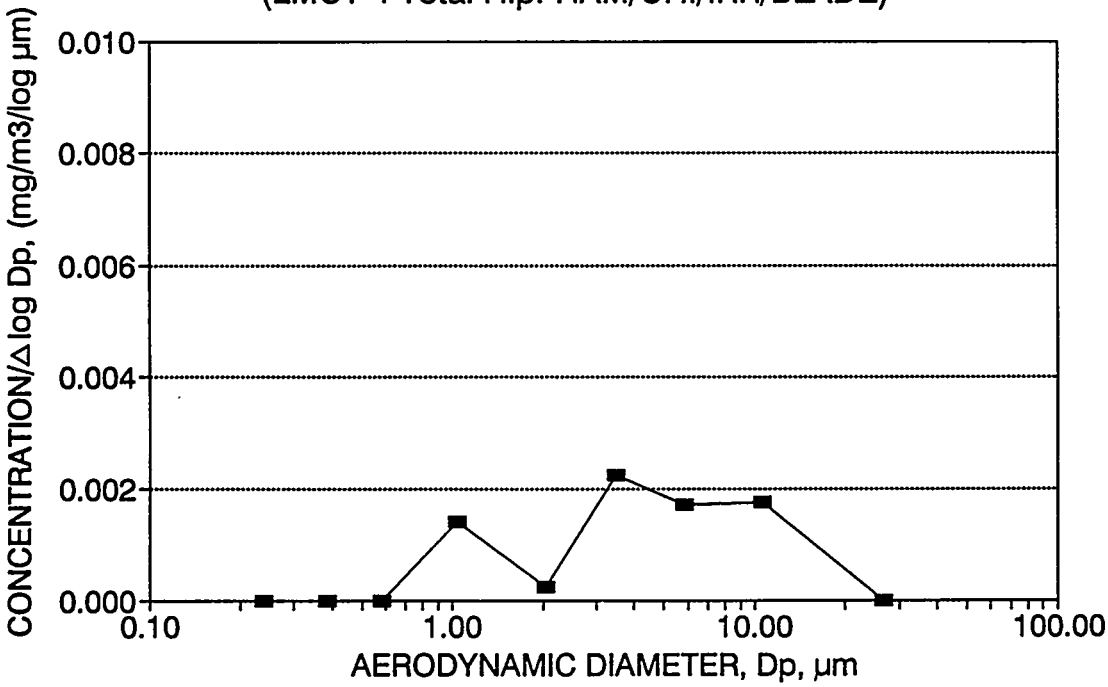
LMC1-4 Total Hip: HAM/CHI/IRR/BLADE (t = 450 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00041	0.74	-0.128	0.290	0.001	1.04	0.2316	0.000
1.00	0.00007	1.45	0.162	0.296	0.000	2.04	0.0395	0.232
2.00	0.00039	2.87	0.457	0.174	0.002	3.50	0.2203	0.271
3.00	0.00046	4.28	0.632	0.269	0.002	5.84	0.2599	0.492
5.60	0.00044	7.96	0.901	0.251	0.002	10.62	0.2486	0.751
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00177						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-4 Total Hip: HAM/CHI/IRR/BLADE)



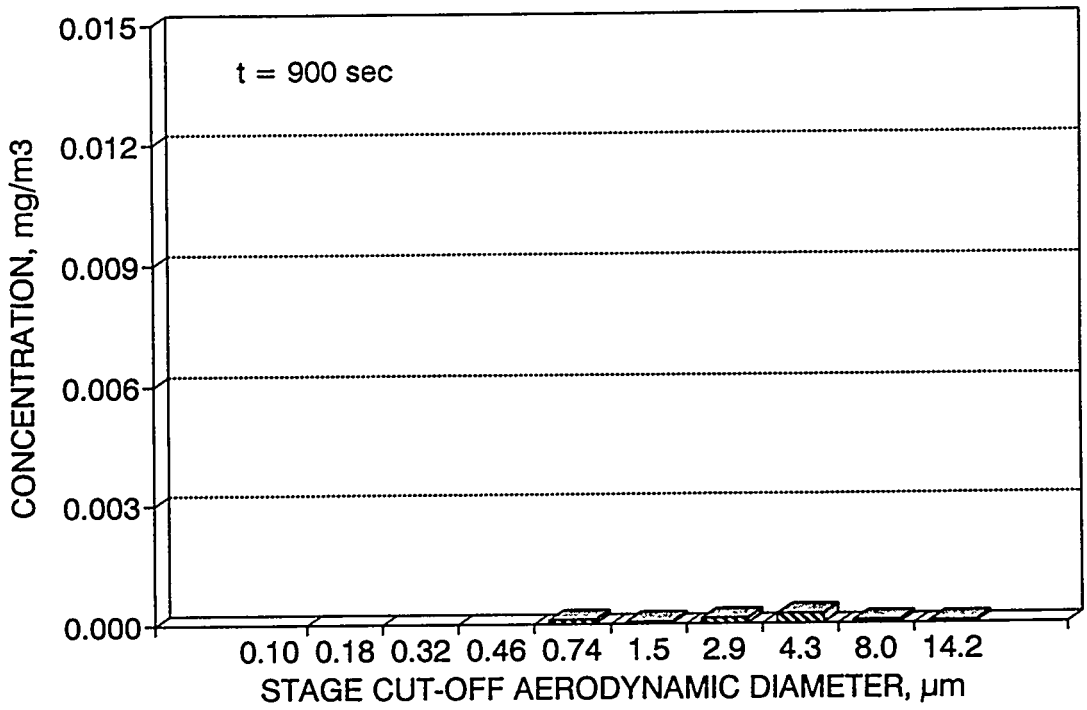
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-4 Total Hip: HAM/CHI/IRR/BLADE)



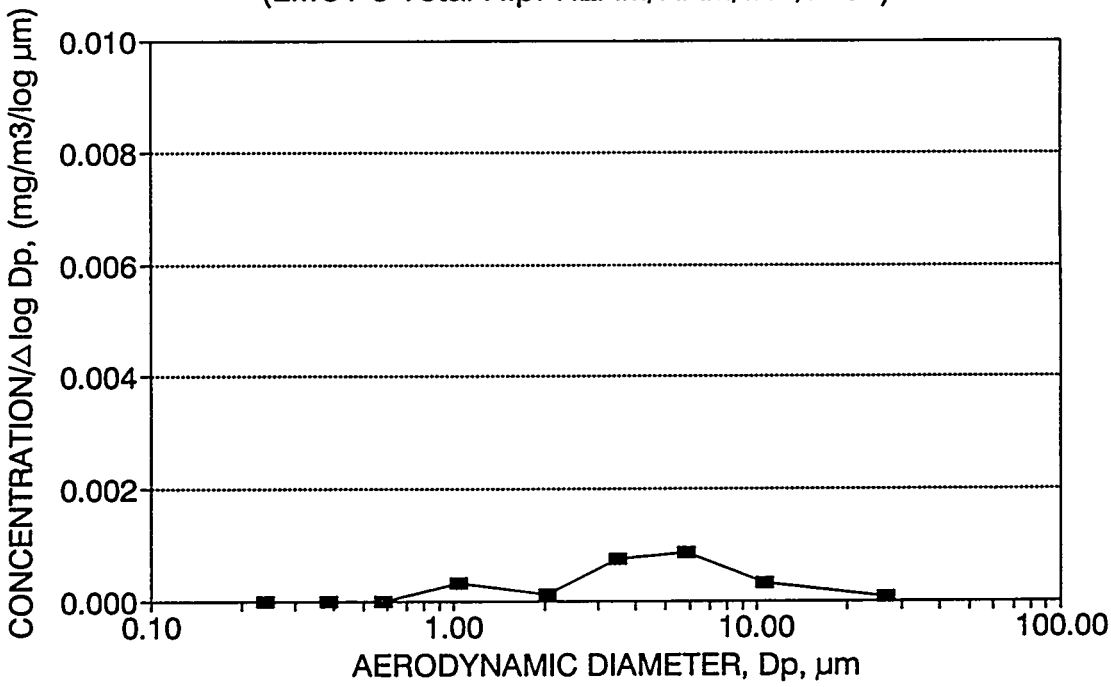
LMC1-5 Total Hip: REAM/HAM/IRR/INST (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00009	0.74	-0.128	0.290	0.000	1.04	0.1500	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.0500	0.150
2.00	0.00013	2.87	0.457	0.174	0.001	3.50	0.2167	0.200
3.00	0.00023	4.28	0.632	0.269	0.001	5.84	0.3833	0.417
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.1333	0.800
10.00	0.00004	14.18	1.152	0.547	0.000	26.63	0.0667	0.933
		50.00	1.699					1.000
Sum	0.0006						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-5 Total Hip: REAM/HAM/IRR/INST)

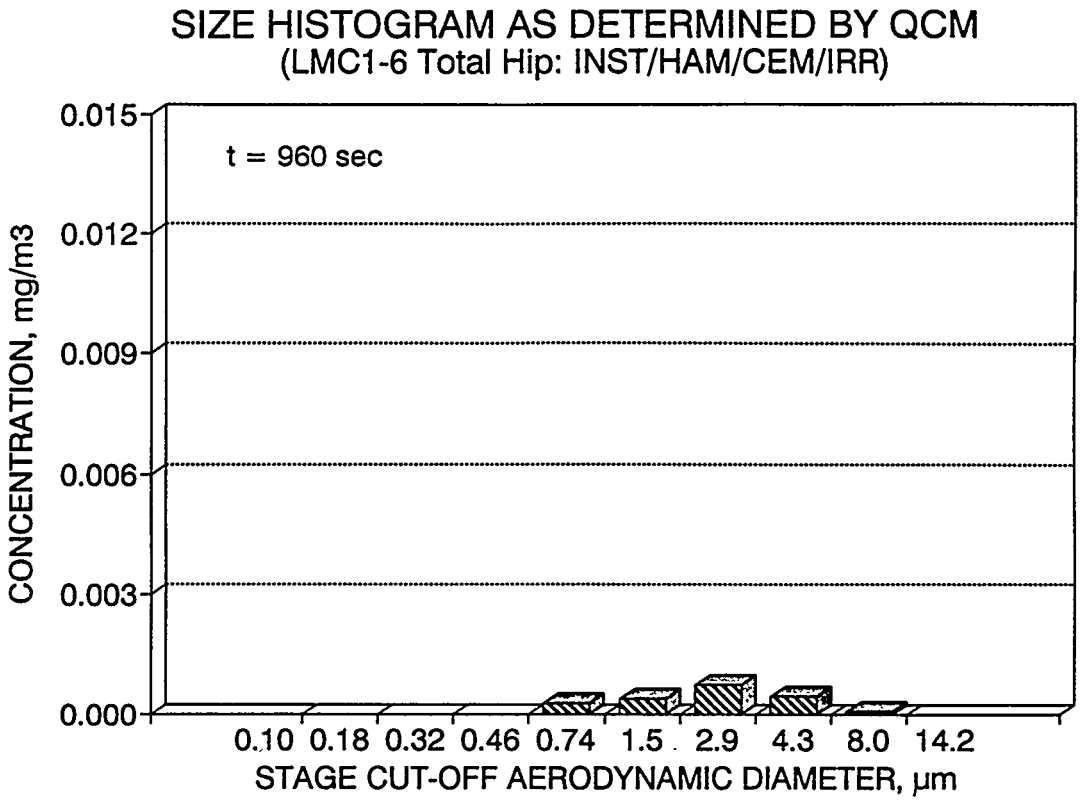


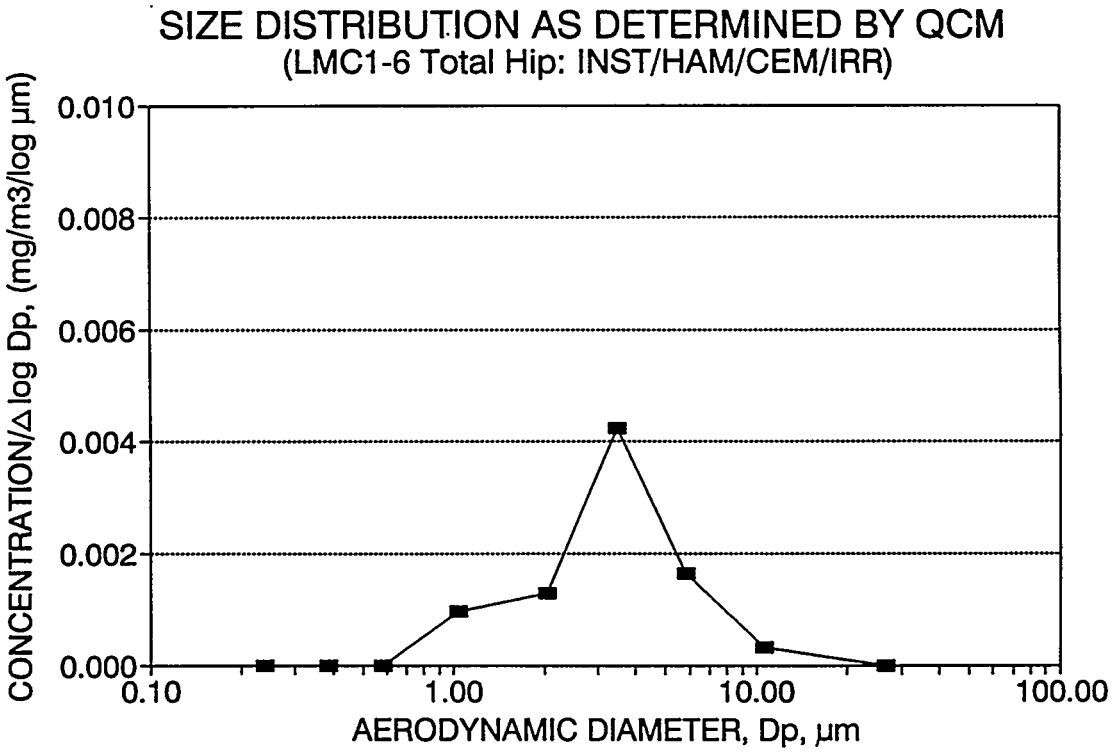
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-5 Total Hip: REAM/HAM/IRR/INST)



LMC1-6 Total Hip: INST/HAM/CEM/IRR (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00028	0.74	-0.128	0.290	0.001	1.04	0.1458	0.000
1.00	0.00038	1.45	0.162	0.296	0.001	2.04	0.1979	0.146
2.00	0.00074	2.87	0.457	0.174	0.004	3.50	0.3854	0.344
3.00	0.00044	4.28	0.632	0.269	0.002	5.84	0.2292	0.729
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.0417	0.958
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00192						1.0000	

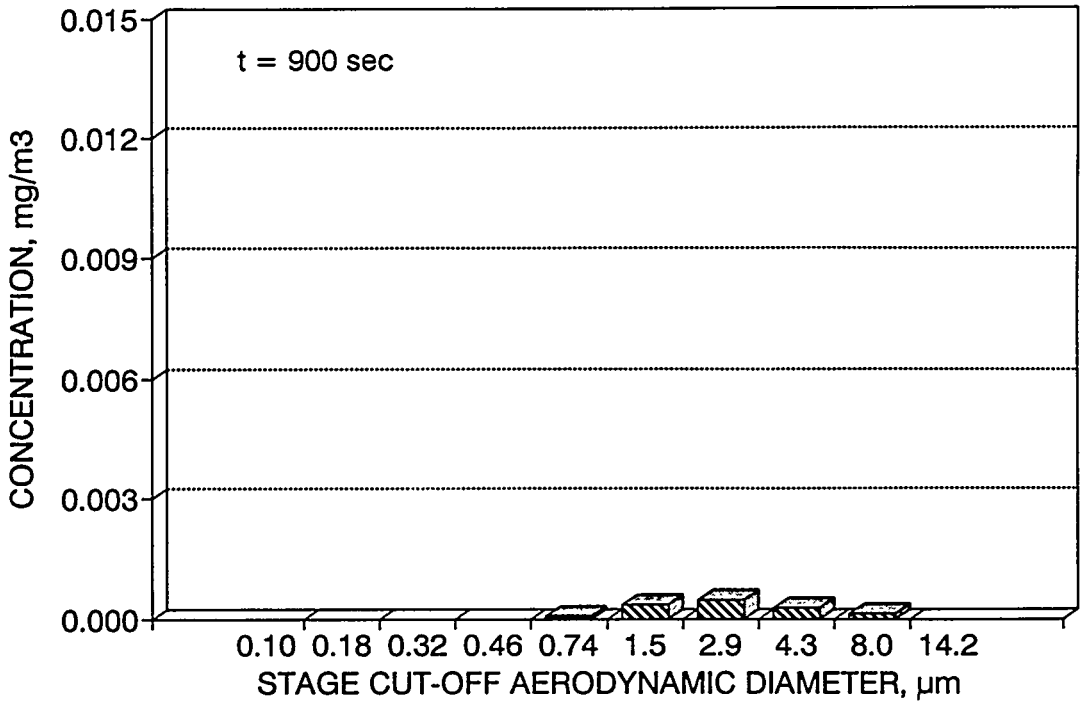

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-6 Total Hip: INST/HAM/CEM/IRR)
t = 960 sec
CONCENTRATION, mg/m3
0.015
0.012
0.009
0.006
0.003
0.000
0.10 0.18 0.32 0.46 0.74 1.5 2.9 4.3 8.0 14.2
STAGE CUT-OFF AERODYNAMIC DIAMETER, µm


SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-6 Total Hip: INST/HAM/CEM/IRR)
CONCENTRATION/Δ log Dp, (mg/m3/log µm)
0.010
0.008
0.006
0.004
0.002
0.000
0.10
1.00
10.00
100.00
AERODYNAMIC DIAMETER, Dp, µm

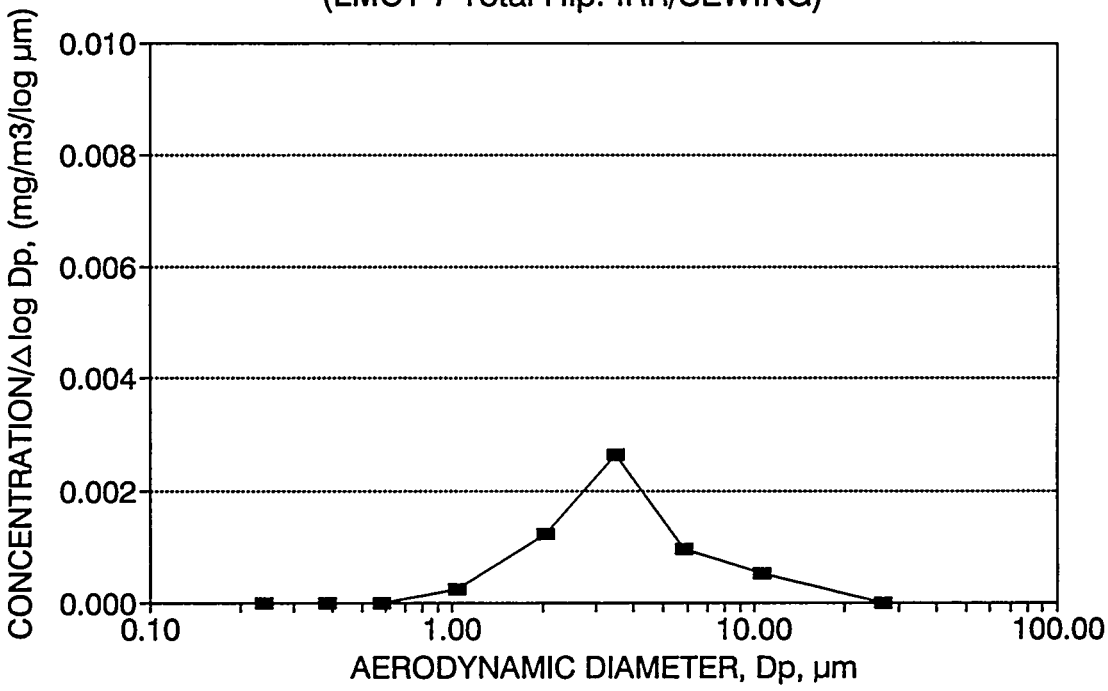
LMC1-7 Total Hip: IRR/SEWING (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.0547	0.000
1.00	0.00036	1.45	0.162	0.296	0.001	2.04	0.2813	0.055
2.00	0.00046	2.87	0.457	0.174	0.003	3.50	0.3594	0.336
3.00	0.00026	4.28	0.632	0.269	0.001	5.84	0.2031	0.695
5.60	0.00013	7.96	0.901	0.251	0.001	10.62	0.1016	0.898
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00128						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-7 Total Hip: IRR/SEWING)



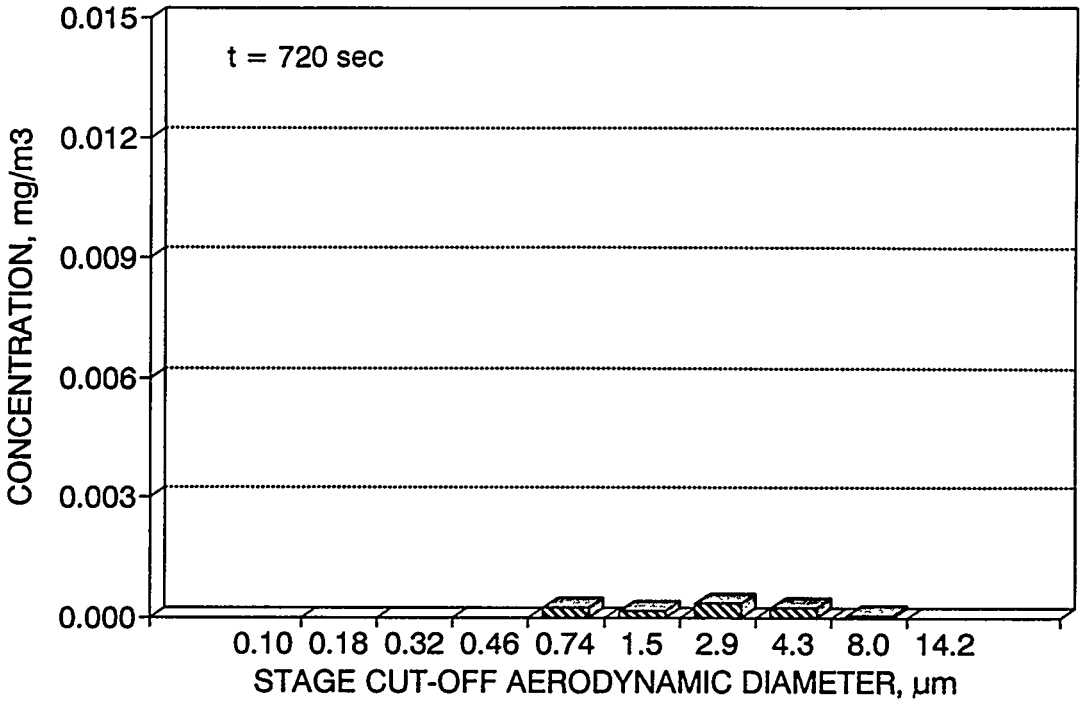
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-7 Total Hip: IRR/SEWING)



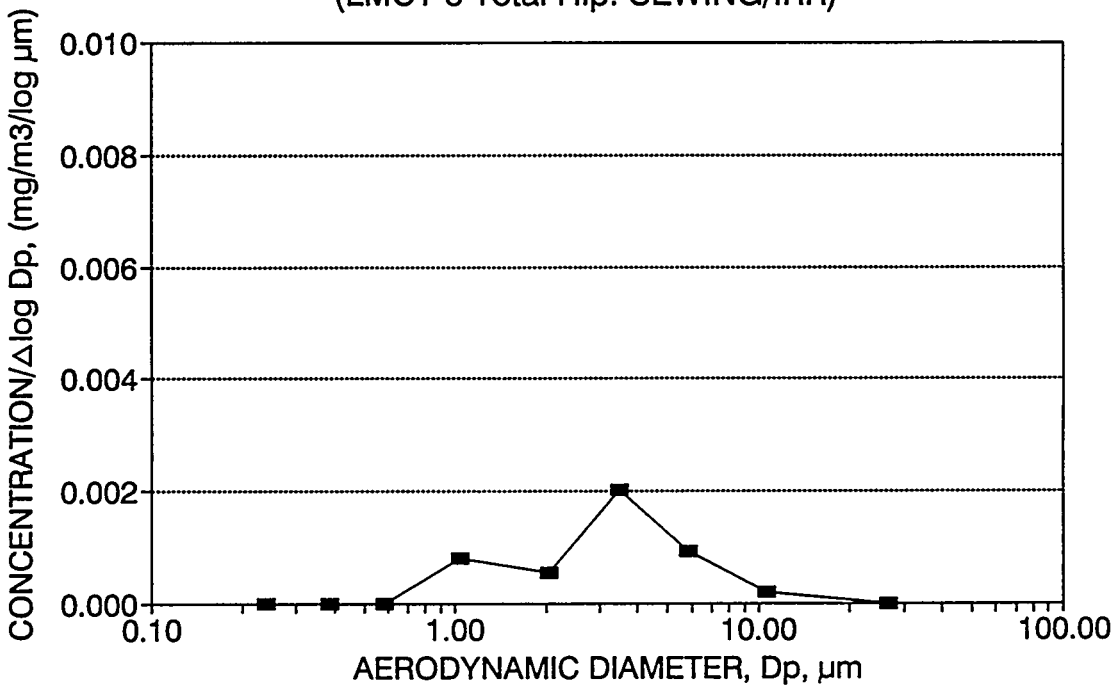
LMC1-8 Total Hip: SEWING/IRR (720 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00023	0.74	-0.128	0.290	0.001	1.04	0.2212	0.000
1.00	0.00016	1.45	0.162	0.296	0.001	2.04	0.1538	0.221
2.00	0.00035	2.87	0.457	0.174	0.002	3.50	0.3365	0.375
3.00	0.00025	4.28	0.632	0.269	0.001	5.84	0.2404	0.712
5.60	0.00005	7.96	0.901	0.251	0.000	10.62	0.0481	0.952
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00104						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-8 Total Hip: SEWING/IRR)



SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-8 Total Hip: SEWING/IRR)

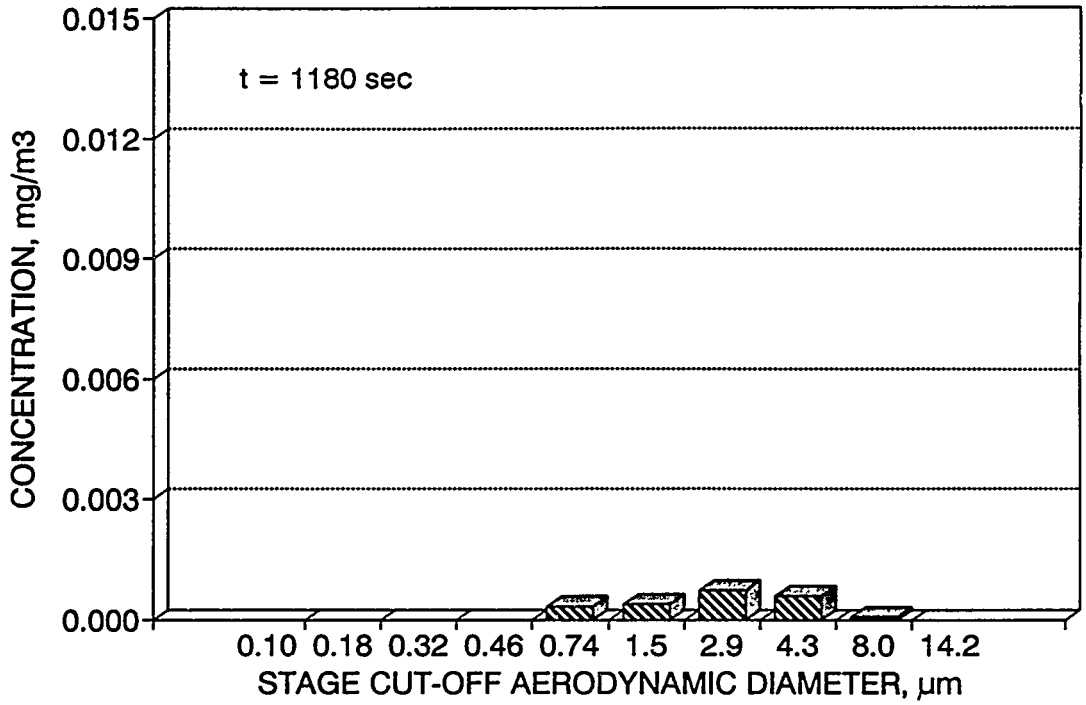


LMC1-9 Total Hip: Room Clean-up (t = 1180 sec)

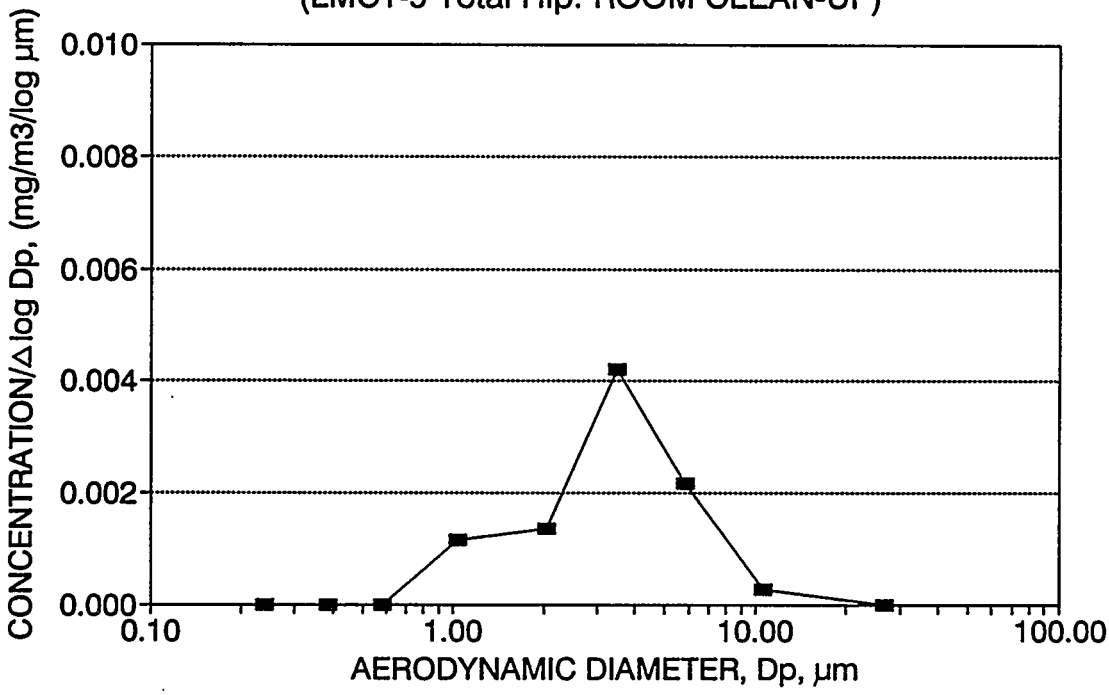
A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00033	0.74	-0.128	0.290	0.001	1.04	0.1578	0.000
1.00	0.00040	1.45	0.162	0.296	0.001	2.04	0.1880	0.158
2.00	0.00073	2.87	0.457	0.174	0.004	3.50	0.3470	0.346
3.00	0.00058	4.28	0.632	0.269	0.002	5.84	0.2754	0.693
5.60	0.00007	7.96	0.901	0.251	0.000	10.62	0.0318	0.968
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00211						1.0000	

Note: Combine last two measurements
in clean-up phase

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC1-9 Total Hip: ROOM CLEAN-UP)



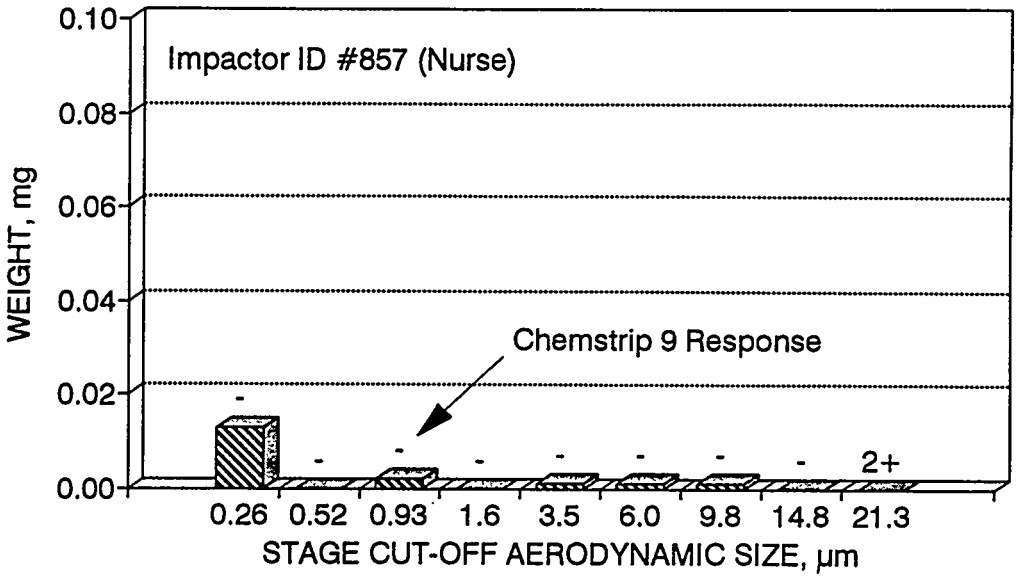
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC1-9 Total Hip: ROOM CLEAN-UP)



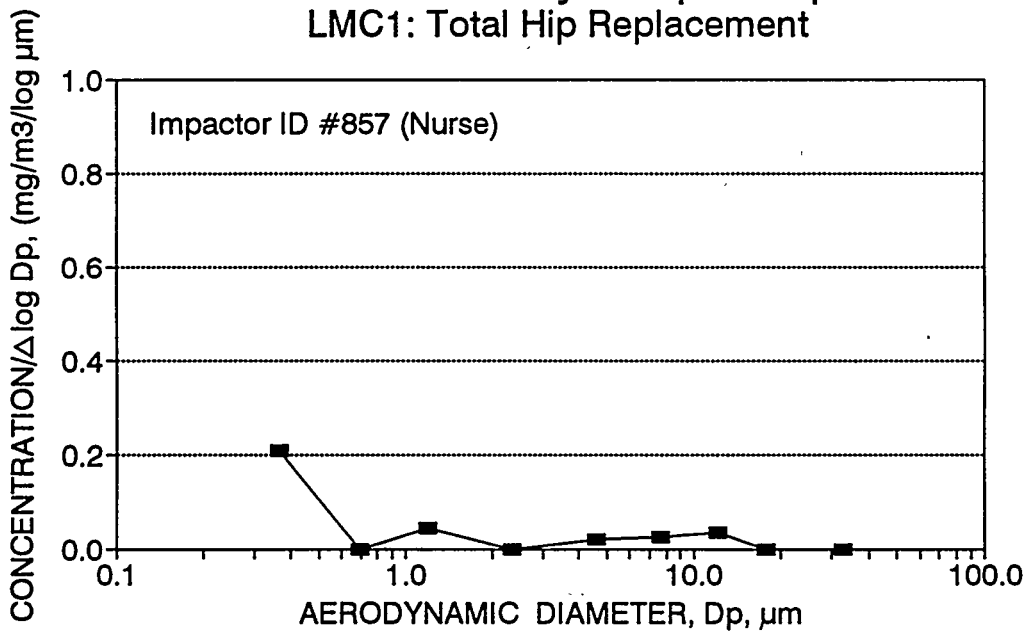
LMC1 Total Hip: Marple Personal Impactor Data (ID No.857: Nurse)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.013	1	0.206	0.063	-0.585	0.301	0.210	0.37	0.702	0.000	-
8	0.52	0.000	0.99	0.206	0.000	-0.284	0.252	0.000	0.70	0.000	0.702	-
7	0.93	0.002	0.97	0.206	0.010	-0.032	0.222	0.045	1.20	0.111	0.702	-
6	1.55	0.000	0.96	0.206	0.000	0.190	0.354	0.000	2.33	0.000	0.813	-
5	3.50	0.001	0.95	0.206	0.005	0.544	0.234	0.022	4.58	0.057	0.813	-
4	6.00	0.001	0.89	0.206	0.005	0.778	0.213	0.026	7.67	0.061	0.870	-
3	9.80	0.001	0.78	0.206	0.006	0.991	0.179	0.035	12.04	0.069	0.931	-
2	14.80	0.000	0.61	0.206	0.000	1.170	0.158	0.000	17.75	0.000	1.000	-
1	21.30	0.000	0.52	0.206	0.000	1.328	0.371	0.000	32.63	0.000	1.000	2+
	50.00					1.699						
Sum		0.018			0.090					1.000		

Marple Personal Impactor Data
LMC1: Total Hip Replacement



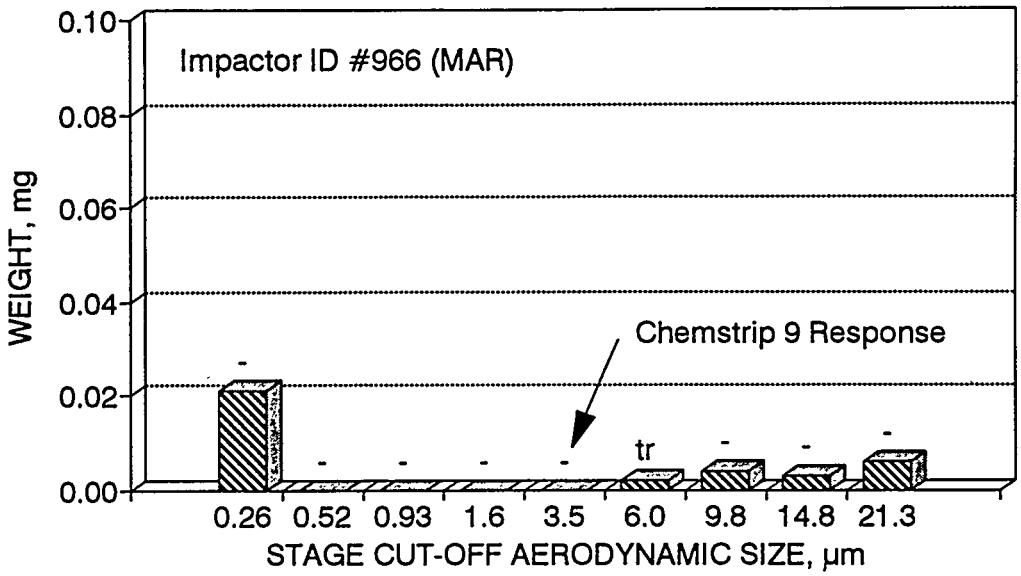
Size distribution by Marple Impactor
LMC1: Total Hip Replacement



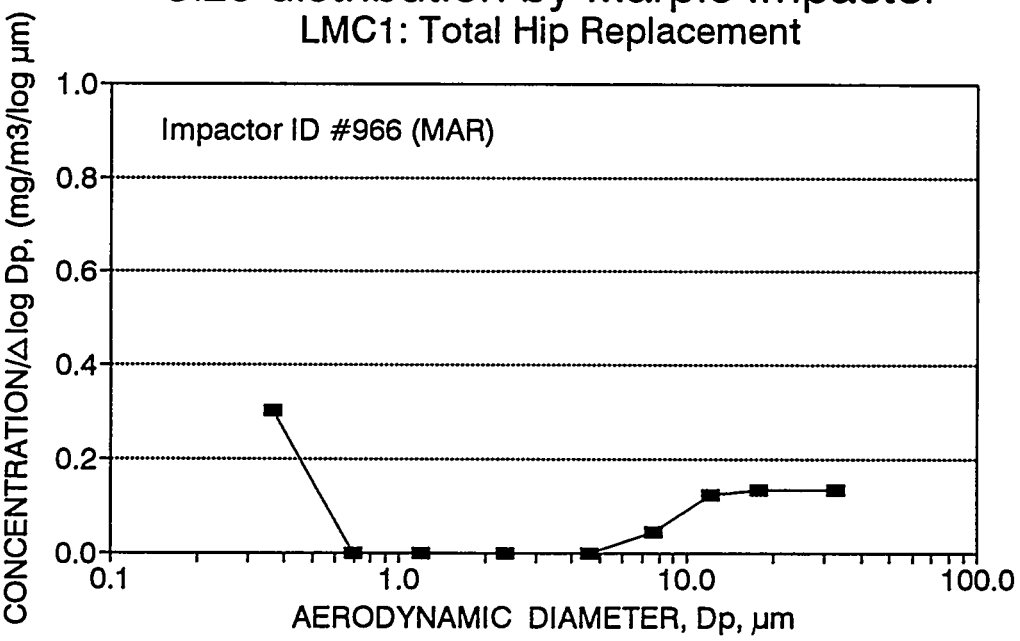
LMC1 Total Hip: Marple Personal Impactor Data (ID No.966: MAR)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.021	1	0.23	0.091	-0.585	0.301	0.303	0.37	0.468	0.000	-
8	0.52	0.000	0.99	0.23	0.000	-0.284	0.252	0.000	0.70	0.000	0.468	-
7	0.93	0.000	0.97	0.23	0.000	-0.032	0.222	0.000	1.20	0.000	0.468	-
6	1.55	0.000	0.96	0.23	0.000	0.190	0.354	0.000	2.33	0.000	0.468	-
5	3.50	0.000	0.95	0.23	0.000	0.544	0.234	0.000	4.58	0.000	0.468	-
4	6.00	0.002	0.89	0.23	0.010	0.778	0.213	0.046	7.67	0.050	0.468	tr
3	9.80	0.004	0.78	0.23	0.022	0.991	0.179	0.125	12.04	0.114	0.519	-
2	14.80	0.003	0.61	0.23	0.021	1.170	0.158	0.135	17.75	0.110	0.633	-
1	21.30	0.006	0.52	0.23	0.050	1.328	0.371	0.135	32.63	0.257	0.743	-
	50.00					1.699						
Sum		0.036			0.195					1.000		

Marple Personal Impactor Data
LMC1: Total Hip Replacement



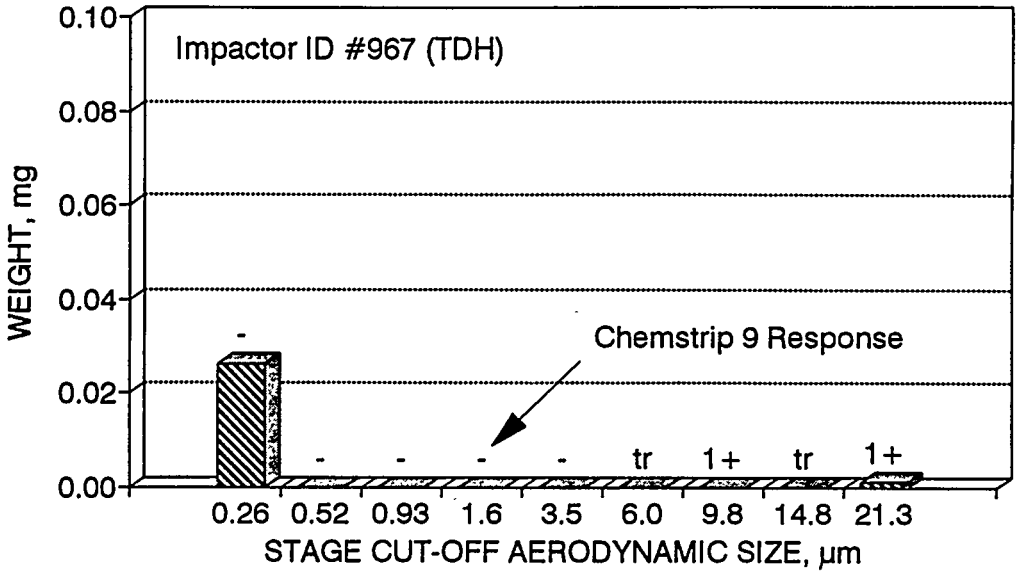
Size distribution by Marple Impactor
LMC1: Total Hip Replacement



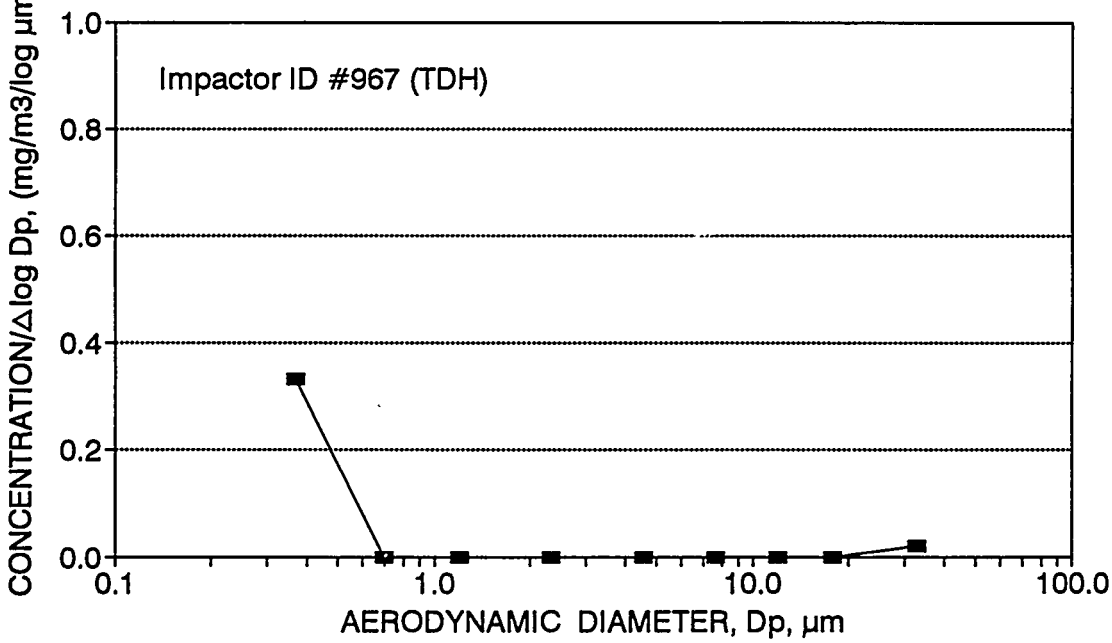
LMC1 Total Hip: Marple Personal Impactor Data (ID No.967: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.026	1	0.26	0.100	-0.585	0.301	0.332	0.37	0.931	0.000	-
8	0.52	0.000	0.99	0.26	0.000	-0.284	0.252	0.000	0.70	0.000	0.931	-
7	0.93	0.000	0.97	0.26	0.000	-0.032	0.222	0.000	1.20	0.000	0.931	-
6	1.55	0.000	0.96	0.26	0.000	0.190	0.354	0.000	2.33	0.000	0.931	-
5	3.50	0.000	0.95	0.26	0.000	0.544	0.234	0.000	4.58	0.000	0.931	-
4	6.00	0.000	0.89	0.26	0.000	0.778	0.213	0.000	7.67	0.000	0.931	tr
3	9.80	0.000	0.78	0.26	0.000	0.991	0.179	0.000	12.04	0.000	0.931	1+
2	14.80	0.000	0.61	0.26	0.000	1.170	0.158	0.000	17.75	0.000	0.931	tr
1	21.30	0.001	0.52	0.26	0.007	1.328	0.371	0.020	32.63	0.069	0.931	1+
	50.00					1.699						
Sum		0.027			0.107					1.000		

Marple Personal Impactor Data
LMC1: Total Hip Replacement



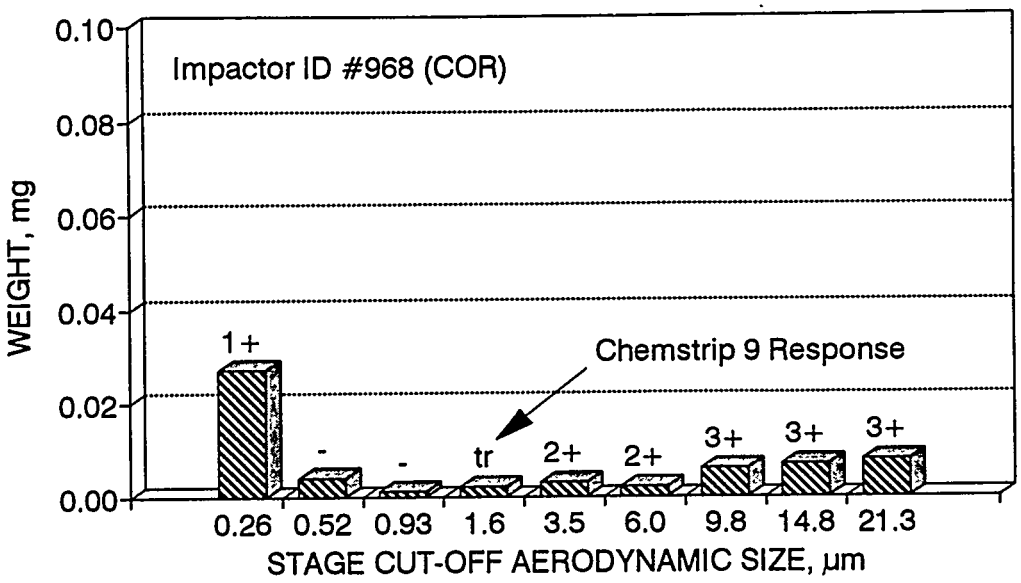
Size distribution by Marple Impactor
LMC1: Total Hip Replacement



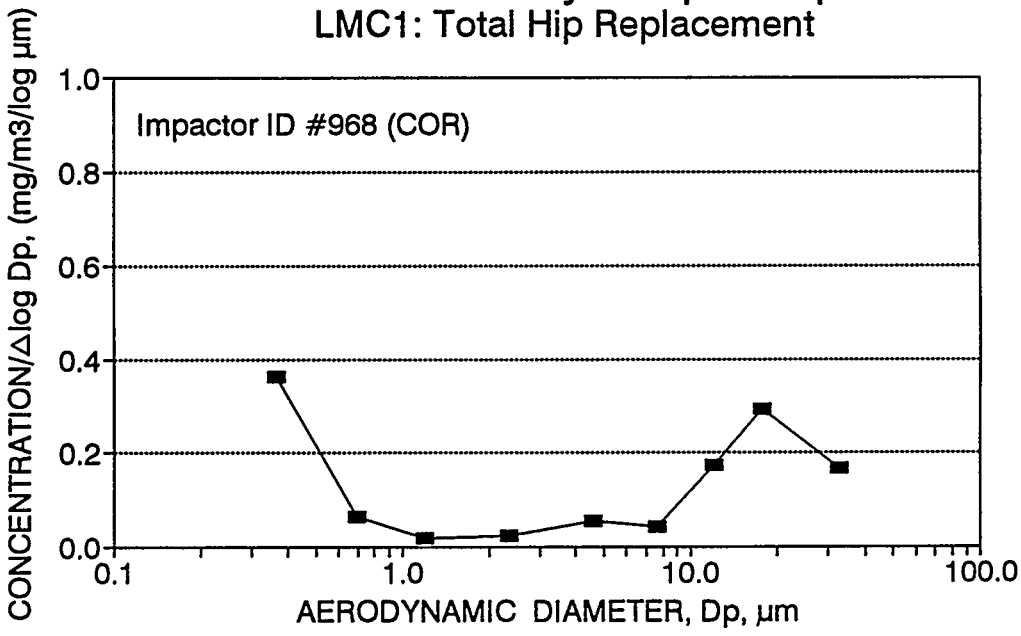
LMC1 Total Hip: Marple Personal Impactor Data (ID No. 968: COR)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.027	1.00	0.248	0.109	-0.585	0.301	0.362	0.37	0.364	0.000	1+
8	0.52	0.004	0.99	0.248	0.016	-0.284	0.252	0.065	0.70	0.055	0.364	-
7	0.93	0.001	0.97	0.248	0.004	-0.032	0.222	0.019	1.20	0.014	0.419	-
6	1.55	0.002	0.96	0.248	0.008	0.190	0.354	0.024	2.33	0.028	0.433	tr
5	3.50	0.003	0.95	0.248	0.013	0.544	0.234	0.054	4.58	0.043	0.461	2+
4	6.00	0.002	0.89	0.248	0.009	0.778	0.213	0.043	7.67	0.030	0.503	2+
3	9.80	0.006	0.78	0.248	0.031	0.991	0.179	0.173	12.04	0.104	0.534	3+
2	14.80	0.007	0.61	0.248	0.046	1.170	0.158	0.293	17.75	0.155	0.638	3+
1	21.30	0.008	0.52	0.248	0.062	1.328	0.371	0.167	32.63	0.208	0.792	3+
	50.00					1.699						
Sum		0.060			0.299					1.000		

Marple Personal Impactor Data
LMC1: Total Hip Replacement



Size distribution by Marple Impactor
LMC1: Total Hip Replacement

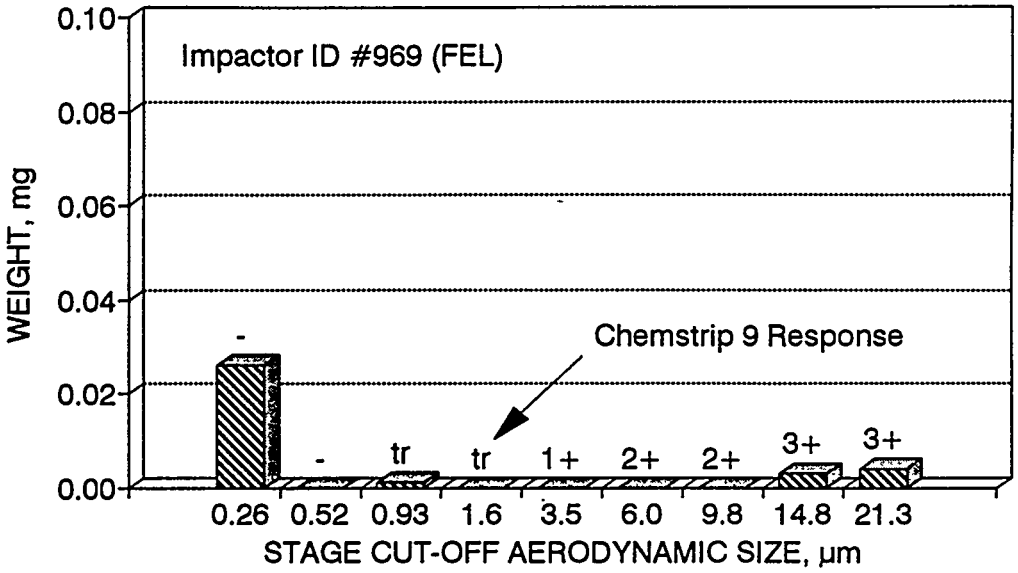


LMC1 Total Hip: Marple Personal Impactor Data (ID No. 969: FEL)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.026	1	0.226	0.115	-0.585	0.301	0.382	0.37	0.656	0.000	-
8	0.52	0.000	0.99	0.226	0.000	-0.284	0.252	0.000	0.70	0.000	0.656	-
7	0.93	0.001	0.97	0.226	0.005	-0.032	0.222	0.021	1.20	0.026	0.656	tr
6	1.55	0.000	0.96	0.226	0.000	0.190	0.354	0.000	2.33	0.000	0.682	tr
5	3.50	0.000	0.95	0.226	0.000	0.544	0.234	0.000	4.58	0.000	0.682	1+
4	6.00	0.000	0.89	0.226	0.000	0.778	0.213	0.000	7.67	0.000	0.682	2+
3	9.80	0.000	0.78	0.226	0.000	0.991	0.179	0.000	12.04	0.000	0.682	2+
2	14.80	0.003	0.61	0.226	0.022	1.170	0.158	0.138	17.75	0.124	0.682	3+
1	21.30	0.004	0.52	0.226	0.034	1.328	0.371	0.092	32.63	0.194	0.806	3+
	50.00					1.699						
Sum		0.034			0.175					1.000		

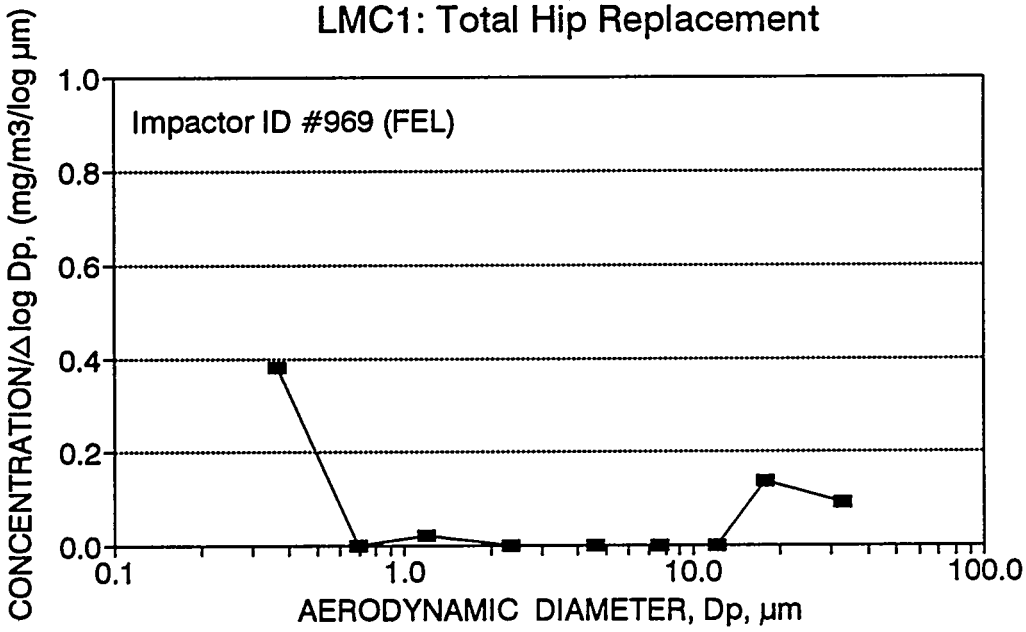
Marple Personal Impactor Data

LMC1: Total Hip Replacement



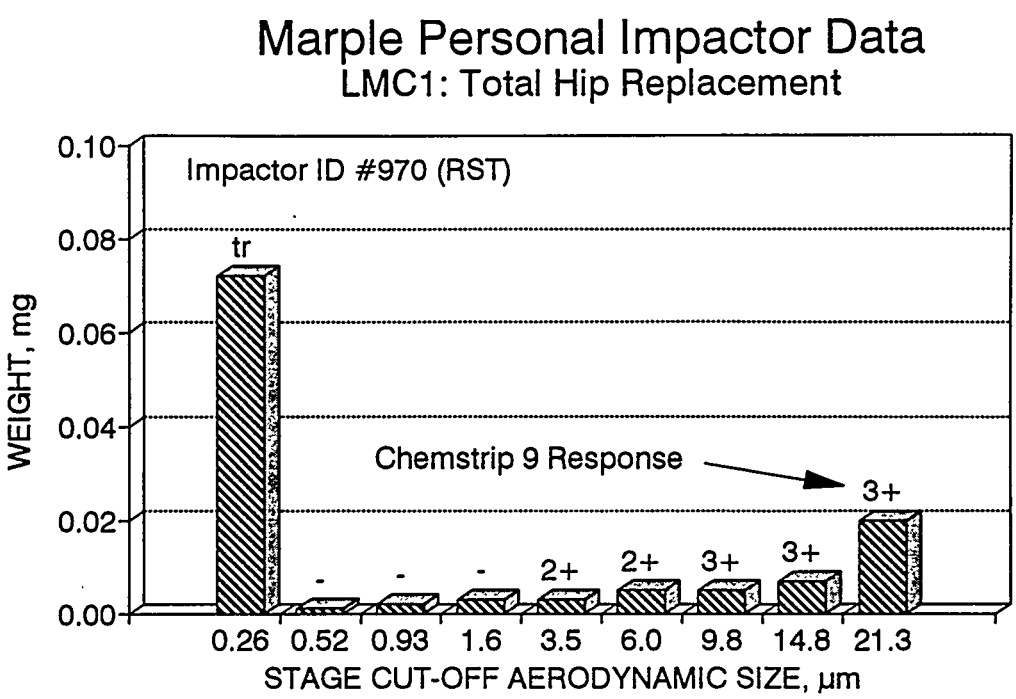
Size distribution by Marple Impactor

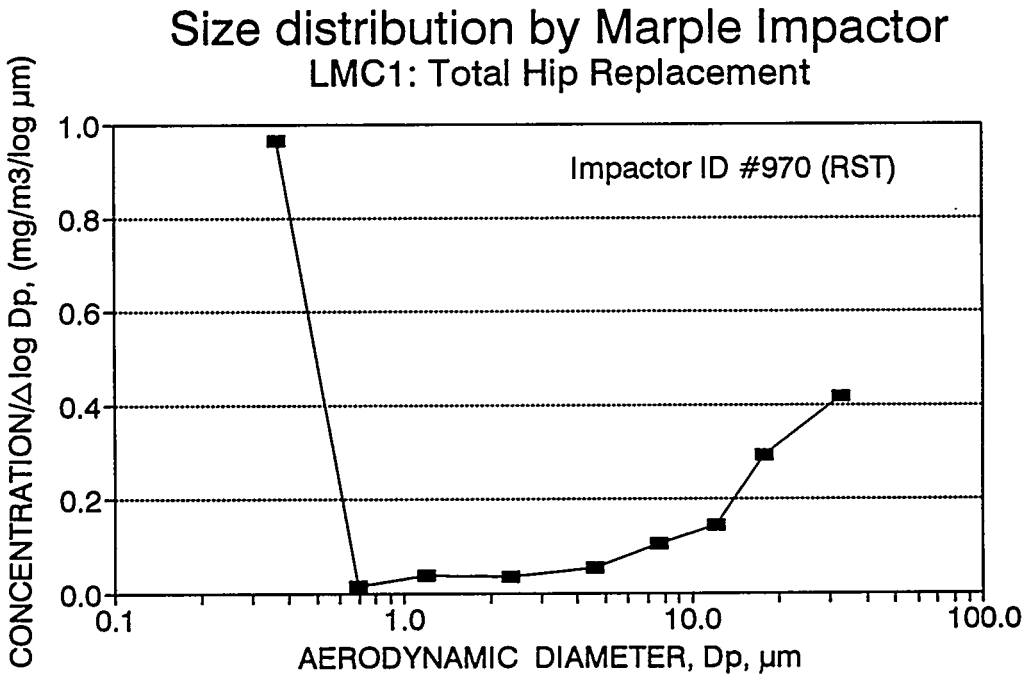
LMC1: Total Hip Replacement



LMC1 Total Hip: Marple Personal Impactor Data (ID No. 970: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.072	1	0.248	0.290	-0.585	0.301	0.964	0.37	0.502	0.000	tr
8	0.52	0.001	0.99	0.248	0.004	-0.284	0.252	0.016	0.70	0.007	0.502	-
7	0.93	0.002	0.97	0.248	0.008	-0.032	0.222	0.037	1.20	0.014	0.509	-
6	1.55	0.003	0.96	0.248	0.013	0.190	0.354	0.036	2.33	0.022	0.524	-
5	3.50	0.003	0.95	0.248	0.013	0.544	0.234	0.054	4.58	0.022	0.546	2+
4	6.00	0.005	0.89	0.248	0.023	0.778	0.213	0.106	7.67	0.039	0.568	2+
3	9.80	0.005	0.78	0.248	0.026	0.991	0.179	0.144	12.04	0.045	0.607	3+
2	14.80	0.007	0.61	0.248	0.046	1.170	0.158	0.293	17.75	0.080	0.652	3+
1	21.30	0.020	0.52	0.248	0.155	1.328	0.371	0.418	32.63	0.268	0.732	3+
	50.00					1.699						
Sum		0.118			0.578					1.000		


Marple Personal Impactor Data
LMC1: Total Hip Replacement
Impactor ID #970 (RST)
WEIGHT, mg
0.10
0.08
0.06
0.04
0.02
0.00
tr
-
-
-
2+
2+
3+
3+
3+
Chemstrip 9 Response
0.26 0.52 0.93 1.6 3.5 6.0 9.8 14.8 21.3
STAGE CUT-OFF AERODYNAMIC SIZE, µm


Size distribution by Marple Impactor
LMC1: Total Hip Replacement
Impactor ID #970 (RST)
CONCENTRATION/Δlog Dp, (mg/m3/log µm)
1.0
0.8
0.6
0.4
0.2
0.0
0.1
1.0
10.0
100.0
AERODYNAMIC DIAMETER, Dp, µm

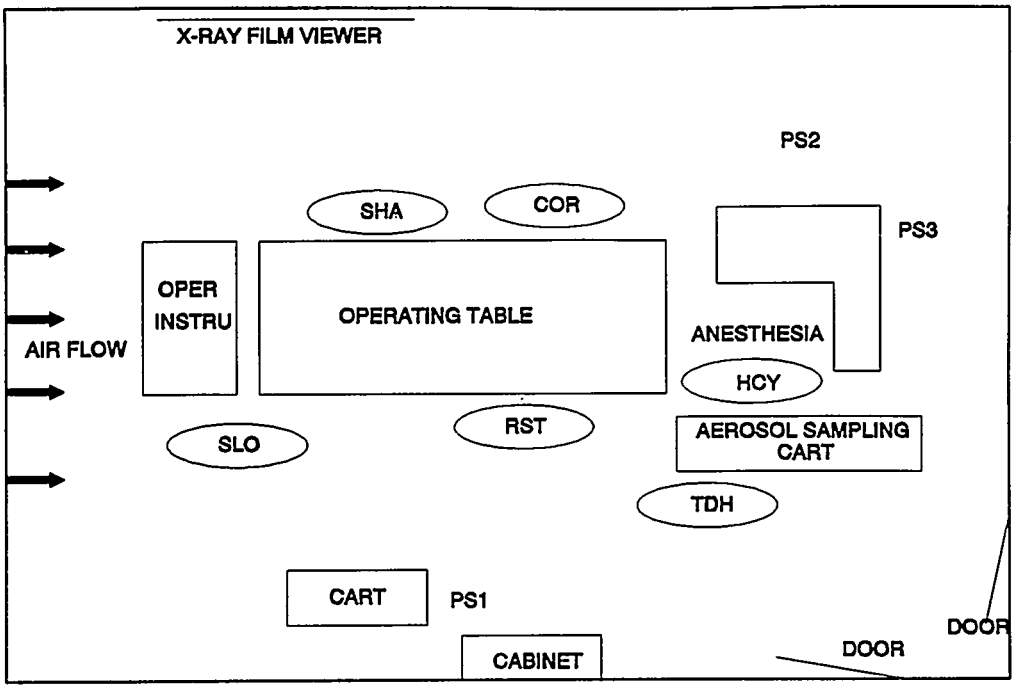
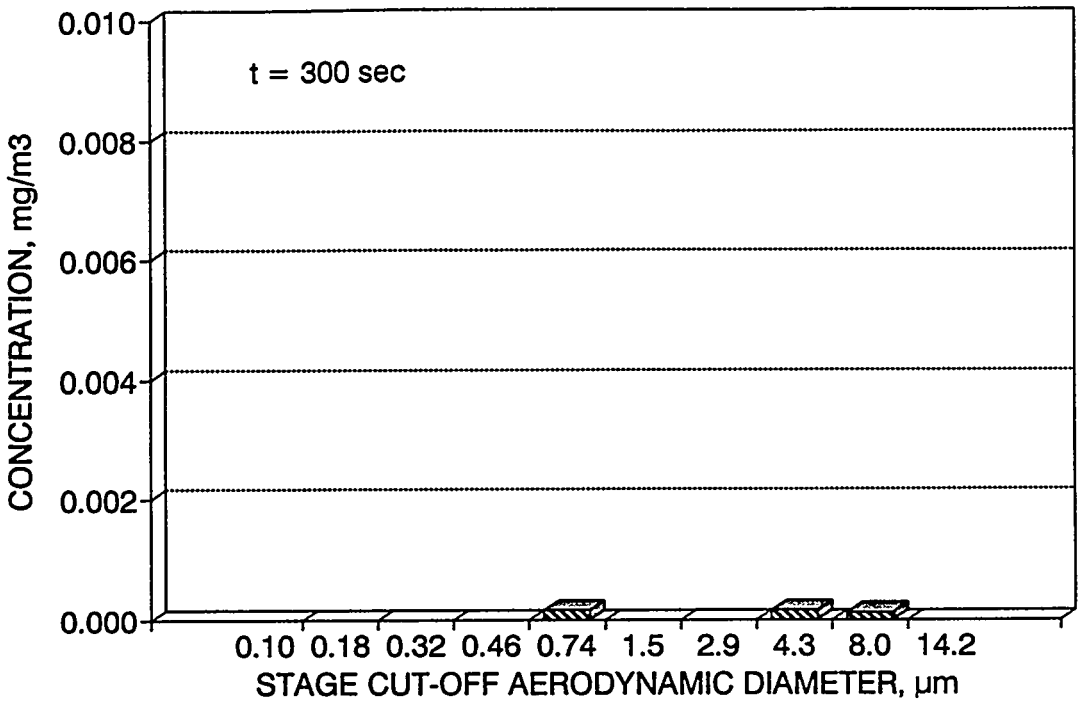


Figure C.2 Initial locations of personnel and area filters during LMC #2 measurement (total hip replacement).

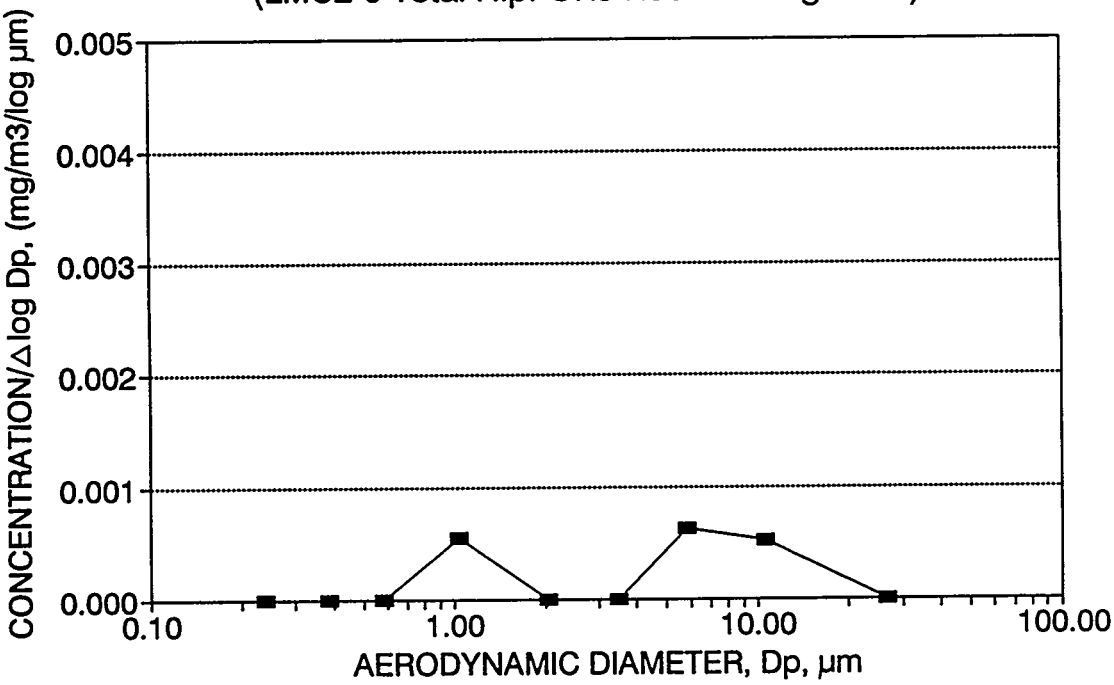
LMC2-0 Total Hip: OR5 Room Background (t = 300 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00016	0.74	-0.128	0.290	0.001	1.04	0.3478	0.000
1.00		1.45	0.162	0.296	0.000	2.04	0.0000	0.348
2.00		2.87	0.457	0.174	0.000	3.50	0.0000	0.348
3.00	0.00017	4.28	0.632	0.269	0.001	5.84	0.3696	0.348
5.60	0.00013	7.96	0.901	0.251	0.001	10.62	0.2826	0.717
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00046						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-0 Total Hip: OR5 Room Background)



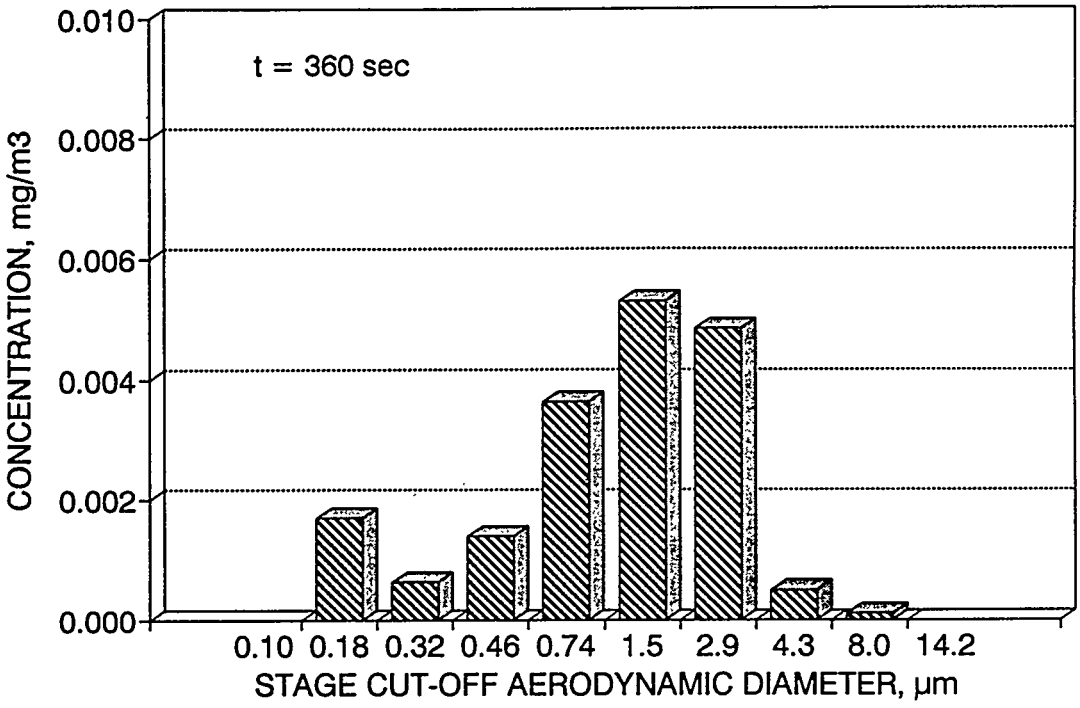
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-0 Total Hip: OR5 Room Background)



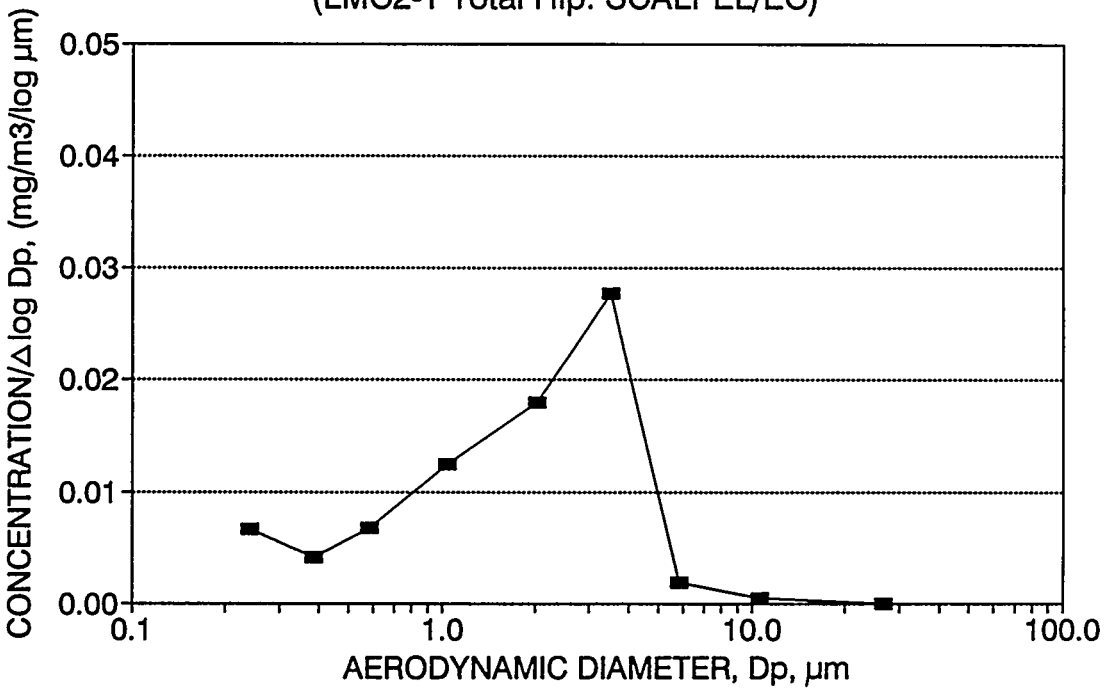
LMC2-1 Total Hip: SCALPEL/EC (t = 360 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B) / (E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00170	0.18	-0.749	0.257	0.007	0.24	0.0937	0.000
0.20	0.00064	0.32	-0.492	0.157	0.004	0.39	0.0353	0.094
0.30	0.00139	0.46	-0.335	0.206	0.007	0.59	0.0766	0.129
0.50	0.00364	0.74	-0.128	0.290	0.013	1.04	0.2007	0.206
1.00	0.00531	1.45	0.162	0.296	0.018	2.04	0.2927	0.406
2.00	0.00484	2.87	0.457	0.174	0.028	3.50	0.2668	0.699
3.00	0.00051	4.28	0.632	0.269	0.002	5.84	0.0281	0.966
5.60	0.00011	7.96	0.901	0.251	0.000	10.62	0.0061	0.994
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.01814						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-1 Total Hip: SCALPEL/EC)



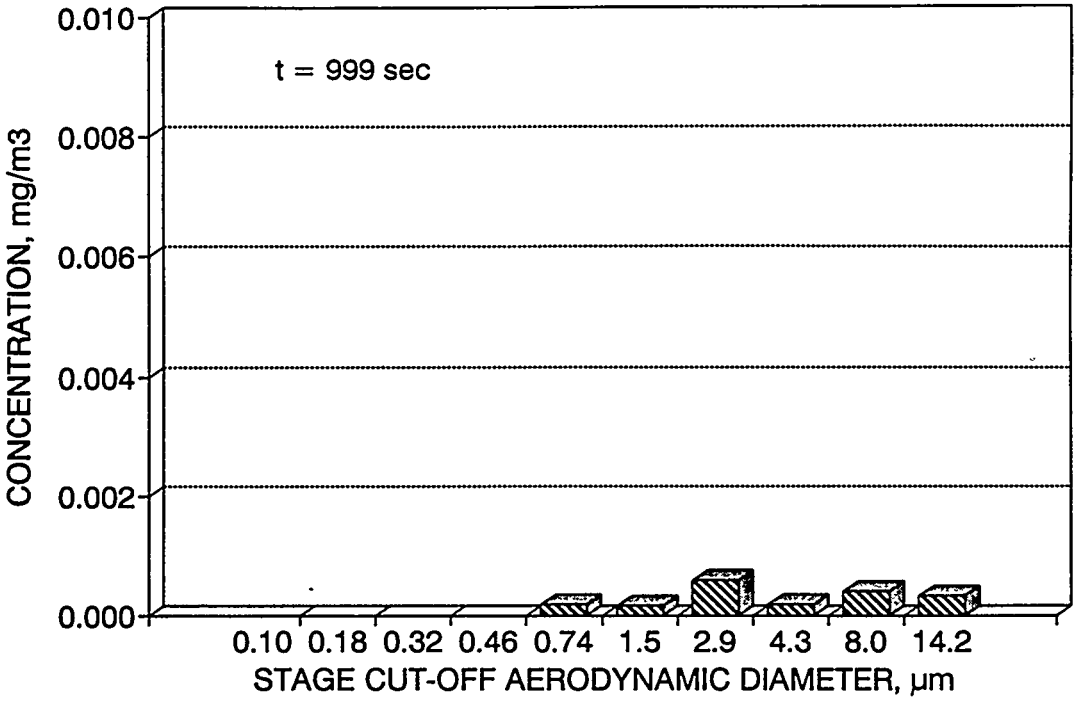
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-1 Total Hip: SCALPEL/EC)



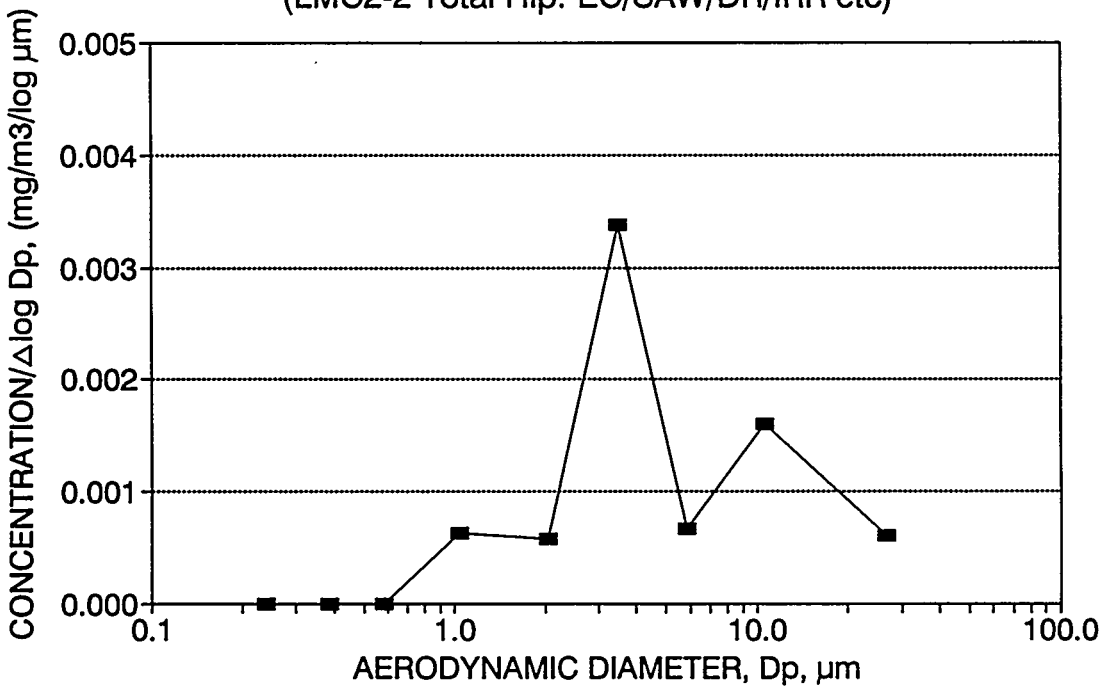
LMC2-2 Total Hip: EC/SAW/DR/IRR etc (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00018	0.74	-0.128	0.290	0.001	1.04	0.0973	0.000
1.00	0.00017	1.45	0.162	0.296	0.001	2.04	0.0919	0.097
2.00	0.00059	2.87	0.457	0.174	0.003	3.50	0.3189	0.189
3.00	0.00018	4.28	0.632	0.269	0.001	5.84	0.0973	0.508
5.60	0.00040	7.96	0.901	0.251	0.002	10.62	0.2162	0.605
10.00	0.00033	14.18	1.152	0.547	0.001	26.63	0.1784	0.822
		50.00	1.699					1.000
Sum	0.00185						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-2 Total Hip: EC/SAW/DR/IRR etc)



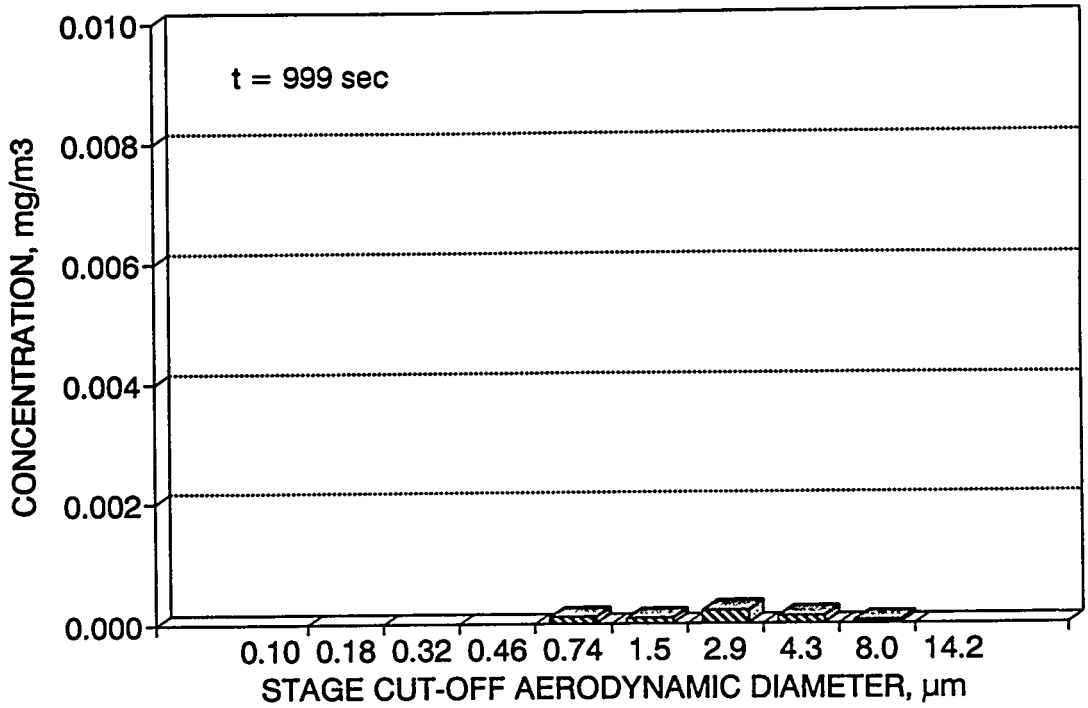
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-2 Total Hip: EC/SAW/DR/IRR etc)



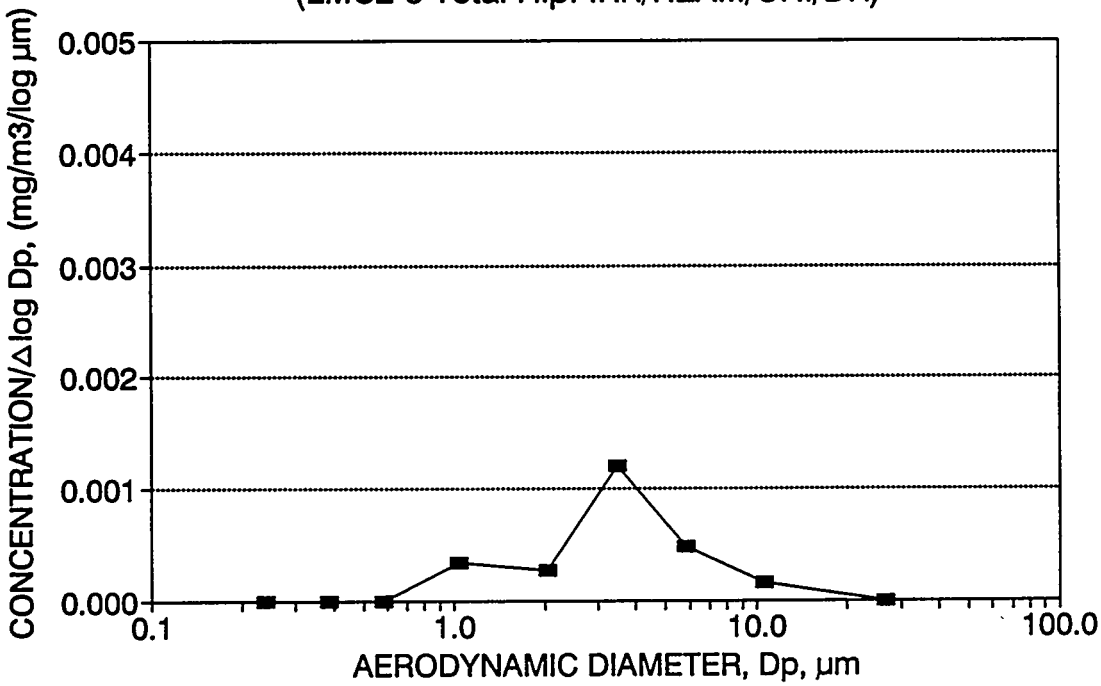
LMC2-3 Total Hip: IRR/REAM/CHI/DR (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00010	0.74	-0.128	0.290	0.000	1.04	0.1786	0.000
1.00	0.00008	1.45	0.162	0.296	0.000	2.04	0.1429	0.179
2.00	0.00021	2.87	0.457	0.174	0.001	3.50	0.3750	0.321
3.00	0.00013	4.28	0.632	0.269	0.000	5.84	0.2321	0.696
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0714	0.929
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00056						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-3 Total Hip: IRR/REAM/CHI/DR)



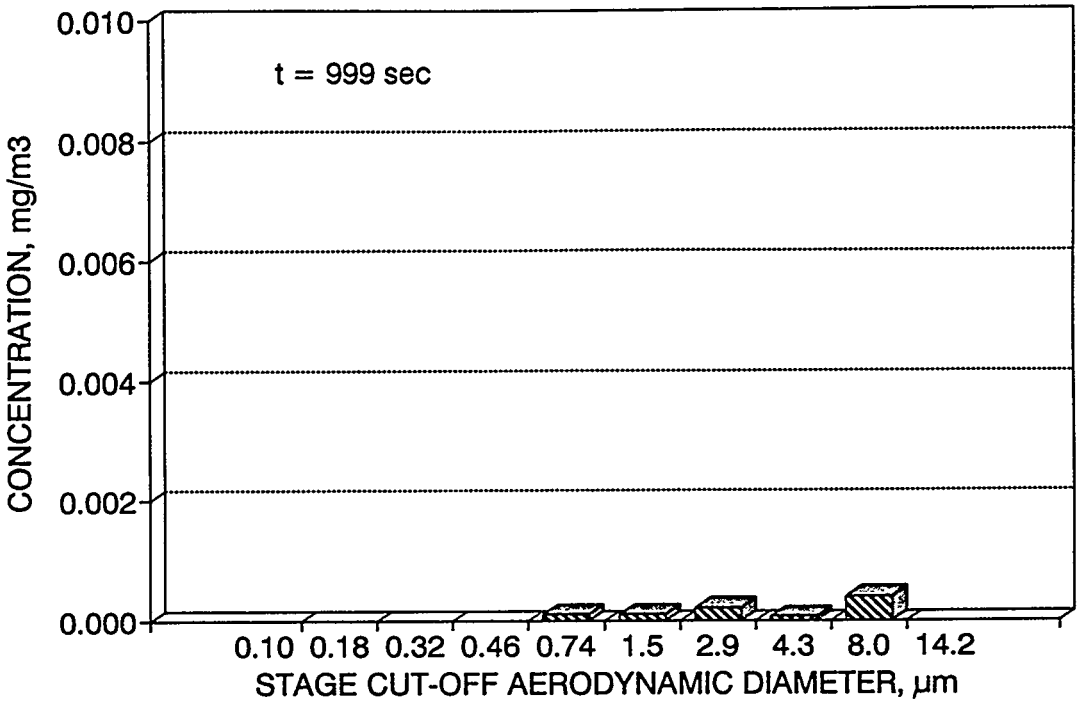
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-3 Total Hip: IRR/REAM/CHI/DR)



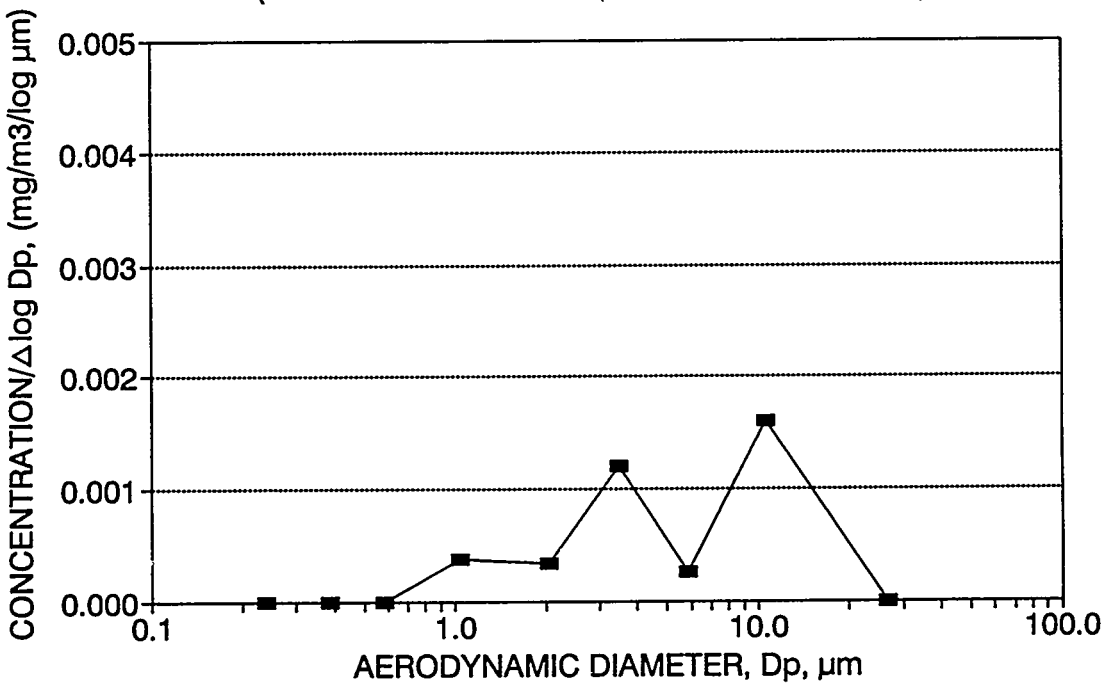
LMC2-4 Total Hip: BROACH/REAM/IRR/FIT LINER (t = 999 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00011	0.74	-0.128	0.290	0.000	1.04	0.1236	0.000
1.00	0.00010	1.45	0.162	0.296	0.000	2.04	0.1124	0.124
2.00	0.00021	2.87	0.457	0.174	0.001	3.50	0.2360	0.236
3.00	0.00007	4.28	0.632	0.269	0.000	5.84	0.0787	0.472
5.60	0.00040	7.96	0.901	0.251	0.002	10.62	0.4494	0.551
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00089						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-4 T.H.: BROACH/REAM/IRR/F LINER)



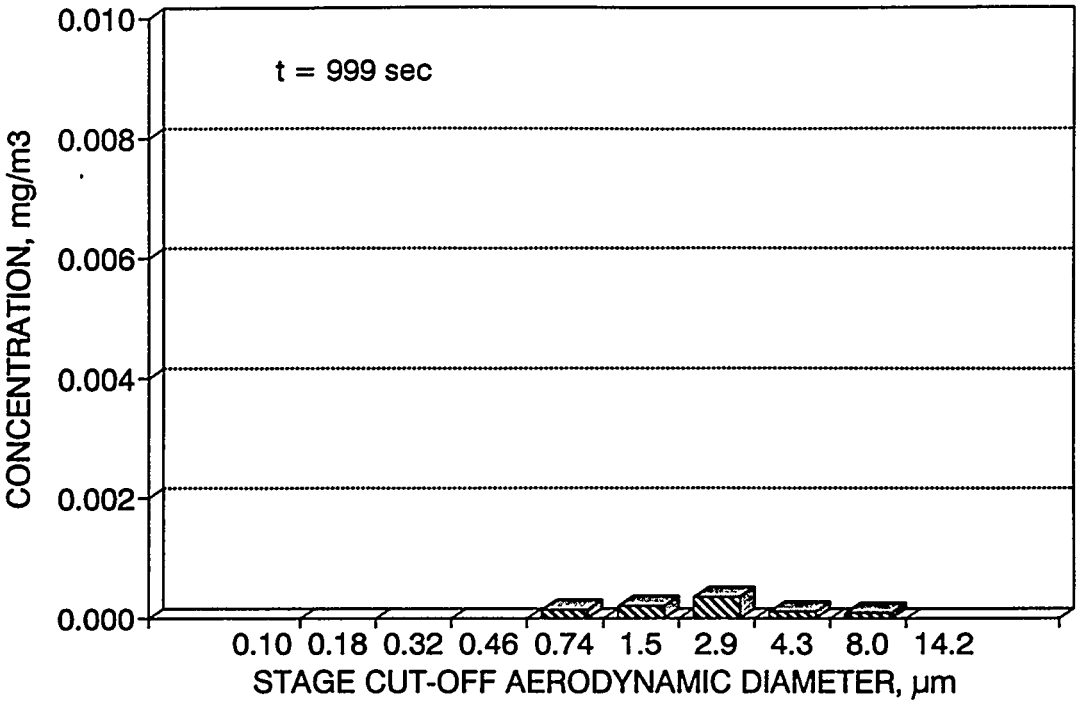
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-4 T.H.: BROACH/REAM/IRR/F LINER)



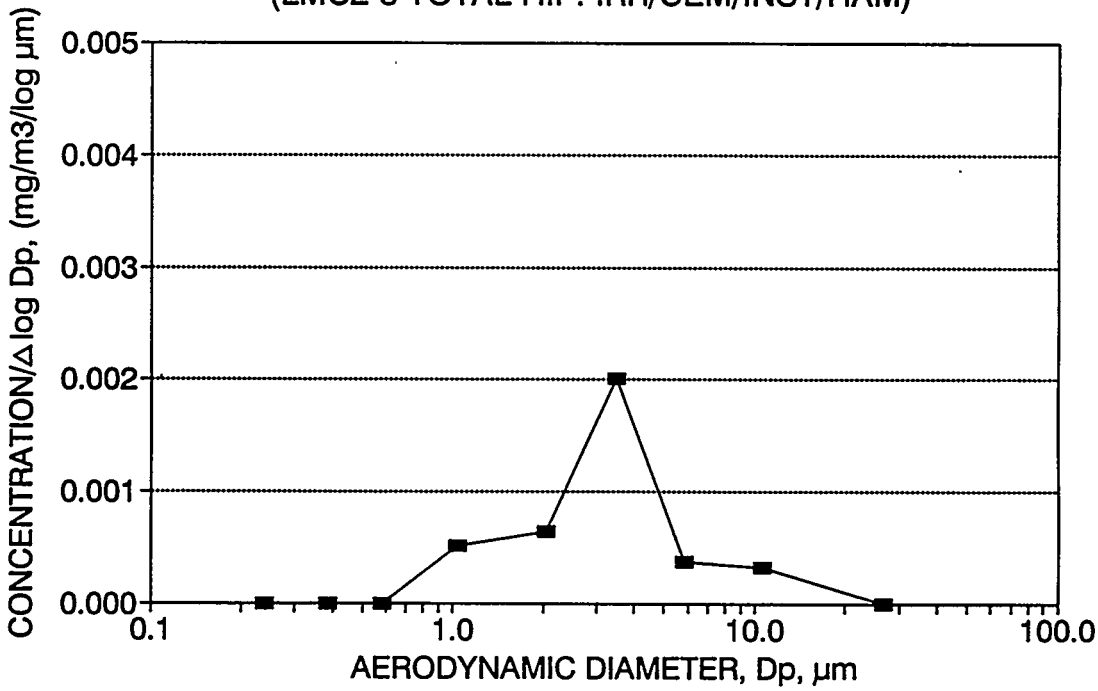
LMC2-5 Total Hip: IRR/CEM/INST/HAM (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00015	0.74	-0.128	0.290	0.001	1.04	0.1724	0.000
1.00	0.00019	1.45	0.162	0.296	0.001	2.04	0.2184	0.172
2.00	0.00035	2.87	0.457	0.174	0.002	3.50	0.4023	0.391
3.00	0.00010	4.28	0.632	0.269	0.000	5.84	0.1149	0.793
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.0920	0.908
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00087						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-5 TOTAL HIP: IRR/CEM/INST/HAM)



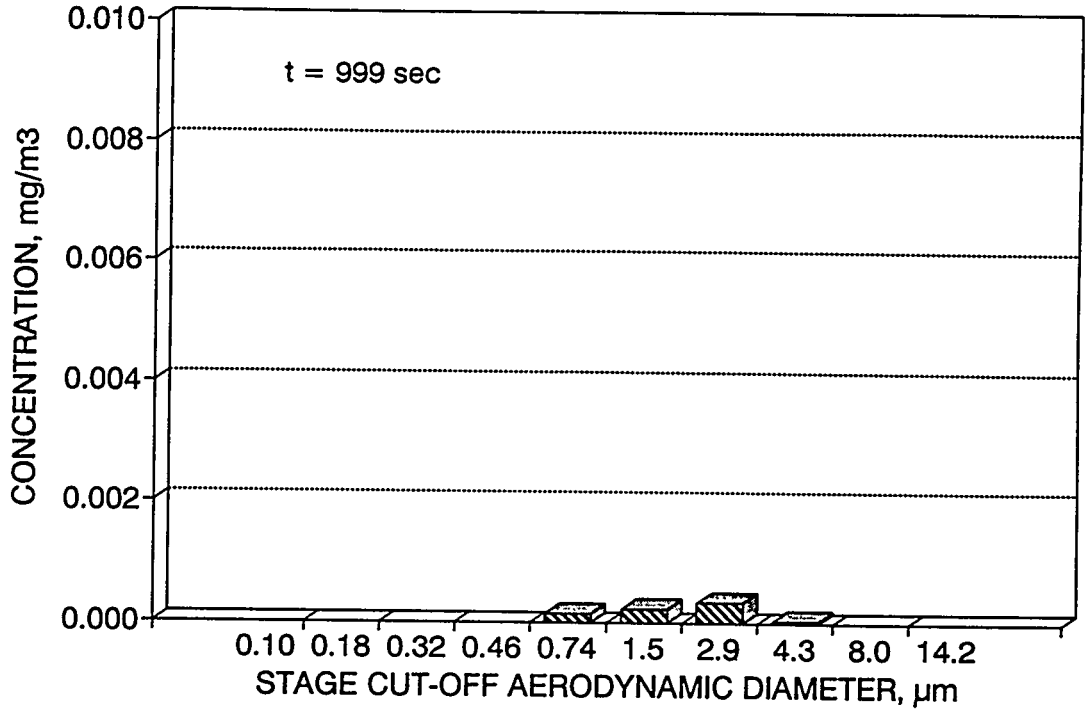
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-5 TOTAL HIP: IRR/CEM/INST/HAM)



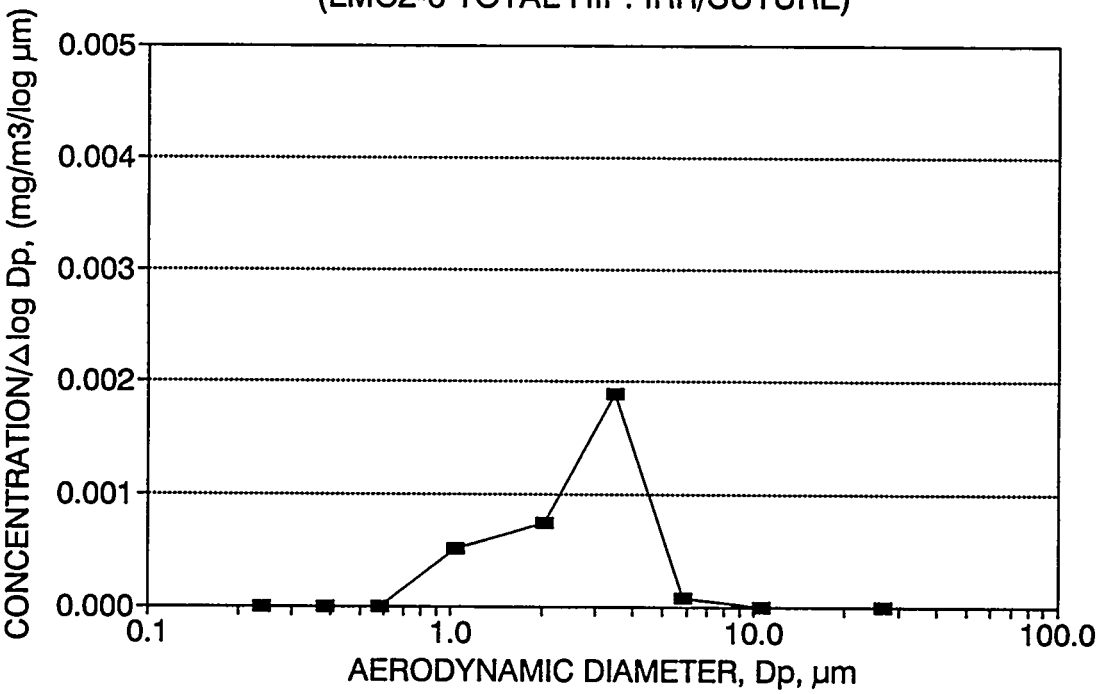
LMC2-6 Total Hip: IRR/SUTURE (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00015	0.74	-0.128	0.290	0.001	1.04	0.2083	0.000
1.00	0.00022	1.45	0.162	0.296	0.001	2.04	0.3056	0.208
2.00	0.00033	2.87	0.457	0.174	0.002	3.50	0.4583	0.514
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.0278	0.972
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00072						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-6 TOTAL HIP: IRR/SUTURE)



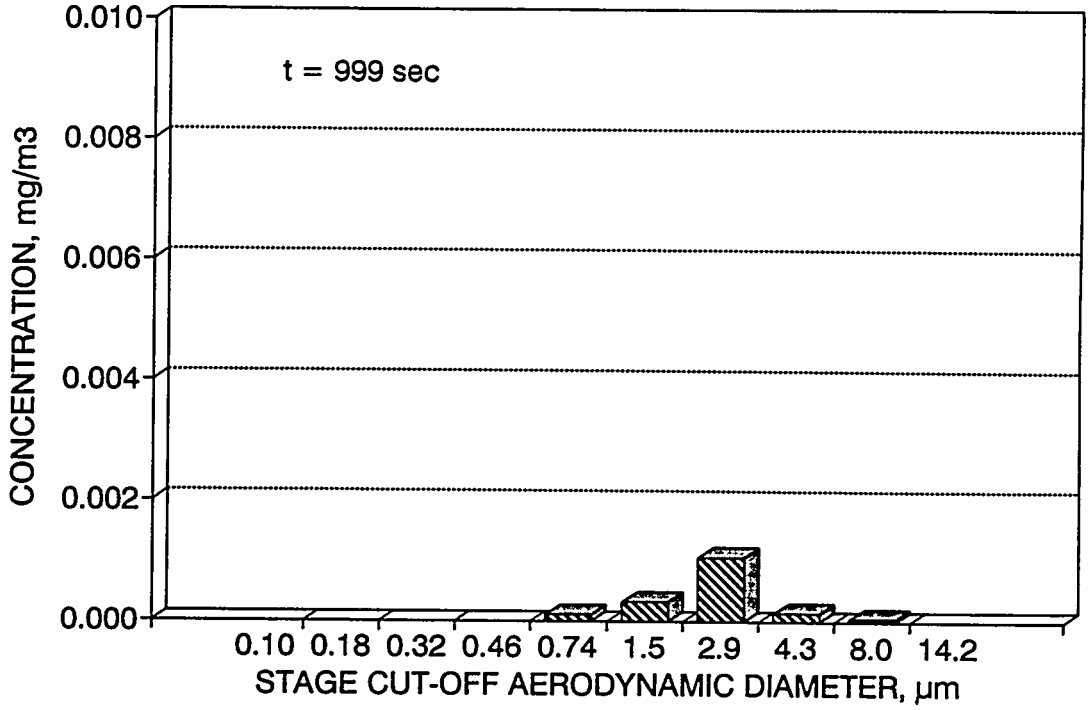
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-6 TOTAL HIP: IRR/SUTURE)



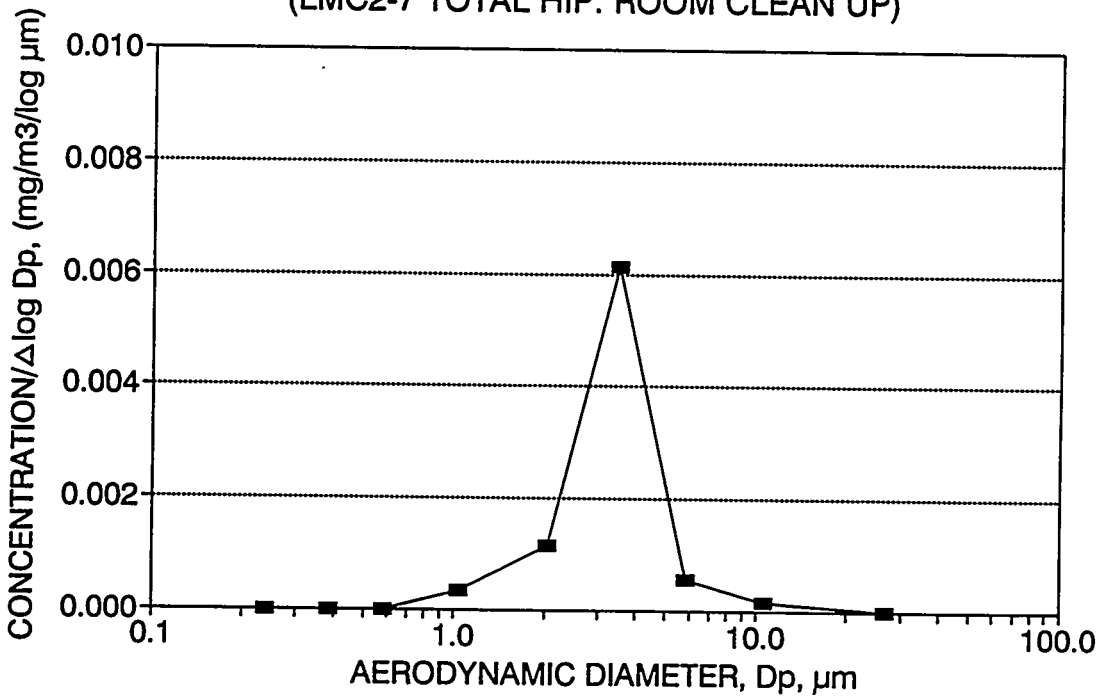
LMC2-7 Total Hip: RC M CLEAN UP (t = 999 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00010	0.74	-0.128	0.290	0.000	1.04	0.0588	0.000
1.00	0.00034	1.45	0.162	0.296	0.001	2.04	0.2000	0.059
2.00	0.00107	2.87	0.457	0.174	0.006	3.50	0.6294	0.259
3.00	0.00015	4.28	0.632	0.269	0.001	5.84	0.0882	0.888
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0235	0.976
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.0017						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-7 TOTAL HIP: ROOM CLEAN UP)



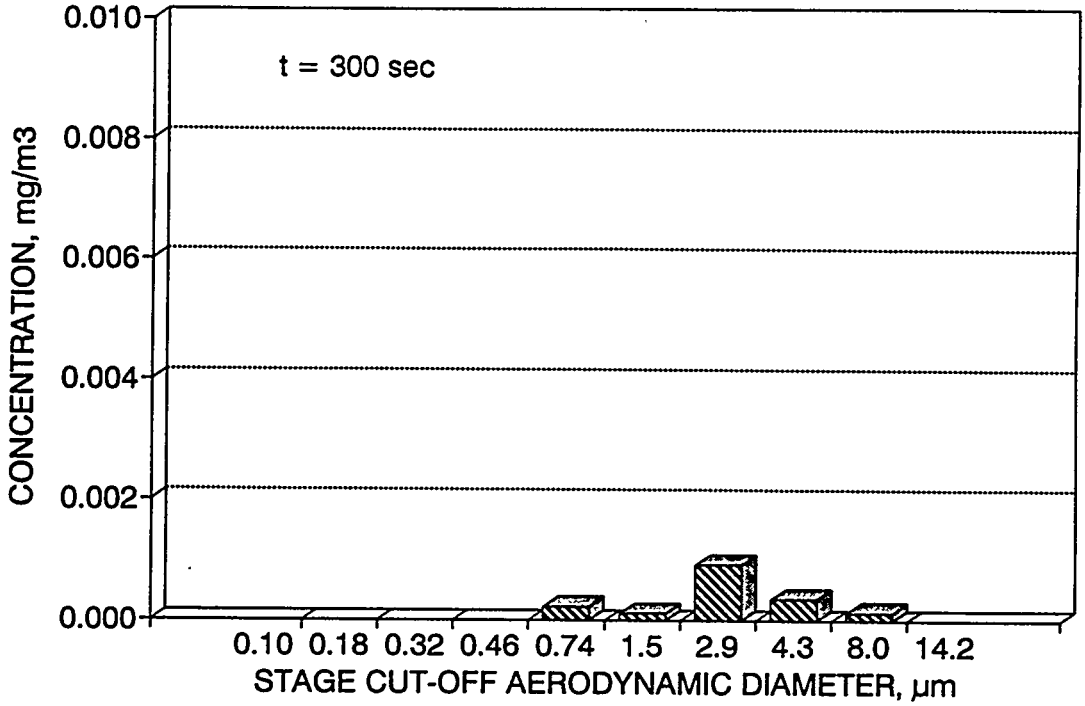
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-7 TOTAL HIP: ROOM CLEAN UP)



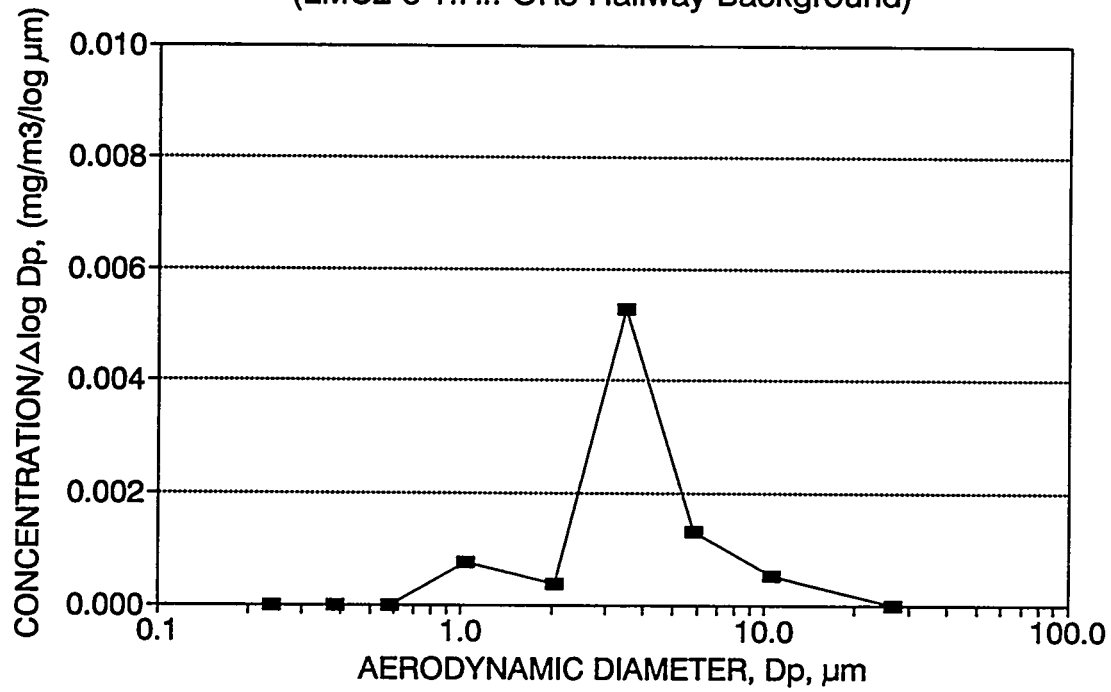
LMC2-8 Total Hip: OR5 Hallway Background (t = 300 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00022	0.74	-0.128	0.290	0.001	1.04	0.1272	0.000
1.00	0.00011	1.45	0.162	0.296	0.000	2.04	0.0636	0.127
2.00	0.00092	2.87	0.457	0.174	0.005	3.50	0.5318	0.191
3.00	0.00035	4.28	0.632	0.269	0.001	5.84	0.2023	0.723
5.60	0.00013	7.96	0.901	0.251	0.001	10.62	0.0751	0.925
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00173						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC2-8 T.H.: OR5 Hallway Background)



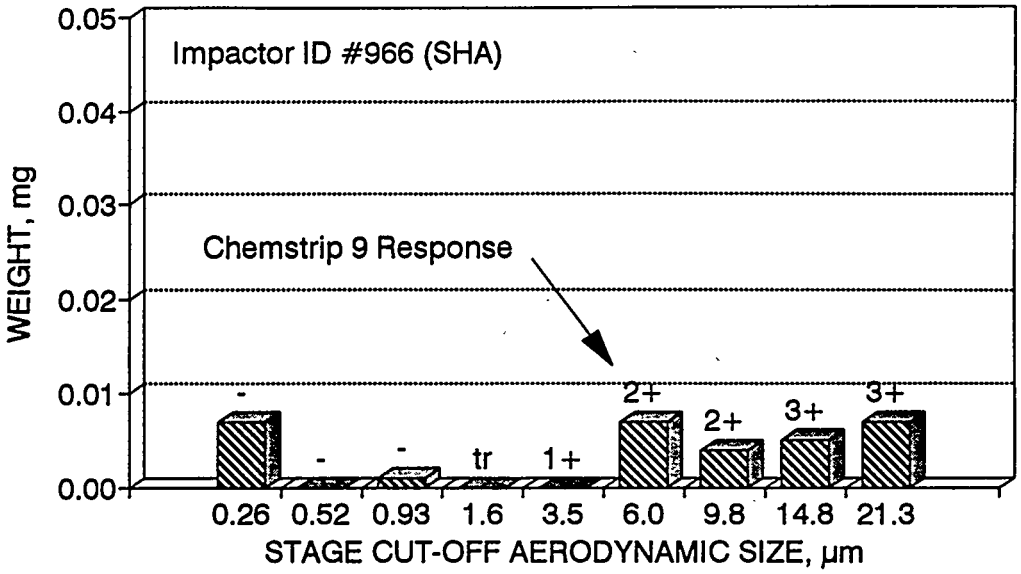
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC2-8 T.H.: OR5 Hallway Background)



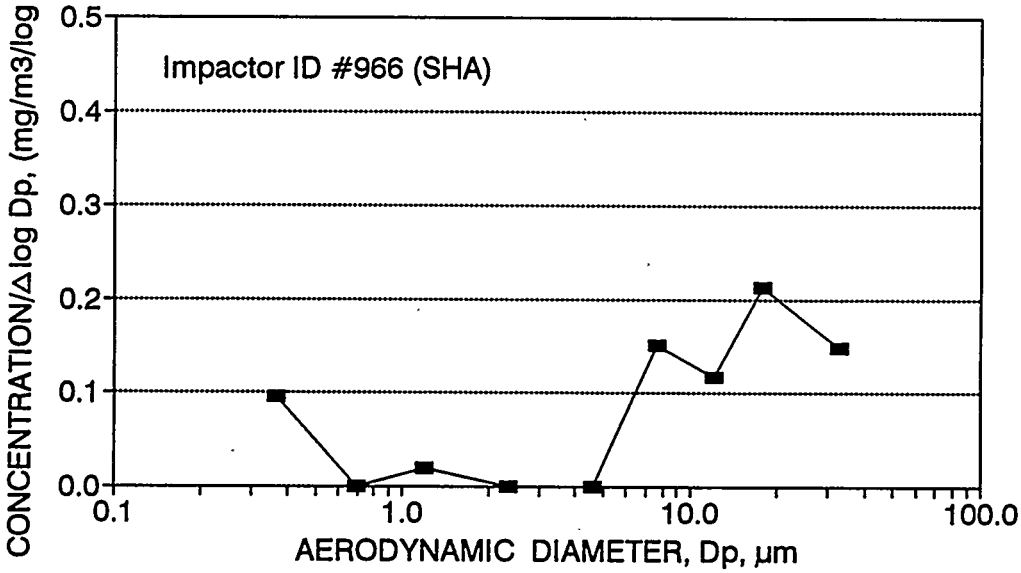
LMC2 Total Hip: Marple Personal Impactor Data (ID No. 966: SHA)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.007	1	0.244	0.029	-0.585	0.301	0.095	0.37	0.164	0.000	-
8	0.52	0.000	0.99	0.244	0.000	-0.284	0.252	0.000	0.70	0.000	0.164	-
7	0.93	0.001	0.97	0.244	0.004	-0.032	0.222	0.019	1.20	0.024	0.164	-
6	1.55	0.000	0.96	0.244	0.000	0.190	0.354	0.000	2.33	0.000	0.188	tr
5	3.50	0.000	0.95	0.244	0.000	0.544	0.234	0.000	4.58	0.000	0.188	1+
4	6.00	0.007	0.89	0.244	0.032	0.778	0.213	0.151	7.67	0.184	0.188	2+
3	9.80	0.004	0.78	0.244	0.021	0.991	0.179	0.117	12.04	0.120	0.372	2+
2	14.80	0.005	0.61	0.244	0.034	1.170	0.158	0.212	17.75	0.192	0.493	3+
1	21.30	0.007	0.52	0.244	0.055	1.328	0.371	0.149	32.63	0.315	0.685	3+
	50.00					1.699						
Sum		0.031			0.175					1.000		

Marple Personal Impactor Data
LMC2: Total Hip Replacement



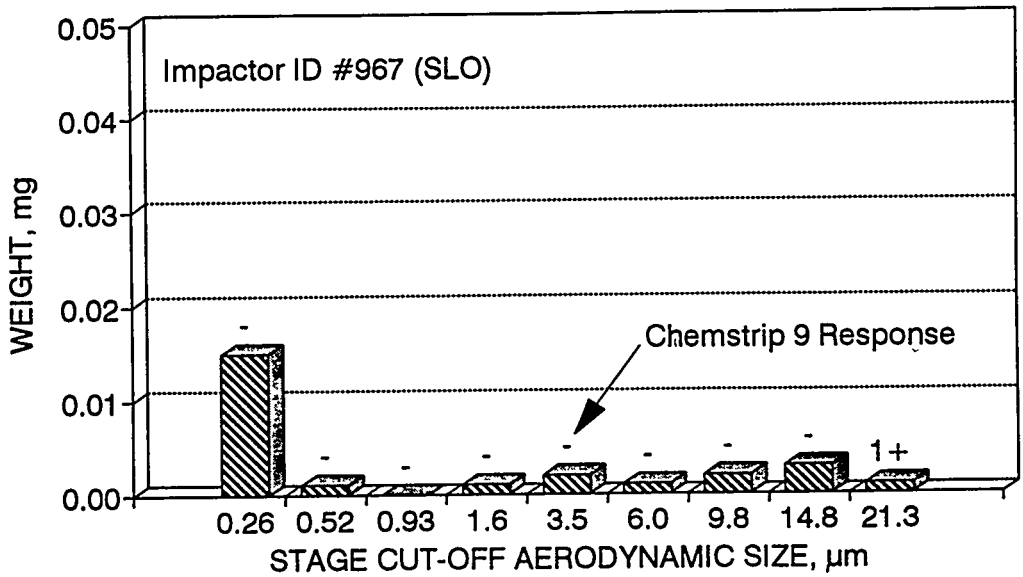
Size distribution by Marple Impactor
LMC2: Total Hip Replacement



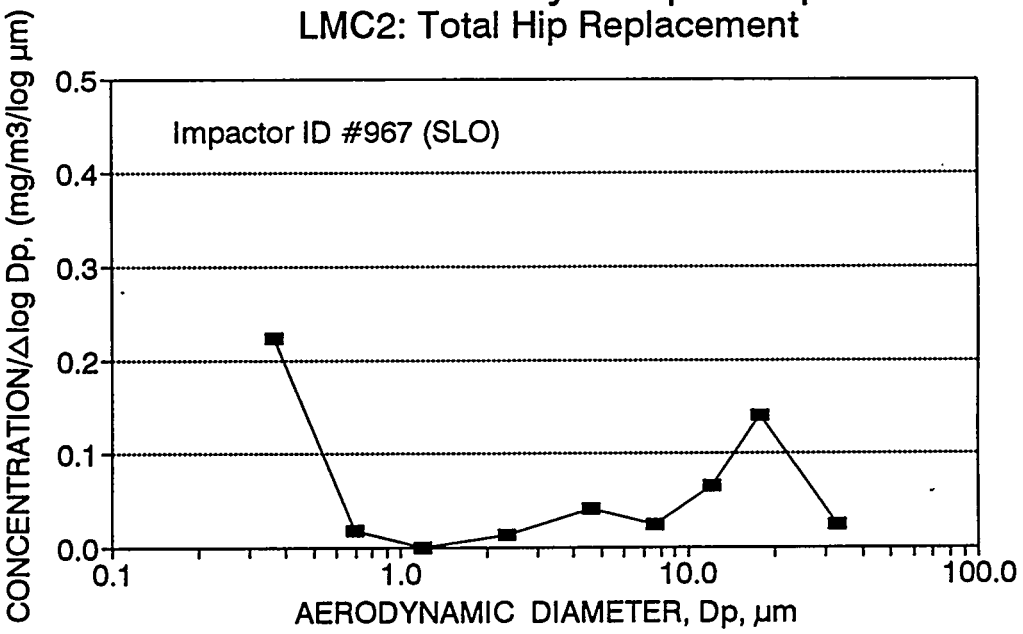
LMC2 Total Hip: Marple Personal Impactor Data (ID No. 967: SLO)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.015	1	0.222	0.068	-0.585	0.301	0.224	0.37	0.505	0.000	-
8	0.52	0.001	0.99	0.222	0.005	-0.284	0.252	0.018	0.70	0.034	0.505	-
7	0.93	0.000	0.97	0.222	0.000	-0.032	0.222	0.000	1.20	0.000	0.539	-
6	1.55	0.001	0.96	0.222	0.005	0.190	0.354	0.013	2.33	0.035	0.539	-
5	3.50	0.002	0.95	0.222	0.009	0.544	0.234	0.041	4.58	0.071	0.574	-
4	6.00	0.001	0.89	0.222	0.005	0.778	0.213	0.024	7.67	0.038	0.645	-
3	9.80	0.002	0.78	0.222	0.012	0.991	0.179	0.065	12.04	0.086	0.683	-
2	14.80	0.003	0.61	0.222	0.022	1.170	0.158	0.140	17.75	0.166	0.770	-
1	21.30	0.001	0.52	0.222	0.009	1.328	0.371	0.023	32.63	0.065	0.935	1+
	50.00					1.699						
Sum		0.026			0.134					1.000		

Marple Personal Impactor Data
LMC2: Total Hip Replacement



Size distribution by Marple Impactor
LMC2: Total Hip Replacement

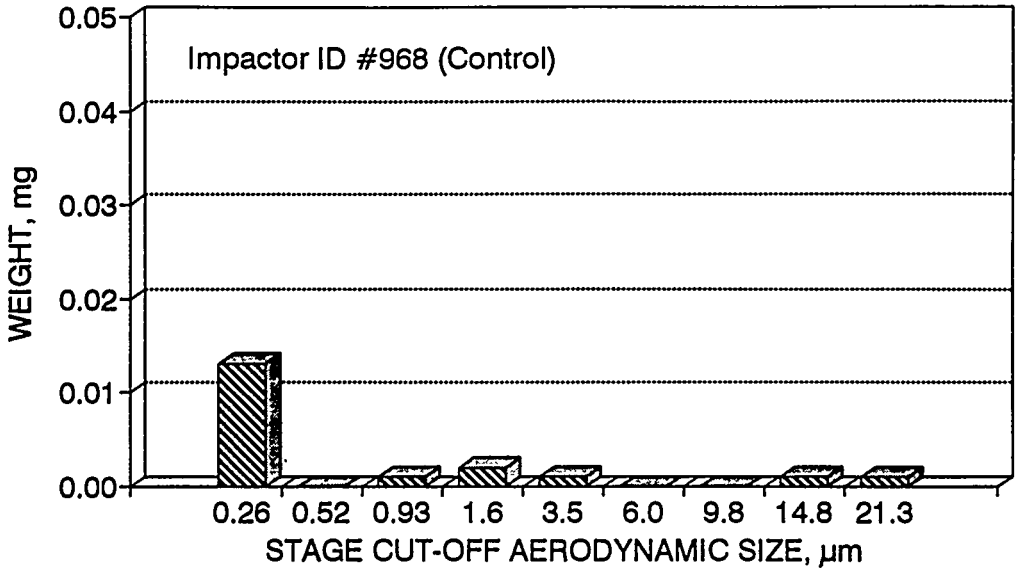


LMC2 Total Hip: Marple Personal Impactor Data (ID No. 968: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.013	1	0.24	0.054	-0.585	0.301	0.180	0.37	0.627	0.000
8	0.52	0.000	0.99	0.24	0.000	-0.284	0.252	0.000	0.70	0.000	0.627
7	0.93	0.001	0.97	0.24	0.004	-0.032	0.222	0.019	1.20	0.050	0.627
6	1.55	0.002	0.96	0.24	0.009	0.190	0.354	0.025	2.33	0.101	0.677
5	3.50	0.001	0.95	0.24	0.004	0.544	0.234	0.019	4.58	0.051	0.777
4	6.00	0.000	0.89	0.24	0.000	0.778	0.213	0.000	7.67	0.000	0.828
3	9.80	0.000	0.78	0.24	0.000	0.991	0.179	0.000	12.04	0.000	0.828
2	14.80	0.001	0.61	0.24	0.007	1.170	0.158	0.043	17.75	0.079	0.828
1	21.30	0.001	0.52	0.24	0.008	1.328	0.371	0.022	32.63	0.093	0.907
	50.00					1.699					
Sum		0.019			0.086					1.000	

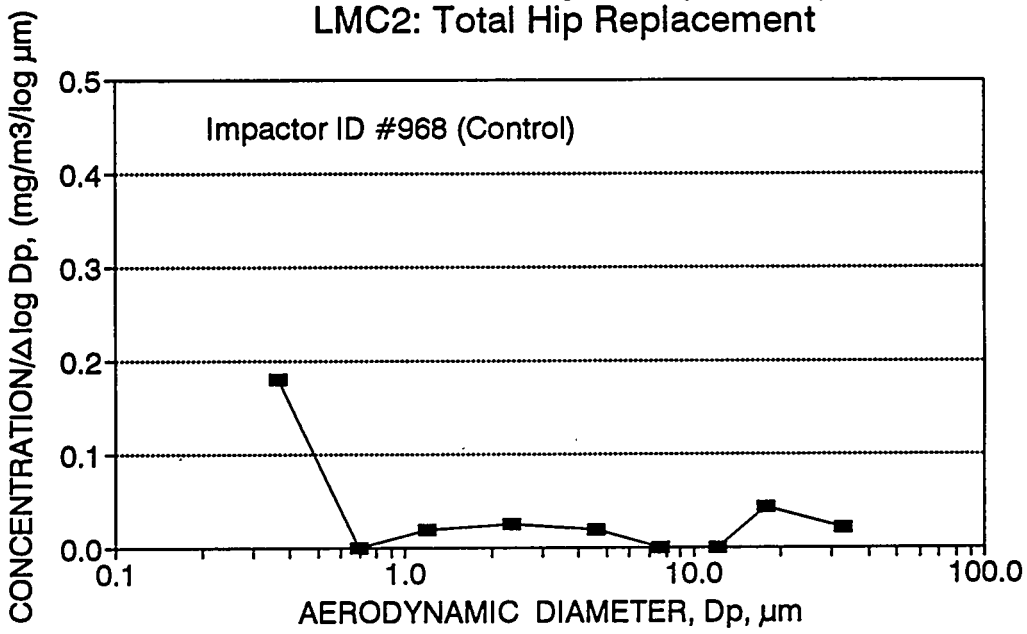
Marple Personal Impactor Data

LMC2: Controlled (not used)



Size distribution by Marple Impactor

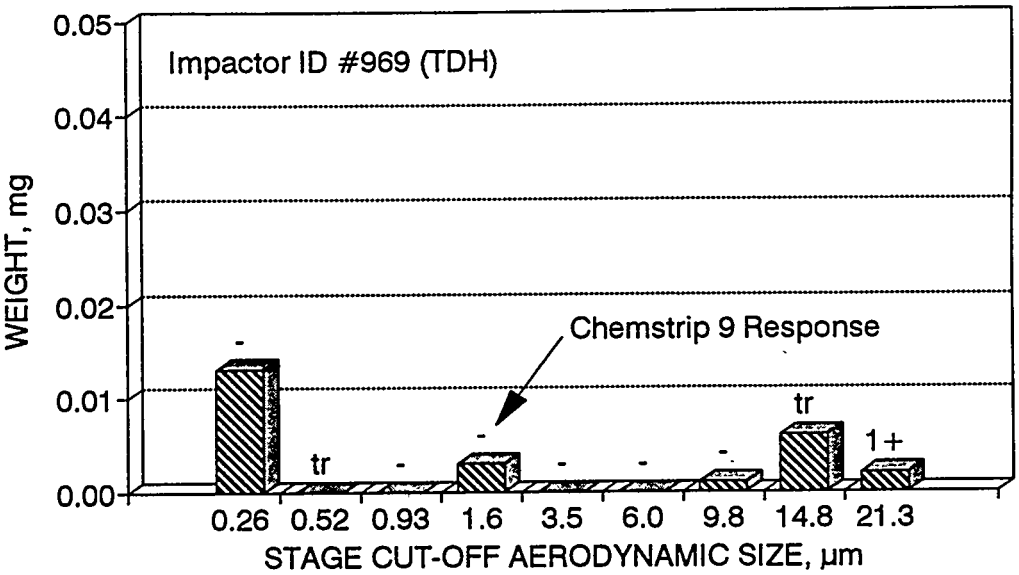
LMC2: Total Hip Replacement



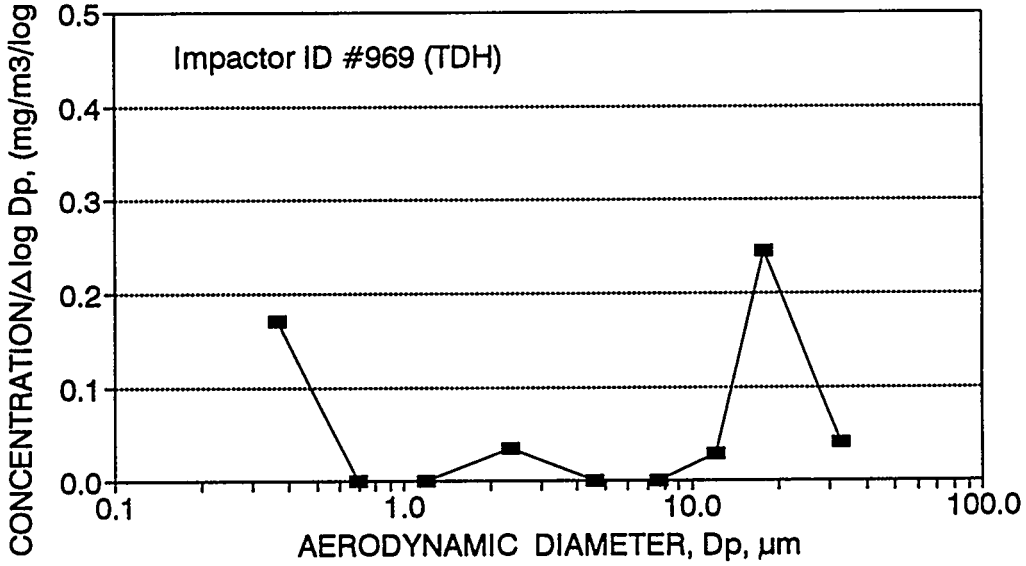
LMC2 Total Hip: Marple Personal Impactor Data (ID No. 969:TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.013	1	0.254	0.051	-0.585	0.301	0.170	0.37	0.418	0.000	-
8	0.52	0.000	0.99	0.254	0.000	-0.284	0.252	0.000	0.70	0.000	0.418	tr
7	0.93	0.000	0.97	0.254	0.000	-0.032	0.222	0.000	1.20	0.000	0.418	-
6	1.55	0.003	0.96	0.254	0.012	0.190	0.354	0.035	2.33	0.101	0.418	-
5	3.50	0.000	0.95	0.254	0.000	0.544	0.234	0.000	4.58	0.000	0.519	-
4	6.00	0.000	0.89	0.254	0.000	0.778	0.213	0.000	7.67	0.000	0.519	-
3	9.80	0.001	0.78	0.254	0.005	0.991	0.179	0.028	12.04	0.041	0.519	-
2	14.80	0.006	0.61	0.254	0.039	1.170	0.158	0.245	17.75	0.316	0.560	tr
1	21.30	0.002	0.52	0.254	0.015	1.328	0.371	0.041	32.63	0.124	0.876	1+
	50.00					1.699						
Sum		0.025			0.122					1.000		

Marple Personal Impactor Data
LMC2: Total Hip Replacement



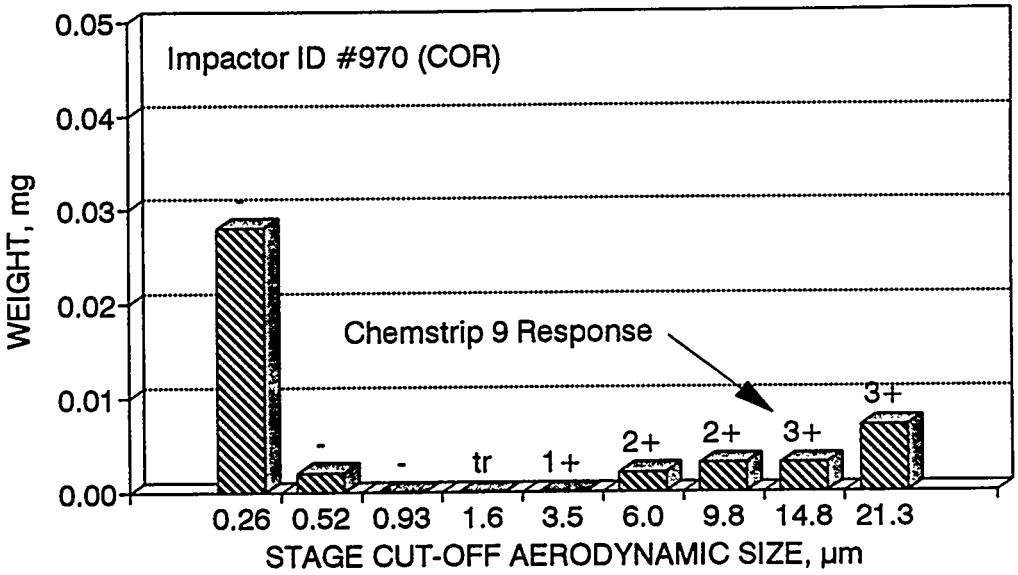
Size distribution by Marple Impactor
LMC2: Total Hip Replacement



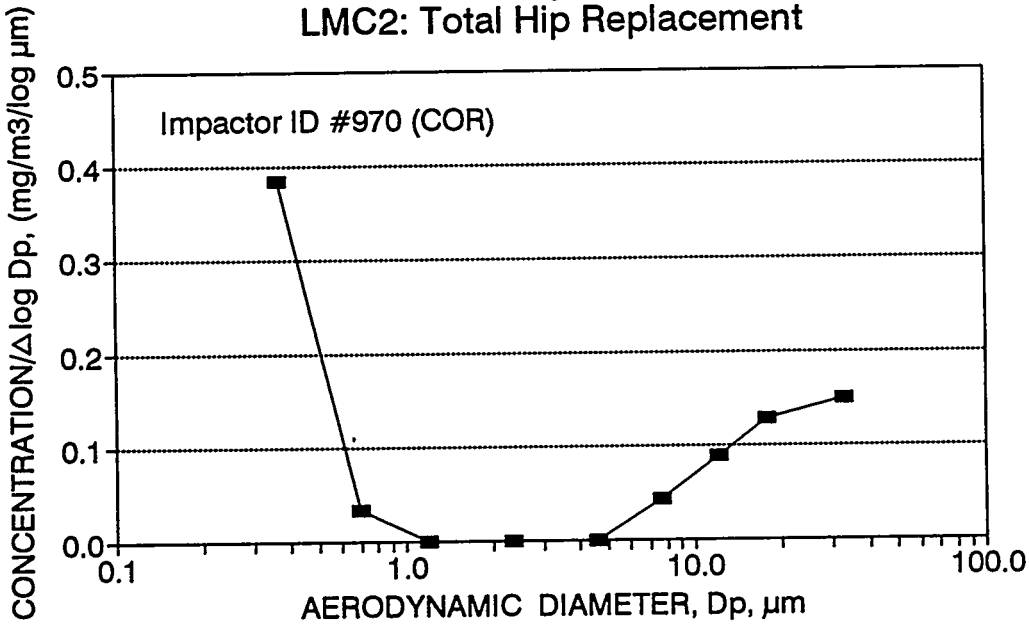
LMC2 Total Hip: Marple Personal Impactor Data (ID No. 970: COR)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.028	1	0.242	0.116	-0.585	0.301	0.384	0.37	0.514	0.000	-
8	0.52	0.002	0.99	0.242	0.008	-0.284	0.252	0.033	0.70	0.037	0.514	-
7	0.93	0.000	0.97	0.242	0.000	-0.032	0.222	0.000	1.20	0.000	0.551	-
6	1.55	0.000	0.96	0.242	0.000	0.190	0.354	0.000	2.33	0.000	0.551	tr
5	3.50	0.000	0.95	0.242	0.000	0.544	0.234	0.000	4.58	0.000	0.551	1+
4	6.00	0.002	0.89	0.242	0.009	0.778	0.213	0.044	7.67	0.041	0.551	2+
3	9.80	0.003	0.78	0.242	0.016	0.991	0.179	0.089	12.04	0.071	0.592	2+
2	14.80	0.003	0.61	0.242	0.020	1.170	0.158	0.129	17.75	0.090	0.663	3+
1	21.30	0.007	0.52	0.242	0.056	1.328	0.371	0.150	32.63	0.247	0.753	3+
	50.00					1.699						
Sum		0.045			0.225					1.000		

Marple Personal Impactor Data
LMC2: Total Hip Replacement



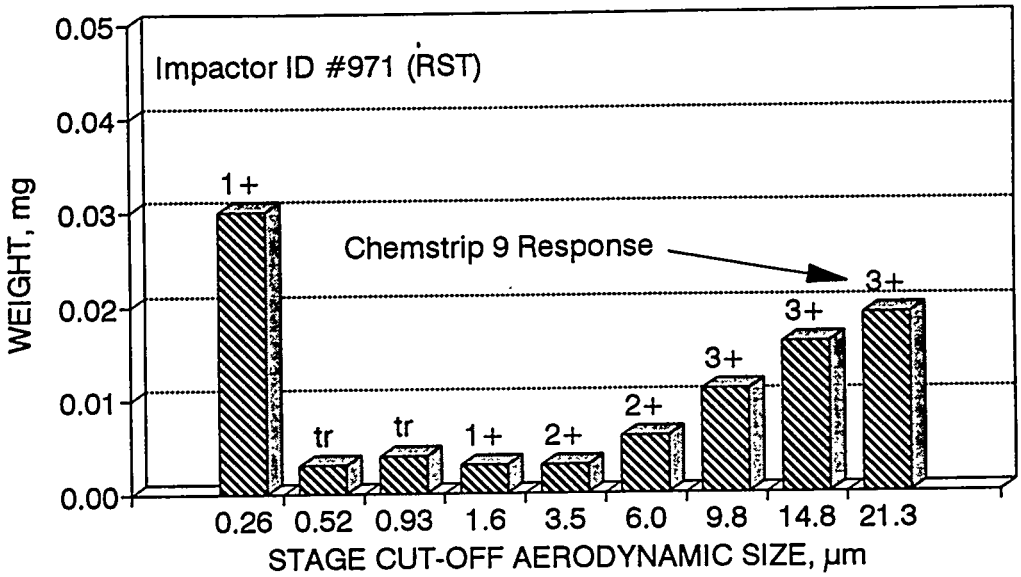
Size distribution by Marple Impactor
LMC2: Total Hip Replacement



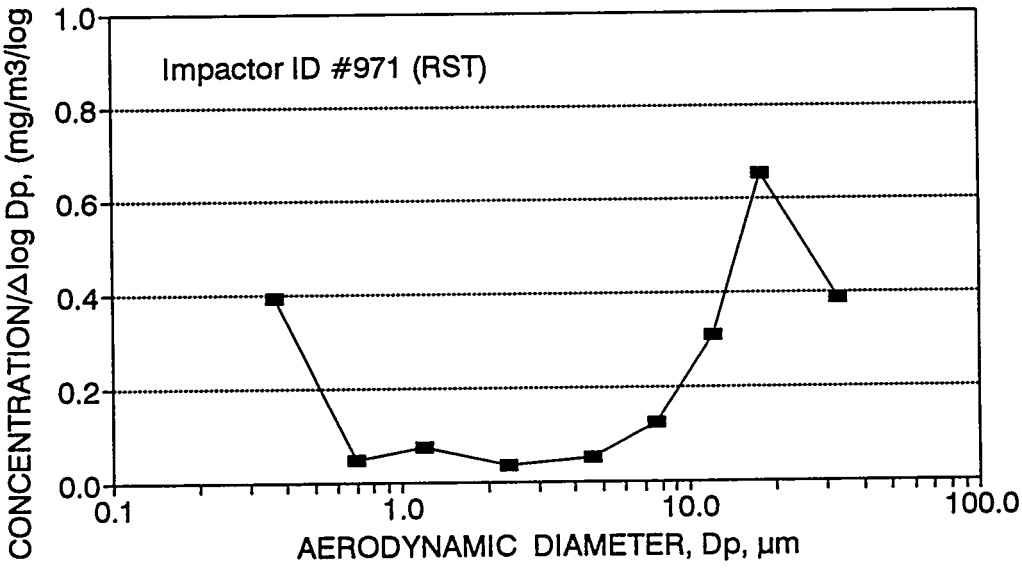
LMC2 Total Hip: Marple Personal Impactor Data (ID No. 971: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.030	1	0.254	0.118	-0.585	0.301	0.392	0.37	0.236	0.000	1+
8	0.52	0.003	0.99	0.254	0.012	-0.284	0.252	0.047	0.70	0.024	0.236	tr
7	0.93	0.004	0.97	0.254	0.016	-0.032	0.222	0.073	1.20	0.032	0.260	tr
6	1.55	0.003	0.96	0.254	0.012	0.190	0.354	0.035	2.33	0.025	0.292	1+
5	3.50	0.003	0.95	0.254	0.012	0.544	0.234	0.053	4.58	0.025	0.317	2+
4	6.00	0.006	0.89	0.254	0.027	0.778	0.213	0.125	7.67	0.053	0.342	2+
3	9.80	0.011	0.78	0.254	0.056	0.991	0.179	0.310	12.04	0.111	0.395	3+
2	14.80	0.016	0.61	0.254	0.103	1.170	0.158	0.653	17.75	0.206	0.506	3+
1	21.30	0.019	0.52	0.254	0.144	1.328	0.371	0.388	32.63	0.288	0.712	3+
	50.00					1.699						
Sum		0.095			0.500					1.000		

Marple Personal Impactor Data
LMC2: Total Hip Replacement



Size distribution by Marple Impactor
LMC2: Total Hip Replacement



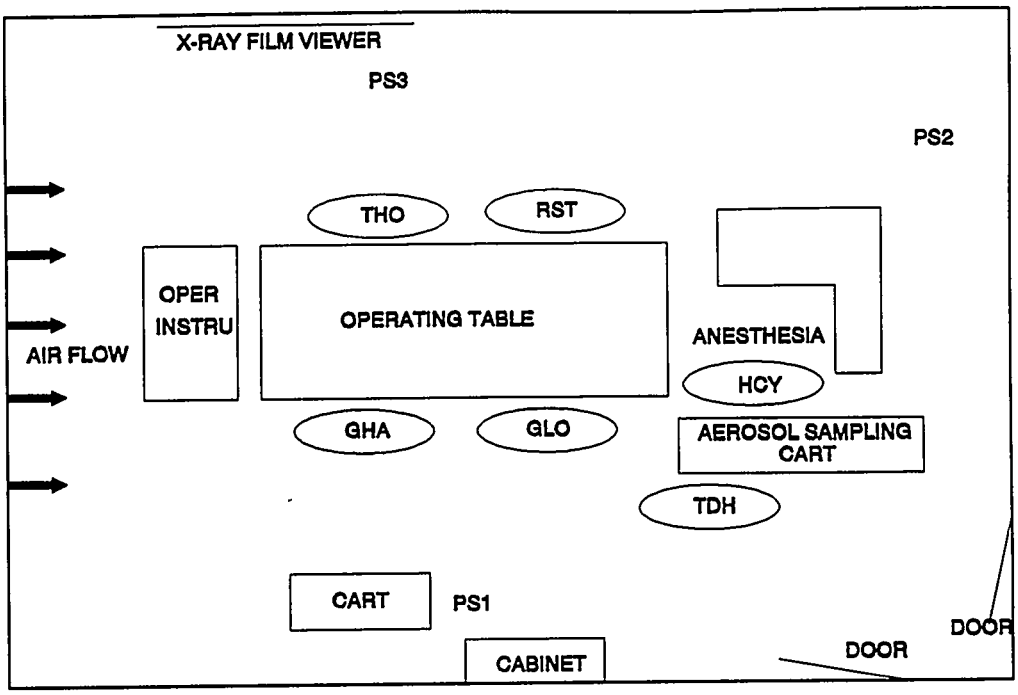
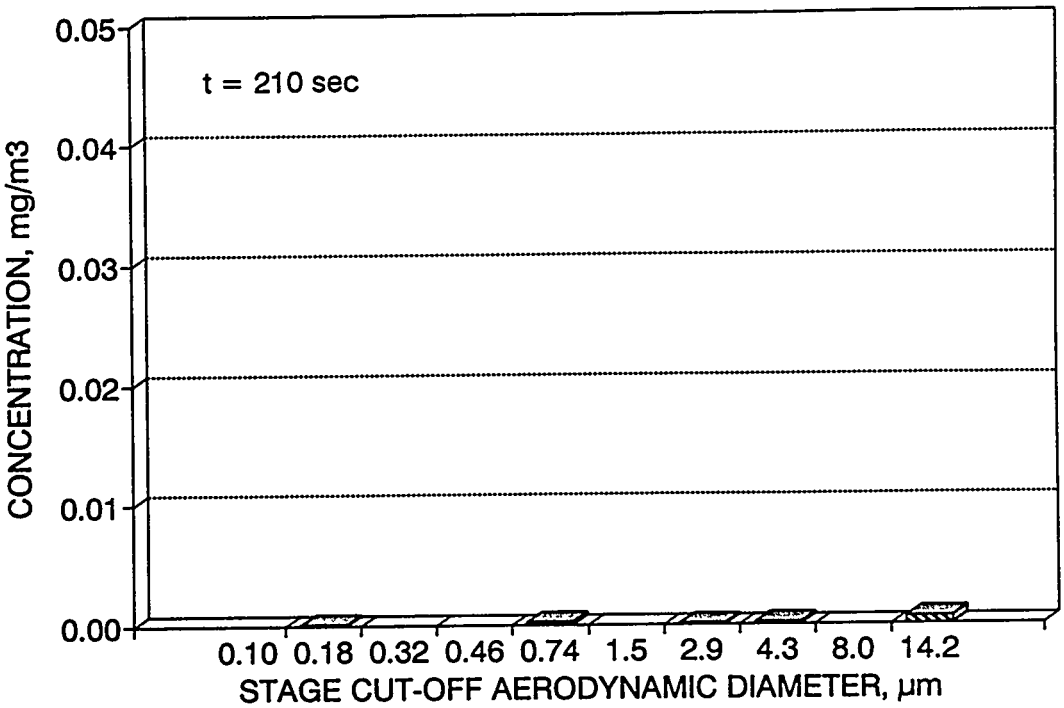


Figure C.3 Initial locations of personnel and area filters during LMC #3 measurement (back fusion).

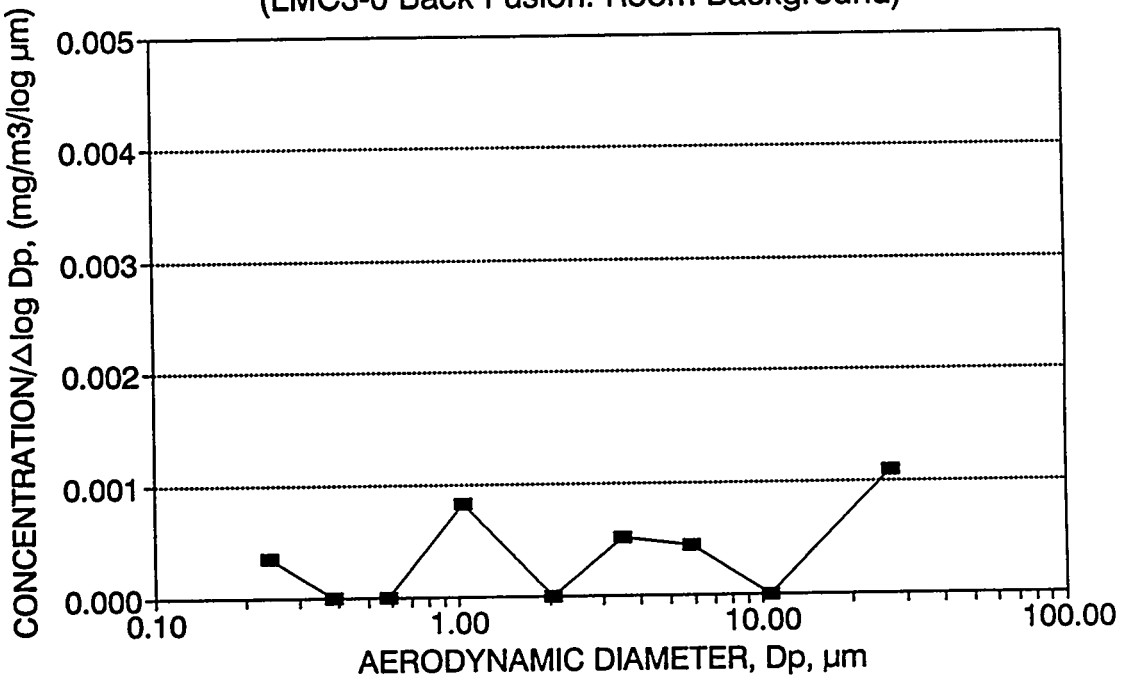
LMC3-0 Back Fusion: OR5 Room Background (t = 210 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00009	0.18	-0.749	0.257	0.000	0.24	0.0789	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.079
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.079
0.50	0.00024	0.74	-0.128	0.290	0.001	1.04	0.2105	0.079
1.00		1.45	0.162	0.296	0.000	2.04	0.0000	0.289
2.00	0.00009	2.87	0.457	0.174	0.001	3.50	0.0789	0.289
3.00	0.00012	4.28	0.632	0.269	0.000	5.84	0.1053	0.368
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	0.474
10.00	0.00060	14.18	1.152	0.547	0.001	26.63	0.5263	0.474
		50.00	1.699					1.000
Sum	0.00114						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-0 Back Fusion: Room Background)



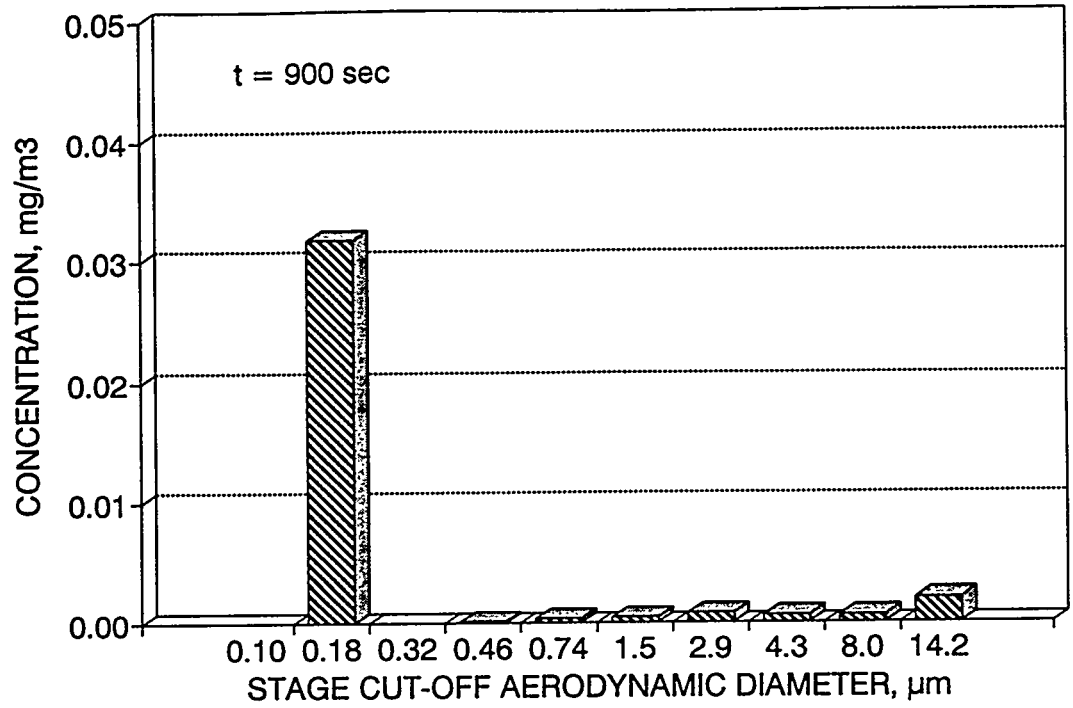
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-0 Back Fusion: Room Background)



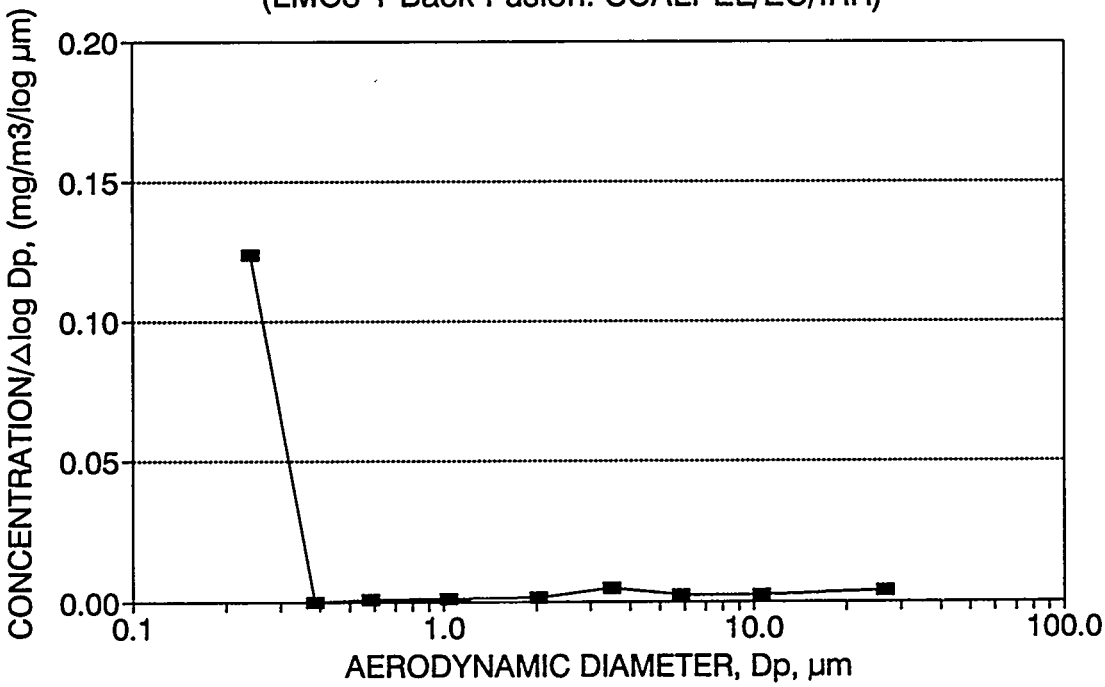
LMC3-1 Back Fusion: SCALPEL/EC/IRR (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.03187	0.18	-0.749	0.257	0.124	0.24	0.8660	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.866
0.30	0.00009	0.46	-0.335	0.206	0.000	0.59	0.0024	0.866
0.50	0.00035	0.74	-0.128	0.290	0.001	1.04	0.0095	0.868
1.00	0.00044	1.45	0.162	0.296	0.001	2.04	0.0120	0.878
2.00	0.00083	2.87	0.457	0.174	0.005	3.50	0.0226	0.890
3.00	0.00064	4.28	0.632	0.269	0.002	5.84	0.0174	0.913
5.60	0.00058	7.96	0.901	0.251	0.002	10.62	0.0158	0.930
10.00	0.00200	14.18	1.152	0.547	0.004	26.63	0.0543	0.946
		50.00	1.699					1.000
Sum	0.0368						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-1 Back Fusion: SCALPEL/EC/IRR)



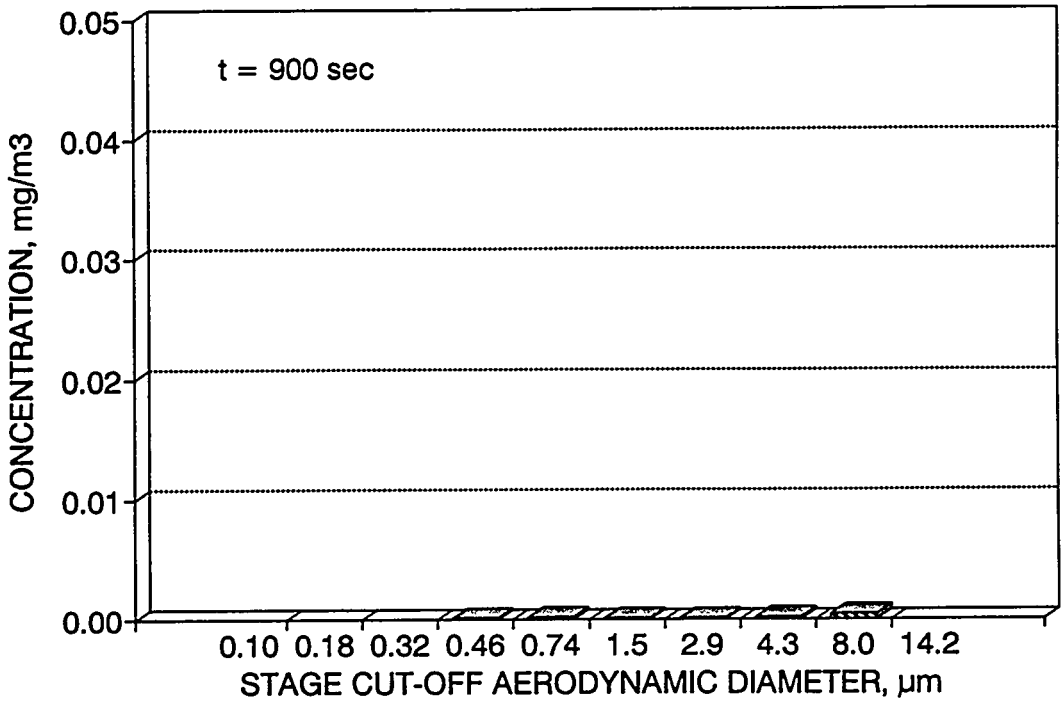
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-1 Back Fusion: SCALPEL/EC/IRR)



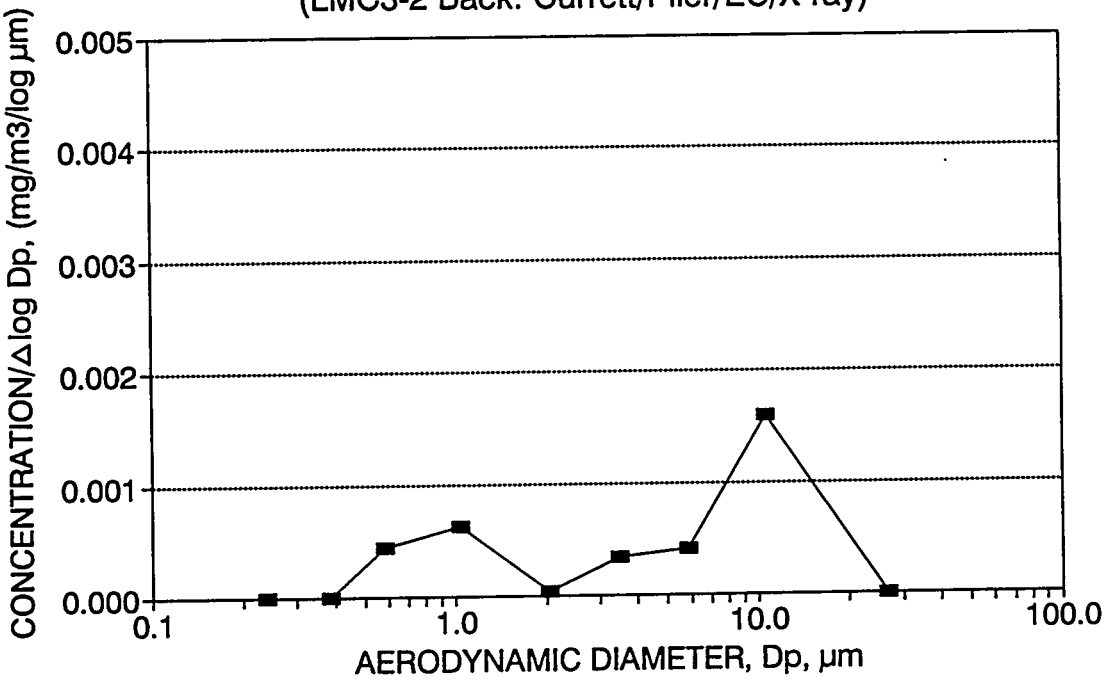
LMC3-2 Back Fusion: Currett/Plier/EC/X-ray (t = 900 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00009	0.46	-0.335	0.206	0.000	0.59	0.1059	0.000
0.50	0.00018	0.74	-0.128	0.290	0.001	1.04	0.2118	0.106
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.0118	0.318
2.00	0.00006	2.87	0.457	0.174	0.000	3.50	0.0706	0.329
3.00	0.00011	4.28	0.632	0.269	0.000	5.84	0.1294	0.400
5.60	0.00040	7.96	0.901	0.251	0.002	10.62	0.4706	0.529
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00085						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-2 Back: Currett/Plier/EC/X-ray)



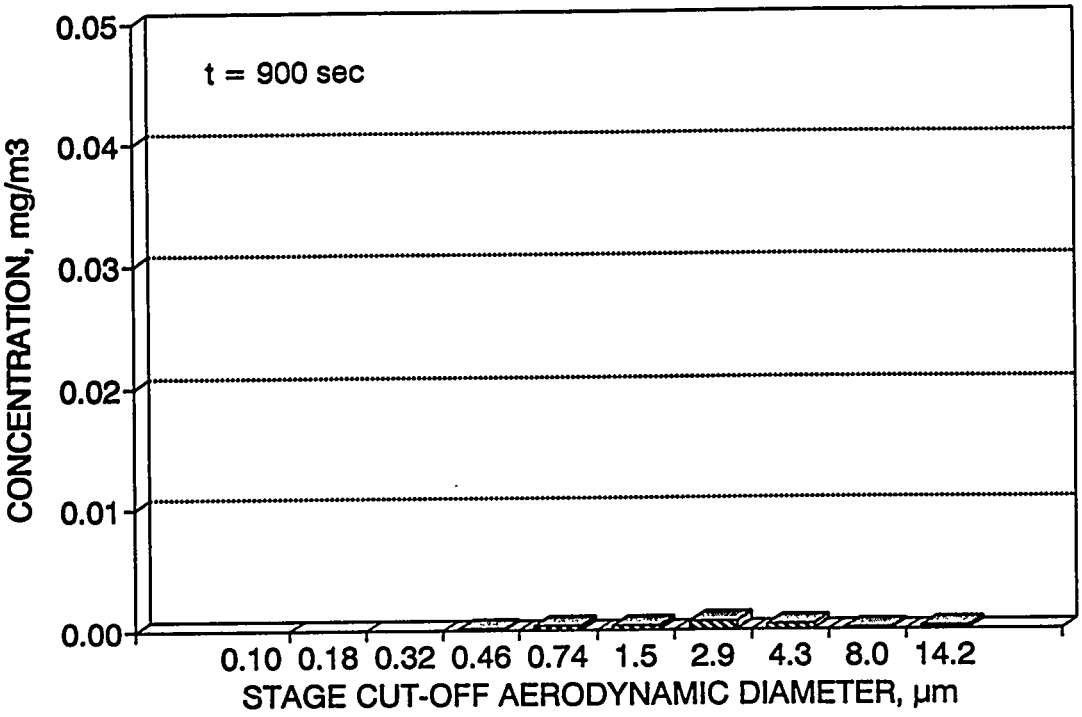
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-2 Back: Currett/Plier/EC/X-ray)



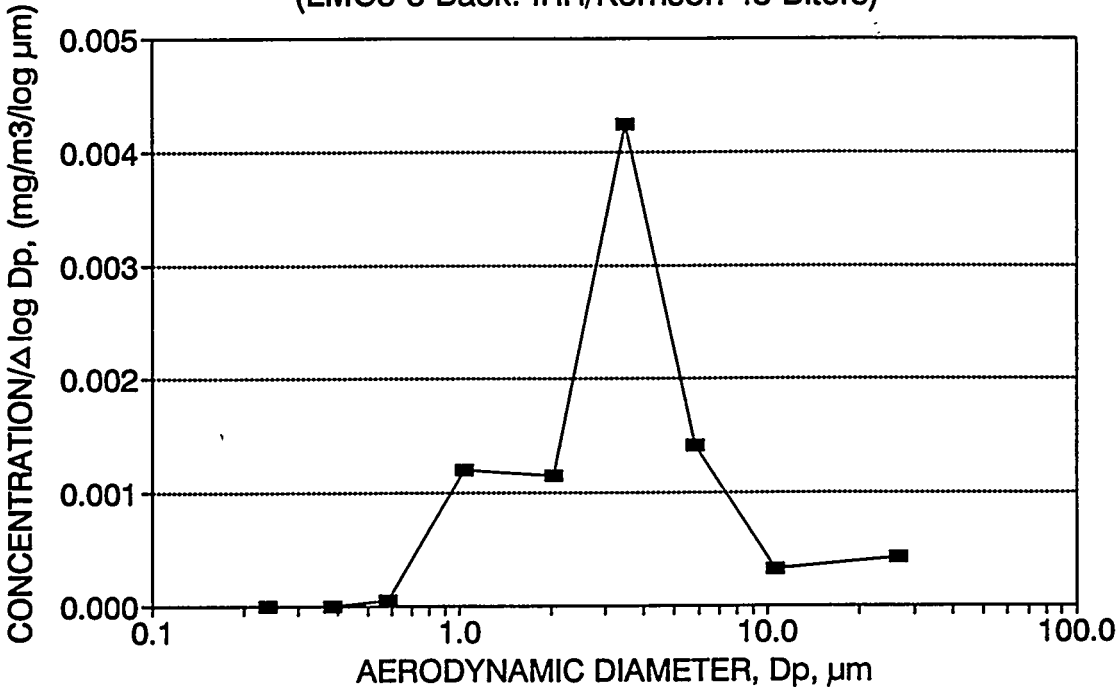
LMC3-3 Back Fusion: IRR/Kerrison 45 Biters (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0047	0.000
0.50	0.00035	0.74	-0.128	0.290	0.001	1.04	0.1643	0.005
1.00	0.00034	1.45	0.162	0.296	0.001	2.04	0.1596	0.169
2.00	0.00074	2.87	0.457	0.174	0.004	3.50	0.3474	0.329
3.00	0.00038	4.28	0.632	0.269	0.001	5.84	0.1784	0.676
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.0376	0.854
10.00	0.00023	14.18	1.152	0.547	0.000	26.63	0.1080	0.892
		50.00	1.699					1.000
Sum	0.00213						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-3 Back: IRR/Kerrison 45 Biters)



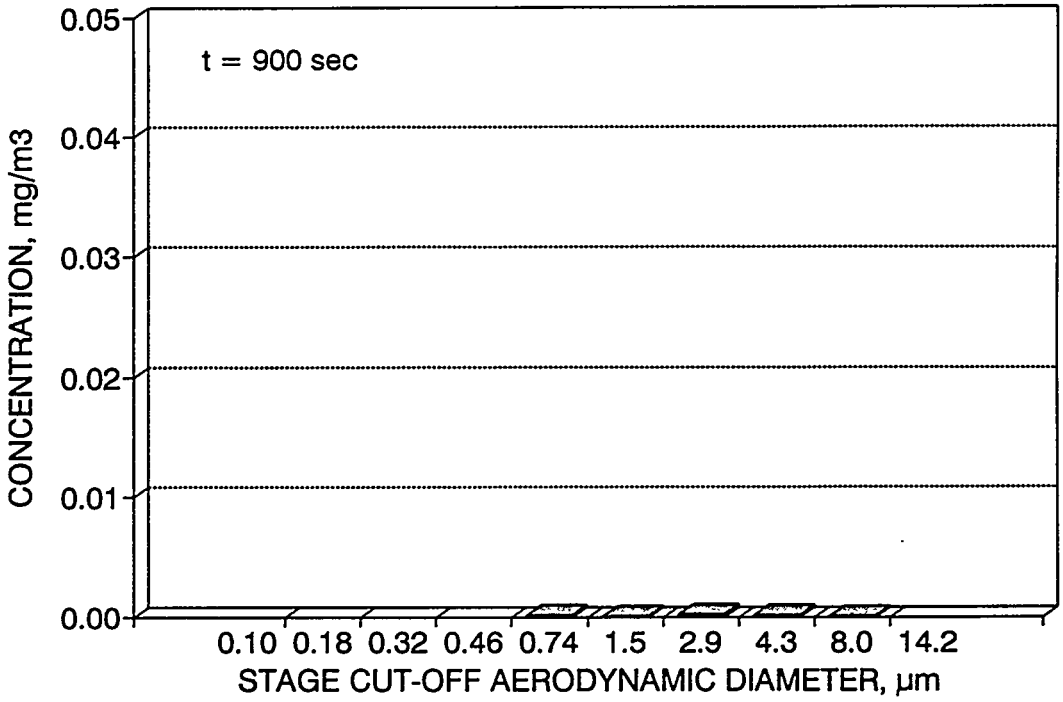
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-3 Back: IRR/Kerrison 45 Biters)



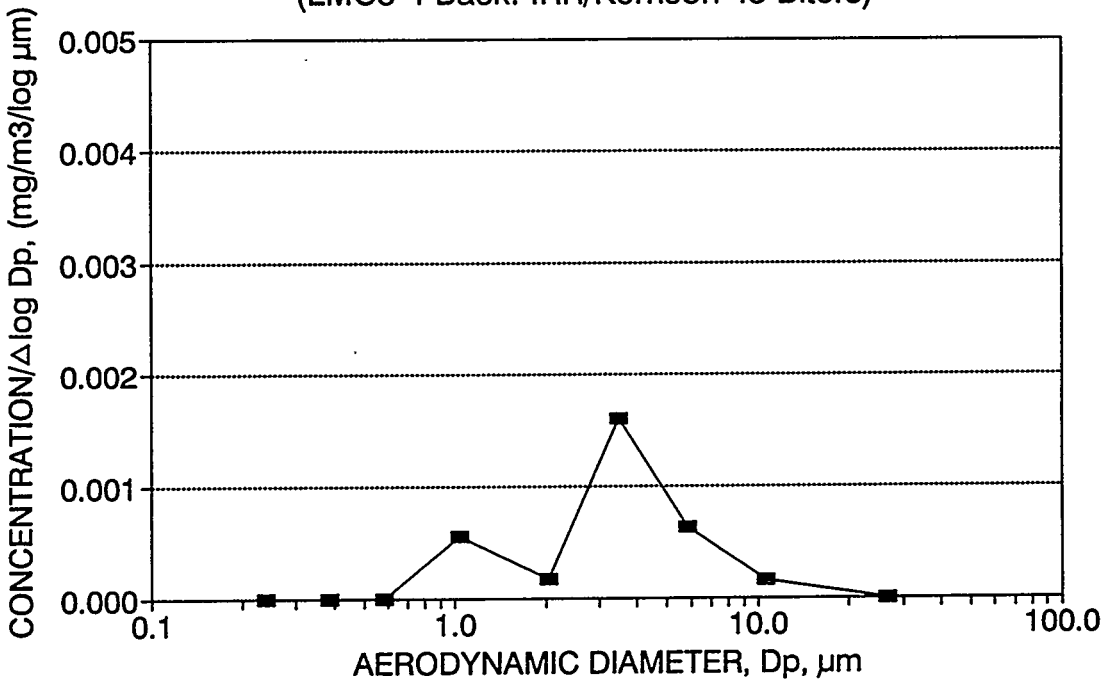
LMC3-4 Back Fusion: IRR/Derrison 45 Biters (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00016	0.74	-0.128	0.290	0.001	1.04	0.2286	0.000
1.00	0.00005	1.45	0.162	0.296	0.000	2.04	0.0714	0.229
2.00	0.00028	2.87	0.457	0.174	0.002	3.50	0.4000	0.300
3.00	0.00017	4.28	0.632	0.269	0.001	5.84	0.2429	0.700
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0571	0.943
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.0007						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-4 Back: IRR/Kerrison 45 Biters)



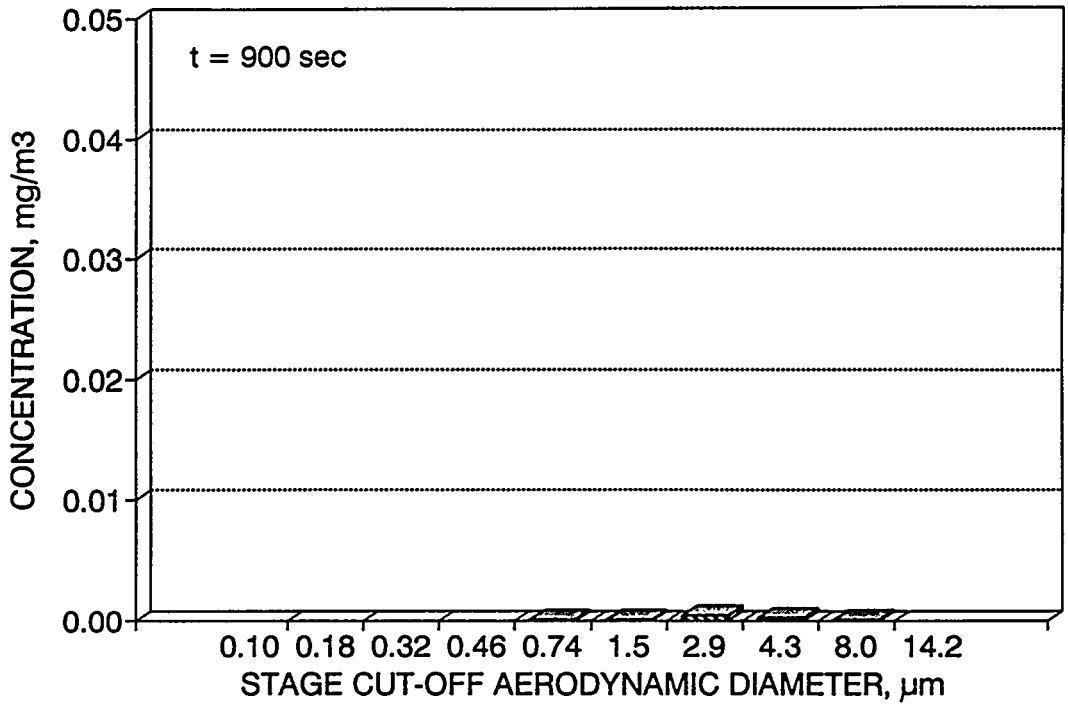
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-4 Back: IRR/Kerrison 45 Biters)



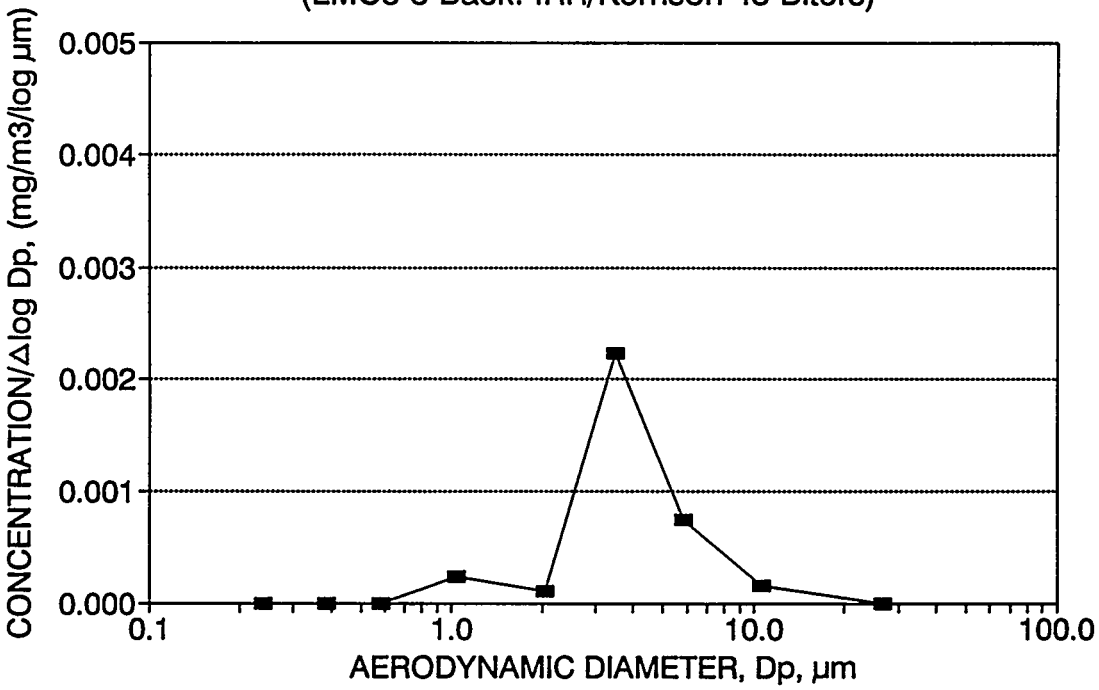
LMC3-5 Back Fusion: IRR/Kerrison 45 Biters (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.0959	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.0411	0.096
2.00	0.00039	2.87	0.457	0.174	0.002	3.50	0.5342	0.137
3.00	0.00020	4.28	0.632	0.269	0.001	5.84	0.2740	0.671
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0548	0.945
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00073						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-5 Back: IRR/Kerrison 45 Biters)



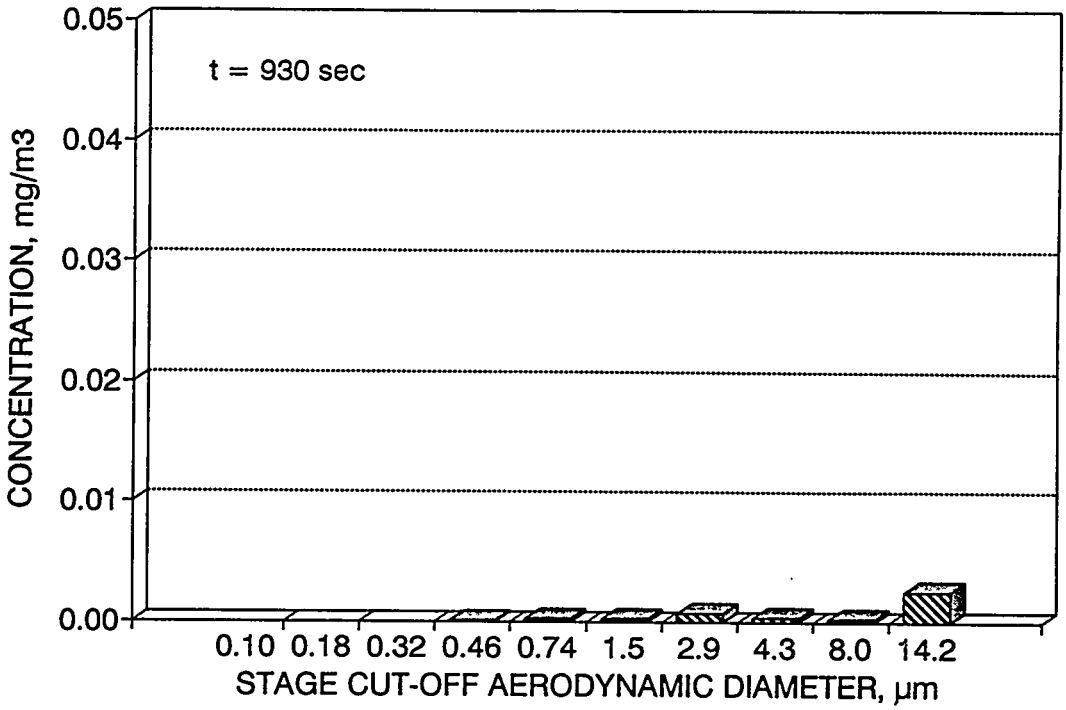
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-5 Back: IRR/Kerrison 45 Biters)



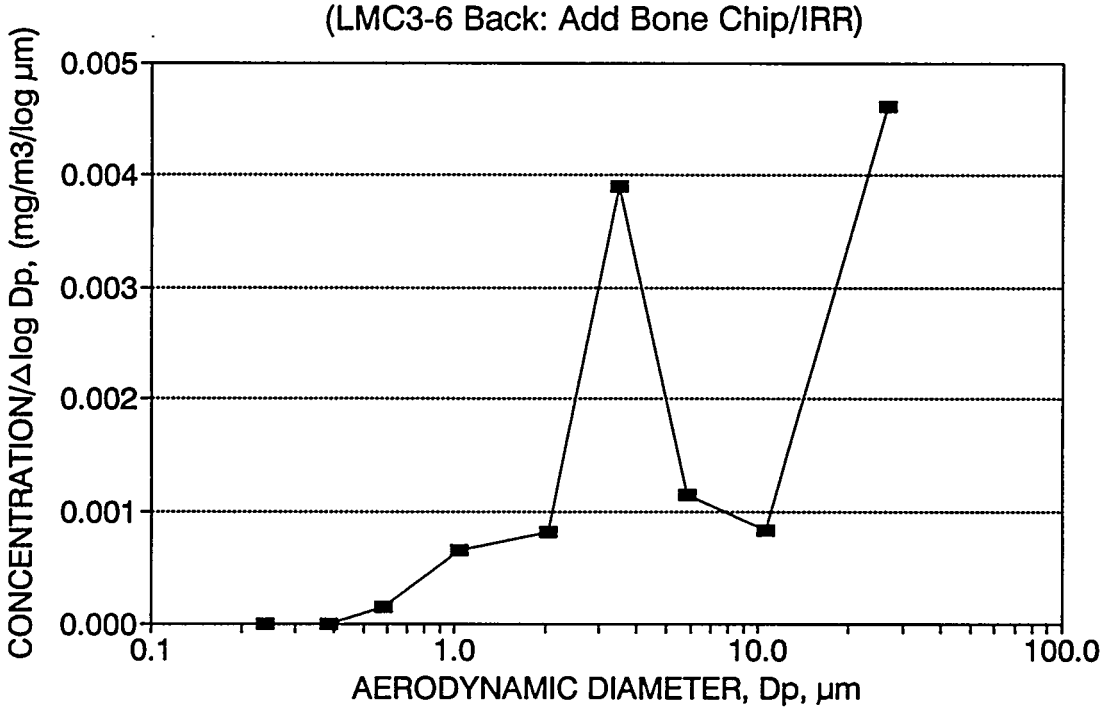
LMC3-6 Back Fusion: Add Bone Chip/IRR (t = 930 sec)

A ECD,μm	B C,mg/m3	C Dae,μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD,μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00003	0.46	-0.335	0.206	0.000	0.59	0.0072	0.000
0.50	0.00019	0.74	-0.128	0.290	0.001	1.04	0.0455	0.007
1.00	0.00024	1.45	0.162	0.296	0.001	2.04	0.0574	0.053
2.00	0.00068	2.87	0.457	0.174	0.004	3.50	0.1627	0.110
3.00	0.00031	4.28	0.632	0.269	0.001	5.84	0.0742	0.273
5.60	0.00021	7.96	0.901	0.251	0.001	10.62	0.0502	0.347
10.00	0.00252	14.18	1.152	0.547	0.005	26.63	0.6029	0.397
		50.00	1.699					1.000
Sum	0.00418						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-6 Back: Add Bone Chip/IRR)



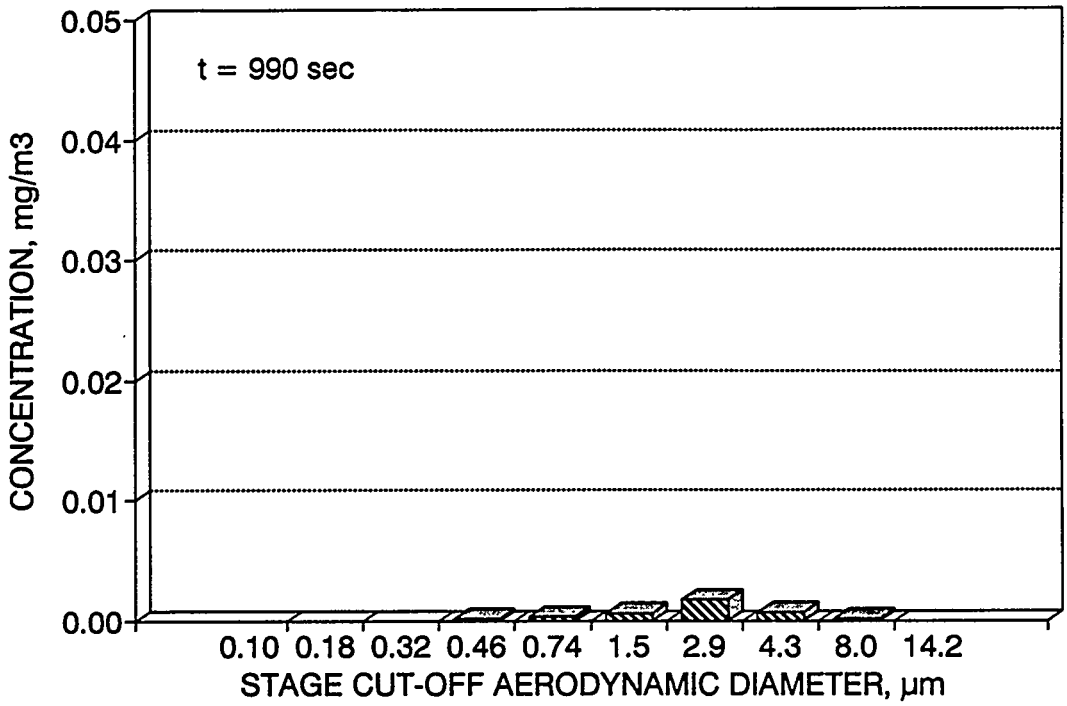
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-6 Back: Add Bone Chip/IRR)



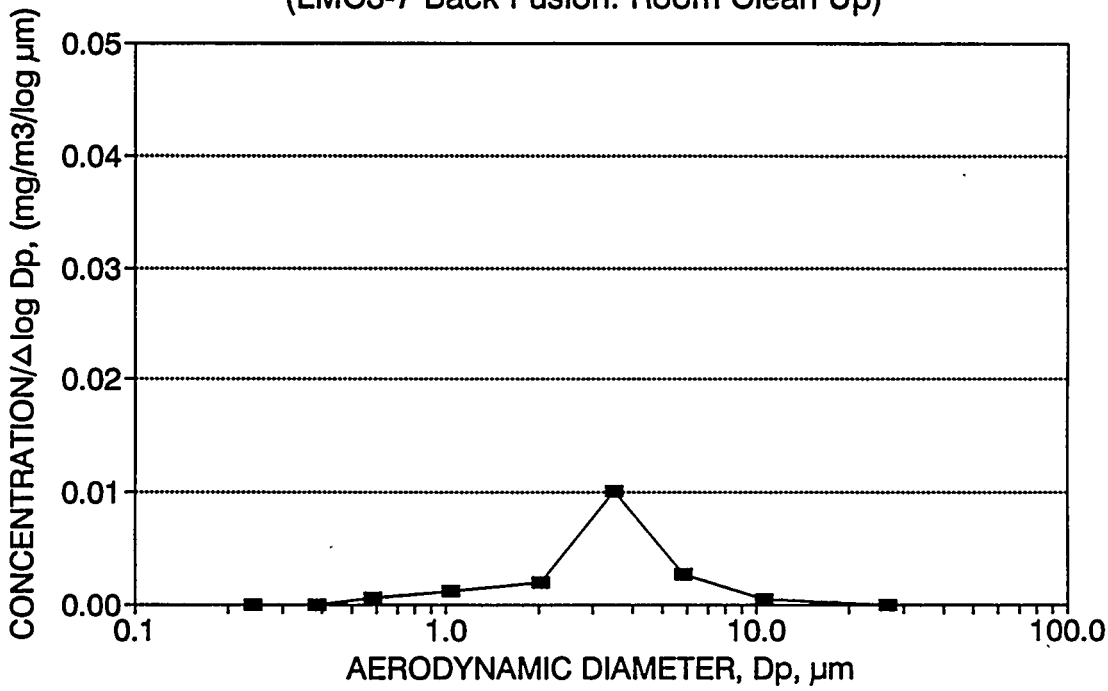
LMC3-7 Back Fusion: Room Clean Up (t = 990 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G CMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00011	0.46	-0.335	0.206	0.001	0.59	0.0303	0.000
0.50	0.00033	0.74	-0.128	0.290	0.001	1.04	0.0909	0.030
1.00	0.00059	1.45	0.162	0.296	0.002	2.04	0.1625	0.121
2.00	0.00176	2.87	0.457	0.174	0.010	3.50	0.4848	0.284
3.00	0.00072	4.28	0.632	0.269	0.003	5.84	0.1983	0.769
5.60	0.00012	7.96	0.901	0.251	0.000	10.62	0.0331	0.967
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00363						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC3-7 Back Fusion: Room Clean Up)



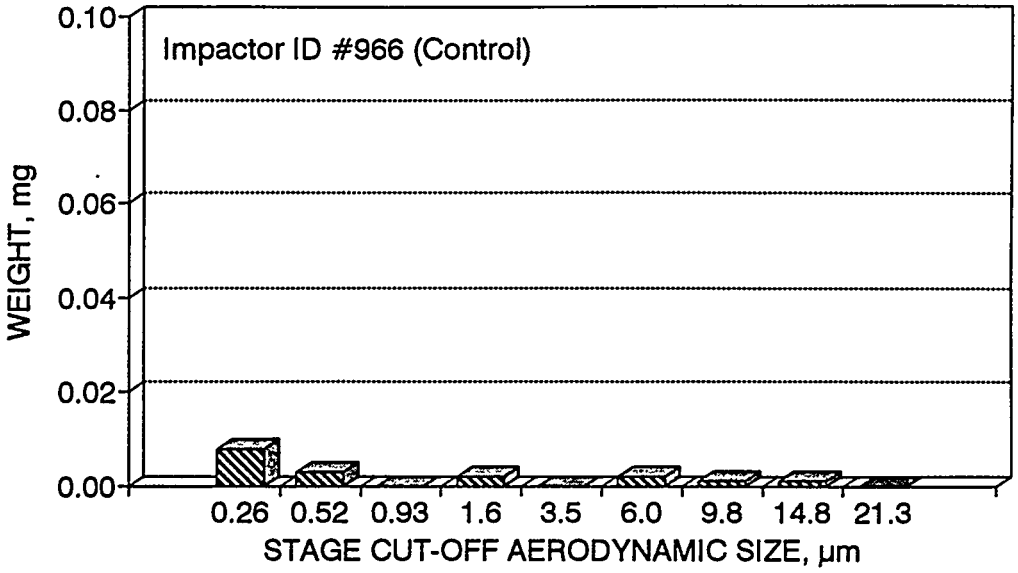
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC3-7 Back Fusion: Room Clean Up)



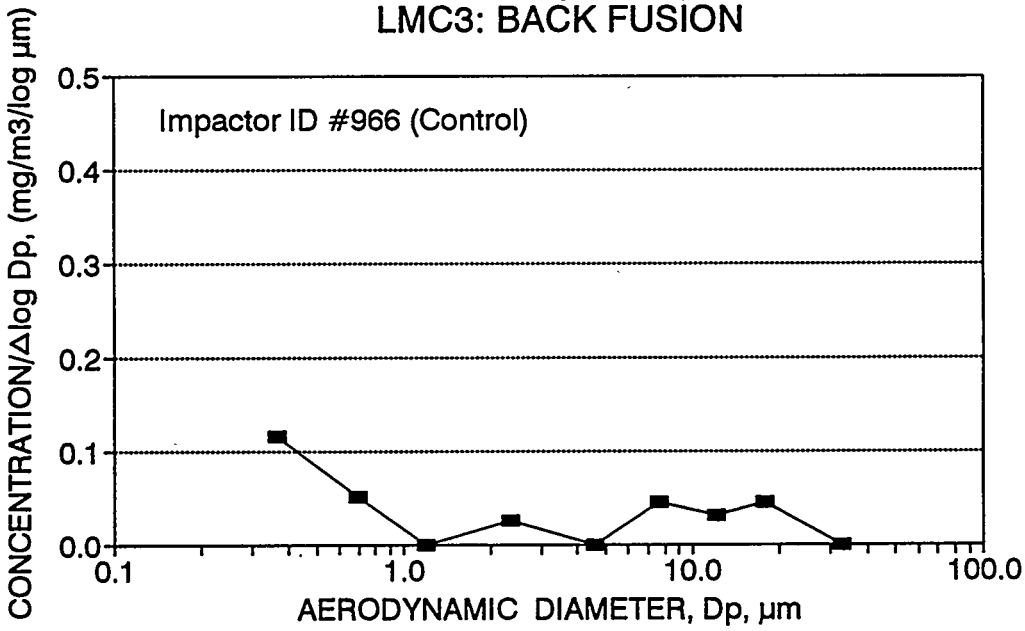
LMC3 Back Fusion: Marple Personal Impactor Data (ID No. 966: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.008	1	0.23	0.035	-0.585	0.301	0.116	0.37	0.438	0.000
8	0.52	0.003	0.99	0.23	0.013	-0.284	0.252	0.052	0.70	0.166	0.438
7	0.93	0.000	0.97	0.23	0.000	-0.032	0.222	0.000	1.20	0.000	0.603
6	1.55	0.002	0.96	0.23	0.009	0.190	0.354	0.026	2.33	0.114	0.603
5	3.50	0.000	0.95	0.23	0.000	0.544	0.234	0.000	4.58	0.000	0.717
4	6.00	0.002	0.89	0.23	0.010	0.778	0.213	0.046	7.67	0.123	0.717
3	9.80	0.001	0.78	0.23	0.006	0.991	0.179	0.031	12.04	0.070	0.840
2	14.80	0.001	0.61	0.23	0.007	1.170	0.158	0.045	17.75	0.090	0.910
1	21.30	0.000	0.52	0.23	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		0.017			0.079					1.000	

Marple Personal Impactor Data
LMC3: BACK FUSION



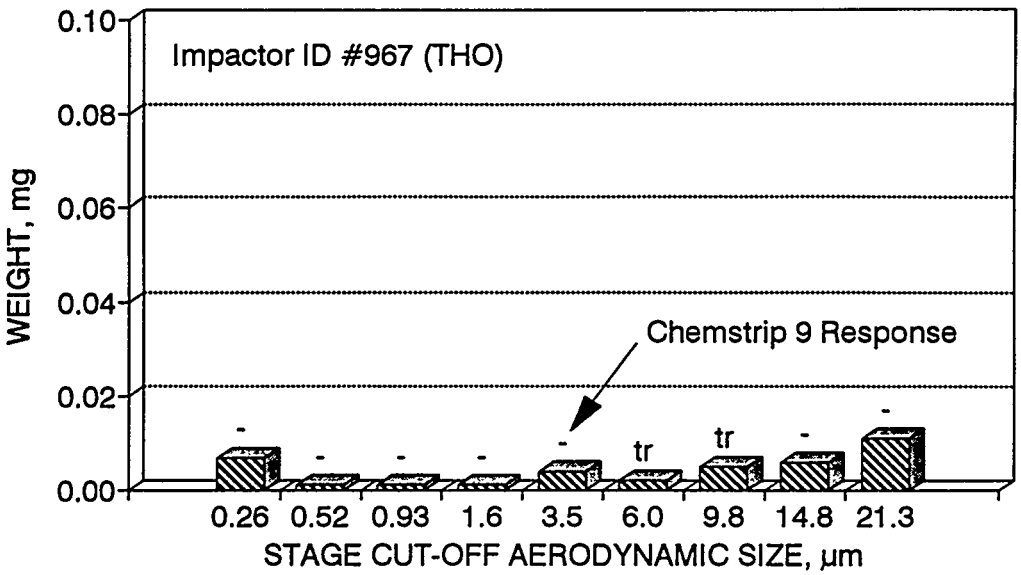
Size distribution by Marple Impactor
LMC3: BACK FUSION



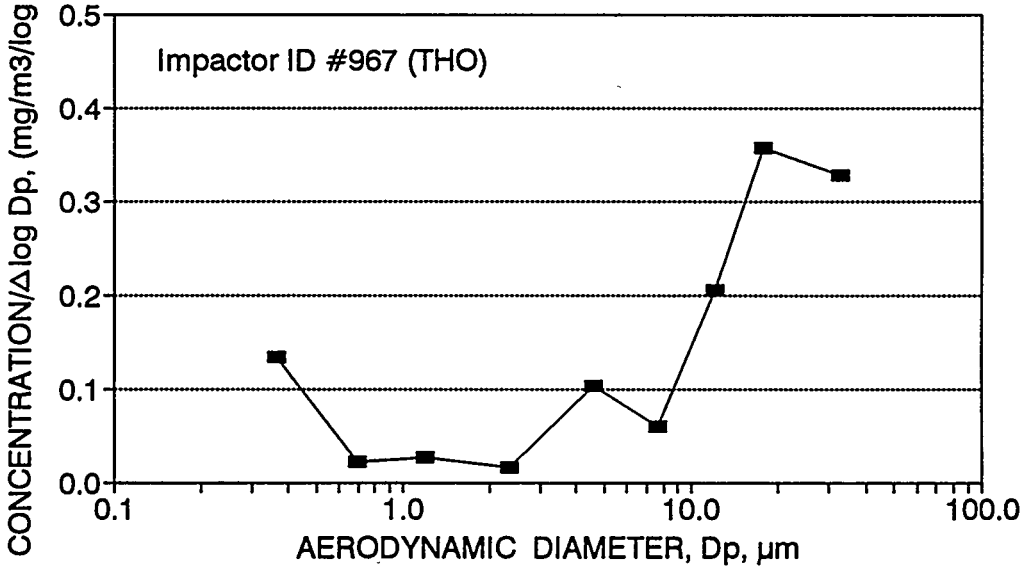
LMC3 Back Fusion: Marple Personal Impactor Data (ID No. 967: THO)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.007	1	0.174	0.040	-0.585	0.301	0.134	0.37	0.130	0.000	-
8	0.52	0.001	0.99	0.174	0.006	-0.284	0.252	0.023	0.70	0.019	0.130	-
7	0.93	0.001	0.97	0.174	0.006	-0.032	0.222	0.027	1.20	0.019	0.148	-
6	1.55	0.001	0.96	0.174	0.006	0.190	0.354	0.017	2.33	0.019	0.168	-
5	3.50	0.004	0.95	0.174	0.024	0.544	0.234	0.103	4.58	0.078	0.187	-
4	6.00	0.002	0.89	0.174	0.013	0.778	0.213	0.061	7.67	0.042	0.265	tr
3	9.80	0.005	0.78	0.174	0.037	0.991	0.179	0.206	12.04	0.119	0.307	tr
2	14.80	0.006	0.61	0.174	0.057	1.170	0.158	0.358	17.75	0.182	0.425	-
1	21.30	0.011	0.52	0.174	0.122	1.328	0.371	0.328	32.63	0.392	0.608	-
	50.00					1.699						
Sum		0.038			0.310					1.000		

Marple Personal Impactor Data
LMC3: Back Fusion



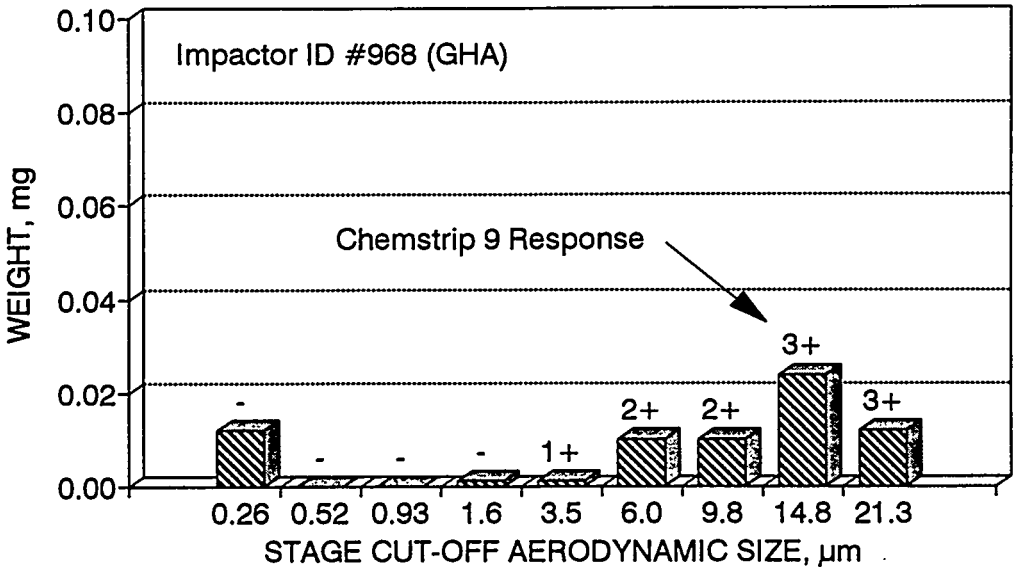
Size distribution by Marple Impactor
LMC3: Back Fusion



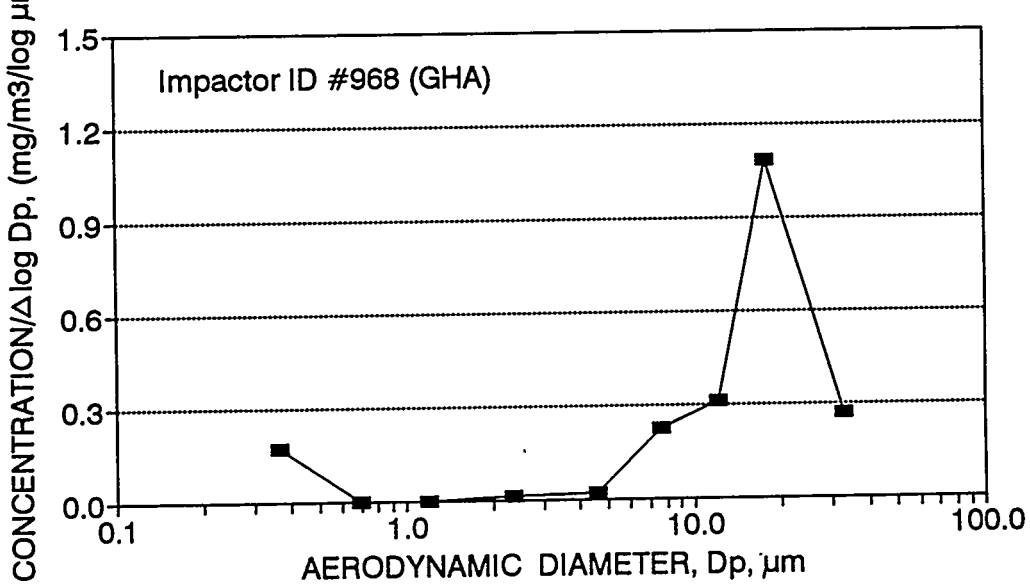
LMC3 Back Fusion : Marple Personal Impactor Data (ID No. 968: GHA)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.012	1	0.23	0.052	-0.585	0.301	0.173	0.37	0.119	0.000	-
8	0.52	0.000	0.99	0.23	0.000	-0.284	0.252	0.000	0.70	0.000	0.119	-
7	0.93	0.000	0.97	0.23	0.000	-0.032	0.222	0.000	1.20	0.000	0.119	-
6	1.55	0.001	0.96	0.23	0.005	0.190	0.354	0.013	2.33	0.010	0.119	-
5	3.50	0.001	0.95	0.23	0.005	0.544	0.234	0.020	4.58	0.010	0.130	1+
4	6.00	0.010	0.89	0.23	0.049	0.778	0.213	0.229	7.67	0.112	0.140	2+
3	9.80	0.010	0.78	0.23	0.056	0.991	0.179	0.311	12.04	0.127	0.252	2+
2	14.80	0.024	0.61	0.23	0.171	1.170	0.158	1.082	17.75	0.391	0.379	3+
1	21.30	0.012	0.52	0.23	0.100	1.328	0.371		32.63	0.229	0.771	3+
	50.00					1.699						
Sum		0.070			0.437					1.000		

Marple Personal Impactor Data
LMC3: Back Fusion



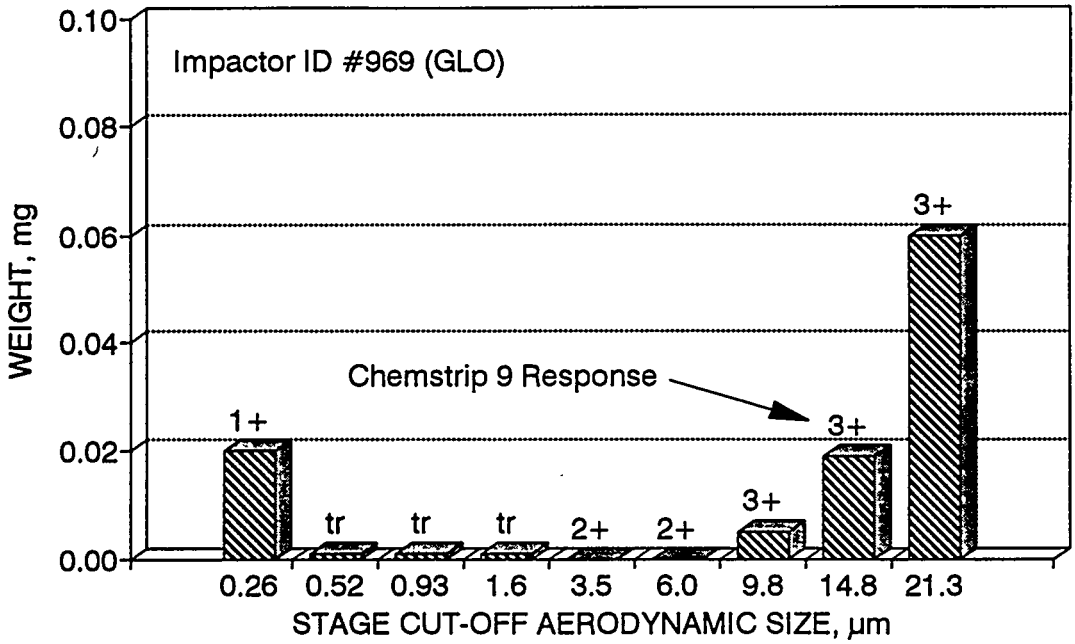
Size distribution by Marple Impactor
LMC3: Back Fusion



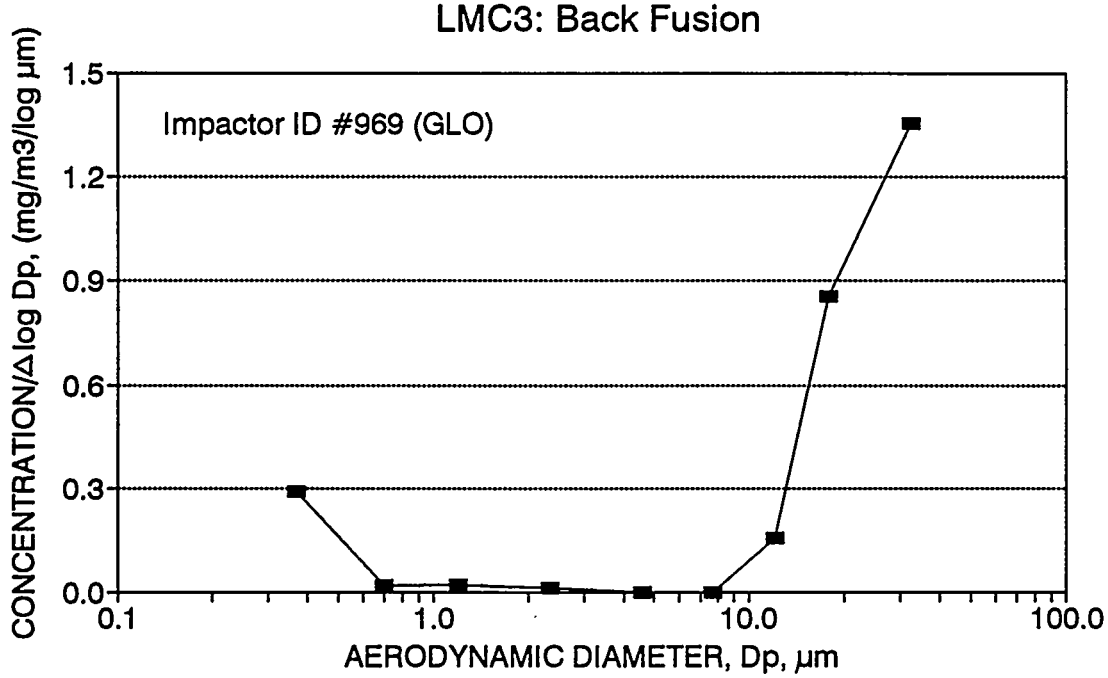
LMC3 Back Fusion: Marple Personal Impactor Data (ID No. 969: GLO)

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD	M Chem.9
F	0.26	0.020	1	0.23	0.087	-0.585	0.301	0.289	0.37	0.114	0.000	1+
8	0.52	0.001	0.99	0.23	0.004	-0.284	0.252	0.017	0.70	0.006	0.114	tr
7	0.93	0.001	0.97	0.23	0.004	-0.032	0.222	0.020	1.20	0.006	0.119	tr
6	1.55	0.001	0.96	0.23	0.005	0.190	0.354	0.013	2.33	0.006	0.125	tr
5	3.50	0.000	0.95	0.23	0.000	0.544	0.234	0.000	4.58	0.000	0.131	2+
4	6.00	0.000	0.89	0.23	0.000	0.778	0.213	0.000	7.67	0.000	0.131	2+
3	9.80	0.005	0.78	0.23	0.028	0.991	0.179	0.156	12.04	0.036	0.131	3+
2	14.80	0.019	0.61	0.23	0.135	1.170	0.158	0.856	17.75	0.177	0.168	3+
1	21.30	0.060	0.52	0.23	0.502	1.328	0.371	1.354	32.63	0.656	0.344	3+
	50.00					1.699						
Sum		0.107			0.765					1.000		

Marple Personal Impactor Data
LMC3: Back Fusion



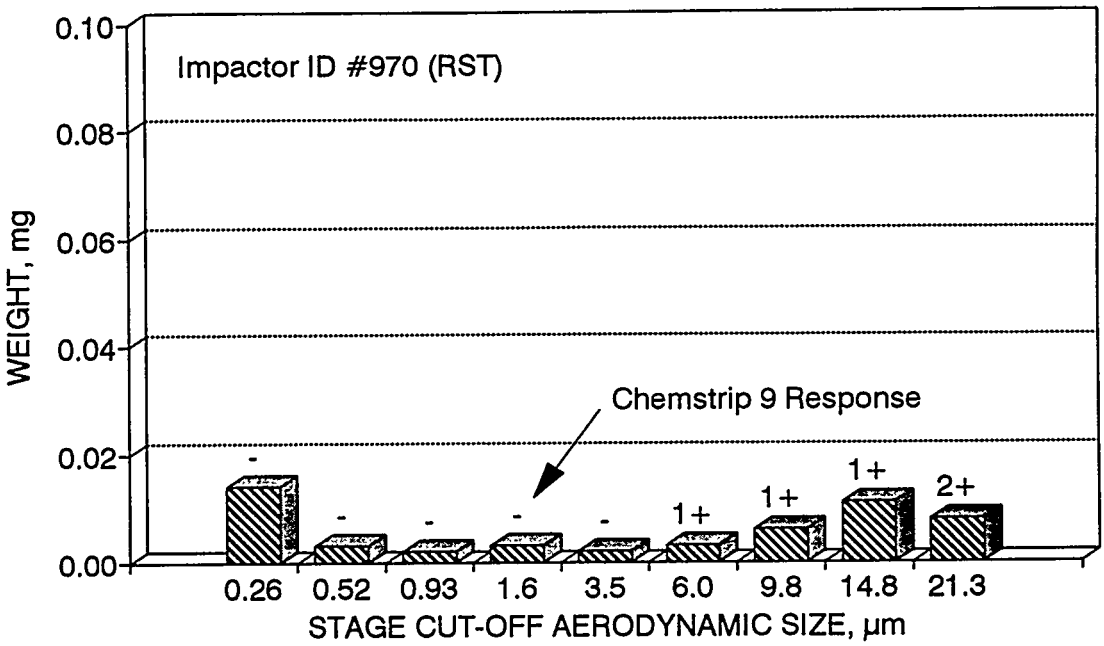
Size distribution by Marple Impactor
LMC3: Back Fusion



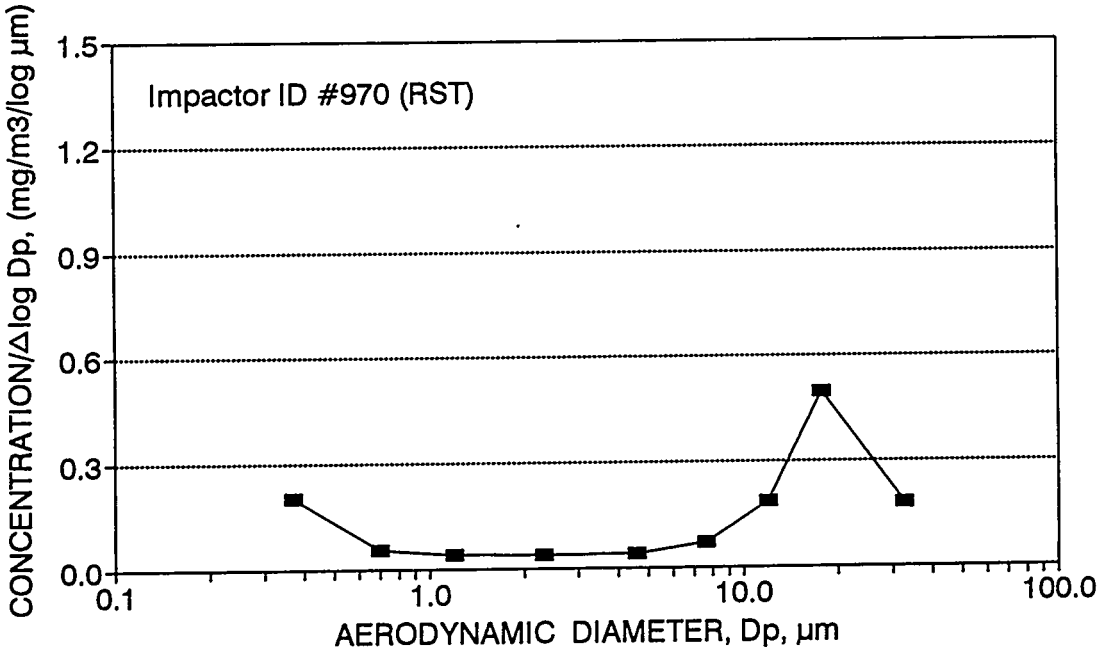
LMC3 Back Fusion: Marple Personal Impactor Data (ID No. 970: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.014	1	0.23	0.061	-0.585	0.301	0.202	0.37	0.203	0.000	-
8	0.52	0.003	0.99	0.23	0.013	-0.284	0.252	0.052	0.70	0.044	0.203	-
7	0.93	0.002	0.97	0.23	0.009	-0.032	0.222	0.040	1.20	0.030	0.248	-
6	1.55	0.003	0.96	0.23	0.014	0.190	0.354	0.038	2.33	0.045	0.277	-
5	3.50	0.002	0.95	0.23	0.009	0.544	0.234	0.039	4.58	0.031	0.323	-
4	6.00	0.003	0.89	0.23	0.015	0.778	0.213	0.069	7.67	0.049	0.354	1+
3	9.80	0.006	0.78	0.23	0.033	0.991	0.179	0.187	12.04	0.112	0.403	1+
2	14.80	0.011	0.61	0.23	0.078	1.170	0.158	0.496	17.75	0.262	0.514	1+
1	21.30	0.008	0.52	0.23	0.067	1.328	0.371	0.180	32.63	0.224	0.776	2+
	50.00					1.699						
Sum		0.052			0.299					1.000		

Marple Personal Impactor Data
LMC3: Back Fusion



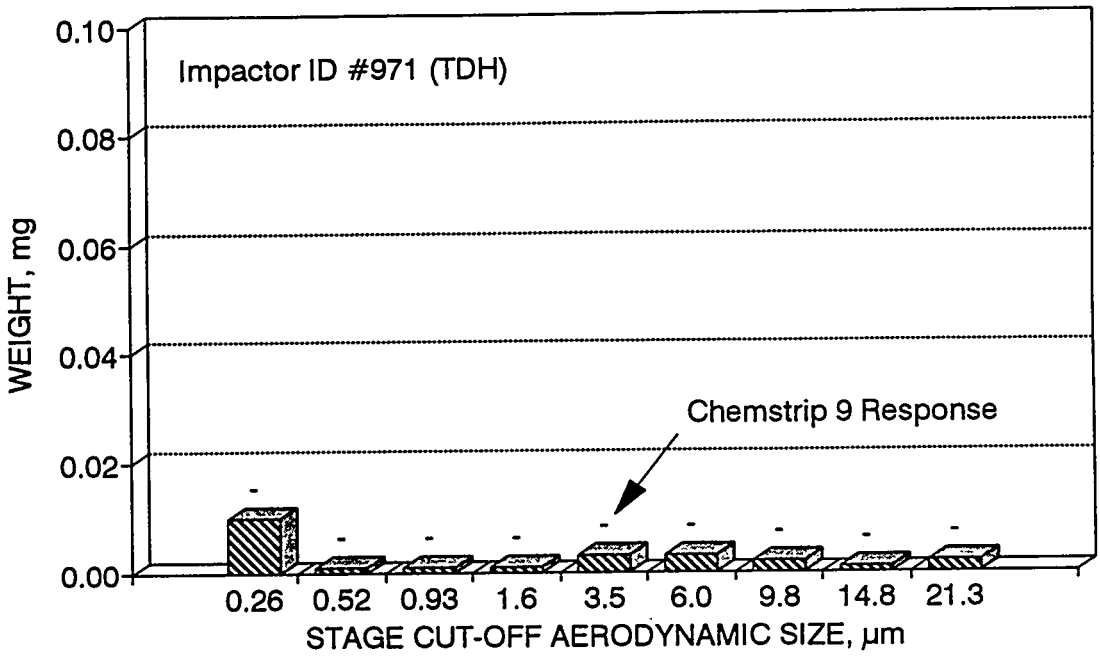
Size distribution by Marple Impactor
LMC3: Back Fusion



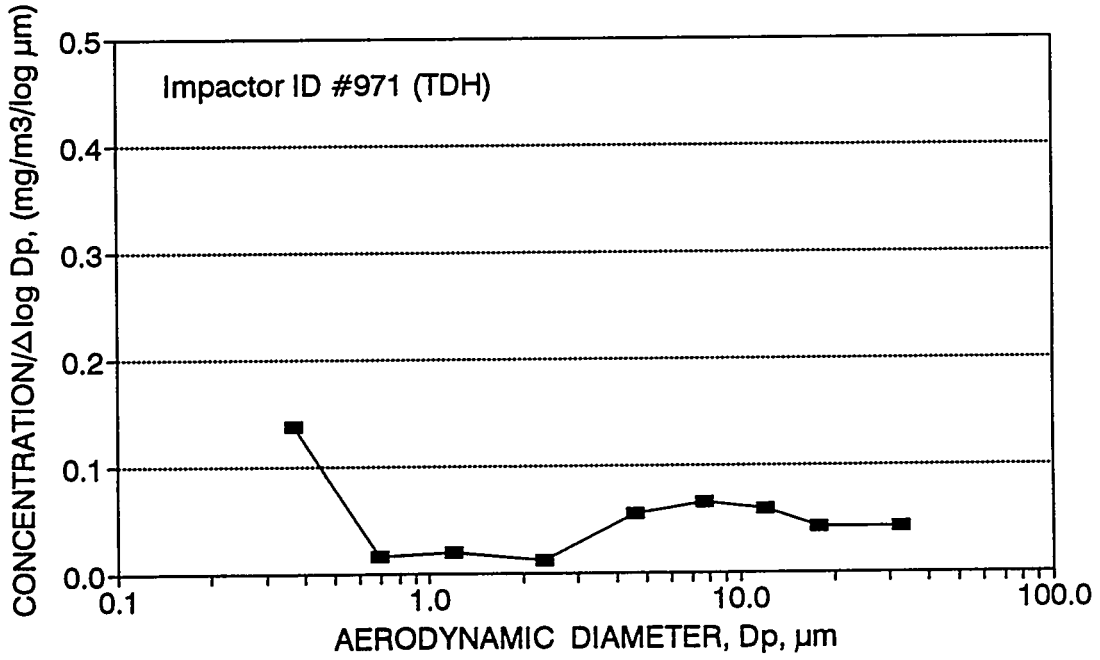
LMC3 Back Fusion: Marple Personal Impactor Data (ID No. 971: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.010	1	0.24	0.042	-0.585	0.301	0.138	0.37	0.362	0.000	-
8	0.52	0.001	0.99	0.24	0.004	-0.284	0.252	0.017	0.70	0.037	0.362	-
7	0.93	0.001	0.97	0.24	0.004	-0.032	0.222	0.019	1.20	0.037	0.398	-
6	1.55	0.001	0.96	0.24	0.004	0.190	0.354	0.012	2.33	0.038	0.435	-
5	3.50	0.003	0.95	0.24	0.013	0.544	0.234	0.056	4.58	0.114	0.473	-
4	6.00	0.003	0.89	0.24	0.014	0.778	0.213	0.066	7.67	0.122	0.587	-
3	9.80	0.002	0.78	0.24	0.011	0.991	0.179	0.060	12.04	0.093	0.709	-
2	14.80	0.001	0.61	0.24	0.007	1.170	0.158	0.043	17.75	0.059	0.802	-
1	21.30	0.002	0.52	0.24	0.016	1.328	0.371	0.043	32.63	0.139	0.861	-
	50.00					1.699						
Sum		0.024			0.115					1.000		

Marple Personal Impactor Data
LMC3: Back Fusion



Size distribution by Marple Impactor
LMC3: Back Fusion



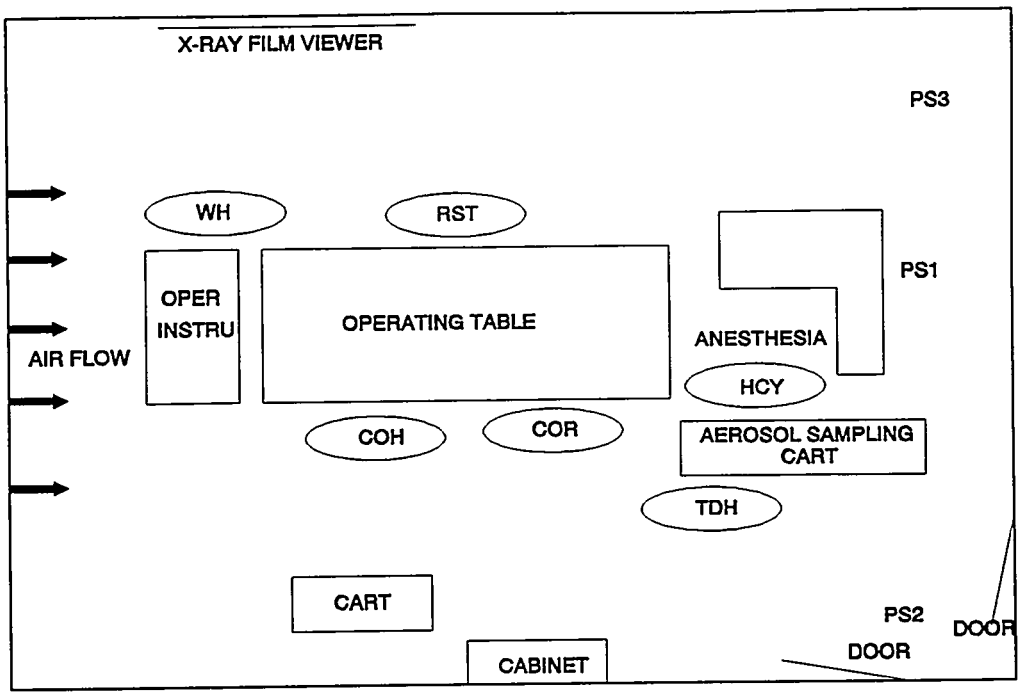
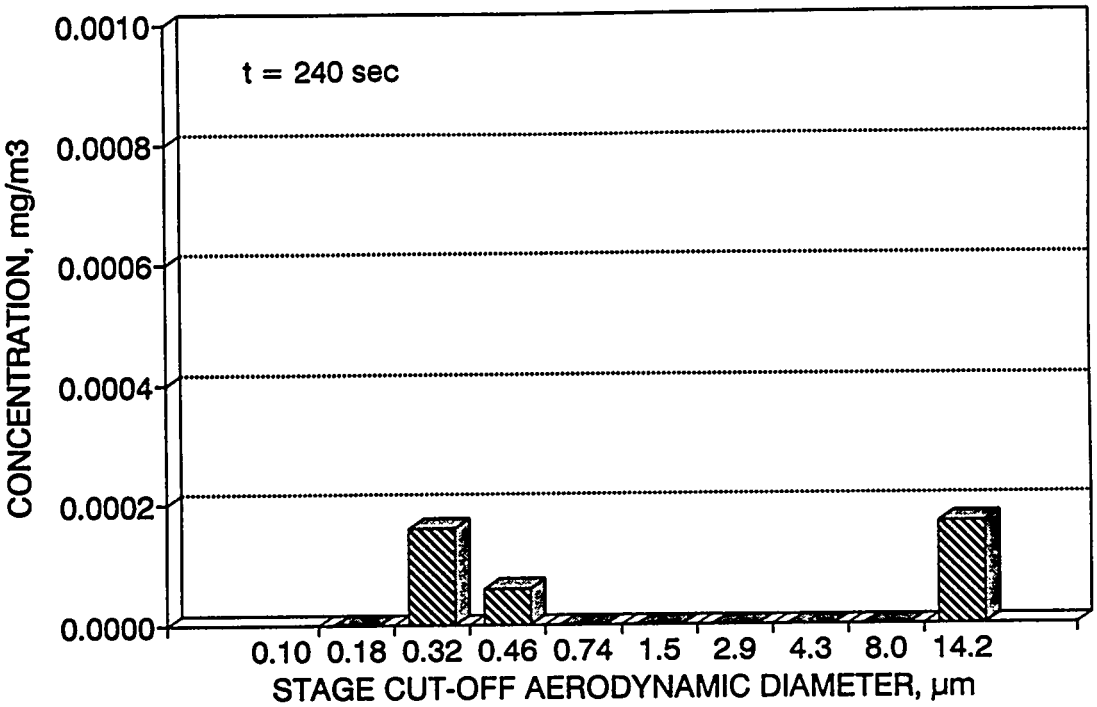


Figure C.4 Initial locations personnel and area filters during LMC #4 measurement (total knee replacement).

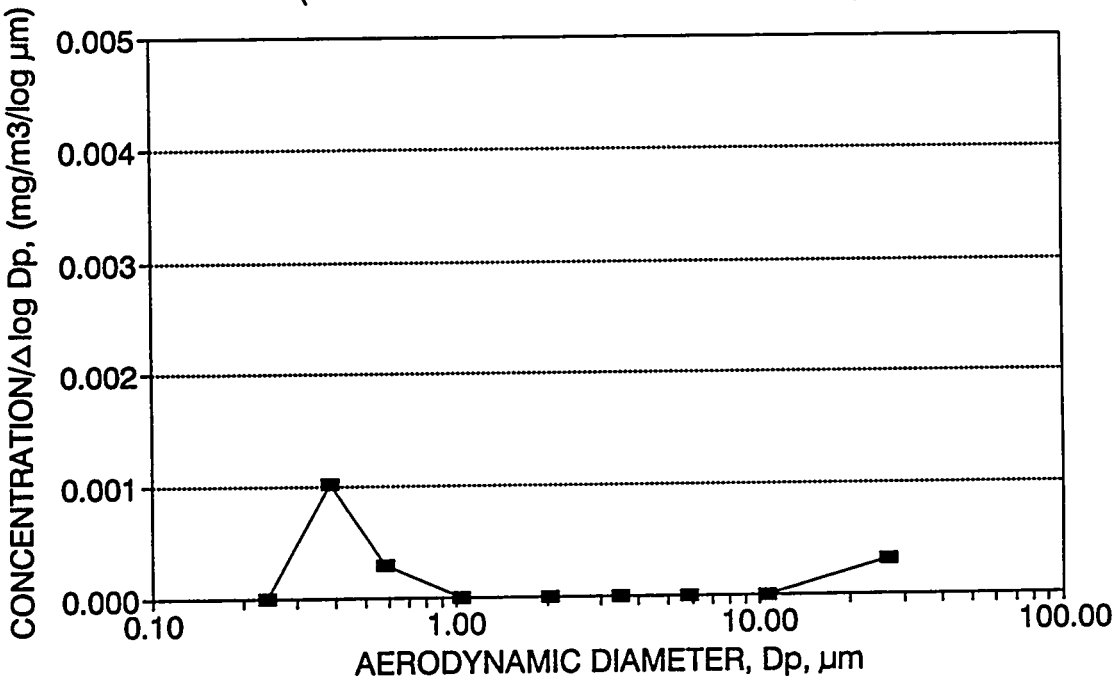
LMC4-0 Total Knee: OR5 Room Background (t = 240 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00016	0.32	-0.492	0.157	0.001	0.39	0.4103	0.000
0.30	0.00006	0.46	-0.335	0.206	0.000	0.59	0.1538	0.410
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.564
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.564
2.00	0.00000	2.87	0.457	0.174	0.000	3.50	0.0000	0.564
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.564
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	0.564
10.00	0.00017	14.18	1.152	0.547	0.000	26.63	0.4359	0.564
		50.00	1.699					1.000
Sum	0.00039						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-0 Total Knee: OR5 Room Bak)



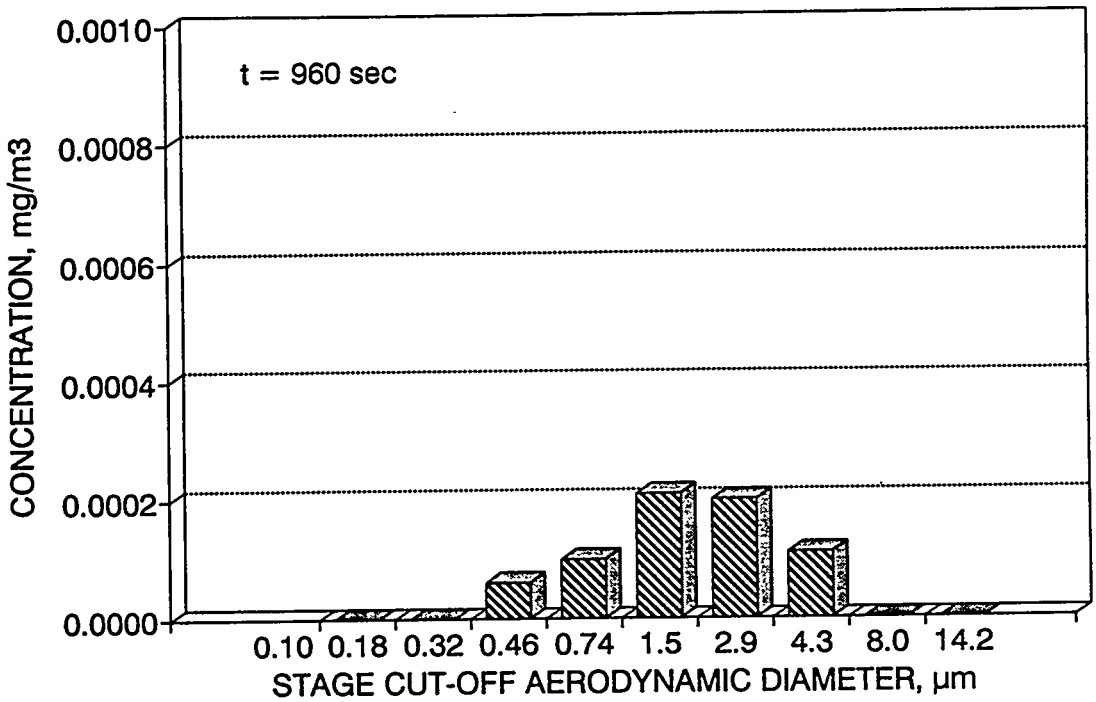
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-0 Total Knee: OR5 Room Bak)



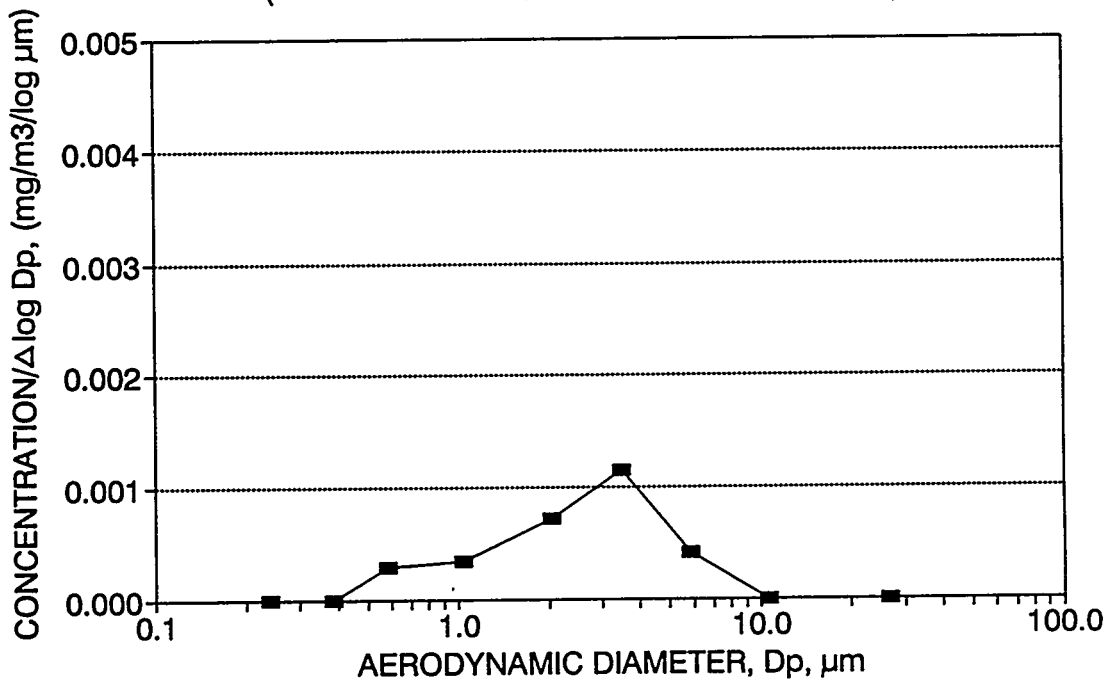
LMC4-1 Total Knee: EC/CUT/IRR/DR/HAM/SAW (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00006	0.46	-0.335	0.206	0.000	0.59	0.0882	0.000
0.50	0.00010	0.74	-0.128	0.290	0.000	1.04	0.1471	0.088
1.00	0.00021	1.45	0.162	0.296	0.001	2.04	0.3088	0.235
2.00	0.00020	2.87	0.457	0.174	0.001	3.50	0.2941	0.544
3.00	0.00011	4.28	0.632	0.269	0.000	5.84	0.1618	0.838
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00068						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-1 T.K.: EC/CUT/IRR/DR/HAM/SAW)



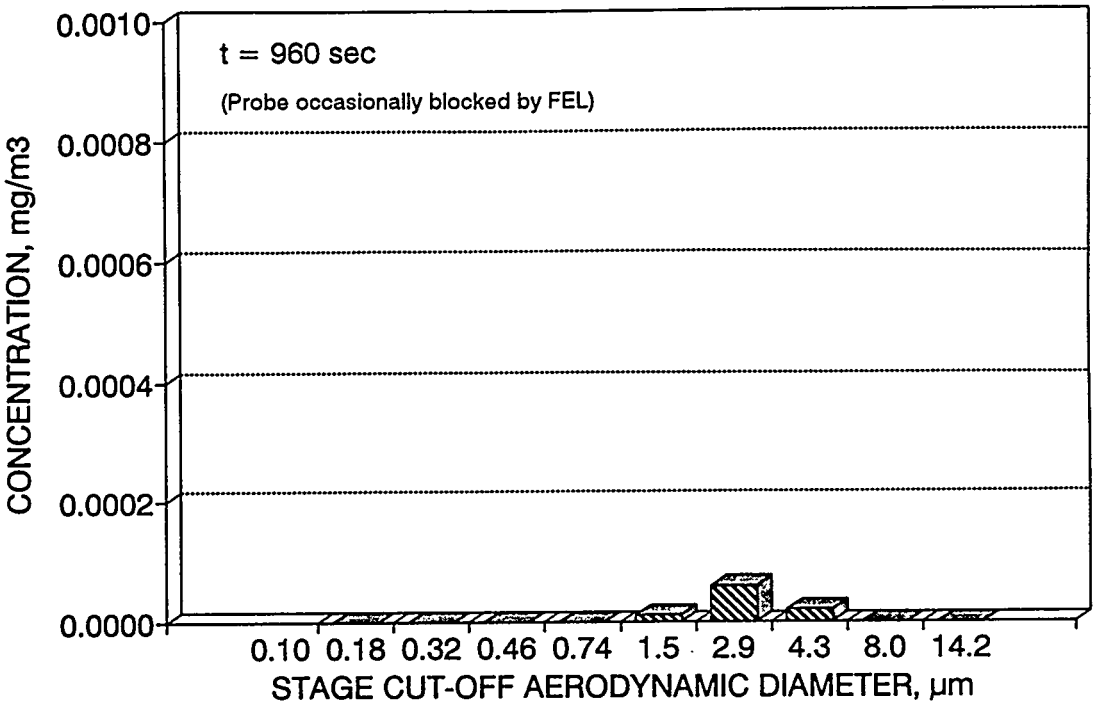
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-1 T.K.: EC/CUT/IRR/DR/HAM/SAW)



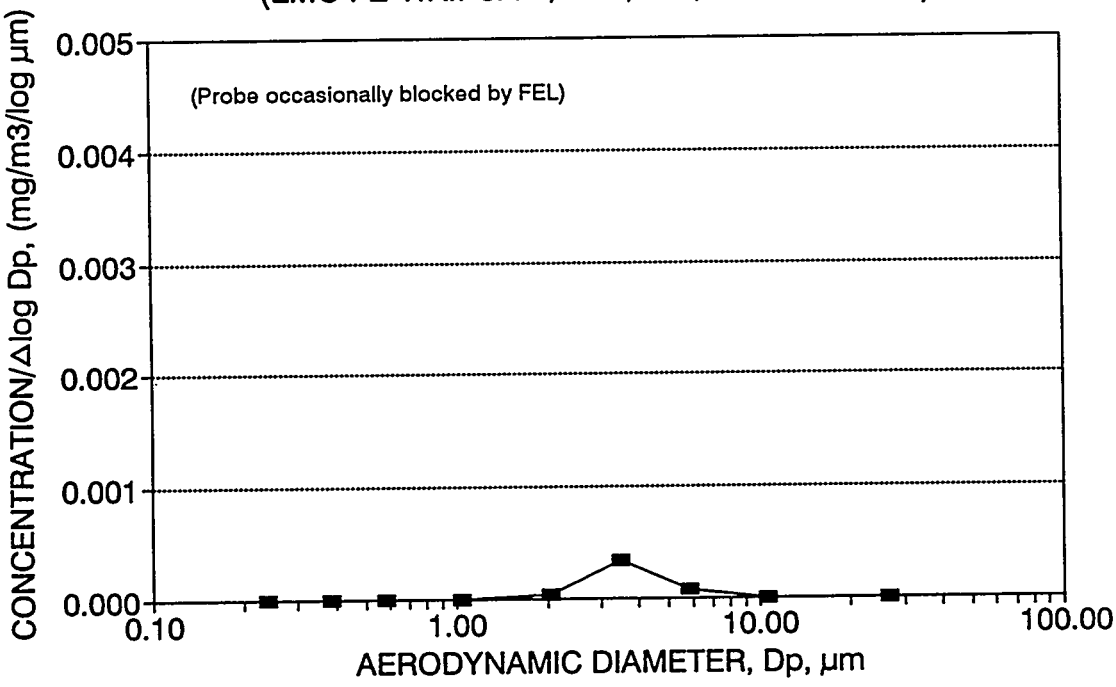
LMC4-2 Total Knee: SAW/CUT/CHI/FIT FEMORAL (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.1111	0.000
2.00	0.00006	2.87	0.457	0.174	0.000	3.50	0.6667	0.111
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.2222	0.778
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	9E-05						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-2 T.K.: SAW/CUT/CHI/FIT FEMORAL)



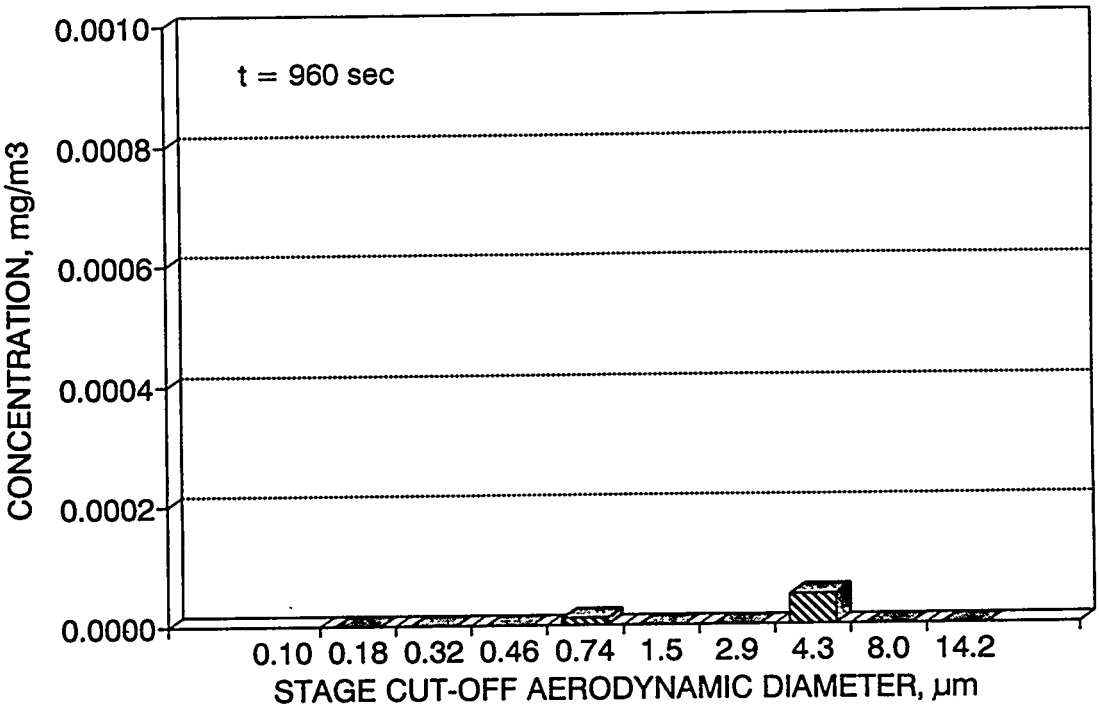
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-2 T.K.: SAW/CUT/CHI/FIT FEMORAL)



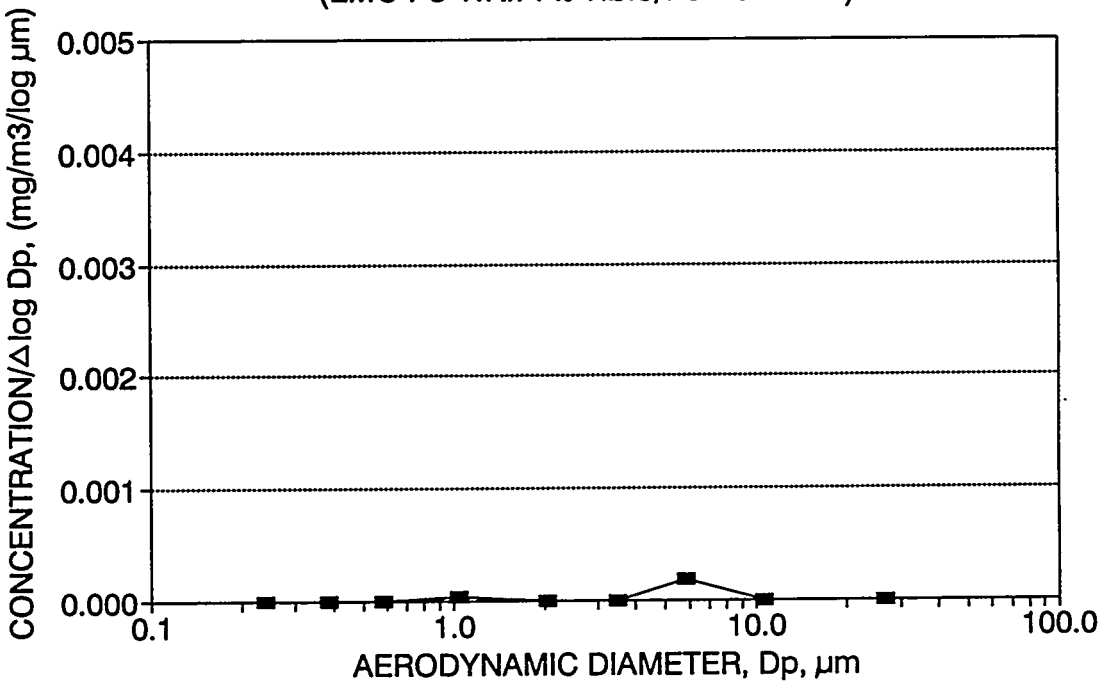
LMC4-3 Total Knee: Fit Tibio/Femoral etc (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00001	0.74	-0.128	0.290	0.000	1.04	0.1667	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.167
2.00	0.00000	2.87	0.457	0.174	0.000	3.50	0.0000	0.167
3.00	0.00005	4.28	0.632	0.269	0.000	5.84	0.8333	0.167
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	6E-05						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-3 T.K.: Fit Tibio/Femoral etc)



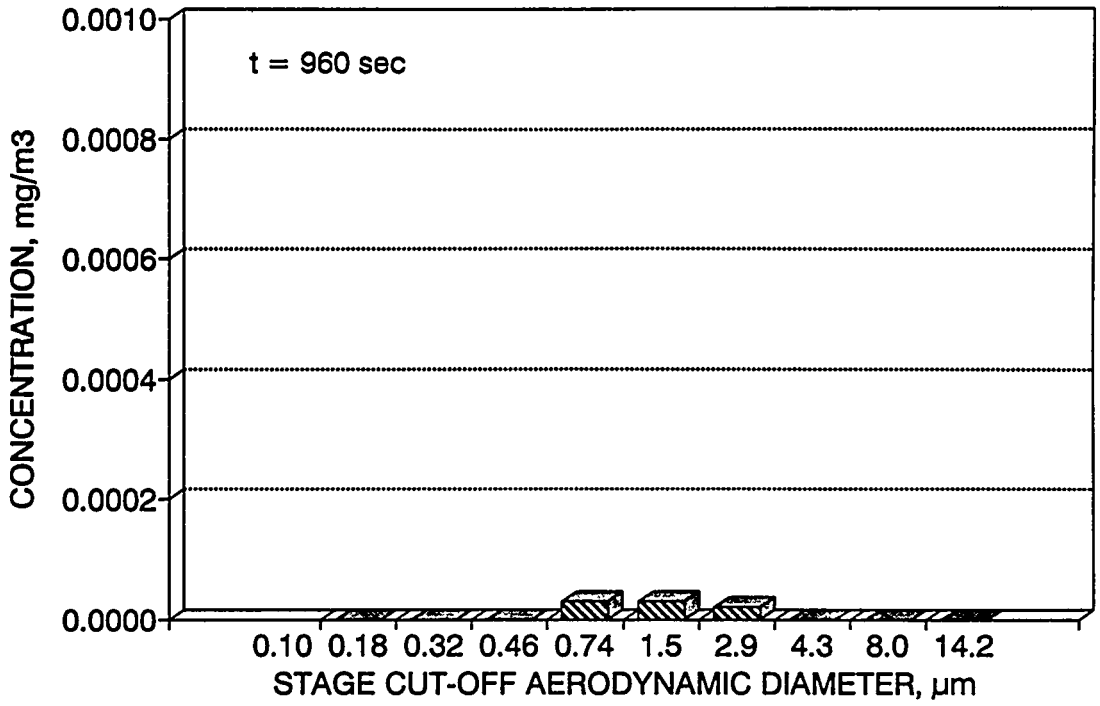
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-3 T.K.: Fit Tibio/Femoral etc)



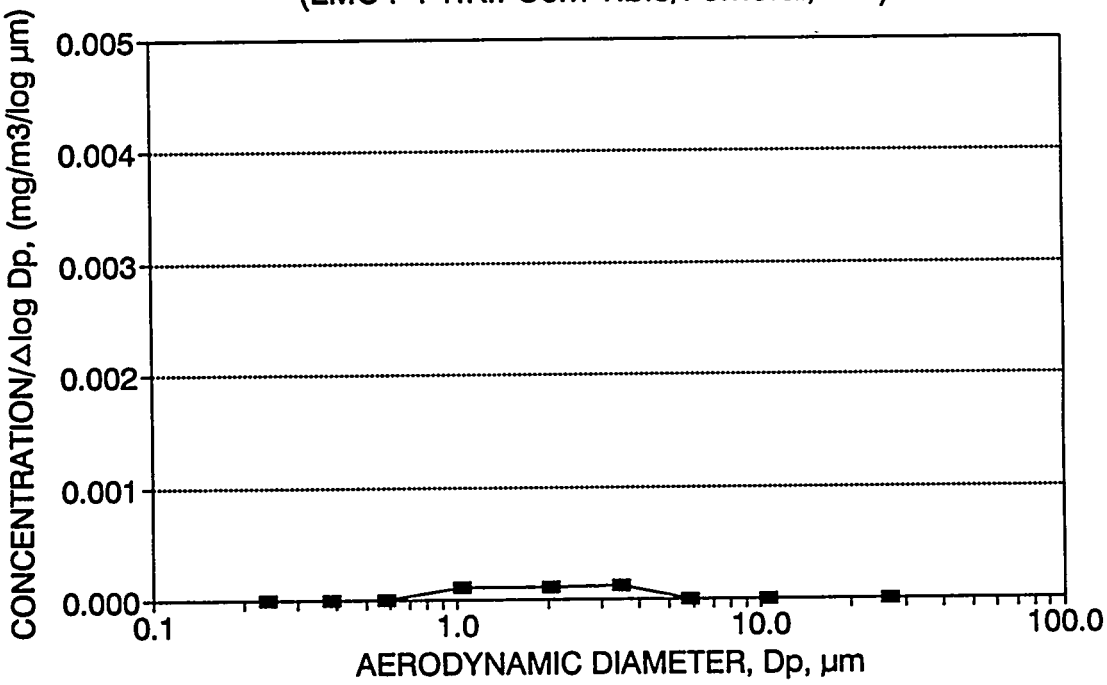
LMC4-4 Total Knee: Cem Tibio/Femoral, IRR (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00003	0.74	-0.128	0.290	0.000	1.04	0.3750	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.3750	0.375
2.00	0.00002	2.87	0.457	0.174	0.000	3.50	0.2500	0.750
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	1.000
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	8E-05						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-4 T.K.: Cem Tibio/Femoral, IRR)



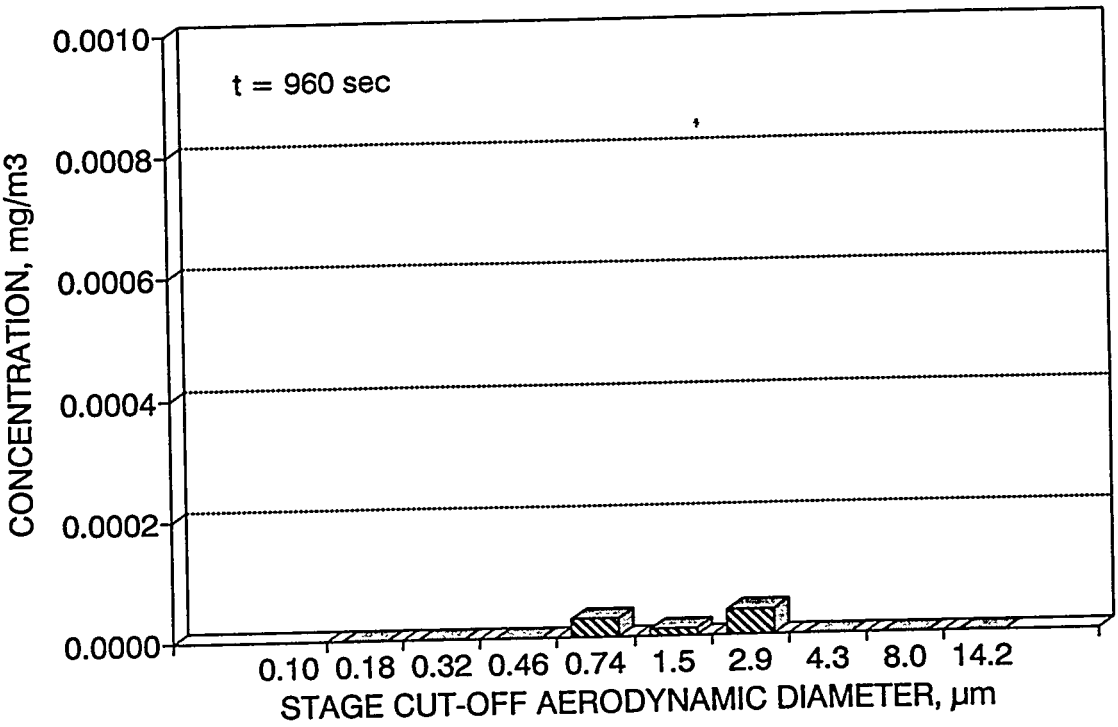
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-4 T.K.: Cem Tibio/Femoral, IRR)



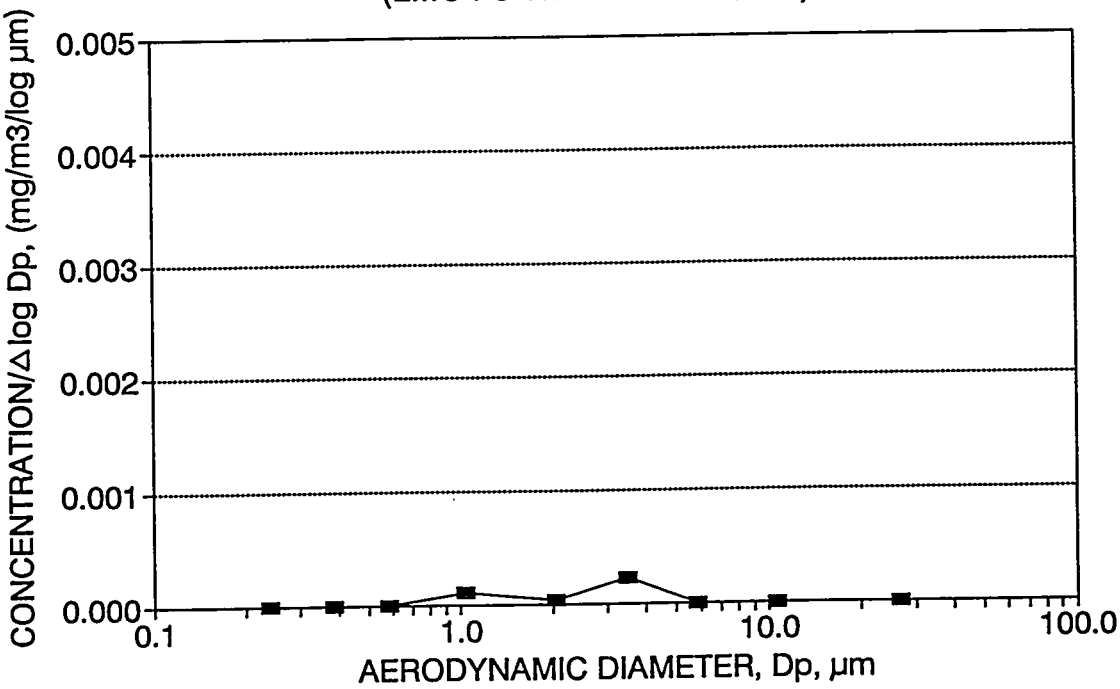
LMC4-5 Total Knee: SUTURE/IRR (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00003	0.74	-0.128	0.290	0.000	1.04	0.3750	0.000
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.1250	0.375
2.00	0.00004	2.87	0.457	0.174	0.000	3.50	0.5000	0.500
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	1.000
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	8E-05						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-5 T.K.: SUTURE/IRR)



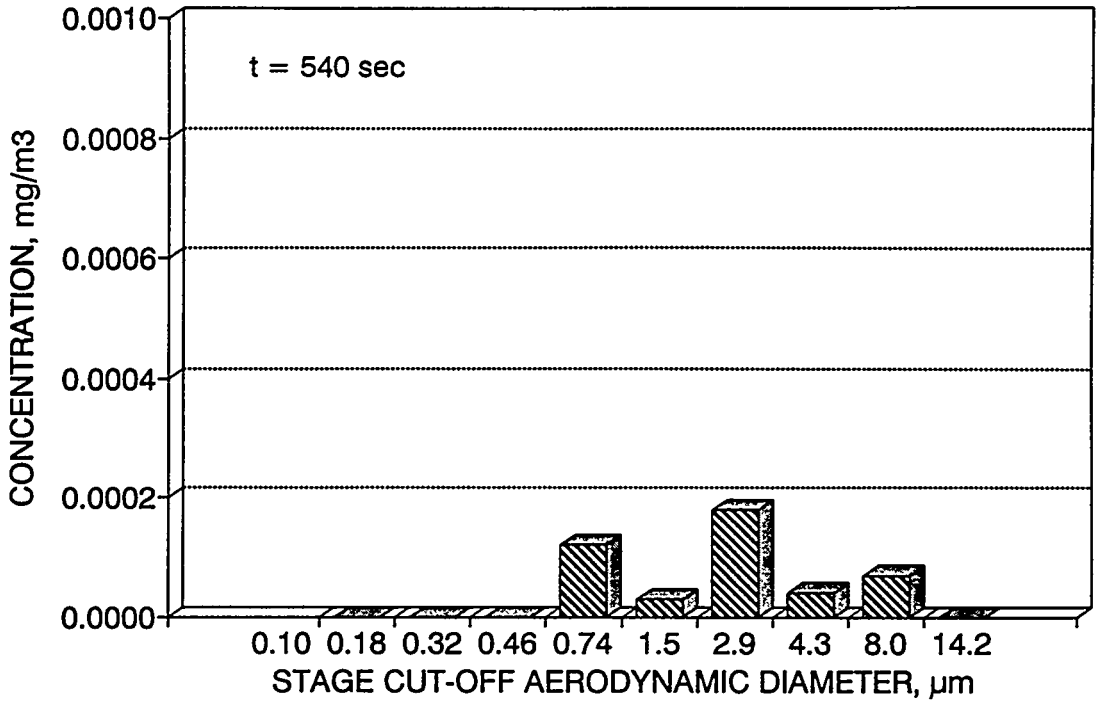
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-5 T.K.: SUTURE/IRR)



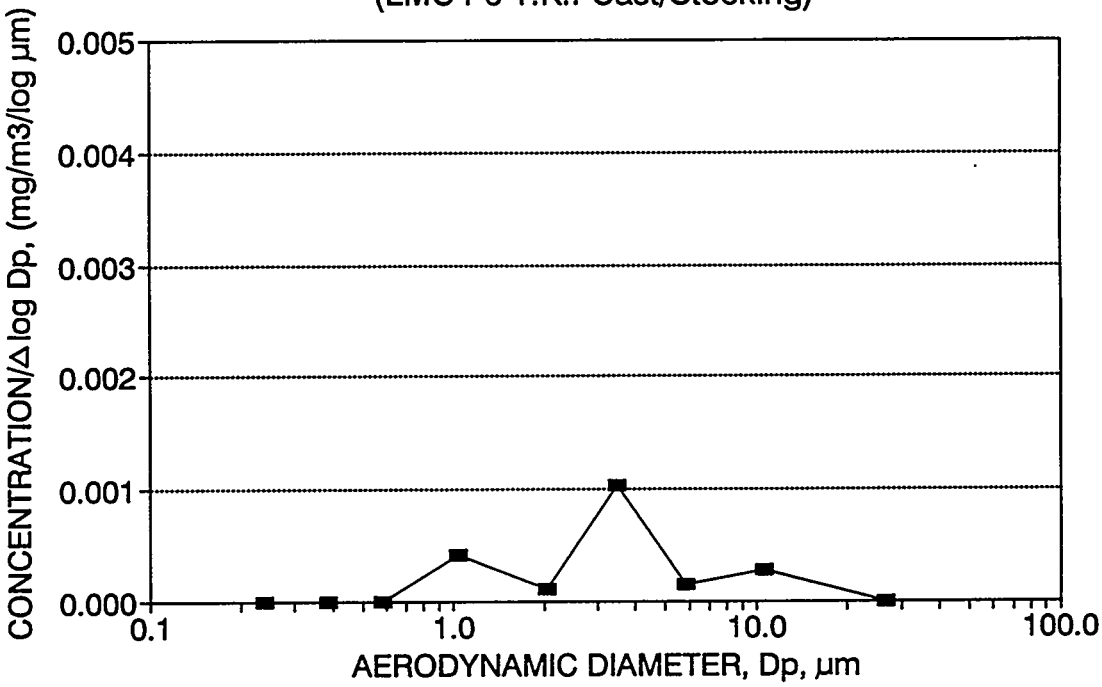
LMC4-6 Total Knee: Cast/Stocking (t = 540 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B) / (E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00012	0.74	-0.128	0.290	0.000	1.04	0.2727	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.0682	0.273
2.00	0.00018	2.87	0.457	0.174	0.001	3.50	0.4091	0.341
3.00	0.00004	4.28	0.632	0.269	0.000	5.84	0.0909	0.750
5.60	0.00007	7.96	0.901	0.251	0.000	10.62	0.1591	0.841
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00044						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC4-6 T.K.: Cast/Stocking)



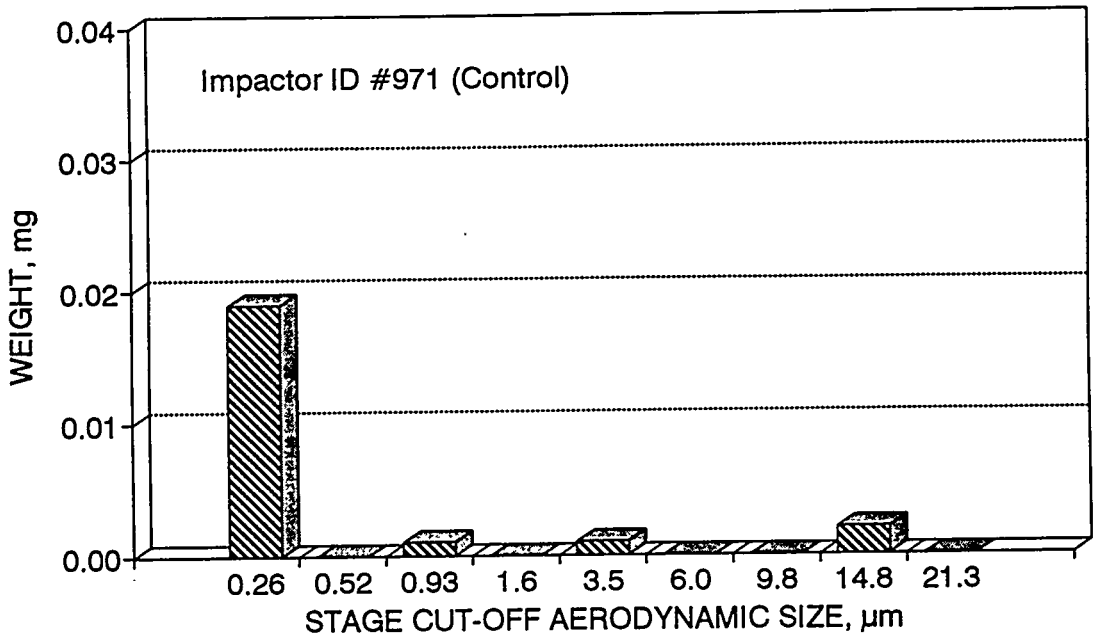
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC4-6 T.K.: Cast/Stocking)



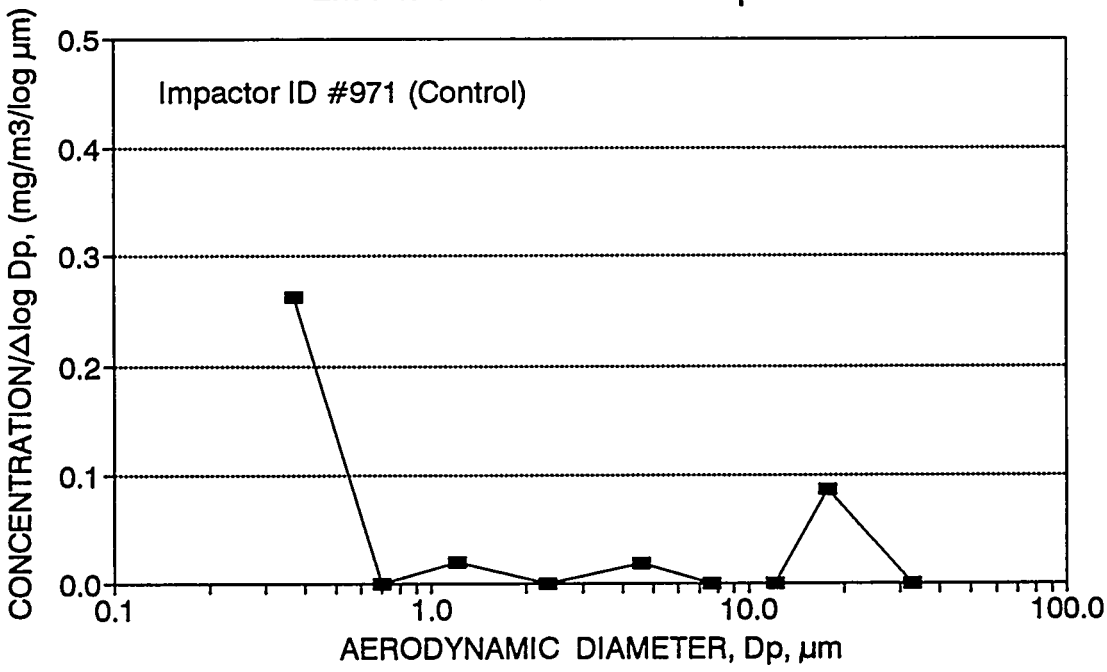
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 971: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.019	1	0.24	0.079	-0.585	0.301	0.263	0.37	0.780	0.000
8	0.52	0.000	0.99	0.24	0.000	-0.284	0.252	0.000	0.70	0.000	0.780
7	0.93	0.001	0.97	0.24	0.004	-0.032	0.222	0.019	1.20	0.042	0.780
6	1.55	0.000	0.96	0.24	0.000	0.190	0.354	0.000	2.33	0.000	0.822
5	3.50	0.001	0.95	0.24	0.004	0.544	0.234	0.019	4.58	0.043	0.822
4	6.00	0.000	0.89	0.24	0.000	0.778	0.213	0.000	7.67	0.000	0.865
3	9.80	0.000	0.78	0.24	0.000	0.991	0.179	0.000	12.04	0.000	0.865
2	14.80	0.002	0.61	0.24	0.014	1.170	0.158	0.086	17.75	0.135	0.865
1	21.30	0.000	0.52	0.24	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		0.023			0.102					1.000	

Marple Personal Impactor Data
LMC4: Total Left Knee Replacement



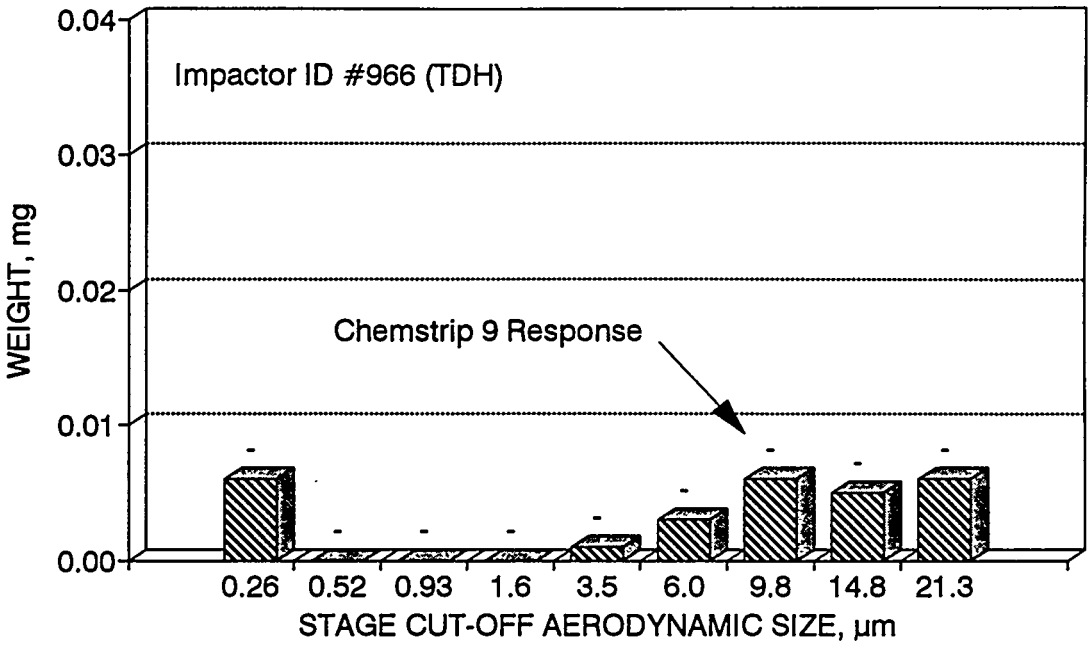
Size distribution by Marple Impactor
LMC4: Total Left Knee Replacement



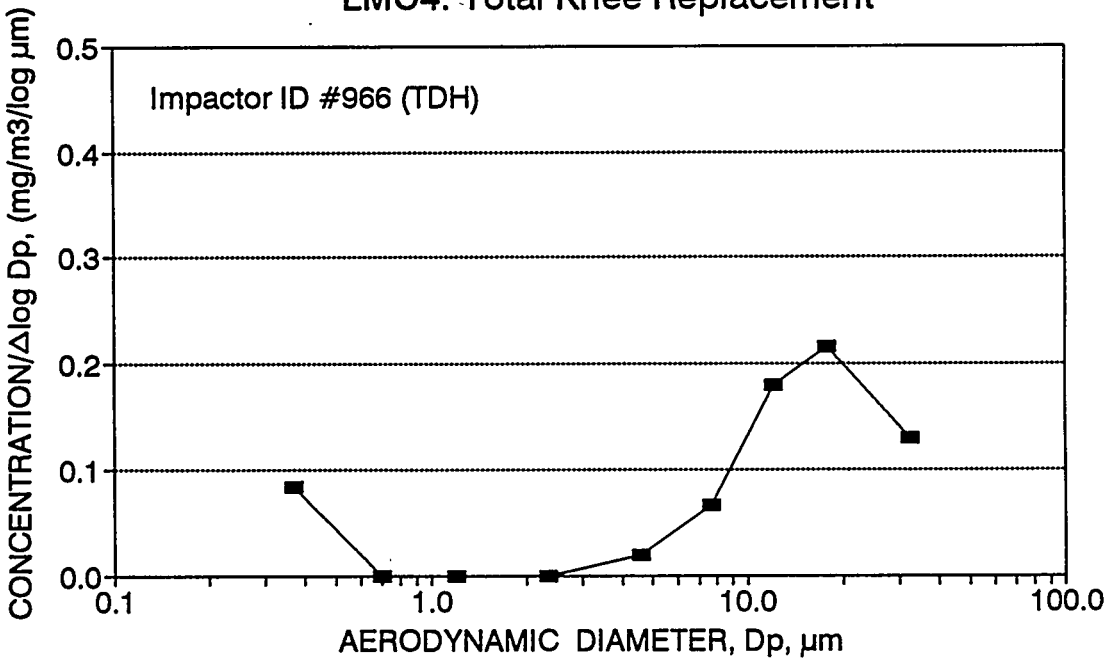
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 966: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.006	1	0.24	0.025	-0.585	0.301	0.083	0.37	0.159	0.000	-
8	0.52	0.000	0.99	0.24	0.000	-0.284	0.252	0.000	0.70	0.000	0.159	-
7	0.93	0.000	0.97	0.24	0.000	-0.032	0.222	0.000	1.20	0.000	0.159	-
6	1.55	0.000	0.96	0.24	0.000	0.190	0.354	0.000	2.33	0.000	0.159	-
5	3.50	0.001	0.95	0.24	0.004	0.544	0.234	0.019	4.58	0.028	0.159	-
4	6.00	0.003	0.89	0.24	0.014	0.778	0.213	0.066	7.67	0.089	0.186	-
3	9.80	0.006	0.78	0.24	0.032	0.991	0.179	0.179	12.04	0.203	0.275	-
2	14.80	0.005	0.61	0.24	0.034	1.170	0.158	0.216	17.75	0.217	0.479	-
1	21.30	0.006	0.52	0.24	0.048	1.328	0.371	0.130	32.63	0.305	0.695	-
	50.00					1.699						
Sum		0.027			0.158					1.000		

Marple Personal Impactor Data
LMC4: Total Knee Replacement



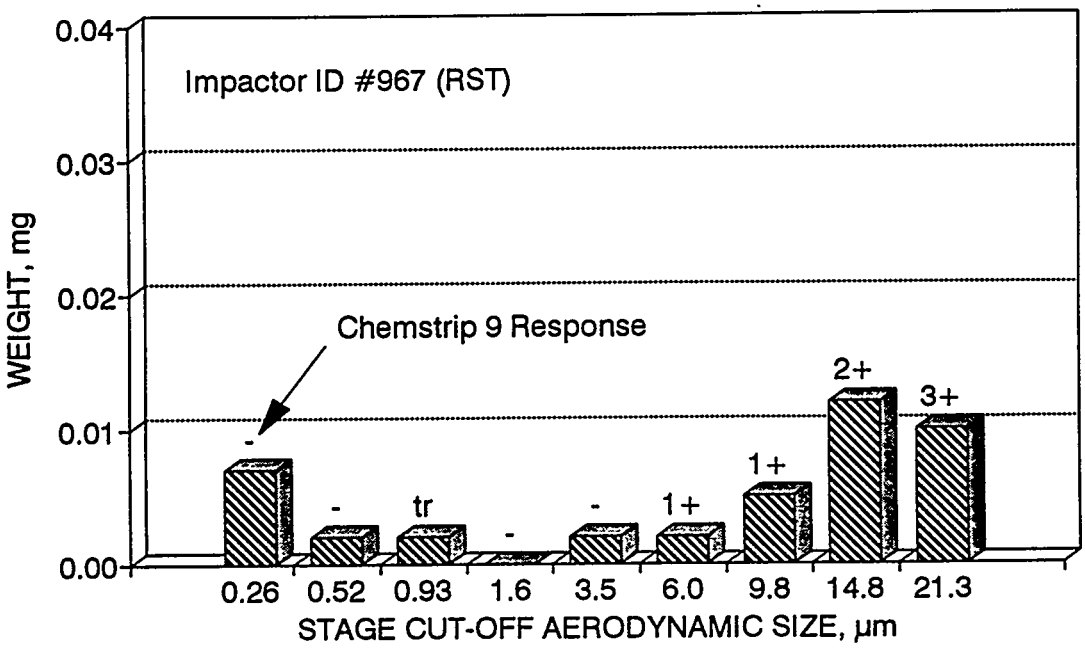
Size distribution by Marple Impactor
LMC4: Total Knee Replacement



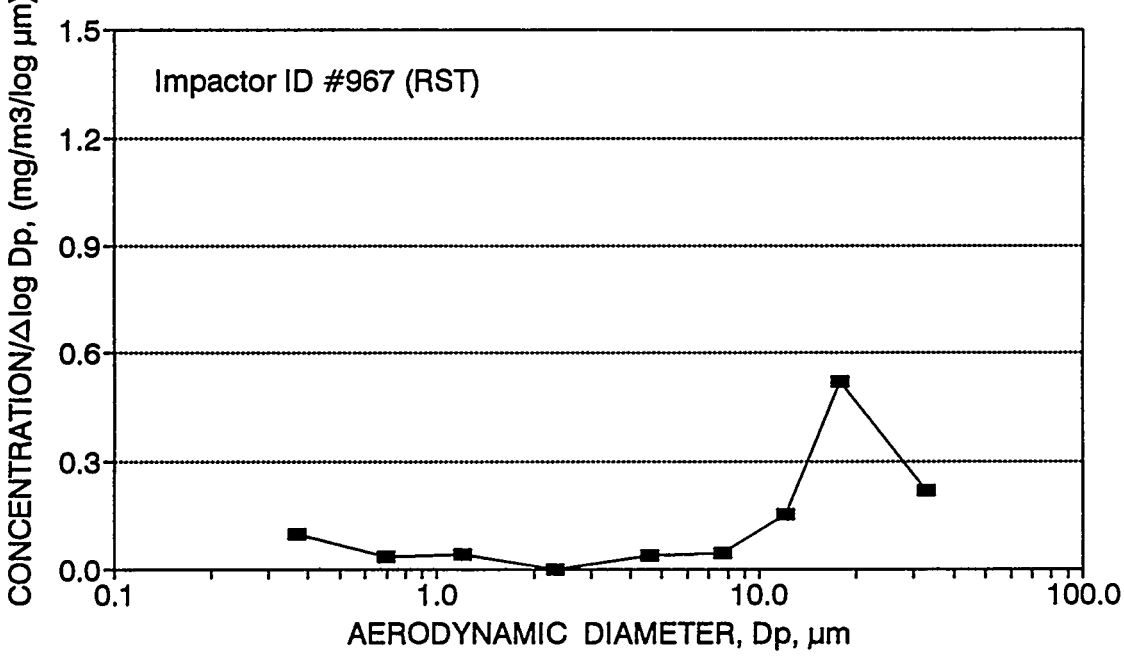
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 967: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.007	1	0.24	0.029	-0.585	0.301	0.097	0.37	0.115	0.000	-
8	0.52	0.002	0.99	0.24	0.008	-0.284	0.252	0.033	0.70	0.033	0.115	-
7	0.93	0.002	0.97	0.24	0.009	-0.032	0.222	0.039	1.20	0.034	0.148	tr
6	1.55	0.000	0.96	0.24	0.000	0.190	0.354	0.000	2.33	0.000	0.182	-
5	3.50	0.002	0.95	0.24	0.009	0.544	0.234	0.037	4.58	0.035	0.182	-
4	6.00	0.002	0.89	0.24	0.009	0.778	0.213	0.044	7.67	0.037	0.217	1+
3	9.80	0.005	0.78	0.24	0.027	0.991	0.179	0.149	12.04	0.106	0.254	1+
2	14.80	0.012	0.61	0.24	0.082	1.170	0.158	0.518	17.75	0.324	0.360	2+
1	21.30	0.010	0.52	0.24	0.080	1.328	0.371	0.216	32.63	0.317	0.683	3+
	50.00					1.699						
Sum		0.042			0.253					1.000		

Marple Personal Impactor Data
LMC4: Total Knee Replacement



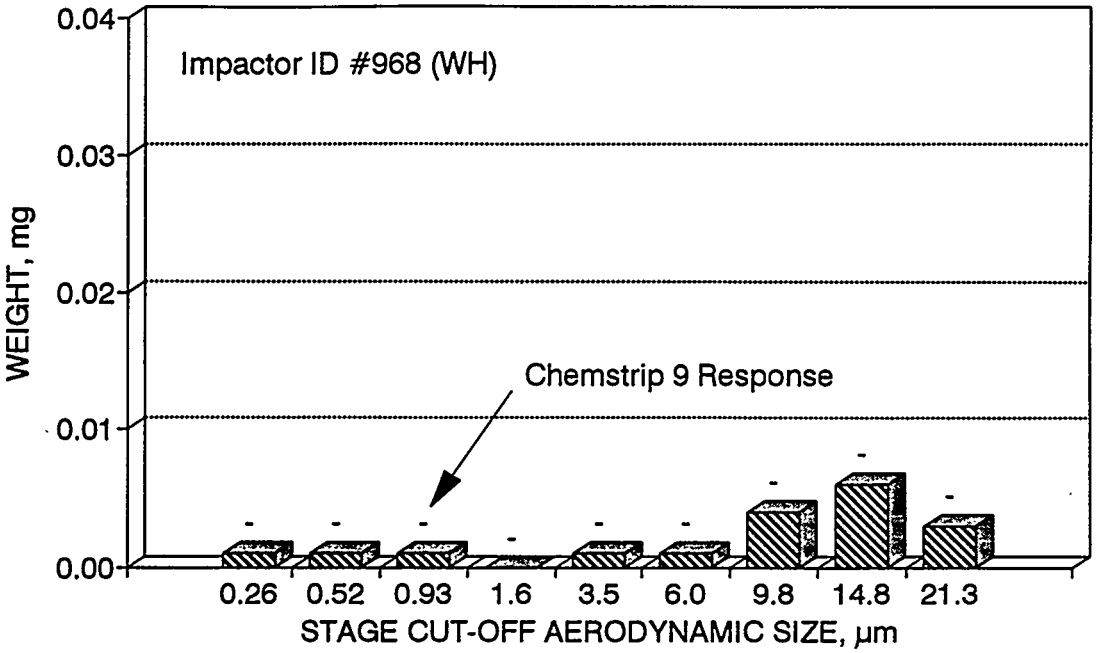
Size distribution by Marple Impactor
LMC4: Total Knee Replacement



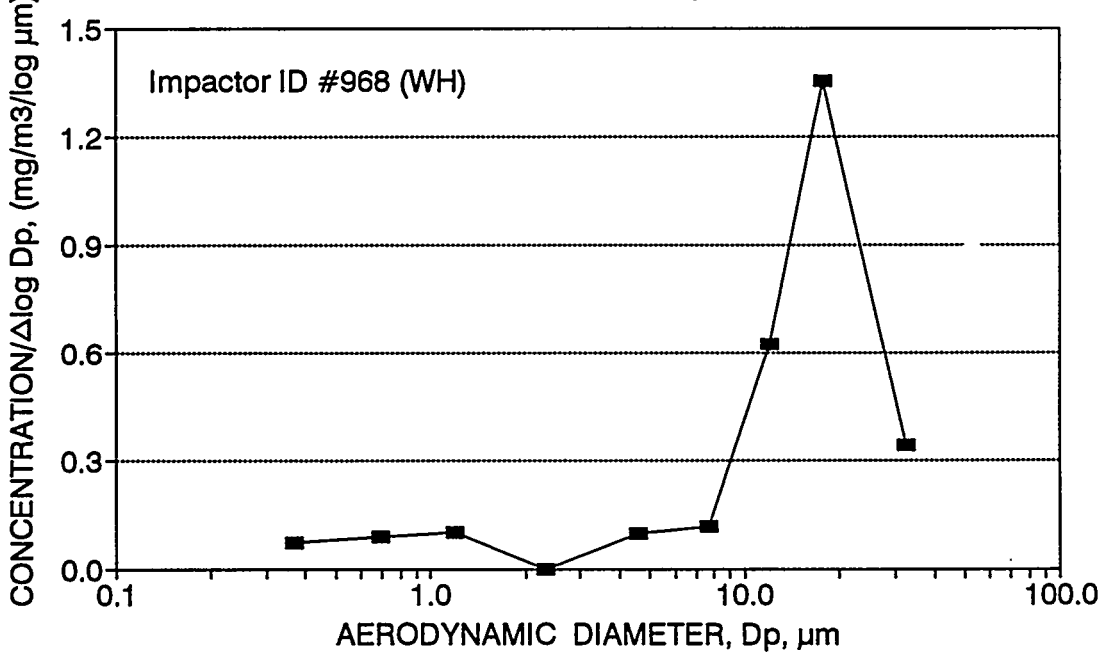
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 968: WH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.001	1	0.046	0.022	-0.585	0.301	0.072	0.37	0.039	0.000	-
8	0.52	0.001	0.99	0.046	0.022	-0.284	0.252	0.087	0.70	0.039	0.039	-
7	0.93	0.001	0.97	0.046	0.022	-0.032	0.222	0.101	1.20	0.040	0.077	-
6	1.55	0.000	0.96	0.046	0.000	0.190	0.354	0.000	2.33	0.000	0.117	-
5	3.50	0.001	0.95	0.046	0.023	0.544	0.234	0.098	4.58	0.041	0.117	-
4	6.00	0.001	0.89	0.046	0.024	0.778	0.213	0.115	7.67	0.043	0.158	-
3	9.80	0.004	0.78	0.046	0.111	0.991	0.179	0.623	12.04	0.198	0.201	-
2	14.80	0.006	0.61	0.046	0.214	1.170	0.158	1.352	17.75	0.379	0.399	-
1	21.30	0.003	0.52	0.046	0.125	1.328	0.371	0.338	32.63	0.222	0.778	-
	50.00					1.699						
Sum		0.018			0.564					1.000		

Marple Personal Impactor Data
LMC4: Total Knee Replacement



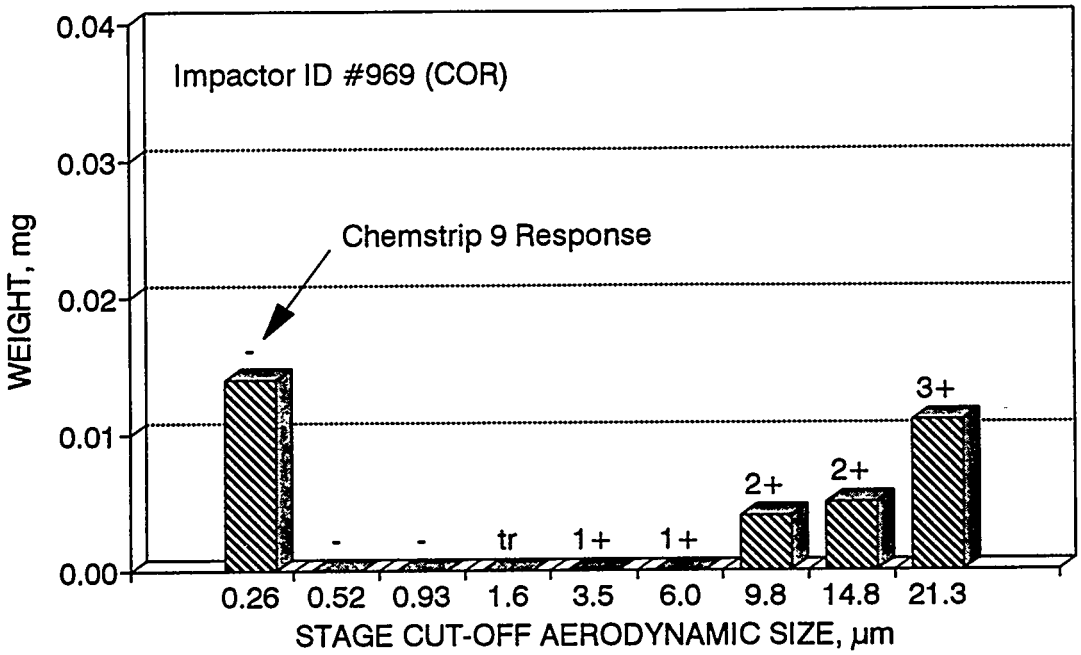
Size distribution by Marple Impactor
LMC4: Total Knee Replacement



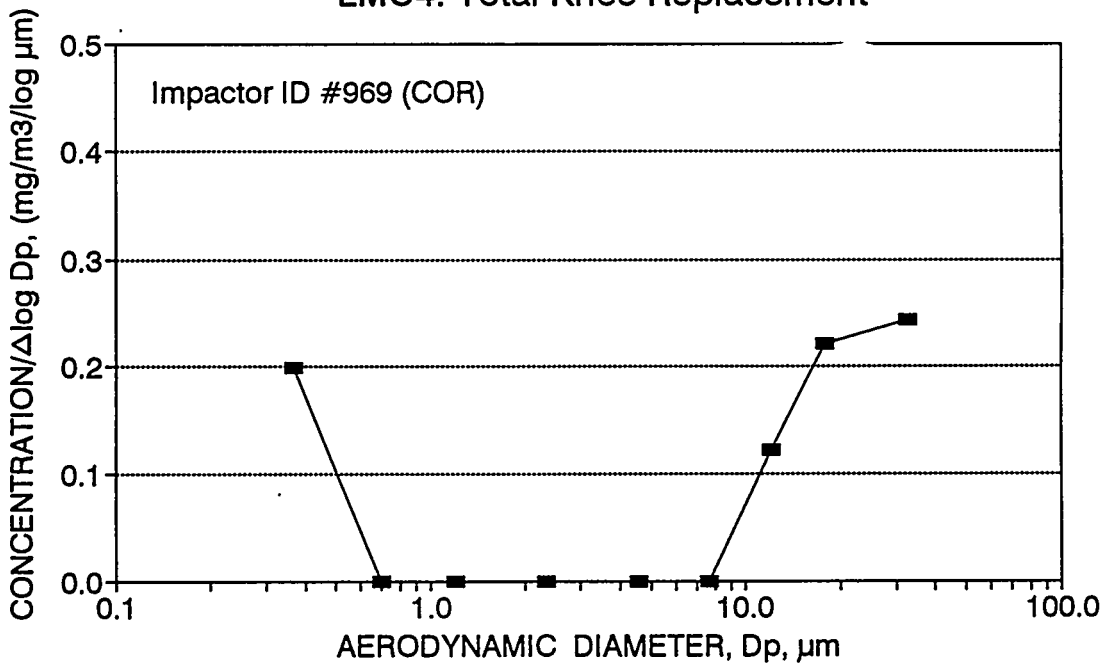
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 969: COR)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.014	1	0.234	0.060	-0.585	0.301	0.199	0.37	0.289	0.000	-
8	0.52	0.000	0.99	0.234	0.000	-0.284	0.252	0.000	0.70	0.000	0.289	-
7	0.93	0.000	0.97	0.234	0.000	-0.032	0.222	0.000	1.20	0.000	0.289	-
6	1.55	0.000	0.96	0.234	0.000	0.190	0.354	0.000	2.33	0.000	0.289	tr
5	3.50	0.000	0.95	0.234	0.000	0.544	0.234	0.000	4.58	0.000	0.289	1+
4	6.00	0.000	0.89	0.234	0.000	0.778	0.213	0.000	7.67	0.000	0.289	1+
3	9.80	0.004	0.78	0.234	0.022	0.991	0.179	0.122	12.04	0.106	0.289	2+
2	14.80	0.005	0.61	0.234	0.035	1.170	0.158	0.222	17.75	0.169	0.395	2+
1	21.30	0.011	0.52	0.234	0.090	1.328	0.371	0.244	32.63	0.436	0.564	3+
	50.00					1.699						
Sum		0.034			0.207					1.000		

Marple Personal Impactor Data
LMC4: Total Knee Replacement



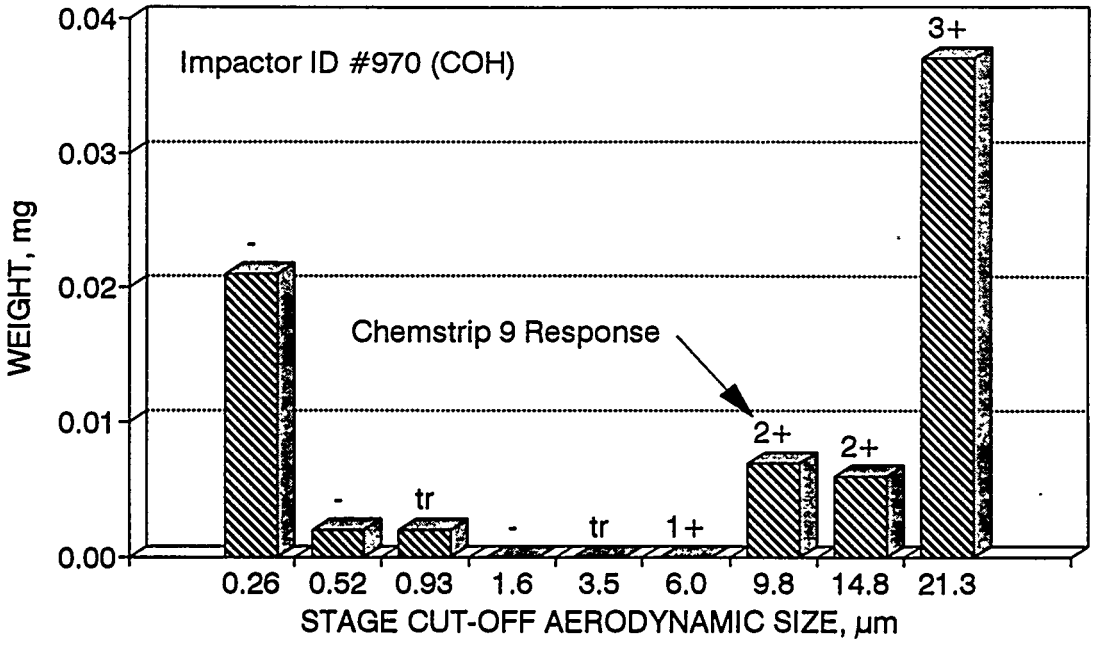
Size distribution by Marple Impactor
LMC4: Total Knee Replacement



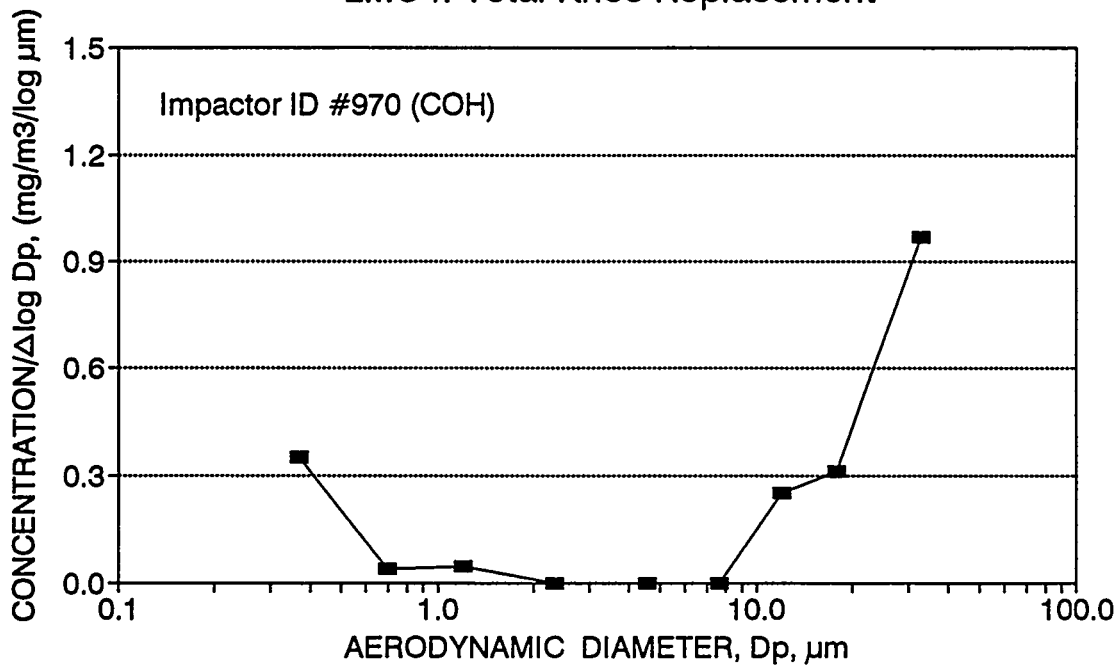
LMC4 Total Left Knee: Marple Personal Impactor Data (ID No. 970: COH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.021	1	0.198	0.106	-0.585	0.301	0.352	0.37	0.183	0.000	-
8	0.52	0.002	0.99	0.198	0.010	-0.284	0.252	0.040	0.70	0.018	0.183	-
7	0.93	0.002	0.97	0.198	0.010	-0.032	0.222	0.047	1.20	0.018	0.200	tr
6	1.55	0.000	0.96	0.198	0.000	0.190	0.354	0.000	2.33	0.000	0.218	-
5	3.50	0.000	0.95	0.198	0.000	0.544	0.234	0.000	4.58	0.000	0.218	tr
4	6.00	0.000	0.89	0.198	0.000	0.778	0.213	0.000	7.67	0.000	0.218	1+
3	9.80	0.007	0.78	0.198	0.045	0.991	0.179	0.253	12.04	0.078	0.218	2+
2	14.80	0.006	0.61	0.198	0.050	1.170	0.158	0.314	17.75	0.085	0.296	2+
1	21.30	0.037	0.52	0.198	0.359	1.328	0.371	0.970	32.63	0.618	0.382	3+
	50.00					1.699						
Sum		0.075			0.581					1.000		

Marple Personal Impactor Data
LMC4: Total Knee Replacement



Size distribution by Marple Impactor
LMC4: Total Knee Replacement



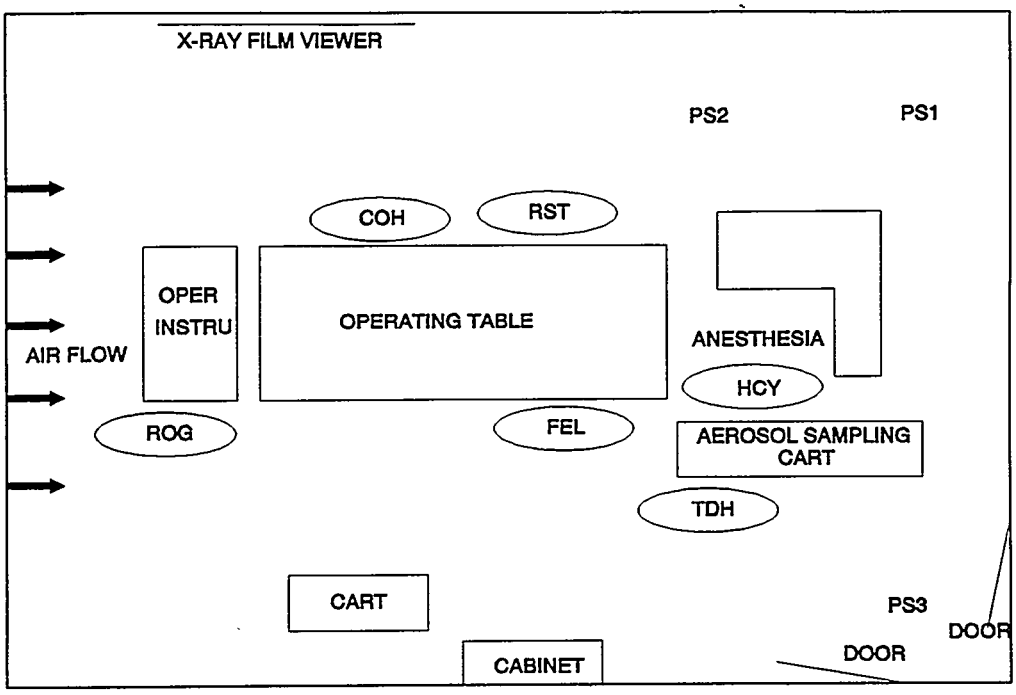
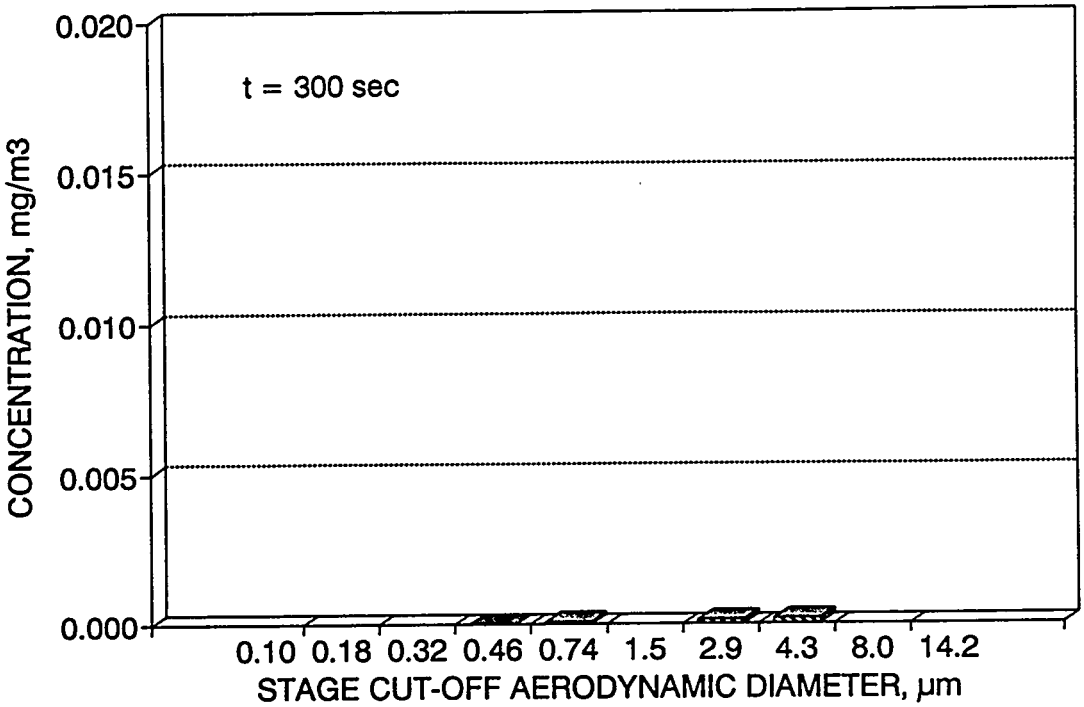


Figure C.5 Initial locations of personnel and area filters during LMC #5 measurement (total hip replacement).

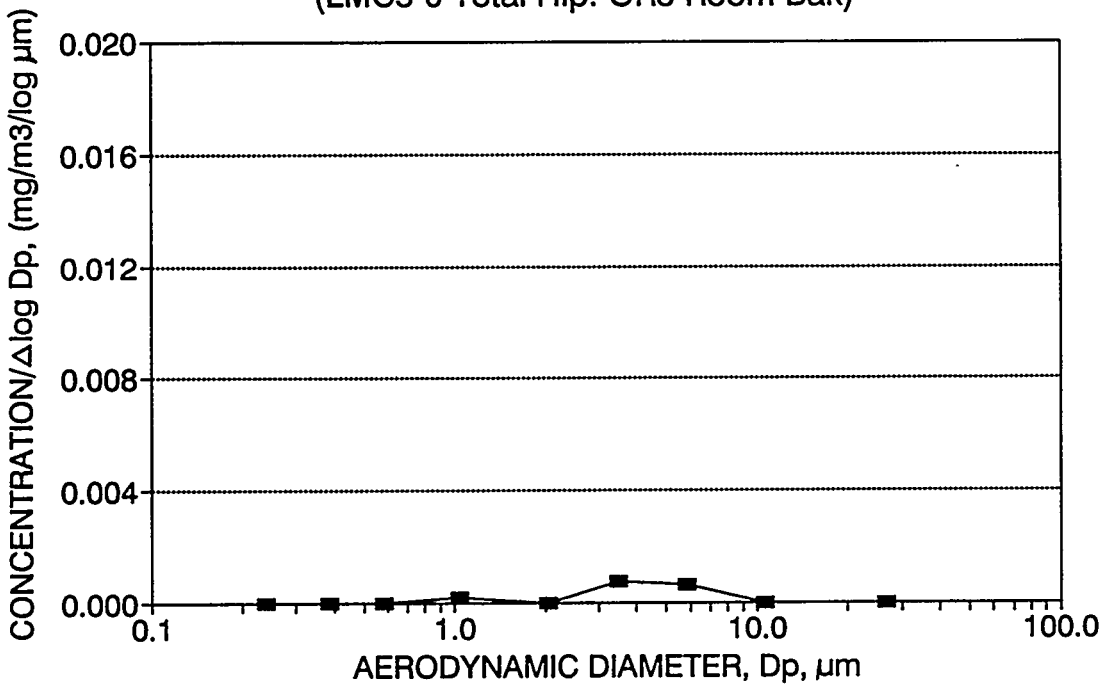
LMC5-0 Total Hip: OR5 Room Background (t = 300 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00005	0.74	-0.128	0.290	0.000	1.04	0.1429	0.000
1.00		1.45	0.162	0.296	0.000	2.04	0.0000	0.143
2.00	0.00013	2.87	0.457	0.174	0.001	3.50	0.3714	0.143
3.00	0.00017	4.28	0.632	0.269	0.001	5.84	0.4857	0.514
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00035						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-0 Total Hip: OR5 Room Bak)



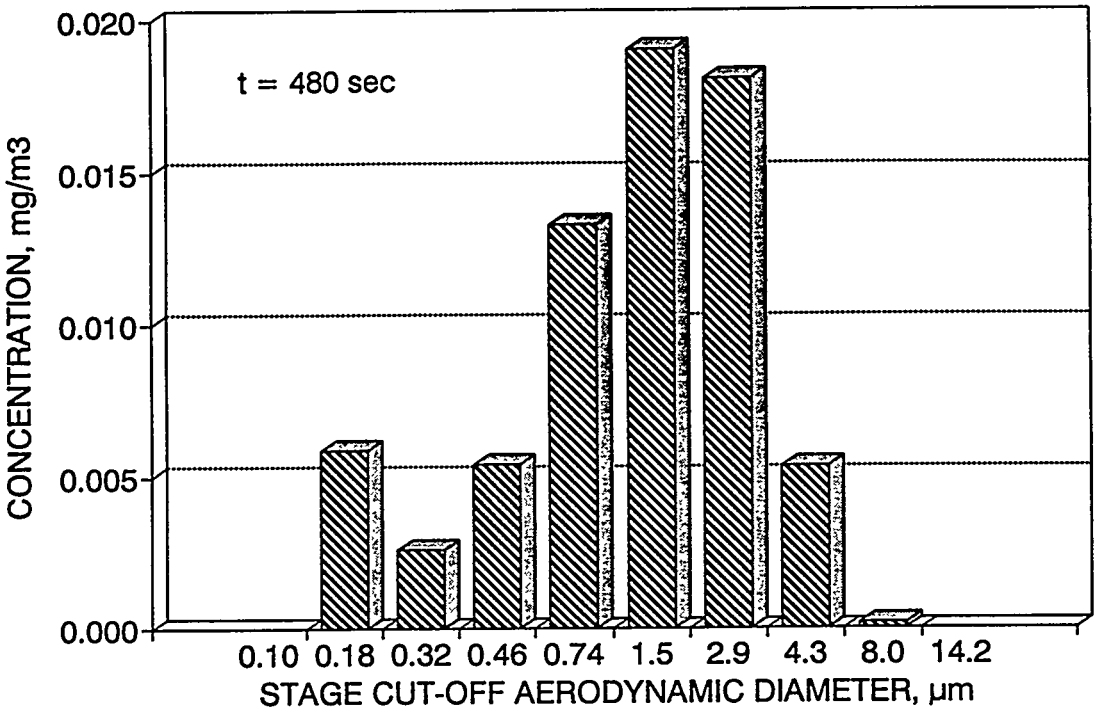
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-0 Total Hip: OR5 Room Bak)



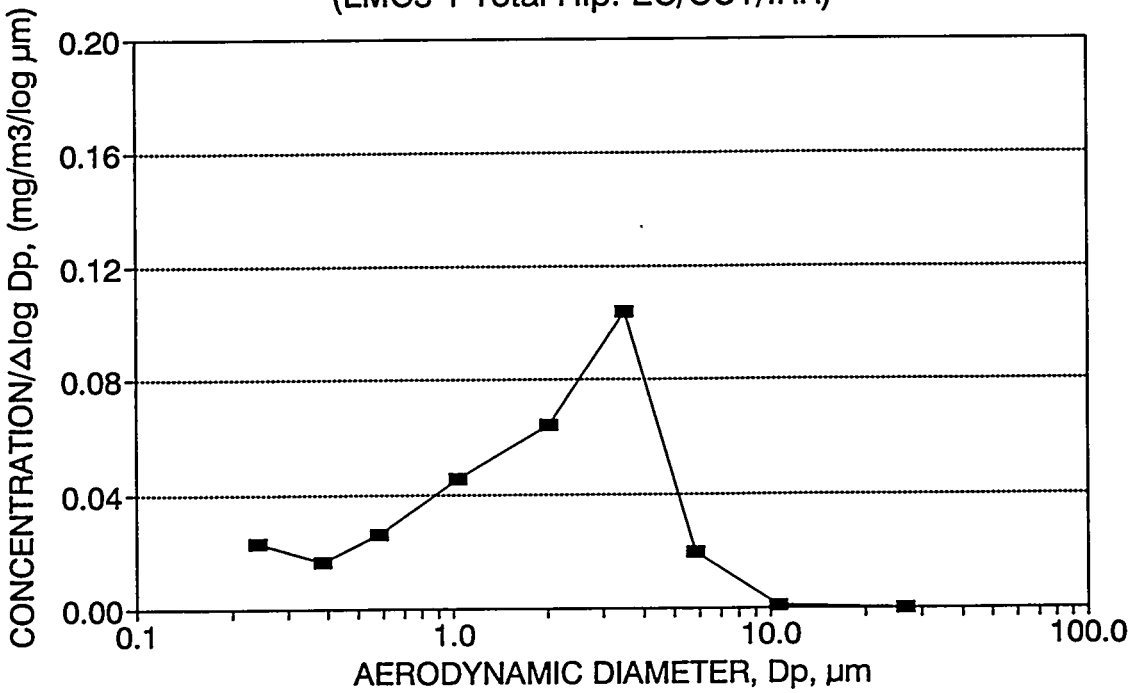
LMC5-1 Total Hip: EC/CUT/IRR (t = 480 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00588	0.18	-0.749	0.257	0.023	0.24	0.0842	0.000
0.20	0.00260	0.32	-0.492	0.157	0.017	0.39	0.0372	0.084
0.30	0.00540	0.46	-0.335	0.206	0.026	0.59	0.0774	0.121
0.50	0.0133	0.74	-0.128	0.290	0.046	1.04	0.1905	0.199
1.00	0.01903	1.45	0.162	0.296	0.064	2.04	0.2726	0.389
2.00	0.01810	2.87	0.457	0.174	0.104	3.50	0.2593	0.662
3.00	0.00533	4.28	0.632	0.269	0.020	5.84	0.0764	0.921
5.60	0.00016	7.96	0.901	0.251	0.001	10.62	0.0023	0.998
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.0698						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-1 Total Hip: EC/CUT/IRR)



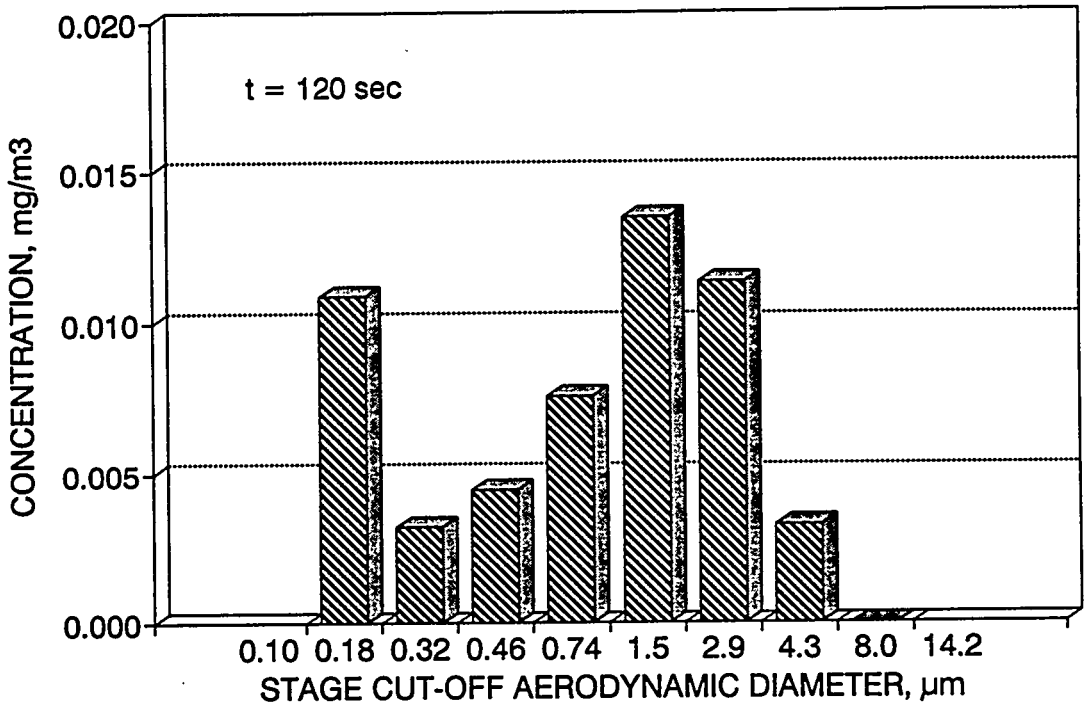
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-1 Total Hip: EC/CUT/IRR)



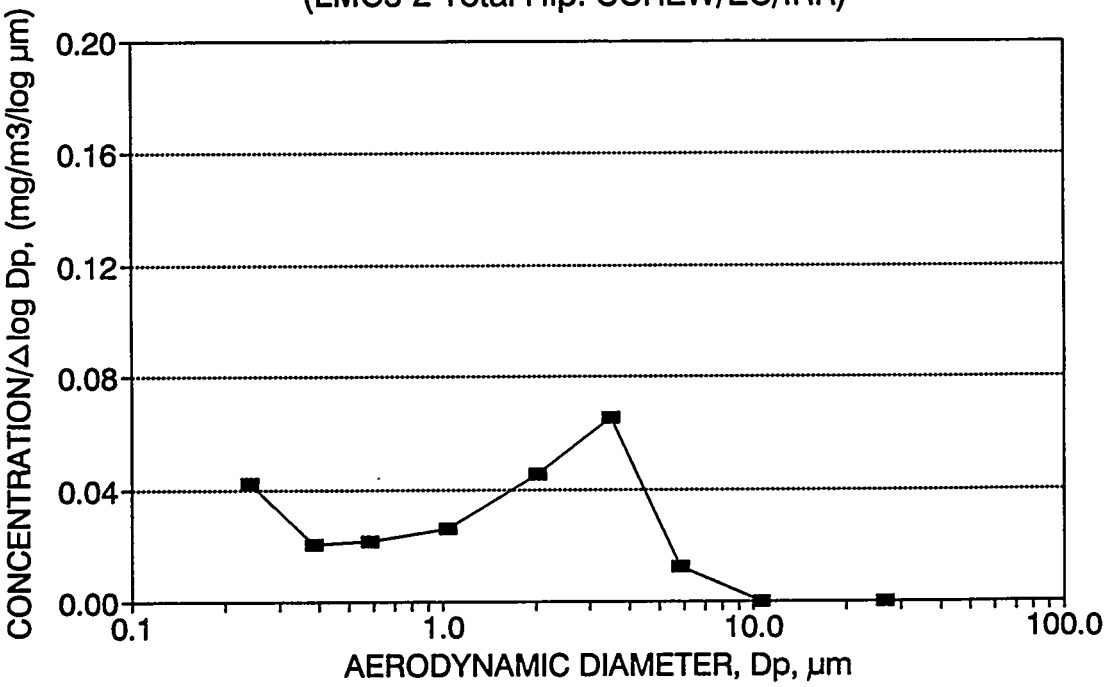
LMC5-2 Total Hip: SCREW/EC/IRR (t = 120 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.01088	0.18	-0.749	0.257	0.042	0.24	0.2006	0.000
0.20	0.00320	0.32	-0.492	0.157	0.020	0.39	0.0590	0.201
0.30	0.00445	0.46	-0.335	0.206	0.022	0.59	0.0820	0.260
0.50	0.00756	0.74	-0.128	0.290	0.026	1.04	0.1394	0.342
1.00	0.01348	1.45	0.162	0.296	0.046	2.04	0.2485	0.481
2.00	0.01138	2.87	0.457	0.174	0.065	3.50	0.2098	0.729
3.00	0.00330	4.28	0.632	0.269	0.012	5.84	0.0608	0.939
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.05425						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-2 Total Hip: SCREW/EC/IRR)



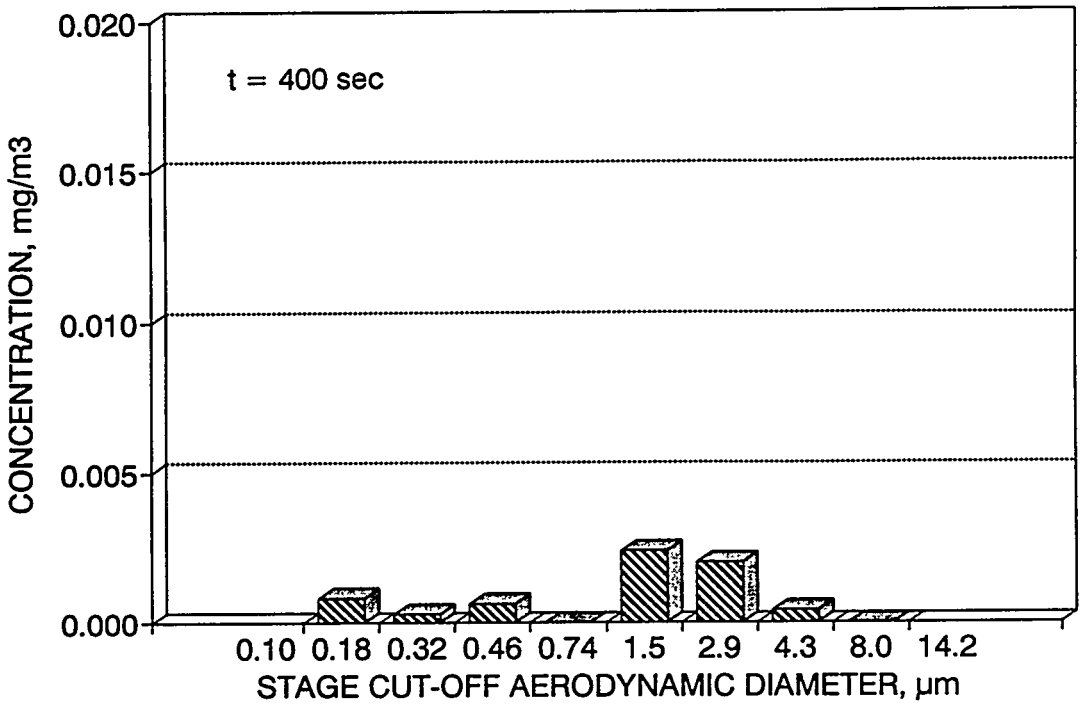
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-2 Total Hip: SCREW/EC/IRR)



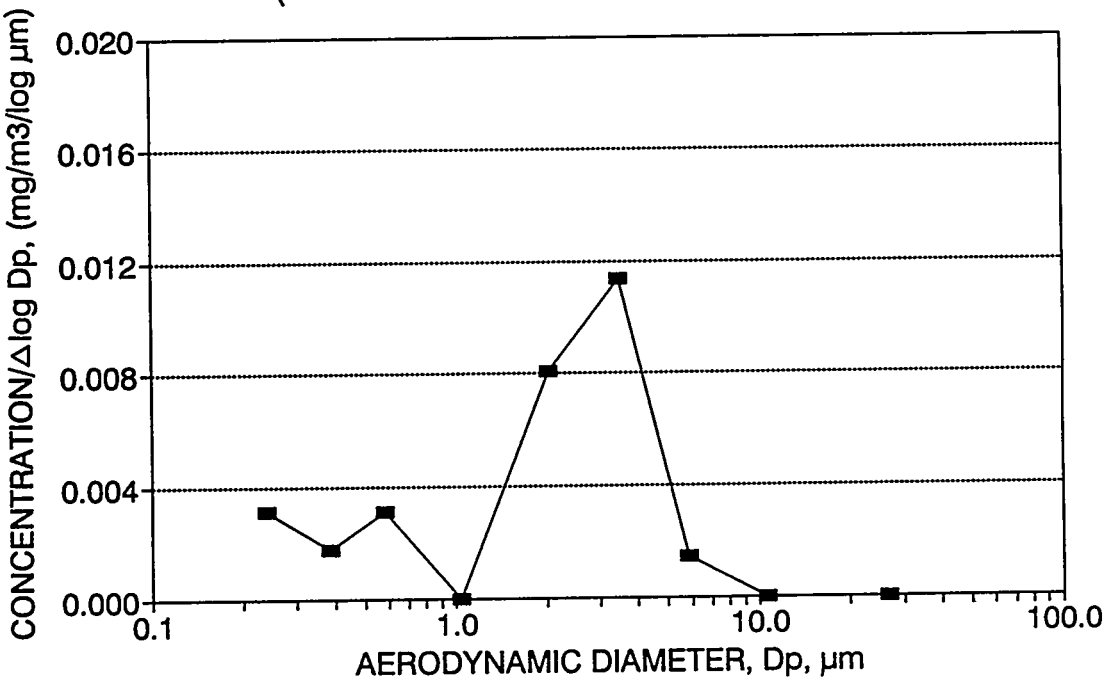
LMC5-3 Total Hip: Saw off Femur/IRR/EC (t = 400 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00081	0.18	-0.749	0.257	0.003	0.24	0.1248	0.000
0.20	0.00028	0.32	-0.492	0.157	0.002	0.39	0.0431	0.125
0.30	0.00064	0.46	-0.335	0.206	0.003	0.59	0.0986	0.168
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.267
1.00	0.00239	1.45	0.162	0.296	0.008	2.04	0.3683	0.267
2.00	0.00198	2.87	0.457	0.174	0.011	3.50	0.3051	0.635
3.00	0.00039	4.28	0.632	0.269	0.001	5.84	0.0601	0.940
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00649						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-3 T. H.: SAW OFF FEMUR/IRR/EC)



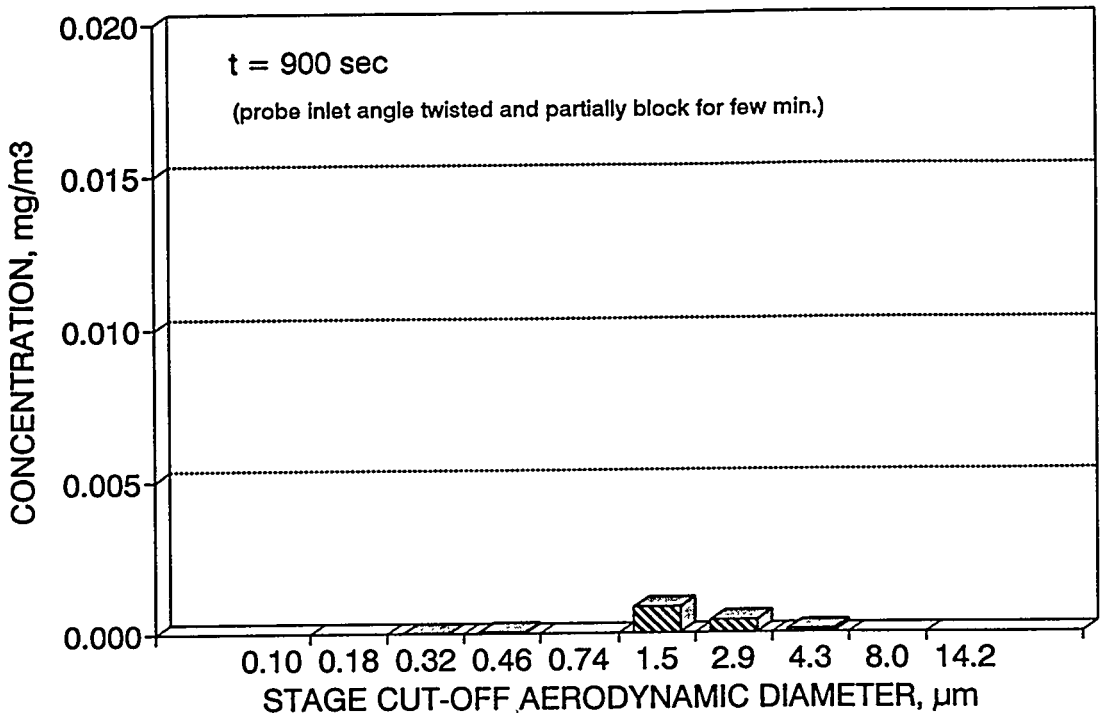
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-3 T.H.: SAW OFF FEMUR/IRR/EC)



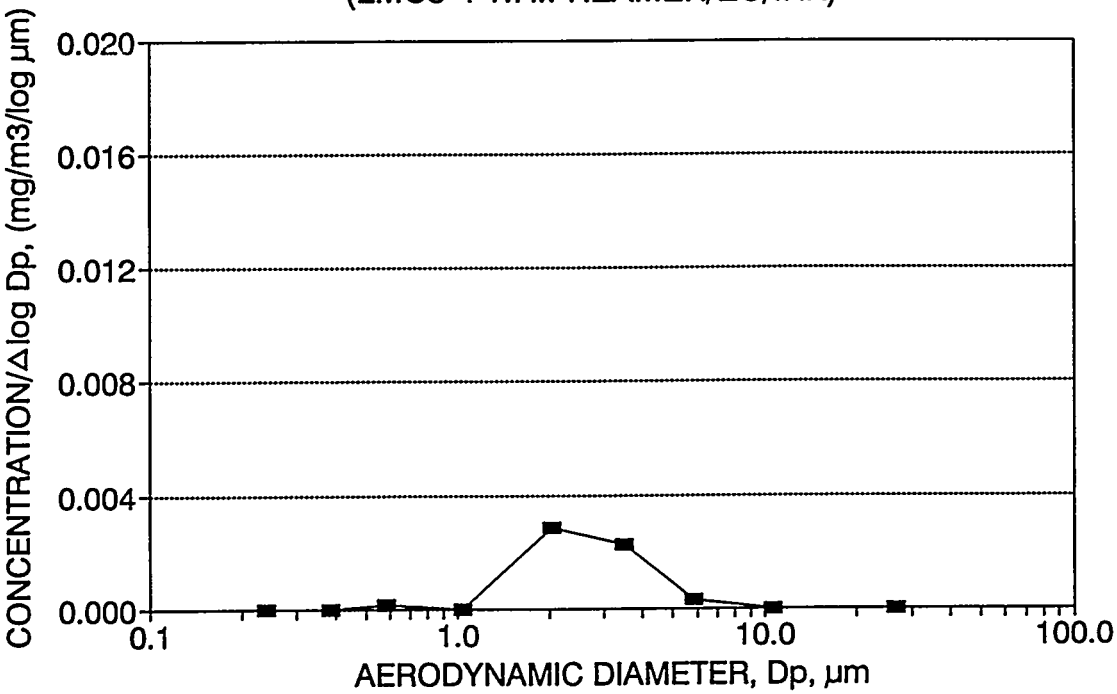
LMC5-4 Total Hip: REAMER/EC/IRR (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00003	0.46	-0.335	0.206	0.000	0.59	0.0222	0.000
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.022
1.00	0.00085	1.45	0.162	0.296	0.003	2.04	0.6296	0.022
2.00	0.00039	2.87	0.457	0.174	0.002	3.50	0.2889	0.652
3.00	0.00008	4.28	0.632	0.269	0.000	5.84	0.0593	0.941
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00135						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-4 T. H.: REAMER/EC/IRR)



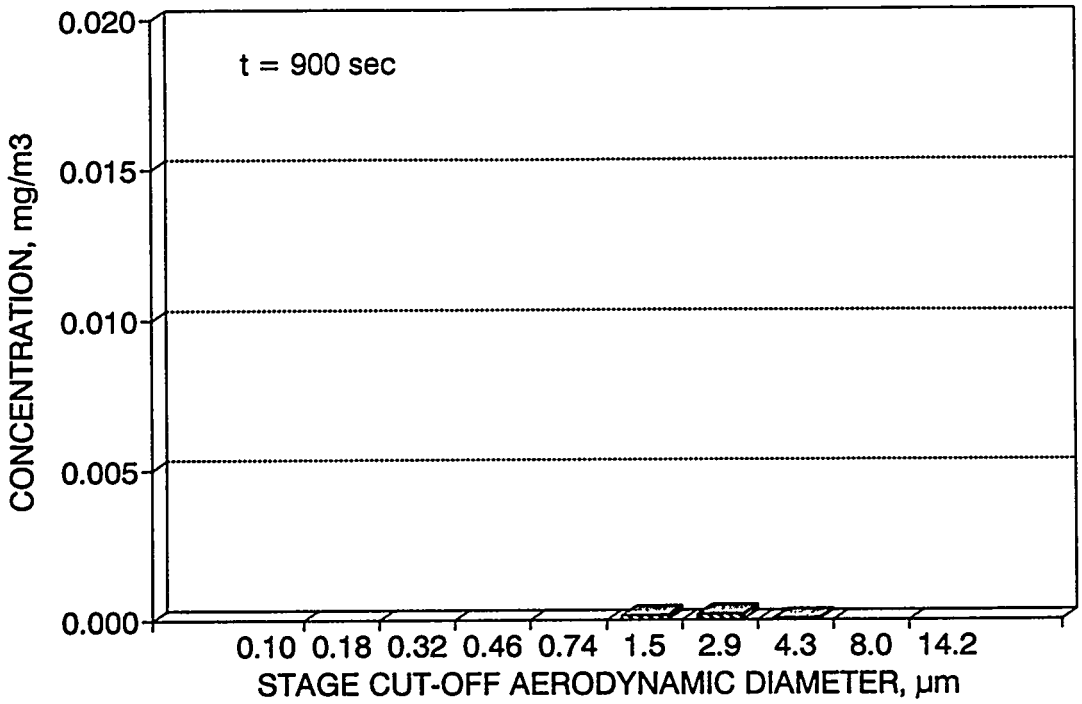
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-4 T.H.: REAMER/EC/IRR)



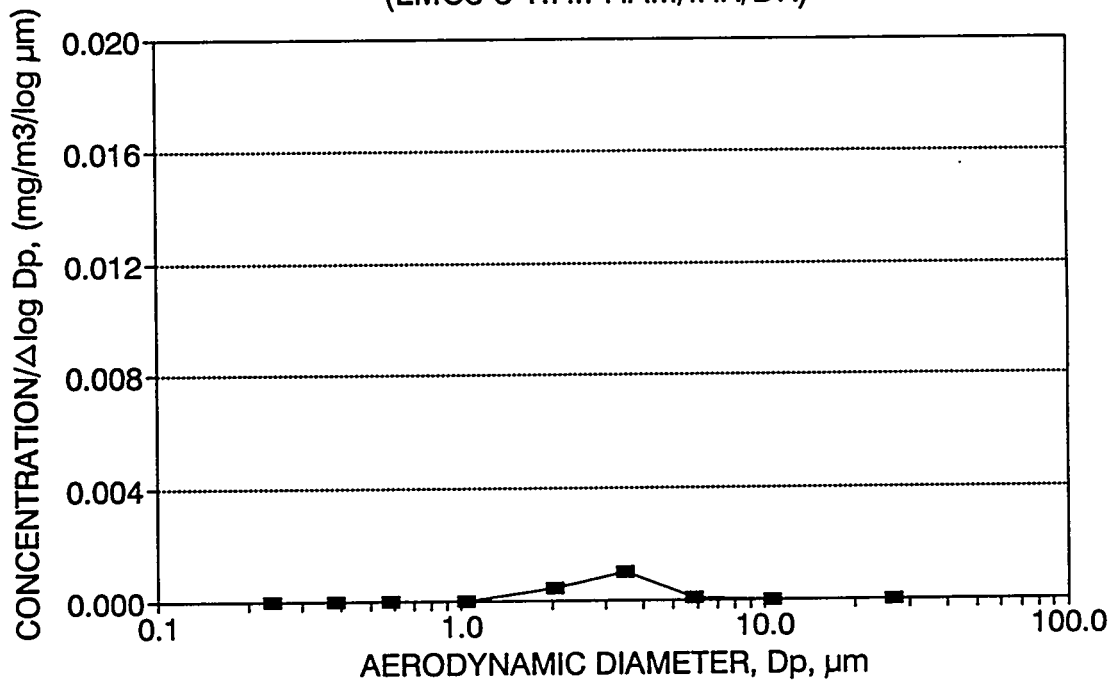
LMC5-5 Total Hip: HAM/IRR/DR (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00013	1.45	0.162	0.296	0.000	2.04	0.4062	0.000
2.00	0.00017	2.87	0.457	0.174	0.001	3.50	0.5313	0.406
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.0625	0.938
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00032						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-5 T. H.: HAM/IRR/DR)



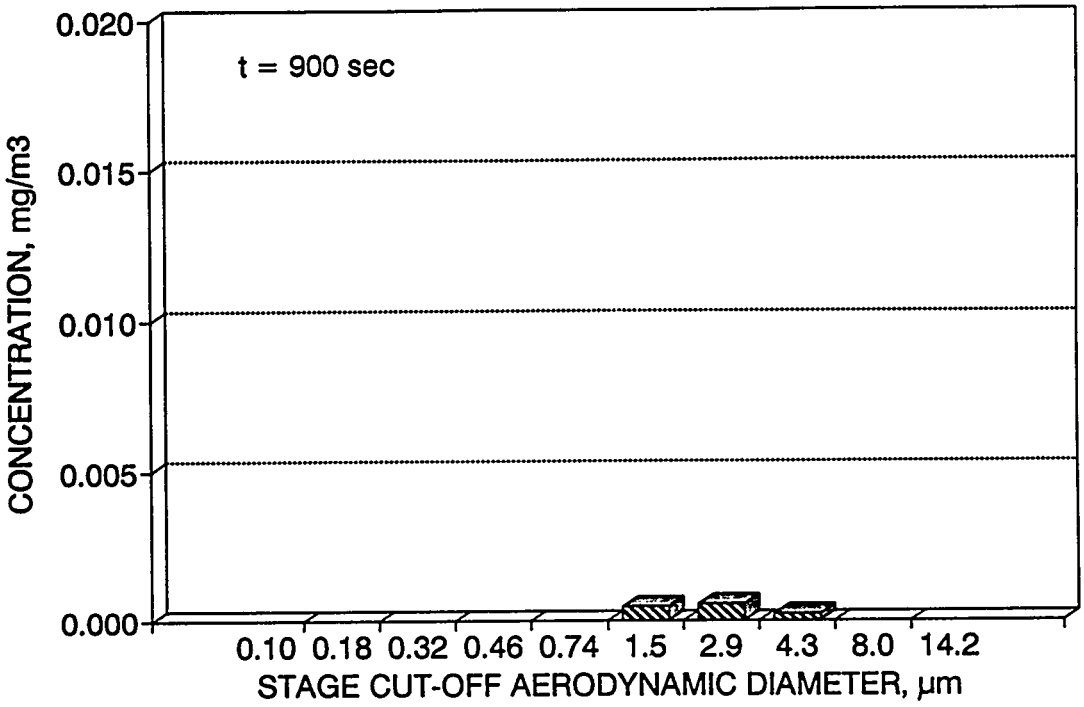
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-5 T.H.: HAM/IRR/DR)



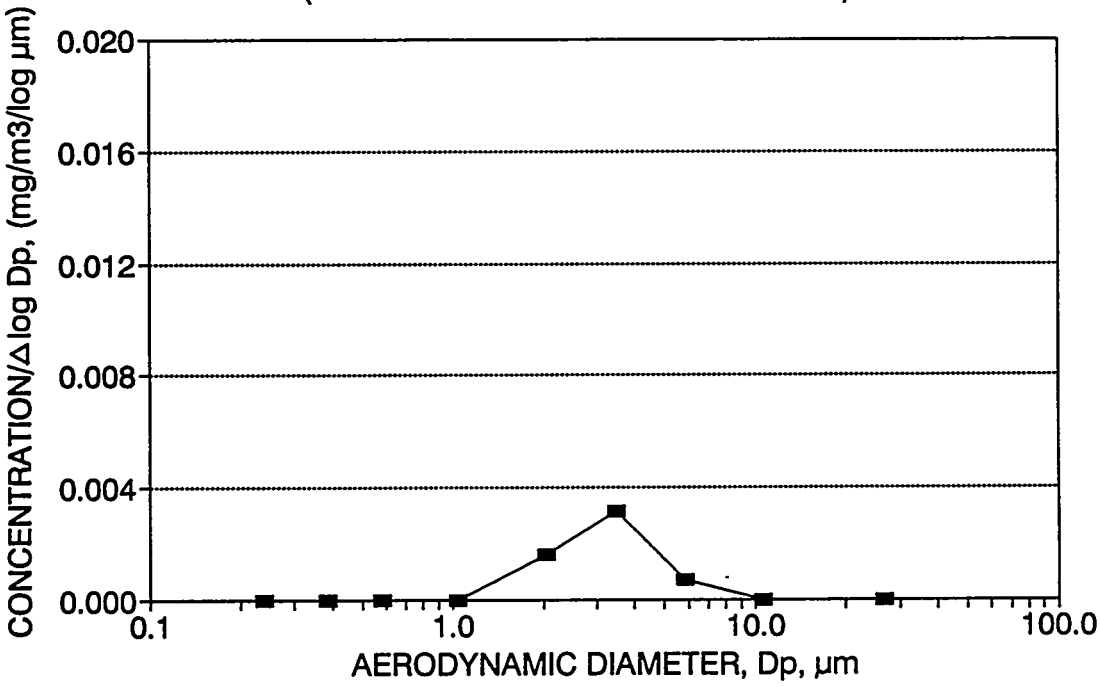
LMC5-6 Total Hip: Fit Prothesis/CHI/GRD (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30		0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00047	1.45	0.162	0.296	0.002	2.04	0.3884	0.000
2.00	0.00055	2.87	0.457	0.174	0.003	3.50	0.4545	0.388
3.00	0.00019	4.28	0.632	0.269	0.001	5.84	0.1570	0.843
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00121						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-6 T. H.: Fit Prothesis/CHI/Grd))



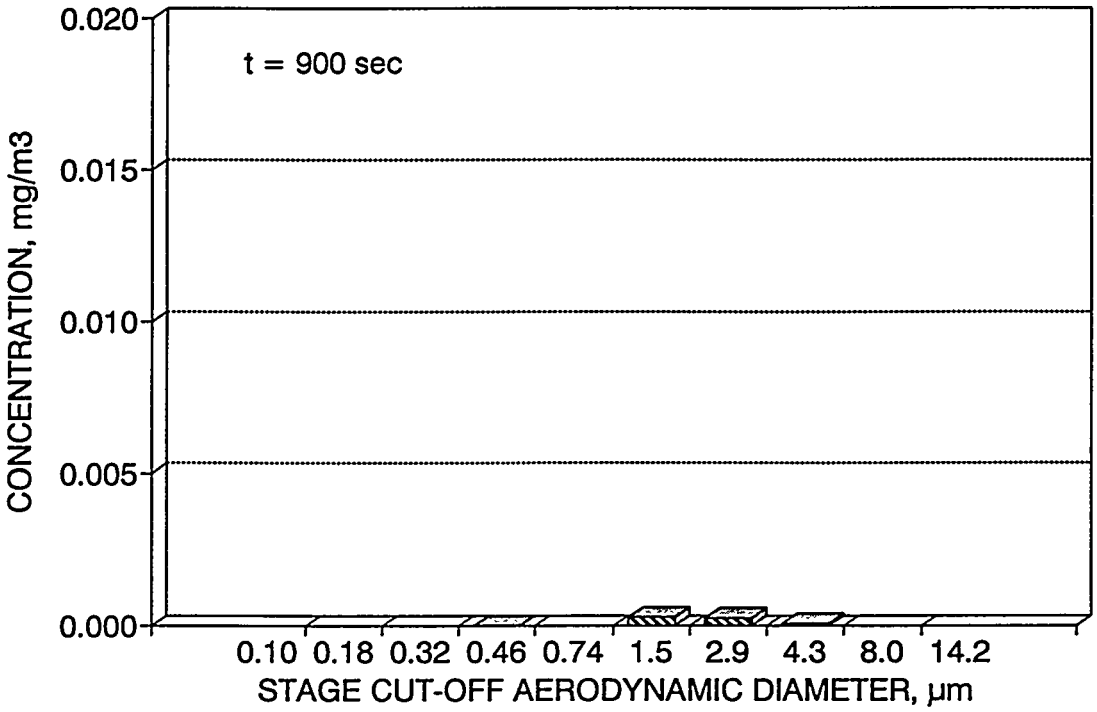
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-6 T.H.: Fit Prothesis/CHI/Grd)



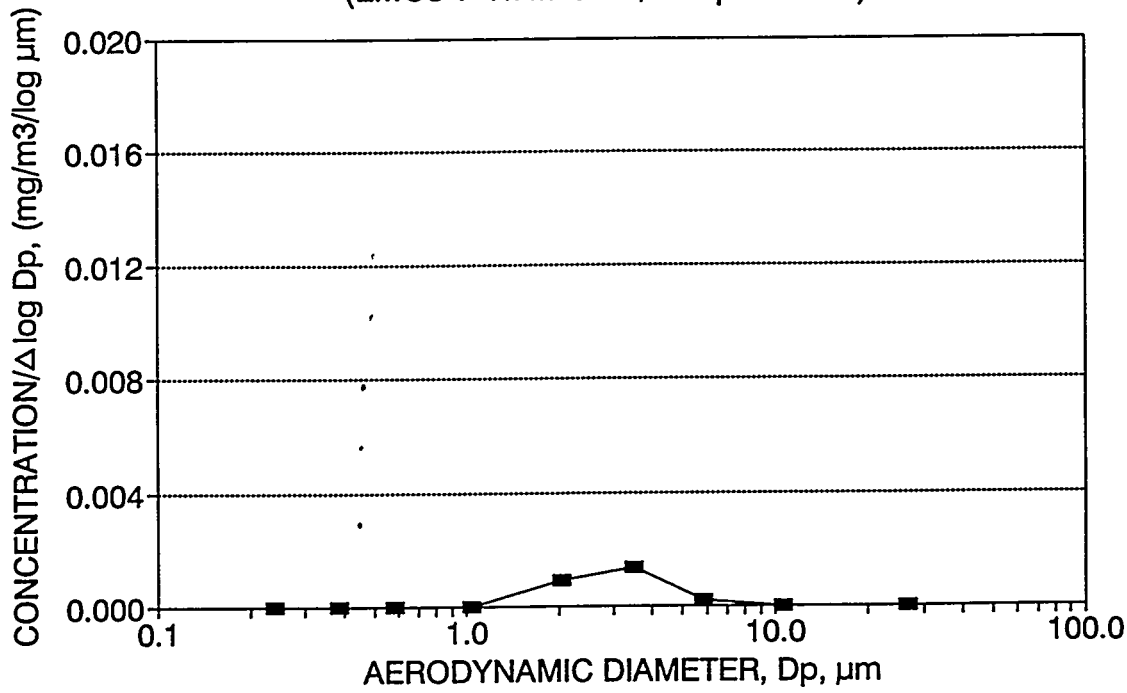
LMC5-7 Total Hip: Cement/Install Prothesis (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00027	1.45	0.162	0.296	0.001	2.04	0.4821	0.000
2.00	0.00024	2.87	0.457	0.174	0.001	3.50	0.4286	0.482
3.00	0.00005	4.28	0.632	0.269	0.000	5.84	0.0893	0.911
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00056						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-7 T. H.: Cem/Inst Prothesis)

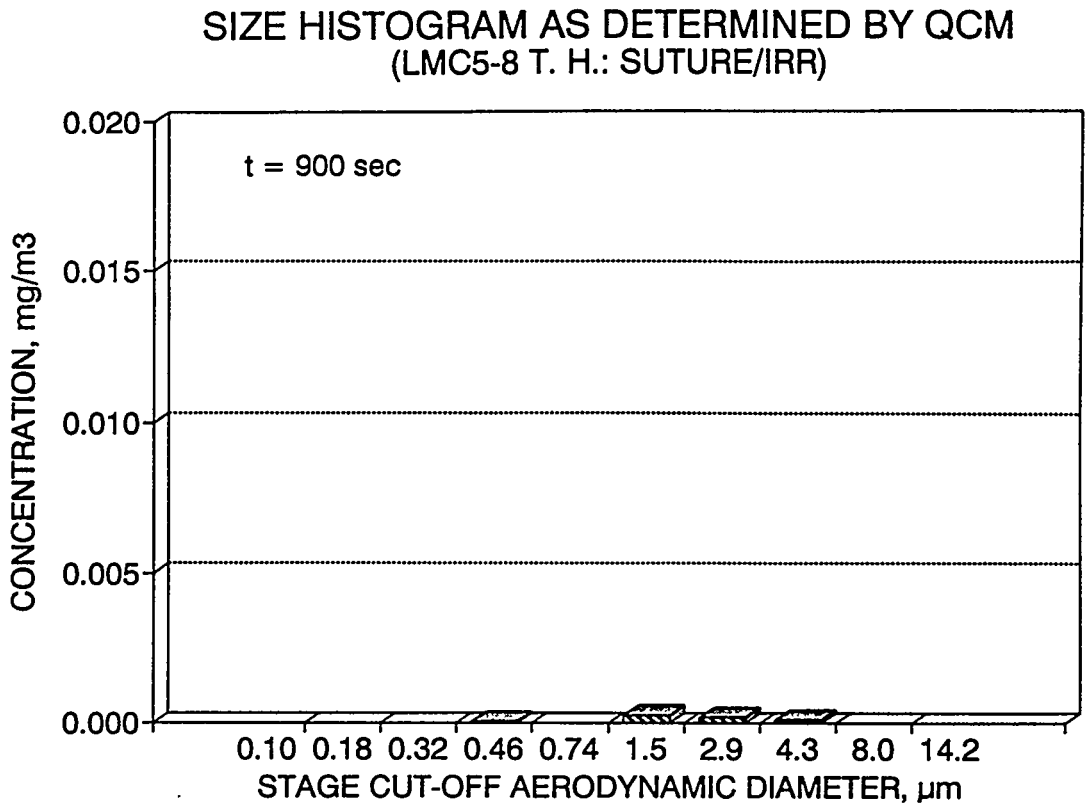


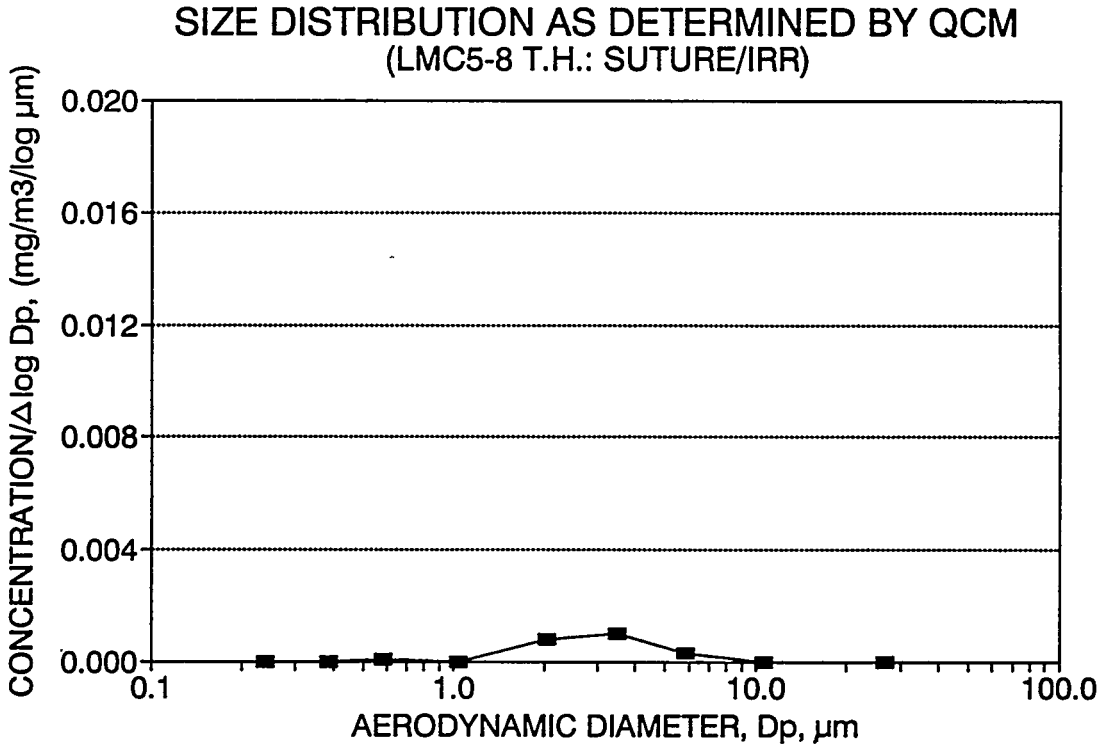
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-7 T.H.: Cem/Inst prothesis)



LMC5-8 Total Hip: Suture/Irrigation (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20		0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0204	0.000
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.020
1.00	0.00023	1.45	0.162	0.296	0.001	2.04	0.4694	0.020
2.00	0.00017	2.87	0.457	0.174	0.001	3.50	0.3469	0.490
3.00	0.00008	4.28	0.632	0.269	0.000	5.84	0.1633	0.837
5.60		7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00049						1.0000	

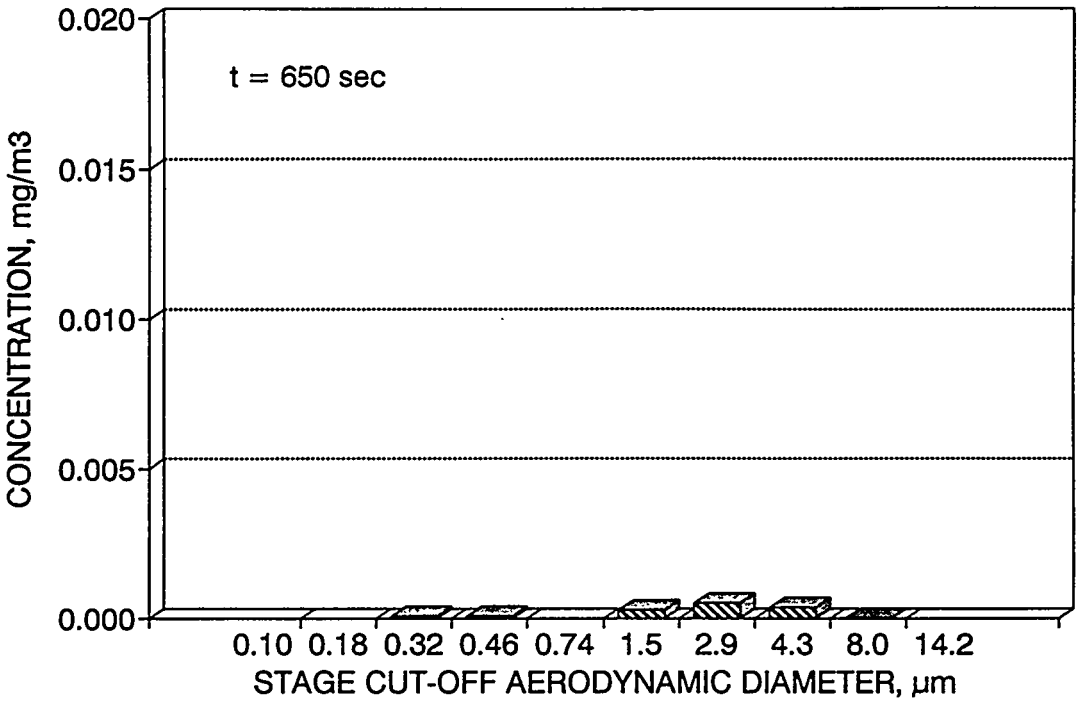

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-8 T. H.: SUTURE/IRR)
t = 900 sec
CONCENTRATION, mg/m3
0.020
0.015
0.010
0.005
0.000
0.10 0.18 0.32 0.46 0.74 1.5 2.9 4.3 8.0 14.2
STAGE CUT-OFF AERODYNAMIC DIAMETER, µm


SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-8 T.H.: SUTURE/IRR)
CONCENTRATION/Δlog Dp, (mg/m3/log µm)
0.020
0.016
0.012
0.008
0.004
0.000
0.1
1.0
10.0
100.0
AERODYNAMIC DIAMETER, Dp, µm

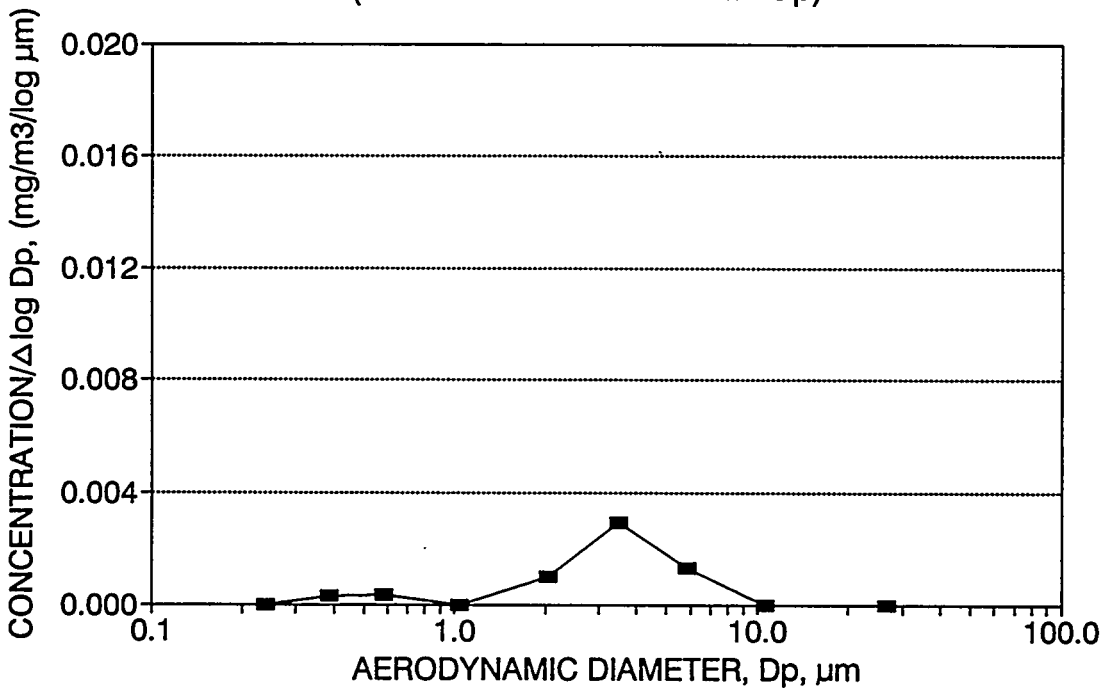
LMC5-9 Total Hip: Room Clean Up (t = 650 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10		0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00005	0.32	-0.492	0.157	0.000	0.39	0.0391	0.000
0.30	0.00007	0.46	-0.335	0.206	0.000	0.59	0.0547	0.039
0.50		0.74	-0.128	0.290	0.000	1.04	0.0000	0.094
1.00	0.00029	1.45	0.162	0.296	0.001	2.04	0.2266	0.094
2.00	0.00051	2.87	0.457	0.174	0.003	3.50	0.3984	0.320
3.00	0.00036	4.28	0.632	0.269	0.001	5.84	0.2813	0.719
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00		14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00128						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC5-9 T. H.: Room Clean Up)



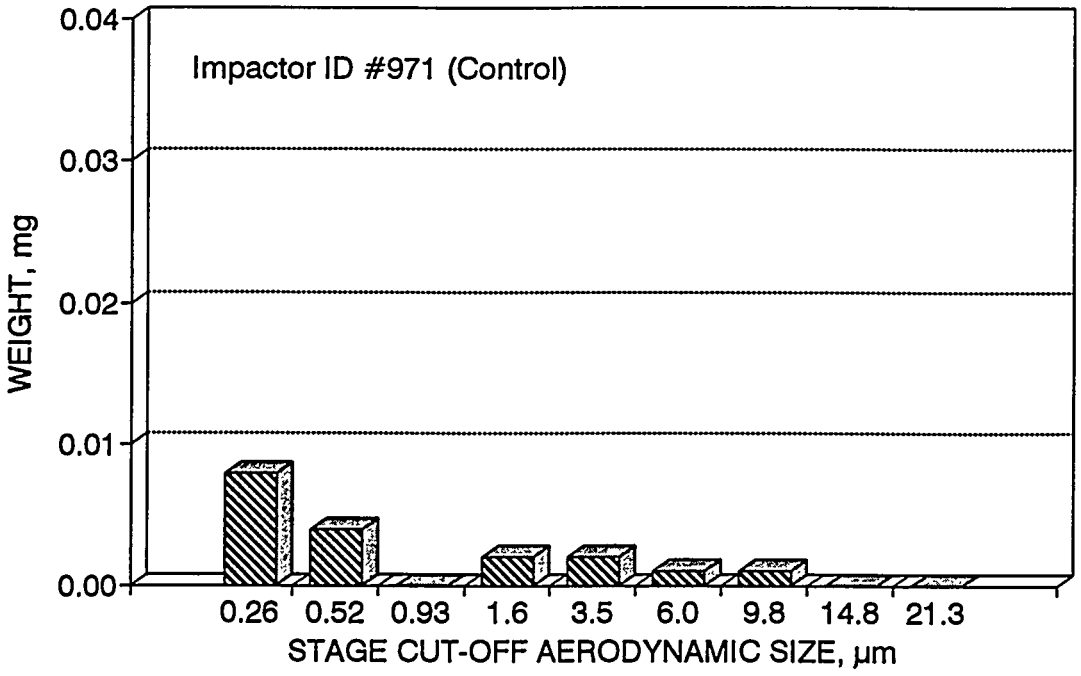
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC5-9 T.H.: Room Clean Up)



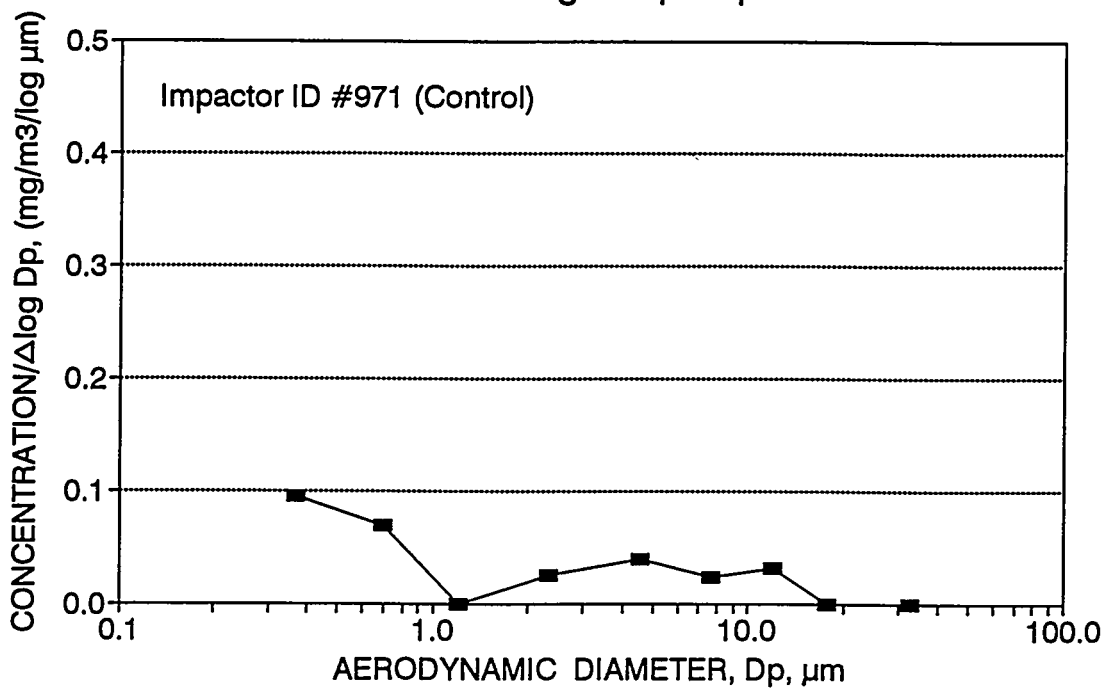
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 971: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.008	1	0.276	0.029	-0.585	0.301	0.096	0.37	0.385	0.000
8	0.52	0.004	0.99	0.23	0.018	-0.284	0.252	0.070	0.70	0.234	0.385
7	0.93	0.000	0.97	0.23	0.000	-0.032	0.222	0.000	1.20	0.000	0.619
6	1.55	0.002	0.96	0.23	0.009	0.190	0.354	0.026	2.33	0.120	0.619
5	3.50	0.002	0.95	0.23	0.009	0.544	0.234	0.039	4.58	0.122	0.739
4	6.00	0.001	0.89	0.23	0.005	0.778	0.213	0.023	7.67	0.065	0.861
3	9.80	0.001	0.78	0.23	0.006	0.991	0.179	0.031	12.04	0.074	0.926
2	14.80	0.000	0.61	0.23	0.000	1.170	0.158	0.000	17.75	0.000	1.000
1	21.30	0.000	0.52	0.23	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		0.018			0.075					1.000	

Marple Personal Impactor Data
LMC5: Total Right Hip Replacement



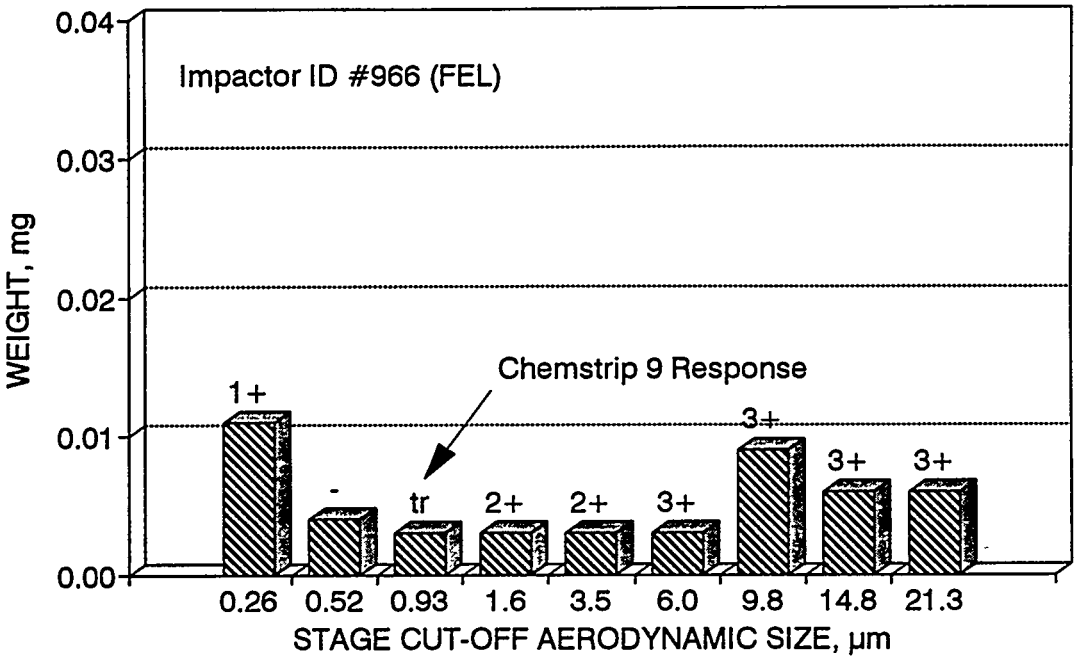
Size distribution by Marple Impactor
LMC5: Total Right Hip Replacement



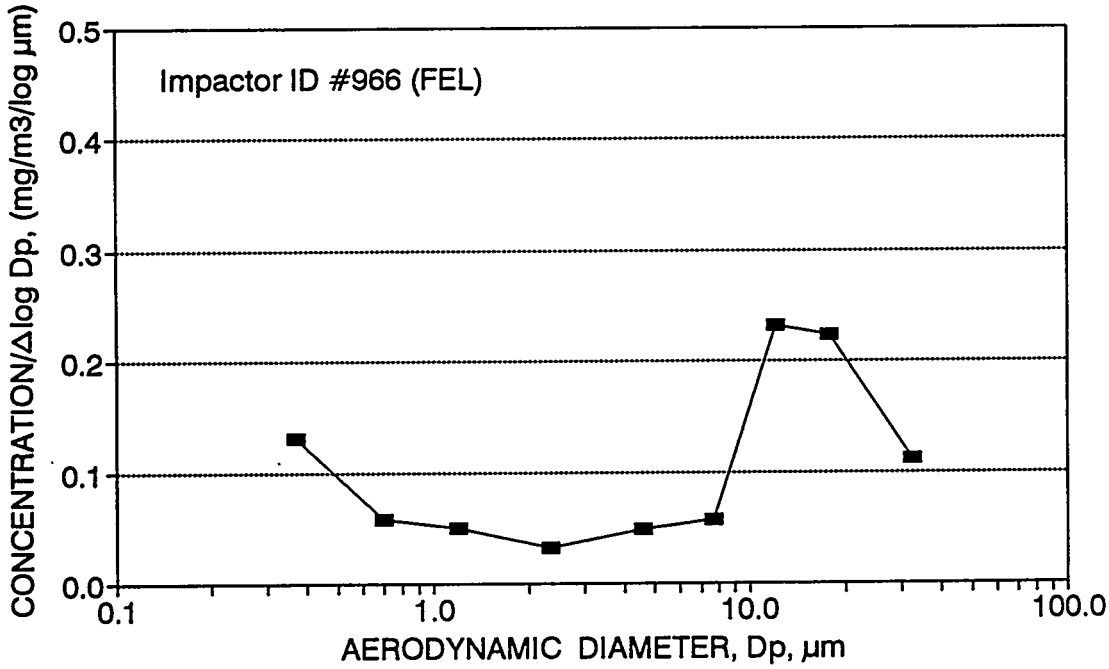
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 966: FEL)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.011	1	0.278	0.040	-0.585	0.301	0.131	0.37	0.181	0.000	1+
8	0.52	0.004	0.99	0.278	0.015	-0.284	0.252	0.058	0.70	0.067	0.181	-
7	0.93	0.003	0.97	0.278	0.011	-0.032	0.222	0.050	1.20	0.051	0.248	tr
6	1.55	0.003	0.96	0.278	0.011	0.190	0.354	0.032	2.33	0.051	0.299	2+
5	3.50	0.003	0.95	0.278	0.011	0.544	0.234	0.049	4.58	0.052	0.350	2+
4	6.00	0.003	0.89	0.278	0.012	0.778	0.213	0.057	7.67	0.056	0.402	3+
3	9.80	0.009	0.78	0.278	0.042	0.991	0.179	0.232	12.04	0.190	0.458	3+
2	14.80	0.006	0.61	0.278	0.035	1.170	0.158	0.224	17.75	0.162	0.648	3+
1	21.30	0.006	0.52	0.278	0.042	1.328	0.371	0.112	32.63	0.190	0.810	3+
	50.00					1.699						
Sum		0.048			0.218					1.000		

Marple Personal Impactor Data
LMC5: Total Hip Replacement



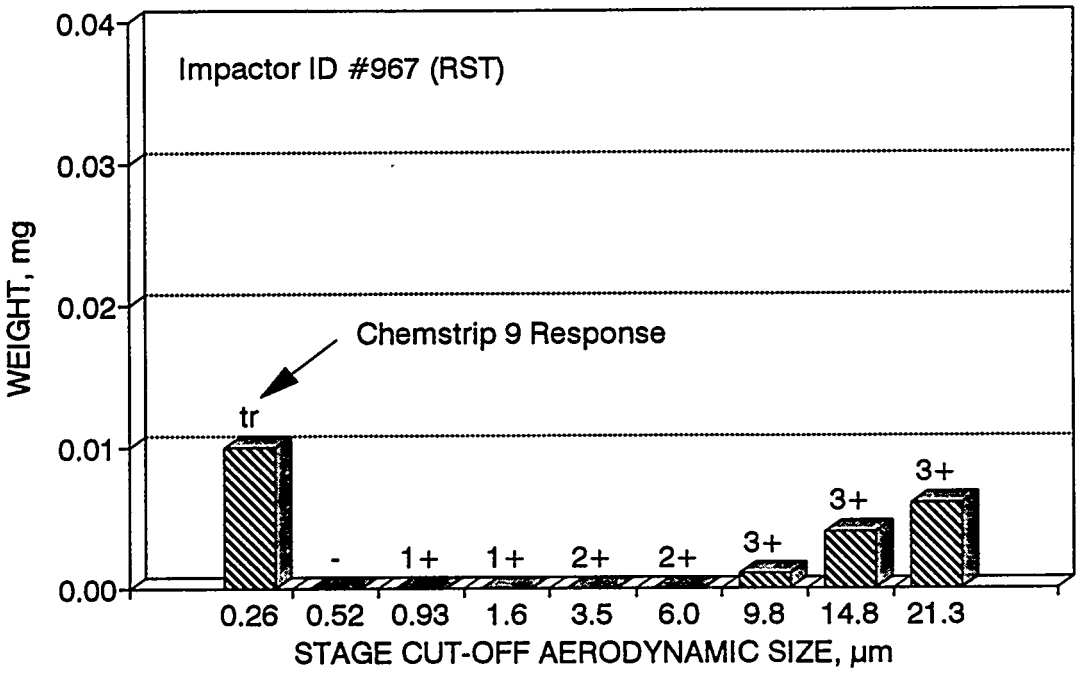
Size distribution by Marple Impactor
LMC5: Total Hip Replacement



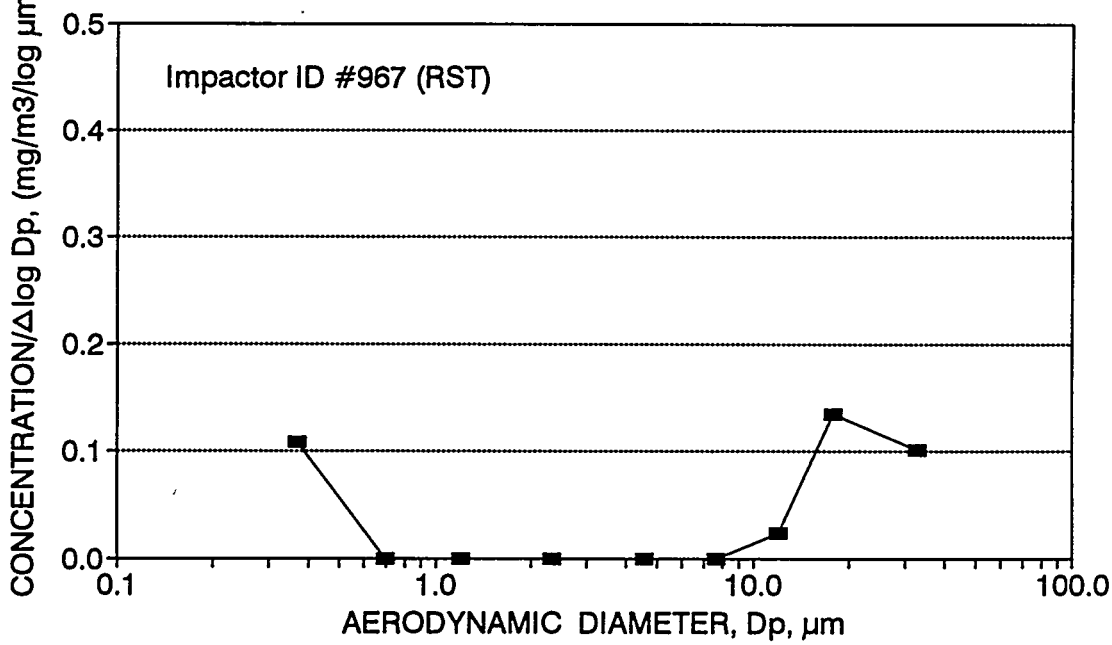
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 967: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.010	1	0.306	0.033	-0.585	0.301	0.109	0.37	0.340	0.000	tr
8	0.52	0.000	0.99	0.306	0.000	-0.284	0.252	0.000	0.70	0.000	0.340	-
7	0.93	0.000	0.97	0.306	0.000	-0.032	0.222	0.000	1.20	0.000	0.340	1+
6	1.55	0.000	0.96	0.306	0.000	0.190	0.354	0.000	2.33	0.000	0.340	1+
5	3.50	0.000	0.95	0.306	0.000	0.544	0.234	0.000	4.58	0.000	0.340	2+
4	6.00	0.000	0.89	0.306	0.000	0.778	0.213	0.000	7.67	0.000	0.340	2+
3	9.80	0.001	0.78	0.306	0.004	0.991	0.179	0.023	12.04	0.044	0.340	3+
2	14.80	0.004	0.61	0.306	0.021	1.170	0.158	0.136	17.75	0.223	0.384	3+
1	21.30	0.006	0.52	0.306	0.038	1.328	0.371	0.102	32.63	0.393	0.607	3+
	50.00					1.699						
Sum		0.021			0.096					1.000		

Marple Personal Impactor Data
LMC5: Total Hip Replacement



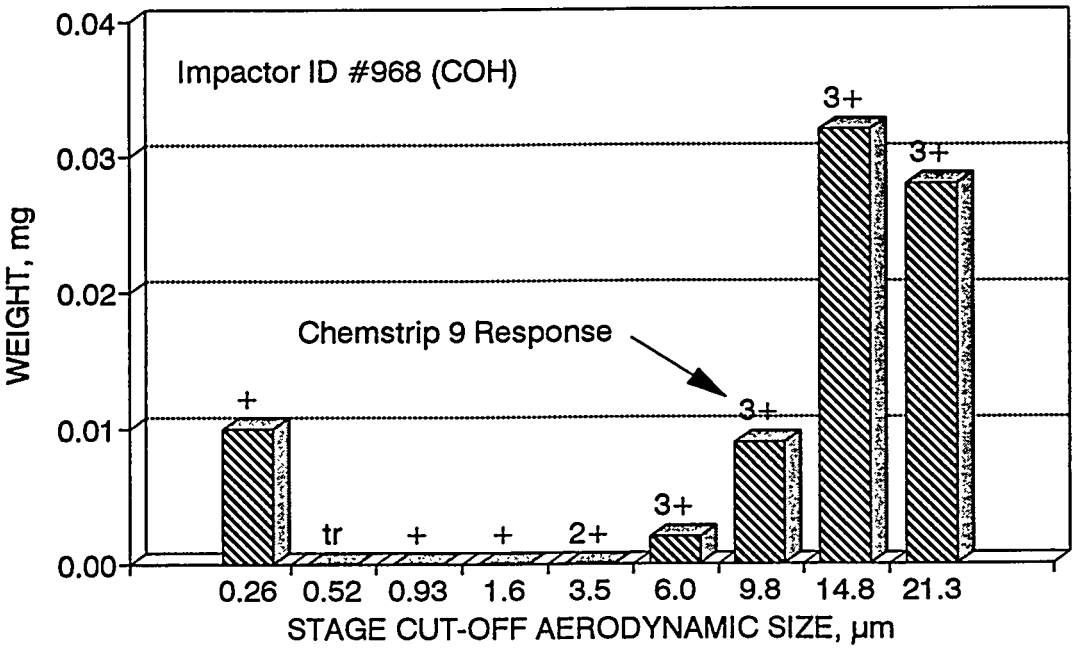
Size distribution by Marple Impactor
LMC5: Total Hip Replacement



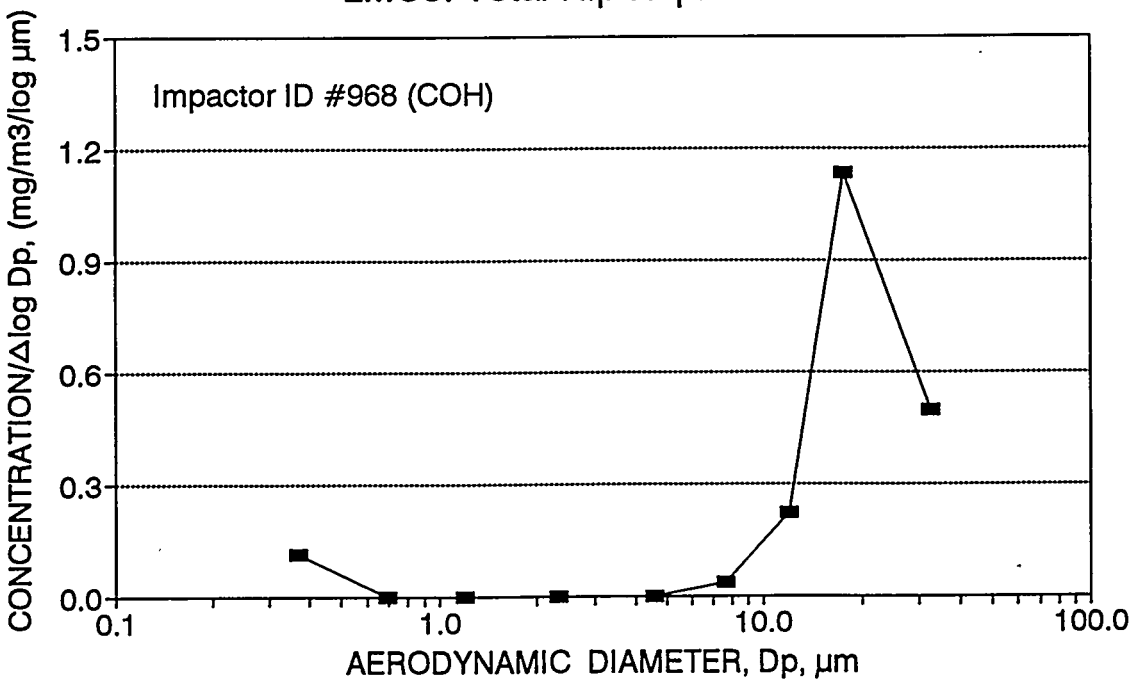
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 968: COH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.010	1	0.292	0.034	-0.585	0.301	0.114	0.37	0.077	0.000	+
8	0.52	0.000	0.99	0.292	0.000	-0.284	0.252	0.000	0.70	0.000	0.077	tr
7	0.93	0.000	0.97	0.292	0.000	-0.032	0.222	0.000	1.20	0.000	0.077	+
6	1.55	0.000	0.96	0.292	0.000	0.190	0.354	0.000	2.33	0.000	0.077	+
5	3.50	0.000	0.95	0.292	0.000	0.544	0.234	0.000	4.58	0.000	0.077	2+
4	6.00	0.002	0.89	0.292	0.008	0.778	0.213	0.036	7.67	0.017	0.077	3+
3	9.80	0.009	0.78	0.292	0.040	0.991	0.179	0.221	12.04	0.089	0.094	3+
2	14.80	0.032	0.61	0.292	0.180	1.170	0.158	1.136	17.75	0.403	0.183	3+
1	21.30	0.028	0.52	0.292	0.184	1.328	0.371	0.498	32.63	0.414	0.586	3+
	50.00					1.699						
Sum		0.081			0.446					1.000		

Marple Personal Impactor Data
LMC5: Total Hip Replacement



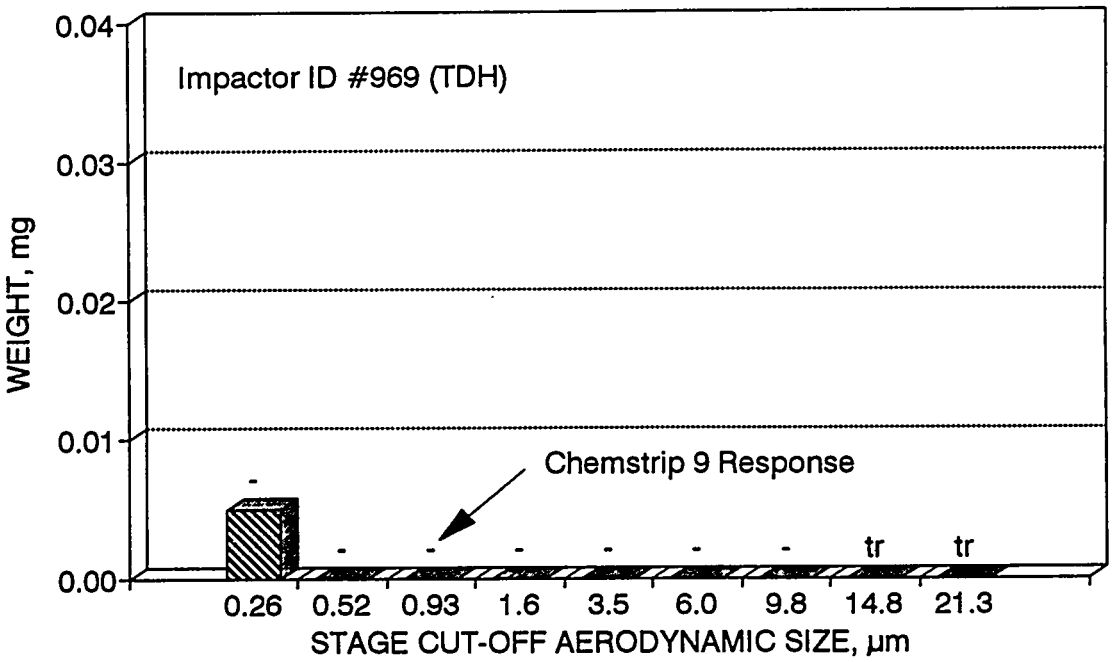
Size distribution by Marple Impactor
LMC5: Total Hip Replacement



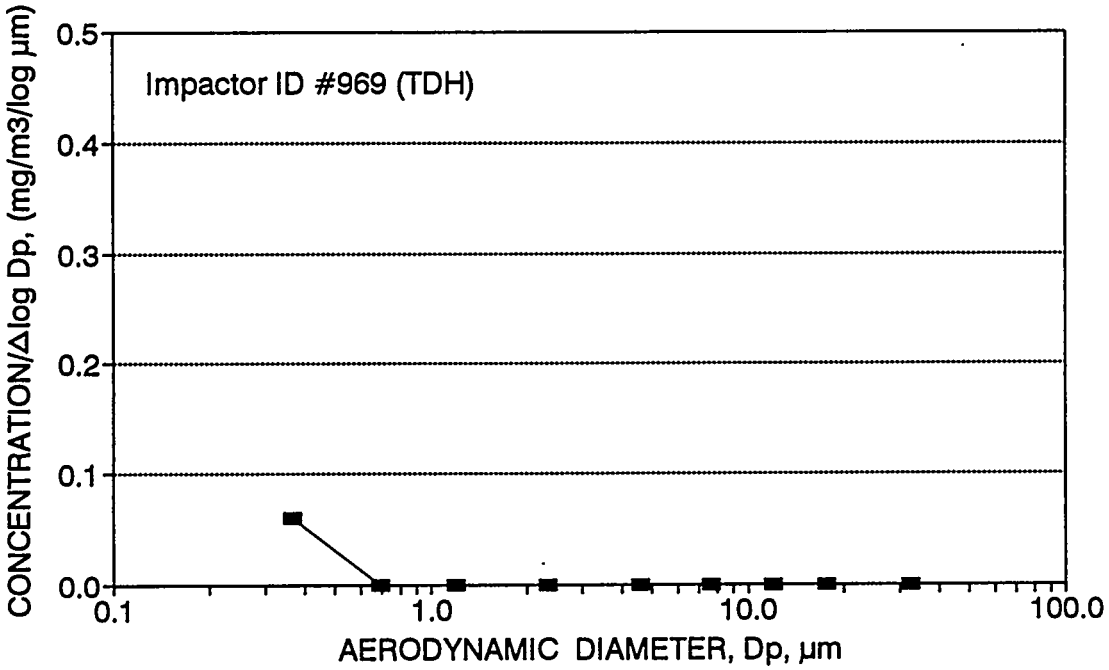
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 969: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.005	1	0.276	0.018	-0.585	0.301	0.060	0.37	1.000	0.000	-
8	0.52	0.000	0.99	0.276	0.000	-0.284	0.252	0.000	0.70	0.000	1.000	-
7	0.93	0.000	0.97	0.276	0.000	-0.032	0.222	0.000	1.20	0.000	1.000	-
6	1.55	0.000	0.96	0.276	0.000	0.190	0.354	0.000	2.33	0.000	1.000	-
5	3.50	0.000	0.95	0.276	0.000	0.544	0.234	0.000	4.58	0.000	1.000	-
4	6.00	0.000	0.89	0.276	0.000	0.778	0.213	0.000	7.67	0.000	1.000	-
3	9.80	0.000	0.78	0.276	0.000	0.991	0.179	0.000	12.04	0.000	1.000	-
2	14.80	0.000	0.61	0.276	0.000	1.170	0.158	0.000	17.75	0.000	1.000	tr
1	21.30	0.000	0.52	0.276	0.000	1.328	0.371	0.000	32.63	0.000	1.000	tr
	50.00					1.699						
Sum		0.005			0.018					1.000		

Marple Personal Impactor Data
LMC5: Total Hip Replacement



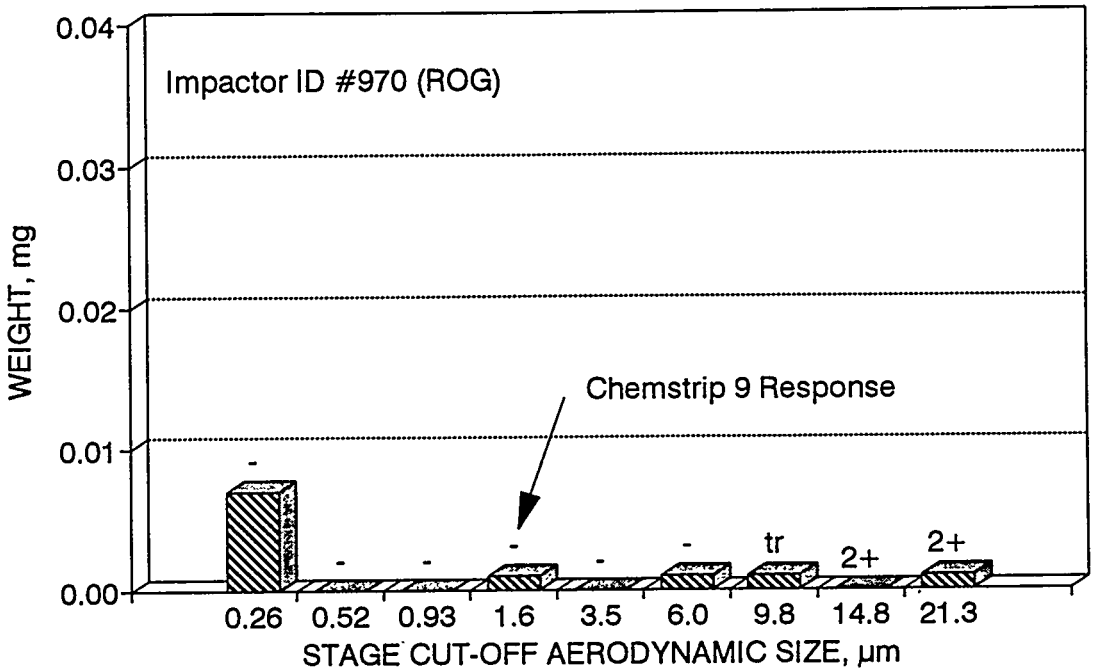
Size distribution by Marple Impactor
LMC5: Total Hip Replacement



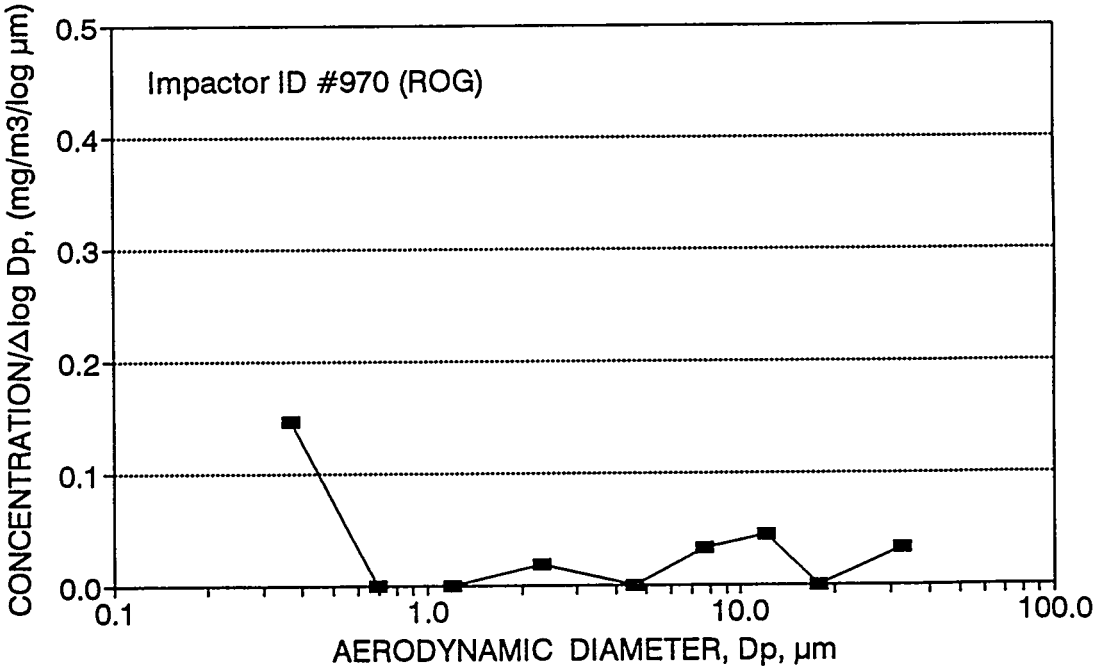
LMC5 Total Hip: Marple Personal Impactor Data (ID No. 970: ROG)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.007	1	0.158	0.044	-0.585	0.301	0.147	0.37	0.566	0.000	-
8	0.52	0.000	0.99	0.158	0.000	-0.284	0.252	0.000	0.70	0.000	0.566	-
7	0.93	0.000	0.97	0.158	0.000	-0.032	0.222	0.000	1.20	0.000	0.566	-
6	1.55	0.001	0.96	0.158	0.007	0.190	0.354	0.019	2.33	0.084	0.566	-
5	3.50	0.000	0.95	0.158	0.000	0.544	0.234	0.000	4.58	0.000	0.650	-
4	6.00	0.001	0.89	0.158	0.007	0.778	0.213	0.033	7.67	0.091	0.650	-
3	9.80	0.001	0.78	0.158	0.008	0.991	0.179	0.045	12.04	0.104	0.741	tr
2	14.80	0.000	0.61	0.158	0.000	1.170	0.158	0.000	17.75	0.000	0.845	2+
1	21.30	0.001	0.52	0.158	0.012	1.328	0.371	0.033	32.63	0.155	0.845	2+
	50.00					1.699						
Sum		0.011			0.078					1.000		

Marple Personal Impactor Data
LMC5: Total Hip Replacement



Size distribution by Marple Impactor
LMC5: Total Hip Replacement



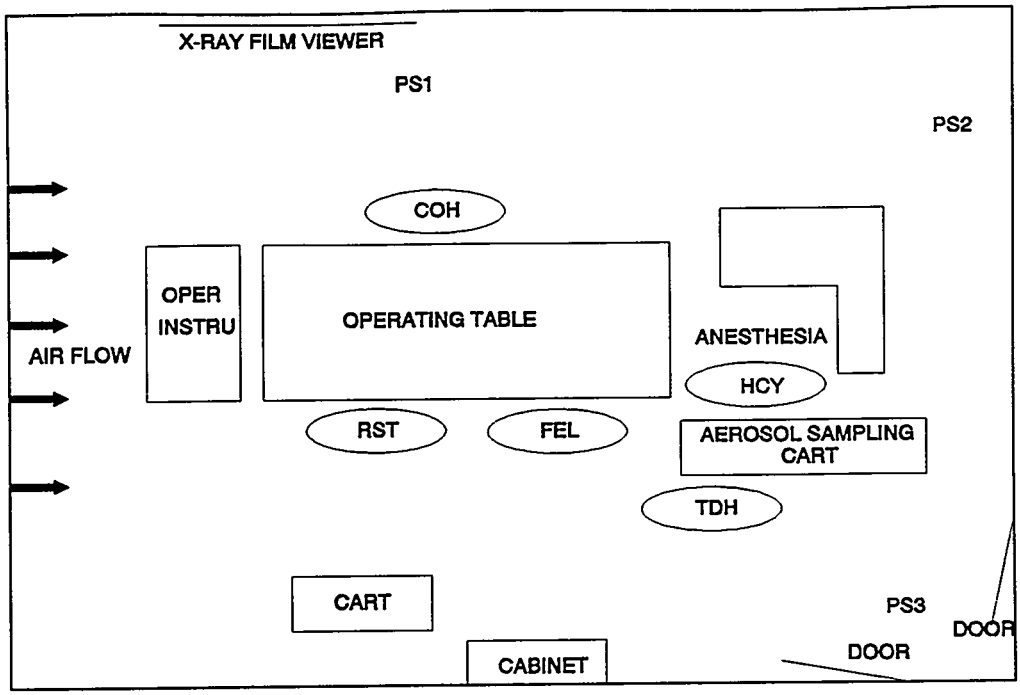
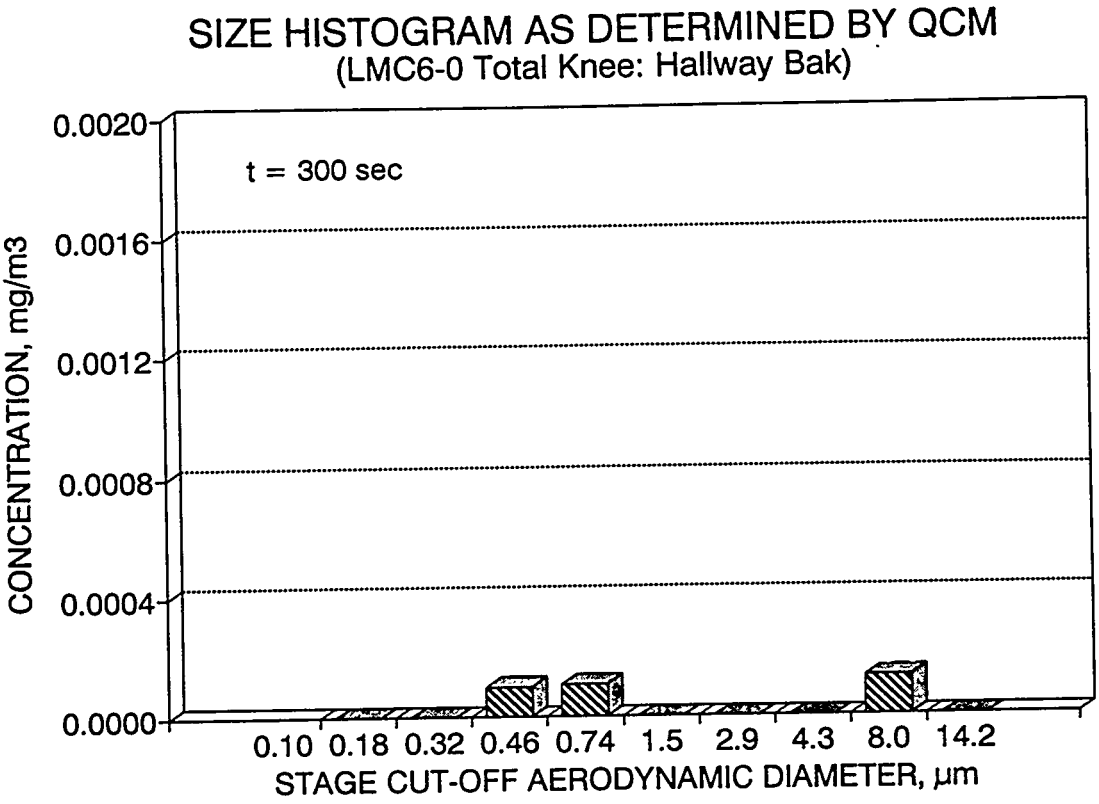
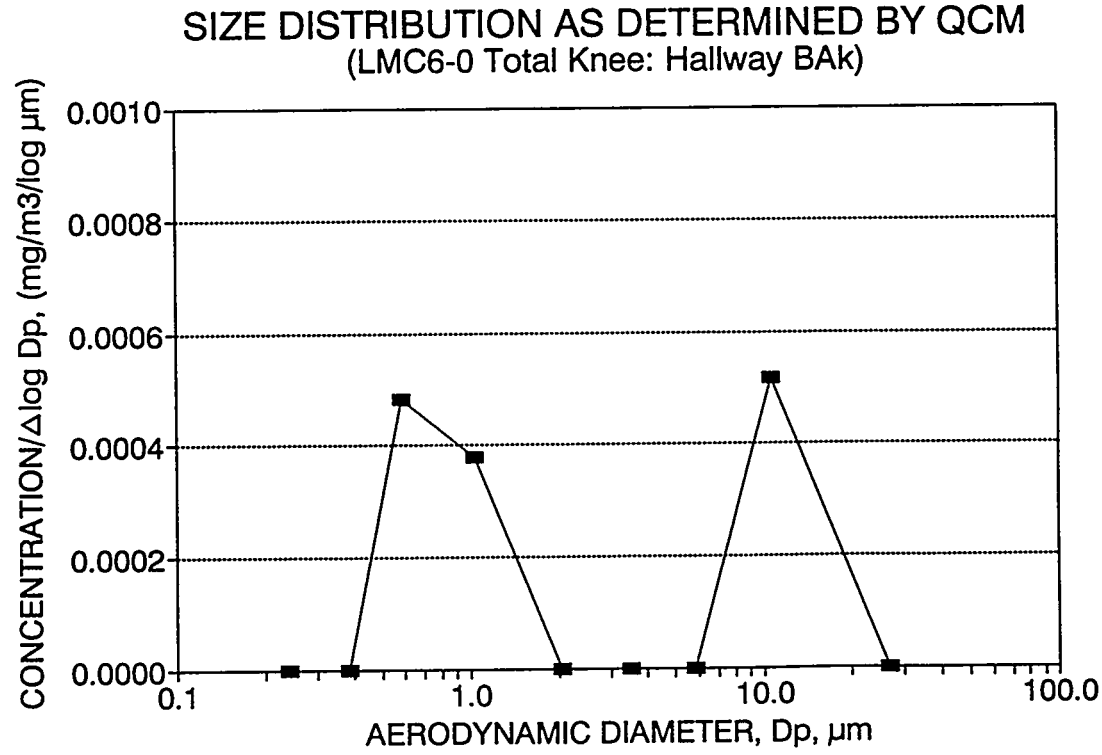


Figure C.6 Initial locations of personnel and area filters during LMC #6 measurement (total knee replacement).

LMC6-0 Total Knee: Hallway Background (t = 300 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00010	0.46	-0.335	0.206	0.000	0.59	0.2941	0.000
0.50	0.00011	0.74	-0.128	0.290	0.000	1.04	0.3235	0.294
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.618
2.00	0.00000	2.87	0.457	0.174	0.000	3.50	0.0000	0.618
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.618
5.60	0.00013	7.96	0.901	0.251	0.001	10.62	0.3824	0.618
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00034						1.0000	

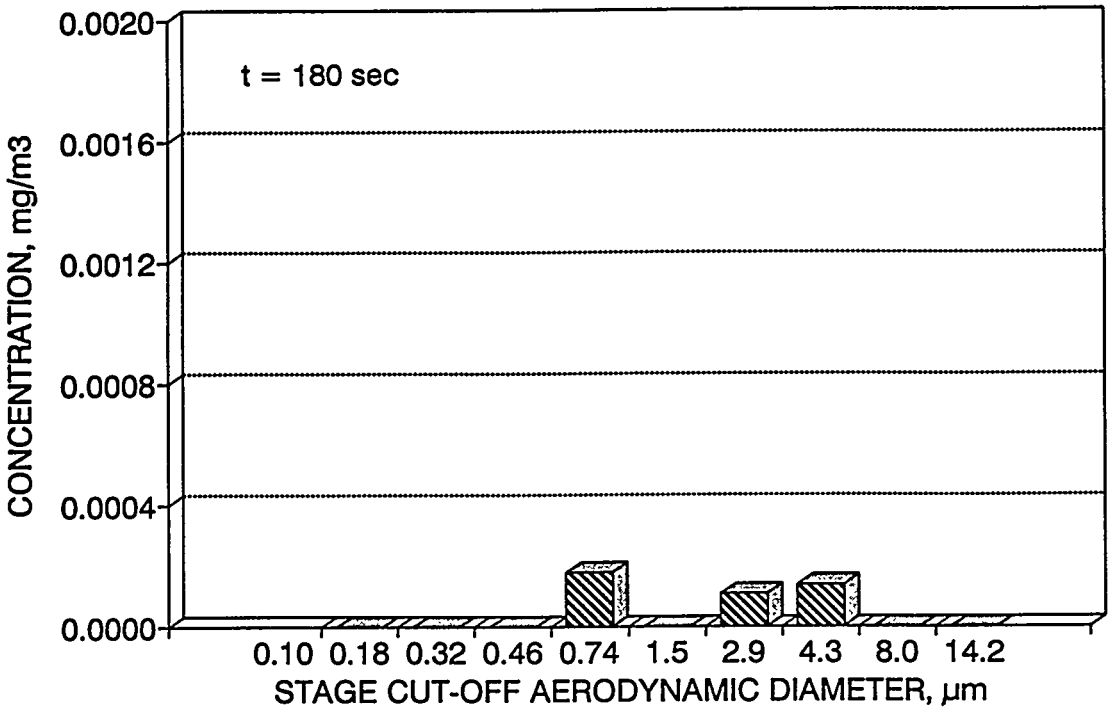

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-0 Total Knee: Hallway Bak)
t = 300 sec
CONCENTRATION, mg/m3
0.0020
0.0016
0.0012
0.0008
0.0004
0.0000
0.10 0.18 0.32 0.46 0.74 1.5 2.9 4.3 8.0 14.2
STAGE CUT-OFF AERODYNAMIC DIAMETER, µm


SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-0 Total Knee: Hallway BAk)
CONCENTRATION/Δlog Dp, (mg/m3/log µm)
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
0.1
1.0
10.0
100.0
AERODYNAMIC DIAMETER, Dp, µm

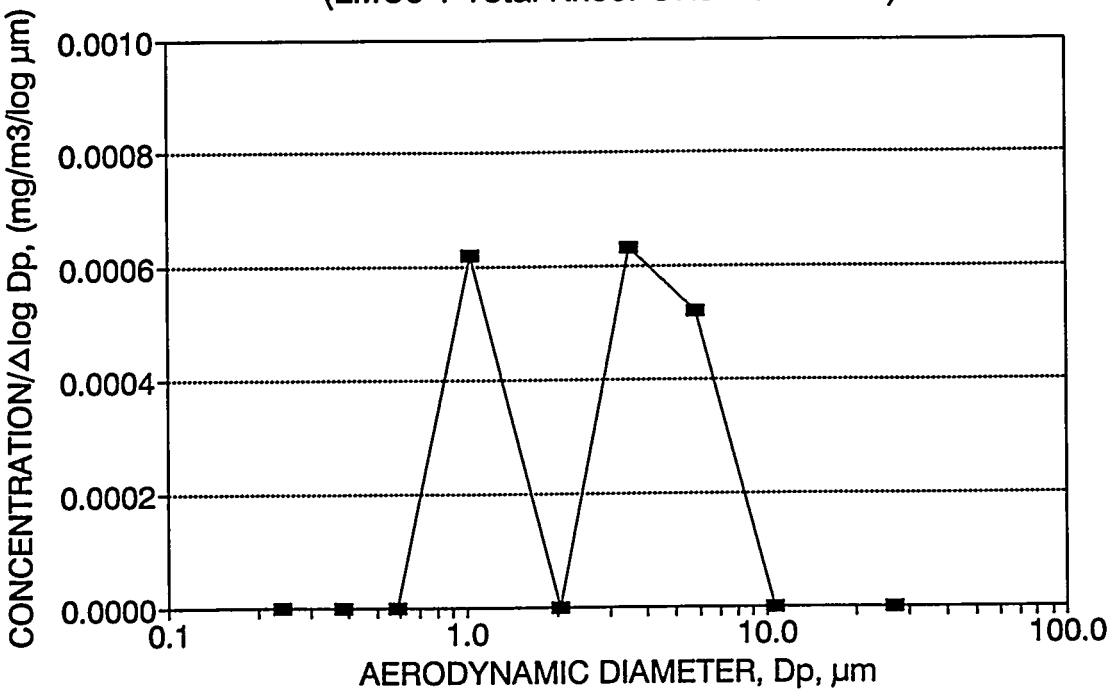
LMC6-1 Total Knee: OR5 Room Background (t = 180 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00018	0.74	-0.128	0.290	0.001	1.04	0.4186	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.419
2.00	0.00011	2.87	0.457	0.174	0.001	3.50	0.2558	0.419
3.00	0.00014	4.28	0.632	0.269	0.001	5.84	0.3256	0.674
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00043						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-1 Total Knee: OR5 Room Bak)



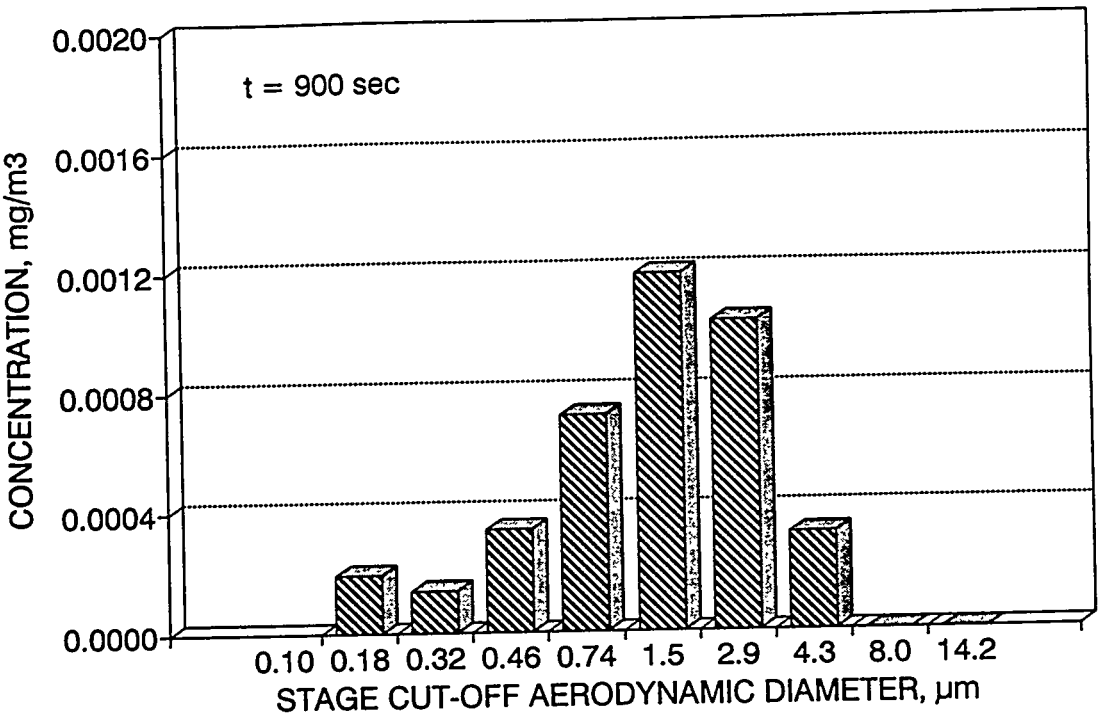
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-1 Total Knee: OR5 Room Bak)



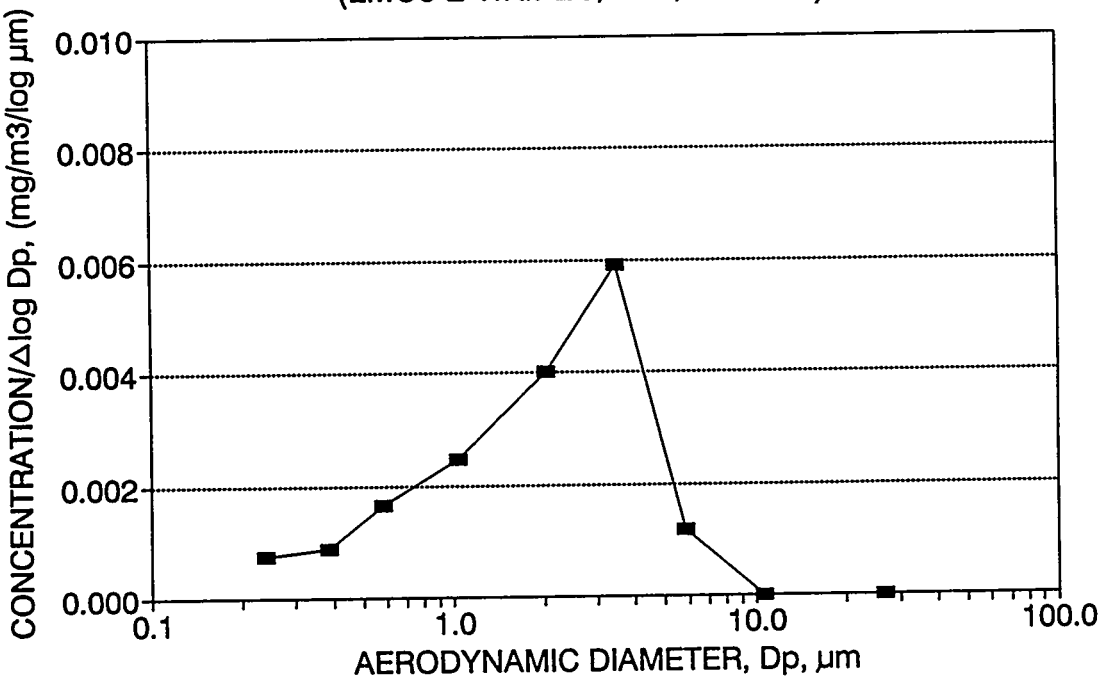
LMC6-2 Total Knee: EC/CUT/DRILL/SAW (t = 900 sec)

A ECD,μm	B C,mg/m3	C Dae,μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD,μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00019	0.18	-0.749	0.257	0.001	0.24	0.0483	0.000
0.20	0.00014	0.32	-0.492	0.157	0.001	0.39	0.0356	0.048
0.30	0.00034	0.46	-0.335	0.206	0.002	0.59	0.0865	0.084
0.50	0.00072	0.74	-0.128	0.290	0.002	1.04	0.1832	0.170
1.00	0.00119	1.45	0.162	0.296	0.004	2.04	0.3028	0.354
2.00	0.00103	2.87	0.457	0.174	0.006	3.50	0.2621	0.656
3.00	0.00032	4.28	0.632	0.269	0.001	5.84	0.0814	0.919
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00393						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-2 T.K.: EC/CUT/DR/SAW)



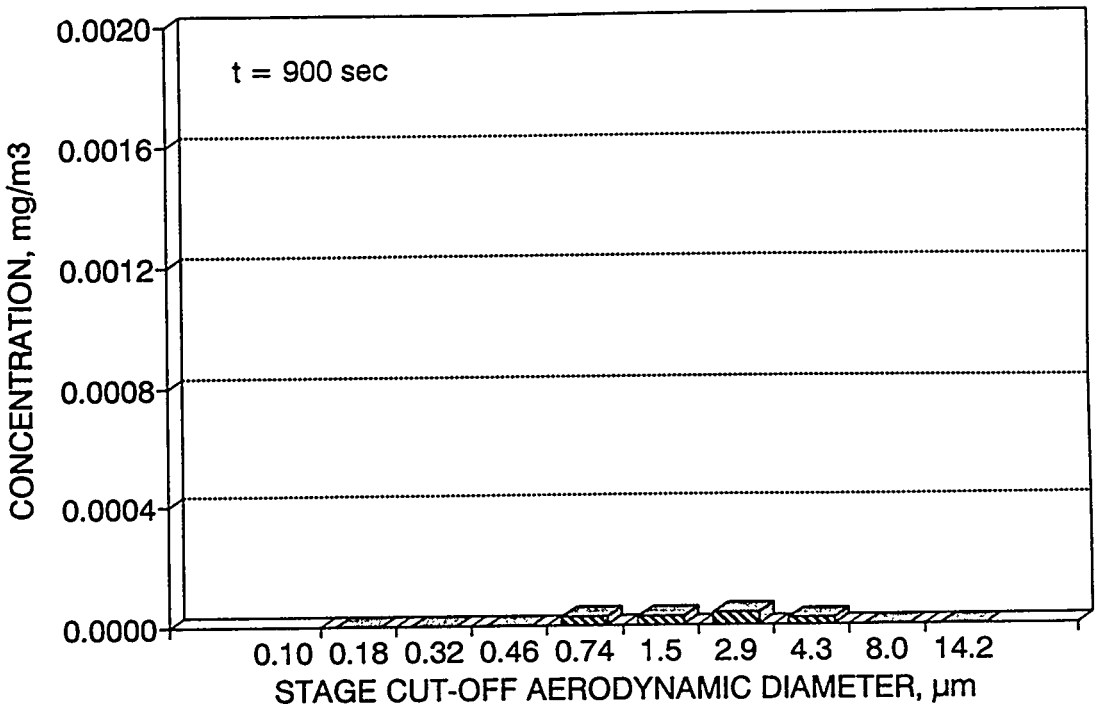
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-2 T.K.: EC/CUT/DR.SAW)



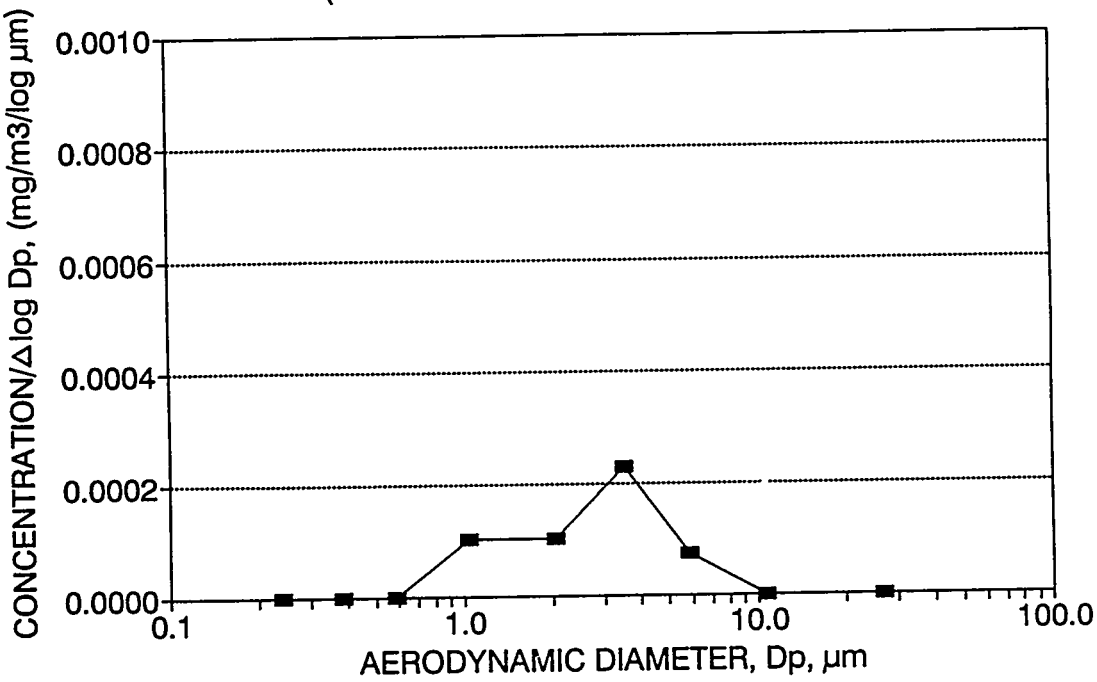
LMC6-3 Total Knee: Saw/Chisel/Fit Femoral (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00003	0.74	-0.128	0.290	0.000	1.04	0.2500	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.2500	0.250
2.00	0.00004	2.87	0.457	0.174	0.000	3.50	0.3333	0.500
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.1667	0.833
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00012						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-3 T.K.: SAW/CHI/Fit Femoral)



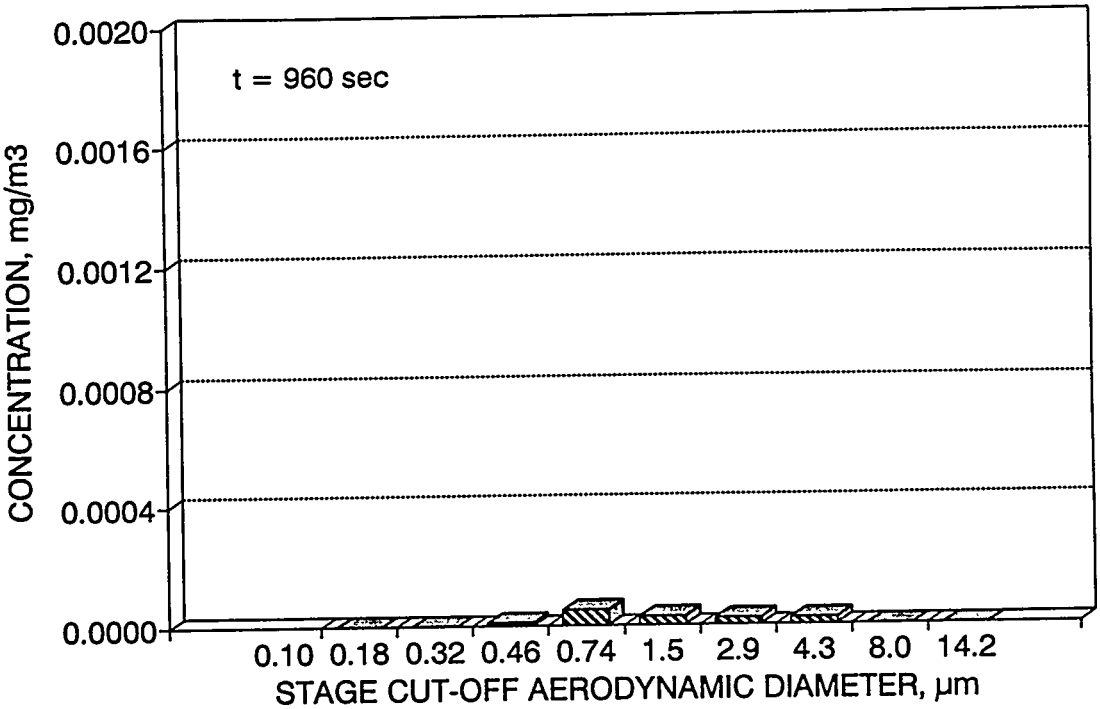
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-3 T.K.: SAW/CHI/Fit Femoral)



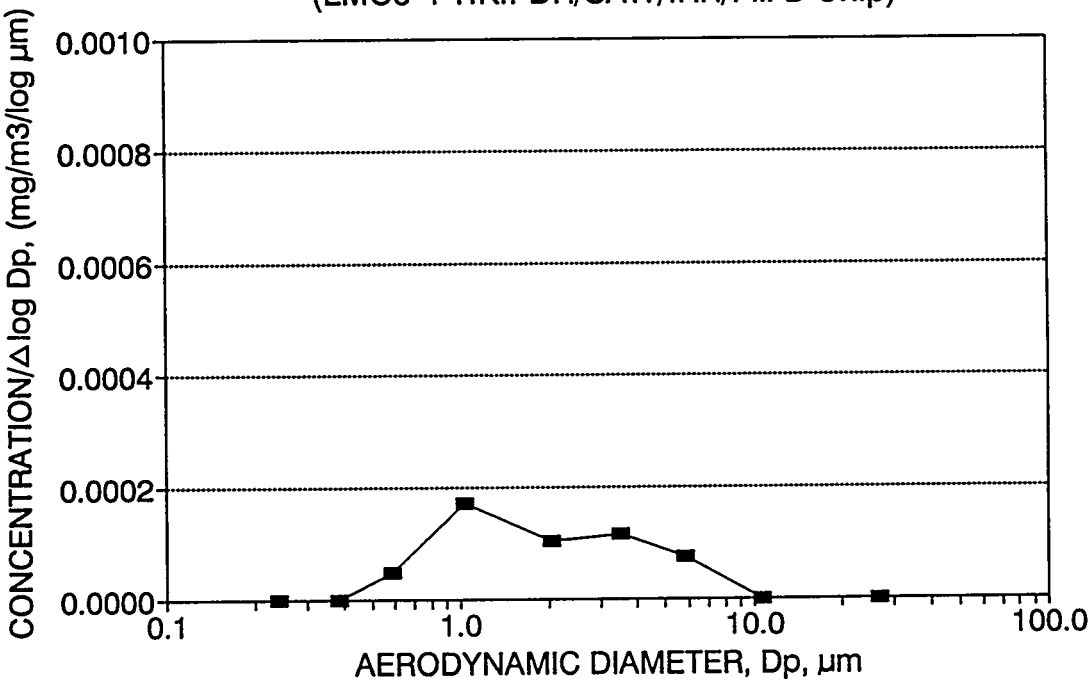
LMC6-4 Total Knee: DR/SAW/IRR/Fill Bone Chip (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0769	0.000
0.50	0.00005	0.74	-0.128	0.290	0.000	1.04	0.3846	0.077
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.2308	0.462
2.00	0.00002	2.87	0.457	0.174	0.000	3.50	0.1538	0.692
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.1538	0.846
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00013						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-4 T.K.: DR/SAW/IRR/Fill B Chip)



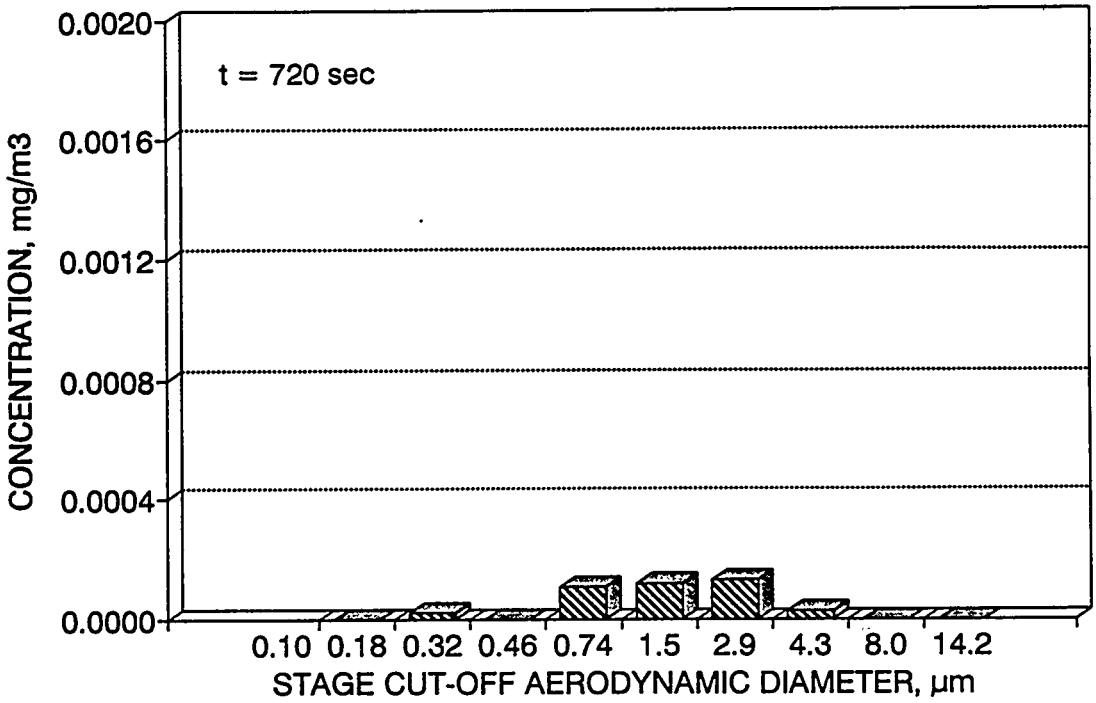
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-4 T.K.: DR/SAW/IRR/Fill B Chip)



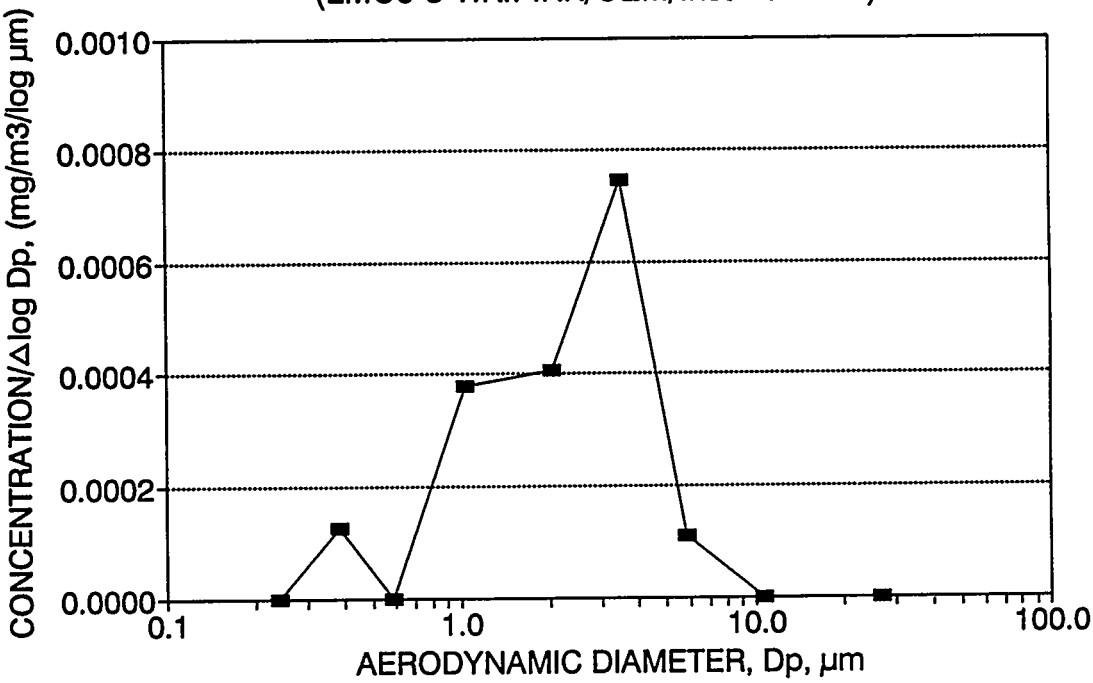
LMC6-5 Total Knee: IRR/CEM/Inst Femoral (t = 720 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00002	0.32	-0.492	0.157	0.000	0.39	0.0488	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.049
0.50	0.00011	0.74	-0.128	0.290	0.000	1.04	0.2683	0.049
1.00	0.00012	1.45	0.162	0.296	0.000	2.04	0.2927	0.317
2.00	0.00013	2.87	0.457	0.174	0.001	3.50	0.3171	0.610
3.00	0.00003	4.28	0.632	0.269	0.000	5.84	0.0732	0.927
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00041						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-5 T.K.: Irr/Cem/Inst Femoral)



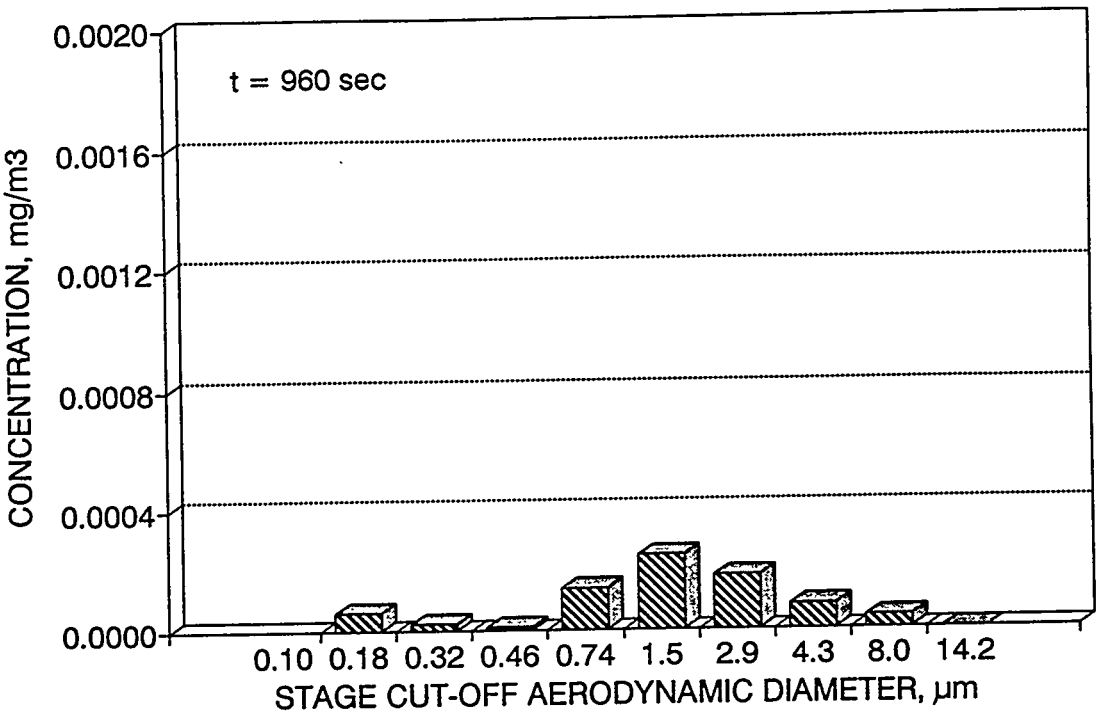
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-5 T.K.: IRR/CEM/Inst Femoral)



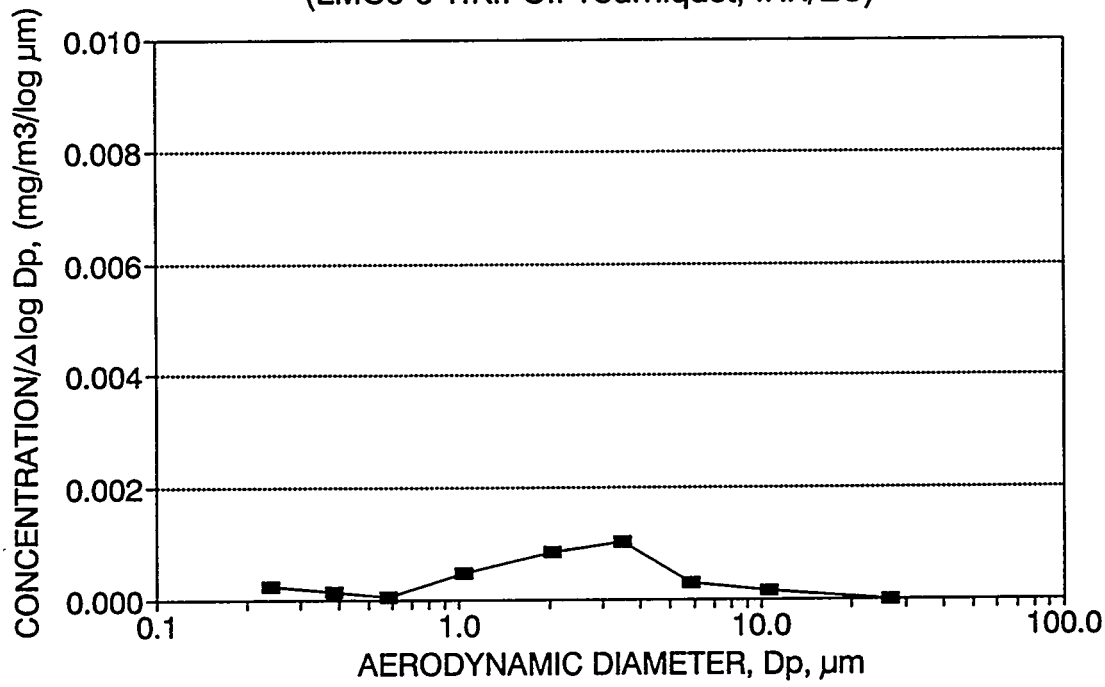
LMC6-6 Total Knee: Off Tourniquet, IRR/EC (t = 960sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00006	0.18	-0.749	0.257	0.000	0.24	0.0769	0.000
0.20	0.00002	0.32	-0.492	0.157	0.000	0.39	0.0256	0.077
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0128	0.103
0.50	0.00014	0.74	-0.128	0.290	0.000	1.04	0.1795	0.115
1.00	0.00025	1.45	0.162	0.296	0.001	2.04	0.3205	0.295
2.00	0.00018	2.87	0.457	0.174	0.001	3.50	0.2308	0.615
3.00	0.00008	4.28	0.632	0.269	0.000	5.84	0.1026	0.846
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0513	0.949
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00078						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-6 T.K.: Off Tourniquet, IRR/EC)



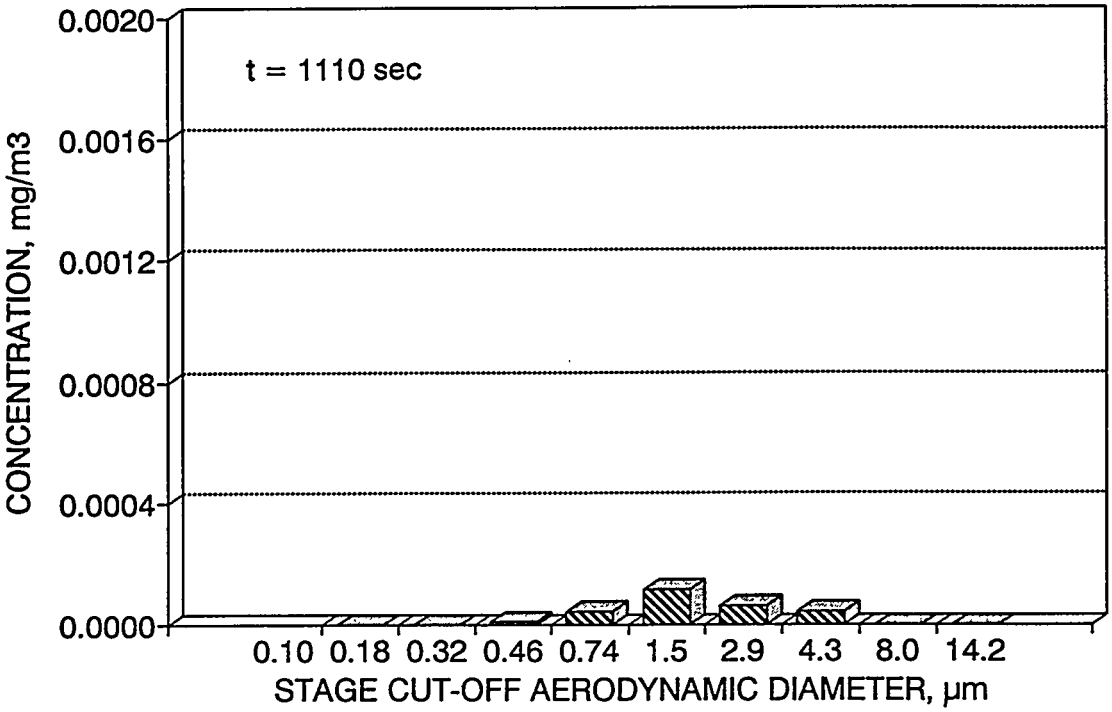
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-6 T.K.: Off Tourniquet, IRR/EC)



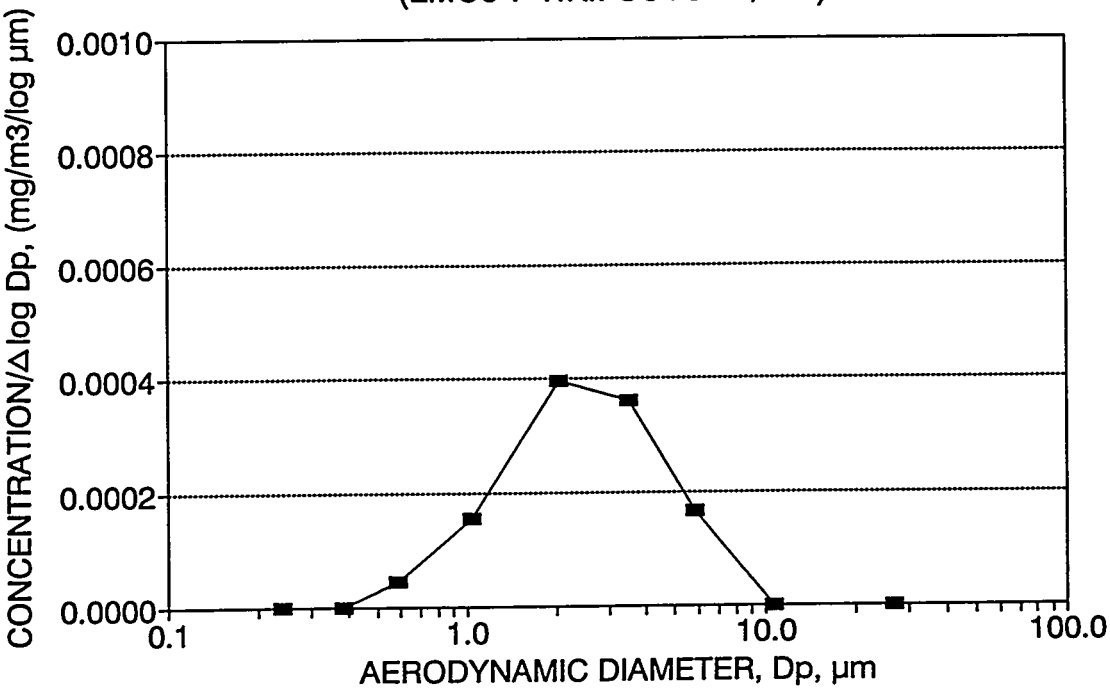
LMC6-7 Total Knee: Suture/Irrigation (t = 1110 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0323	0.000
0.50	0.00005	0.74	-0.128	0.290	0.000	1.04	0.1613	0.032
1.00	0.00012	1.45	0.162	0.296	0.000	2.04	0.4194	0.194
2.00	0.00006	2.87	0.457	0.174	0.000	3.50	0.2258	0.613
3.00	0.00005	4.28	0.632	0.269	0.000	5.84	0.1613	0.839
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.000279						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-7 T.K.: SUTURE/IRR)



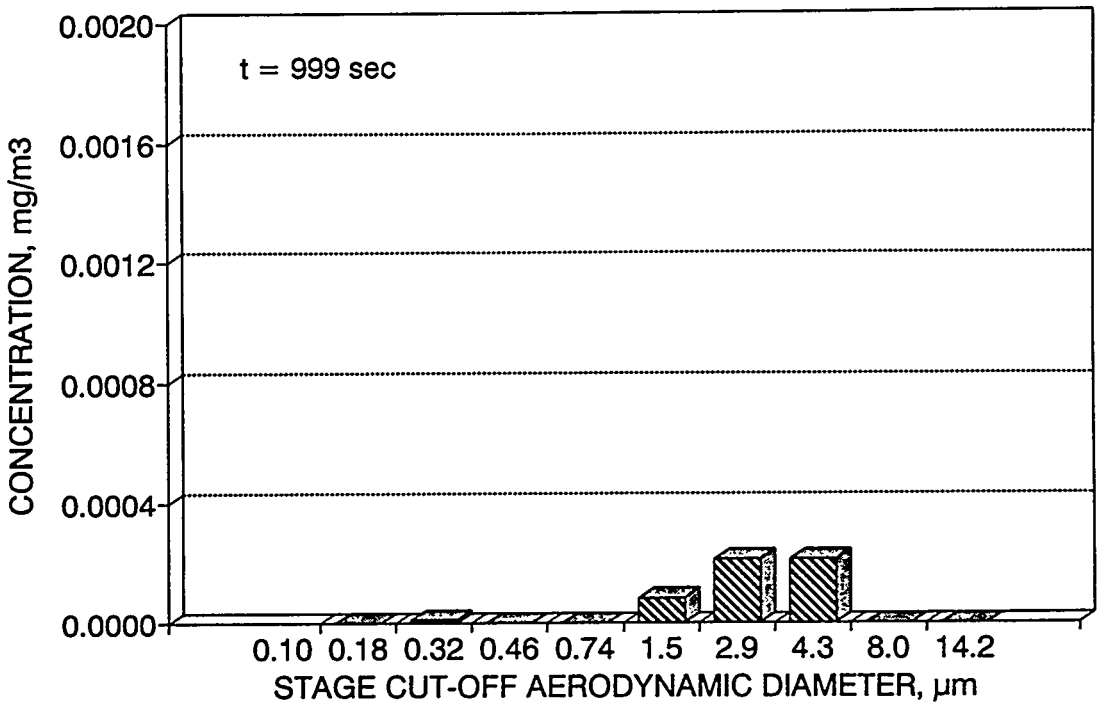
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-7 T.K.: SUTURE/IRR)



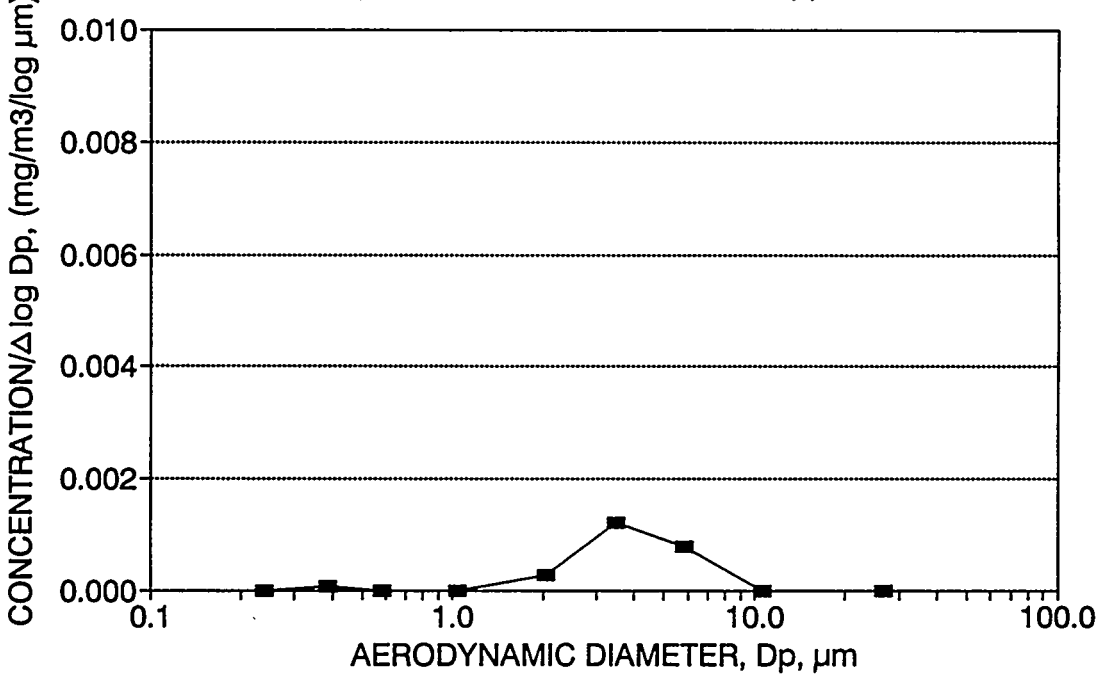
LMC6-8 Total Knee: Room Clean Up (t = 999 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00001	0.32	-0.492	0.157	0.000	0.39	0.0196	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.020
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.020
1.00	0.00008	1.45	0.162	0.296	0.000	2.04	0.1569	0.020
2.00	0.00021	2.87	0.457	0.174	0.001	3.50	0.4118	0.176
3.00	0.00021	4.28	0.632	0.269	0.001	5.84	0.4118	0.588
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00051						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC6-8 T.K.: Room Clean Up)



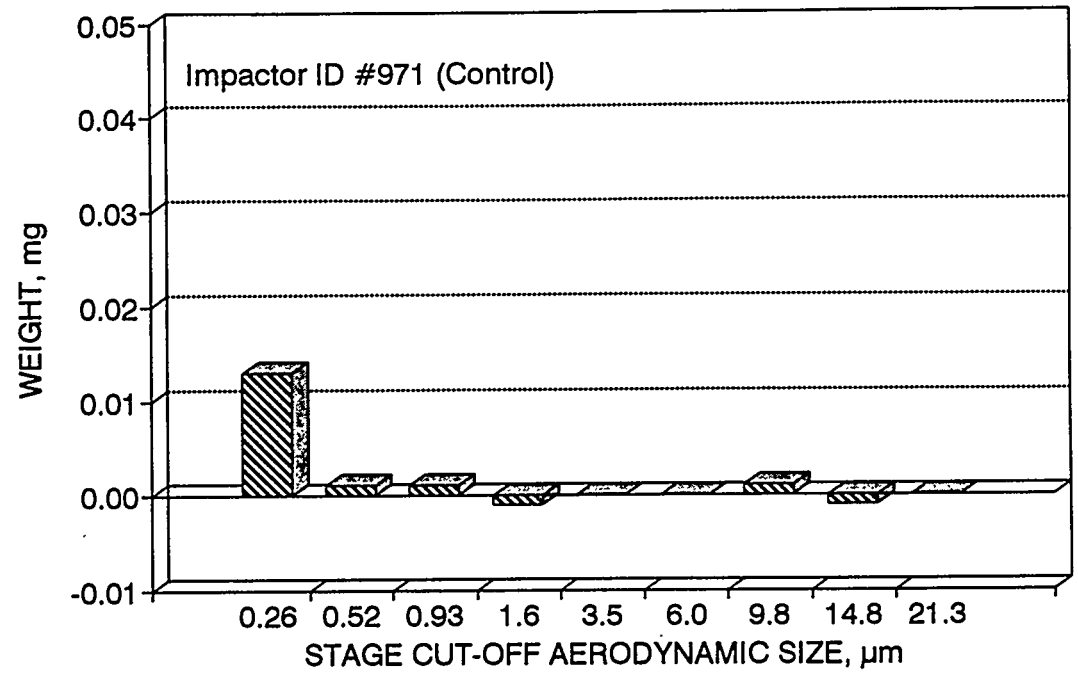
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC6-8 T.K.: Room Clean Up)



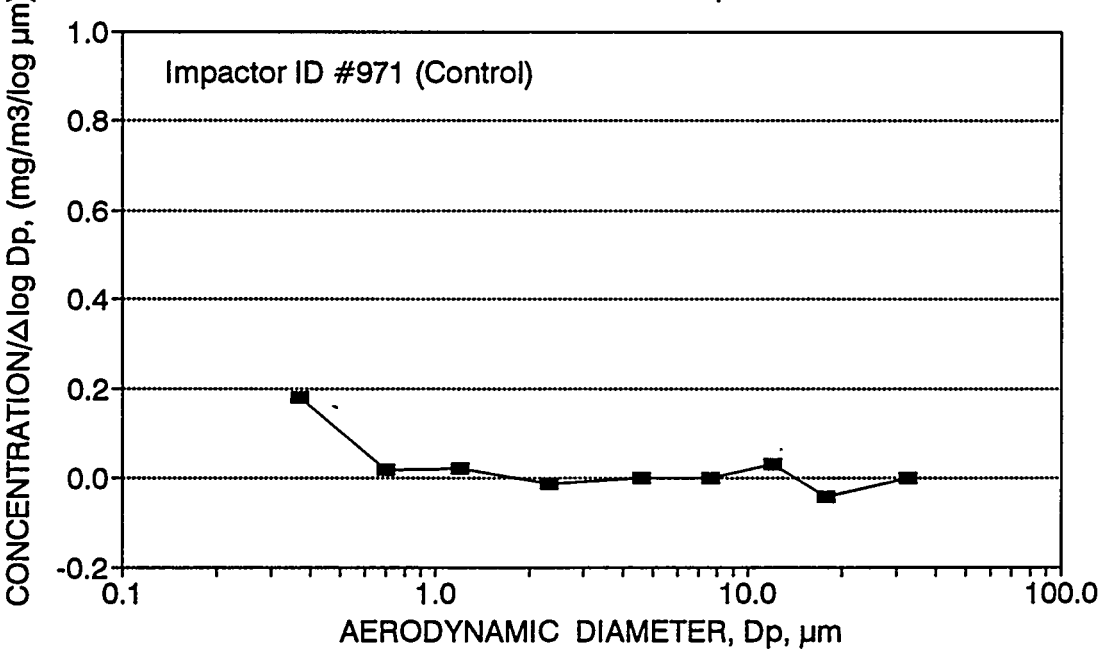
LMC6 Total Knee: Marple Personal Impactor Data (ID No. 971: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.013	1	0.24	0.054	-0.585	0.301	0.180	0.37	0.953	0.000
8	0.52	0.001	0.99	0.24	0.004	-0.284	0.252	0.017	0.70	0.074	0.953
7	0.93	0.001	0.97	0.24	0.004	-0.032	0.222	0.019	1.20	0.076	1.027
6	1.55	-0.001	0.96	0.24	-0.004	0.190	0.354	-0.012	2.33	-0.076	1.103
5	3.50	0.000	0.95	0.24	0.000	0.544	0.234	0.000	4.58	0.000	1.026
4	6.00	0.000	0.89	0.24	0.000	0.778	0.213	0.000	7.67	0.000	1.026
3	9.80	0.001	0.78	0.24	0.005	0.991	0.179	0.030	12.04	0.094	1.026
2	14.80	-0.001	0.61	0.24	-0.007	1.170	0.158	-0.043	17.75	-0.120	1.120
1	21.30	0.000	0.52	0.24	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		0.014			0.057					1.000	

Marple Personal Impactor Data
LMC6: Total Left Knee Replacement



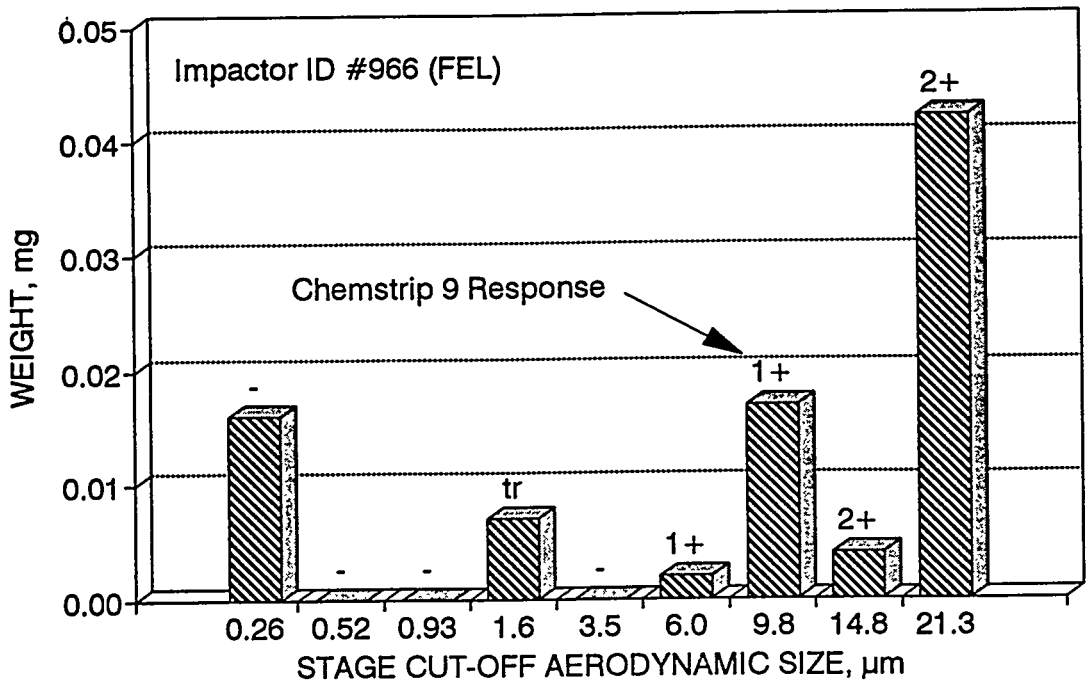
Size distribution by Marple Impactor
LMC6: Total Left Knee Replacement



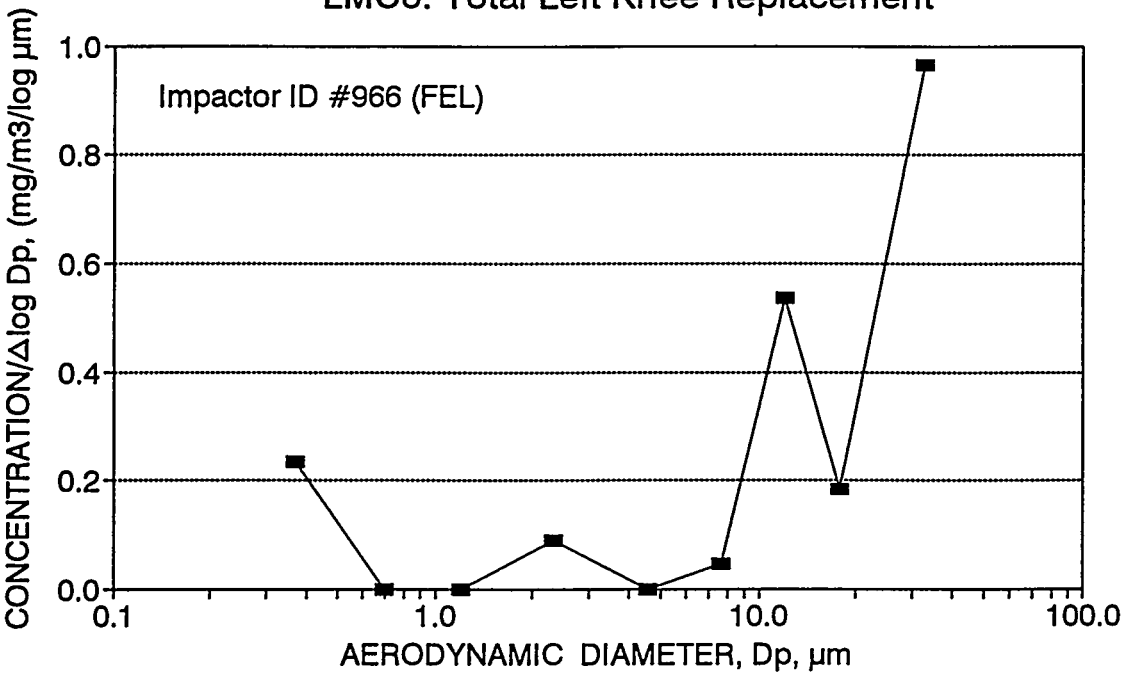
LMC6 Total Knee: Marple Personal Impactor Data (ID No. 966: FEL)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.016	1	0.226	0.071	-0.585	0.301	0.235	0.37	0.119	0.000	-
8	0.52	0.000	0.99	0.226	0.000	-0.284	0.252	0.000	0.70	0.000	0.119	-
7	0.93	0.000	0.97	0.226	0.000	-0.032	0.222	0.000	1.20	0.000	0.119	-
6	1.55	0.007	0.96	0.226	0.032	0.190	0.354	0.091	2.33	0.054	0.119	tr
5	3.50	0.000	0.95	0.226	0.000	0.544	0.234	0.000	4.58	0.000	0.173	-
4	6.00	0.002	0.89	0.226	0.010	0.778	0.213	0.047	7.67	0.017	0.173	1+
3	9.80	0.017	0.78	0.226	0.096	0.991	0.179	0.539	12.04	0.162	0.190	1+
2	14.80	0.004	0.61	0.226	0.029	1.170	0.158	0.184	17.75	0.049	0.352	2+
1	21.30	0.042	0.52	0.226	0.357	1.328	0.371	0.964	32.63	0.600	0.400	2+
	50.00					1.699						
Sum		0.088			0.596					1.000		

Marple Personal Impactor Data
LMC6: Total Left Knee Replacement



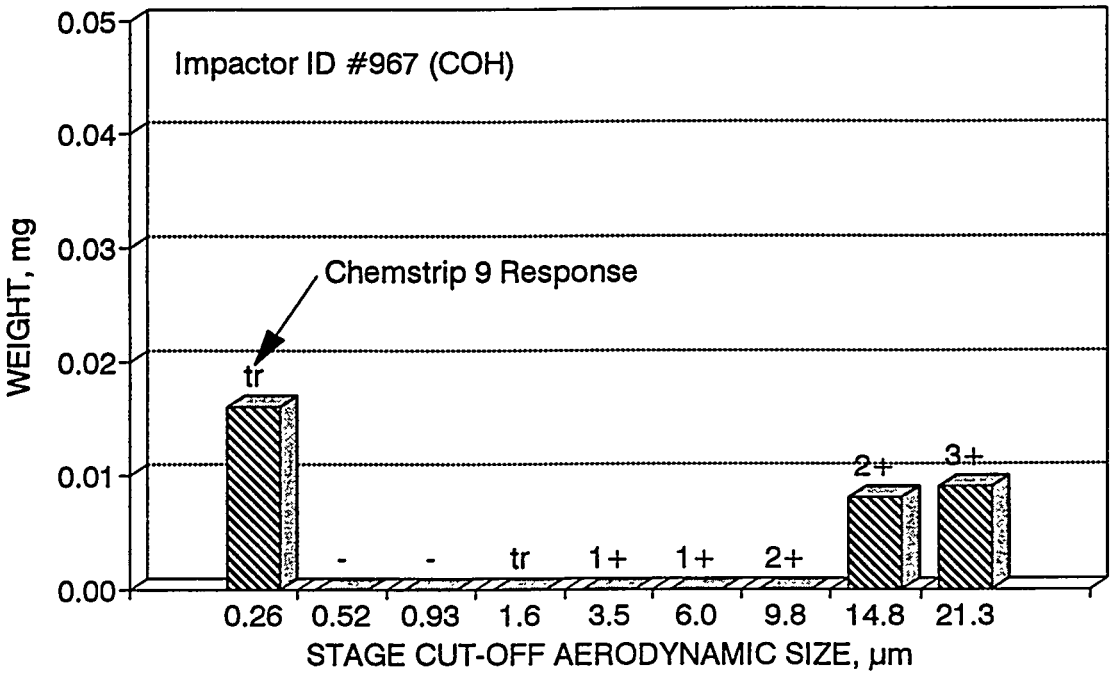
Size distribution by Marple Impactor
LMC6: Total Left Knee Replacement



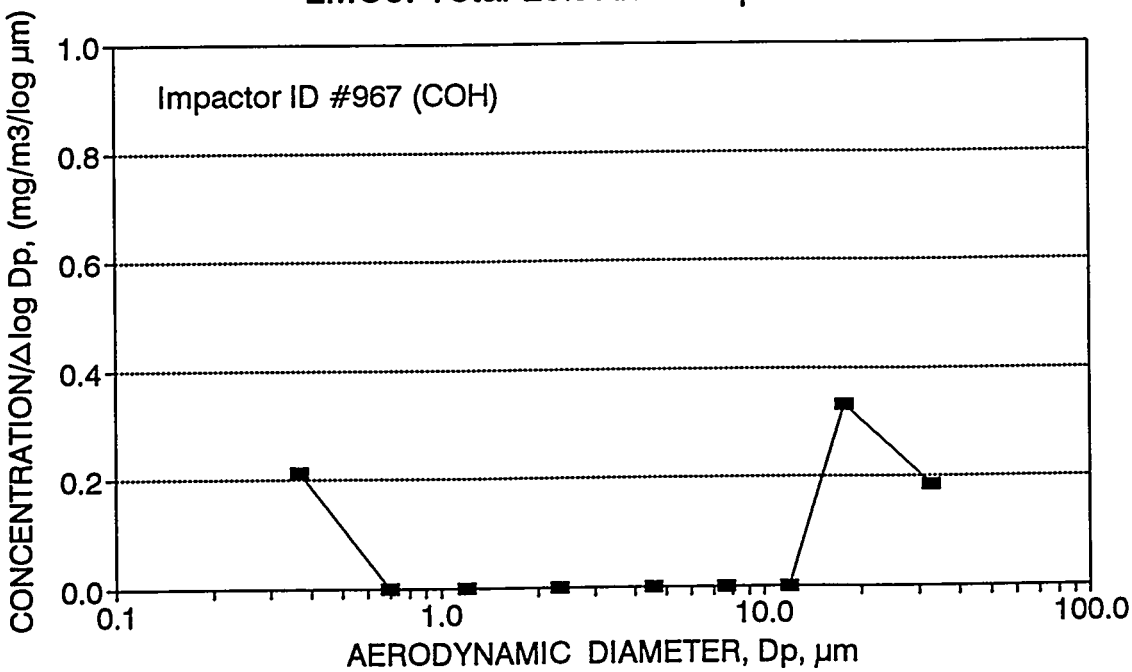
LMC6 Total Knee: Marple Personal Impactor Data (ID No. 967: COH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.016	1	0.25	0.064	-0.585	0.301	0.213	0.37	0.345	0.000	tr
8	0.52	0.000	0.99	0.25	0.000	-0.284	0.252	0.000	0.70	0.000	0.345	-
7	0.93	0.000	0.97	0.25	0.000	-0.032	0.222	0.000	1.20	0.000	0.345	-
6	1.55	0.000	0.96	0.25	0.000	0.190	0.354	0.000	2.33	0.000	0.345	tr
5	3.50	0.000	0.95	0.25	0.000	0.544	0.234	0.000	4.58	0.000	0.345	1+
4	6.00	0.000	0.89	0.25	0.000	0.778	0.213	0.000	7.67	0.000	0.345	1+
3	9.80	0.000	0.78	0.25	0.000	0.991	0.179	0.000	12.04	0.000	0.345	2+
2	14.80	0.008	0.61	0.25	0.052	1.170	0.158	0.332	17.75	0.283	0.345	2+
1	21.30	0.009	0.52	0.25	0.069	1.328	0.371	0.187	32.63	0.373	0.627	3+
	50.00					1.699						
Sum		0.033			0.186					1.000		

Marple Personal Impactor Data
LMC6: Total Left Knee Replacement



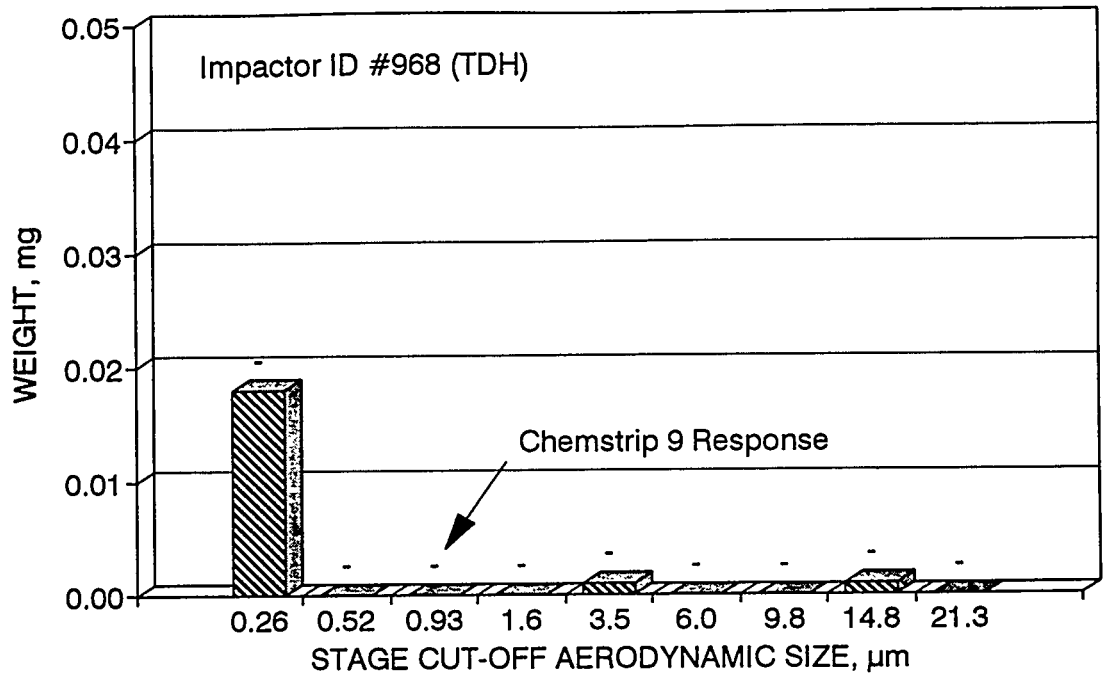
Size distribution by Marple Impactor
LMC6: Total Left Knee Replacement



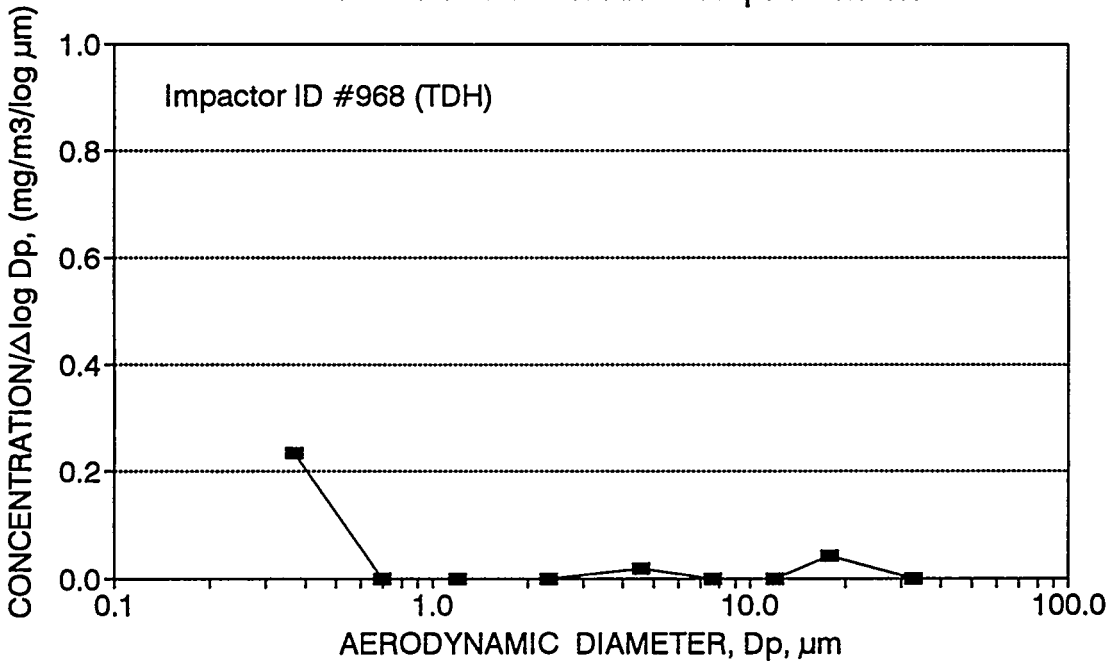
LMC6 Total Knee: Marple Personal Impactor Data (ID No. 968: TDH)

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD	M Chem.9
F	0.26	0.018	1	0.256	0.070	-0.585	0.301	0.234	0.37	0.870	0.000	-
8	0.52	0.000	0.99	0.256	0.000	-0.284	0.252	0.000	0.70	0.000	0.870	-
7	0.93	0.000	0.97	0.256	0.000	-0.032	0.222	0.000	1.20	0.000	0.870	-
6	1.55	0.000	0.96	0.256	0.000	0.190	0.354	0.000	2.33	0.000	0.870	-
5	3.50	0.001	0.95	0.256	0.004	0.544	0.234	0.018	4.58	0.051	0.870	-
4	6.00	0.000	0.89	0.256	0.000	0.778	0.213	0.000	7.67	0.000	0.921	-
3	9.80	0.000	0.78	0.256	0.000	0.991	0.179	0.000	12.04	0.000	0.921	-
2	14.80	0.001	0.61	0.256	0.006	1.170	0.158	0.040	17.75	0.079	0.921	-
1	21.30	0.000	0.52	0.256	0.000	1.328	0.371	0.000	32.63	0.000	1.000	-
	50.00					1.699						
Sum		0.020			0.081					1.000		

Marple Personal Impactor Data
LMC6: Total Left Knee Replacement



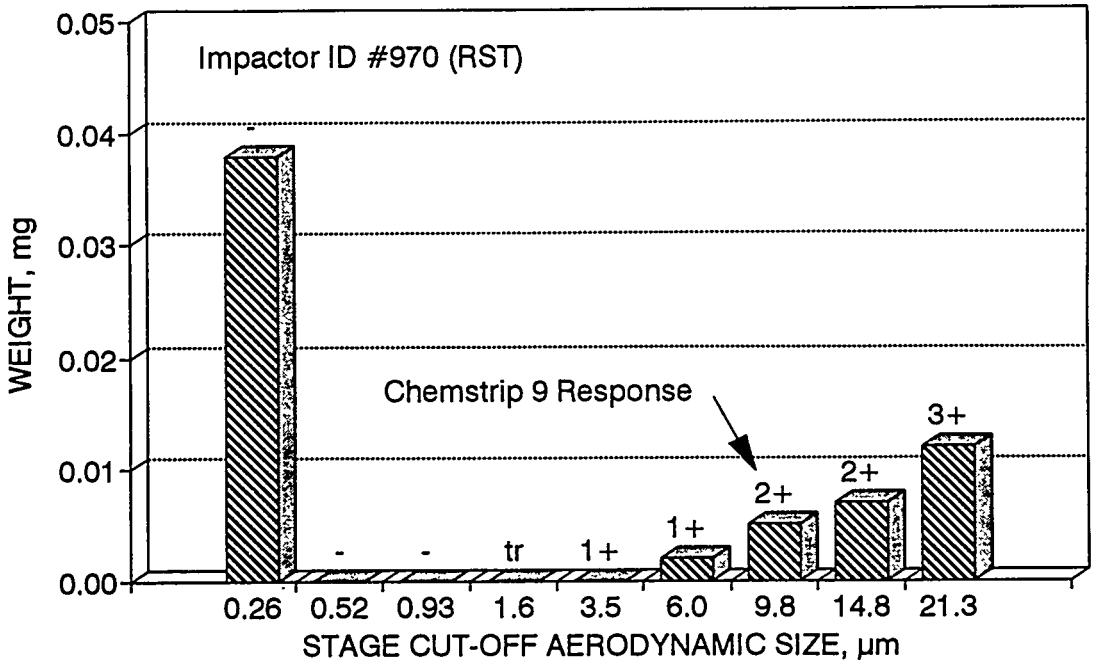
Size distribution by Marple Impactor
LMC6: Total Left Knee Replacement



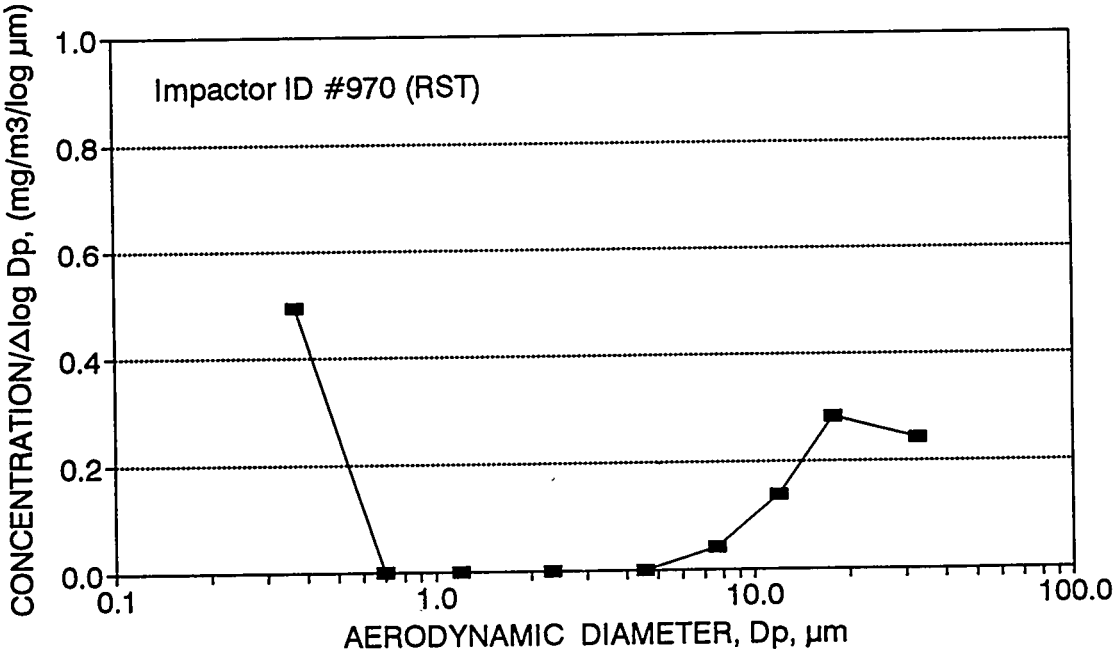
LMC6 Total Knee: Marple Personal Impactor Data (ID No. 970: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.038	1	0.256	0.148	-0.585	0.301	0.493	0.37	0.468	0.000	-
8	0.52	0.000	0.99	0.256	0.000	-0.284	0.252	0.000	0.70	0.000	0.468	-
7	0.93	0.000	0.97	0.256	0.000	-0.032	0.222	0.000	1.20	0.000	0.468	-
6	1.55	0.000	0.96	0.256	0.000	0.190	0.354	0.000	2.33	0.000	0.468	tr
5	3.50	0.000	0.95	0.256	0.000	0.544	0.234	0.000	4.58	0.000	0.468	1+
4	6.00	0.002	0.89	0.256	0.009	0.778	0.213	0.041	7.67	0.028	0.468	1+
3	9.80	0.005	0.78	0.256	0.025	0.991	0.179	0.140	12.04	0.079	0.496	2+
2	14.80	0.007	0.61	0.256	0.045	1.170	0.158	0.283	17.75	0.141	0.575	2+
1	21.30	0.012	0.52	0.256	0.090	1.328	0.371	0.243	32.63	0.284	0.716	3+
	50.00					1.699						
Sum		0.064			0.317					1.000		

Marple Personal Impactor Data
LMC6: Total Left Knee Replacement



Size distribution by Marple Impactor
LMC6: Total Left Knee Replacement



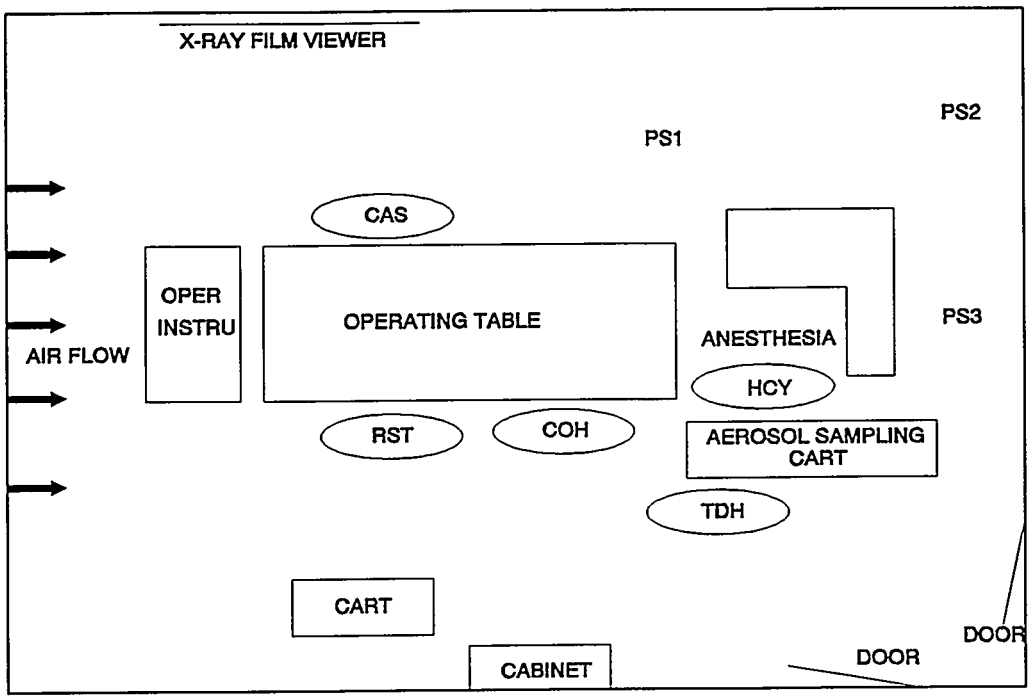
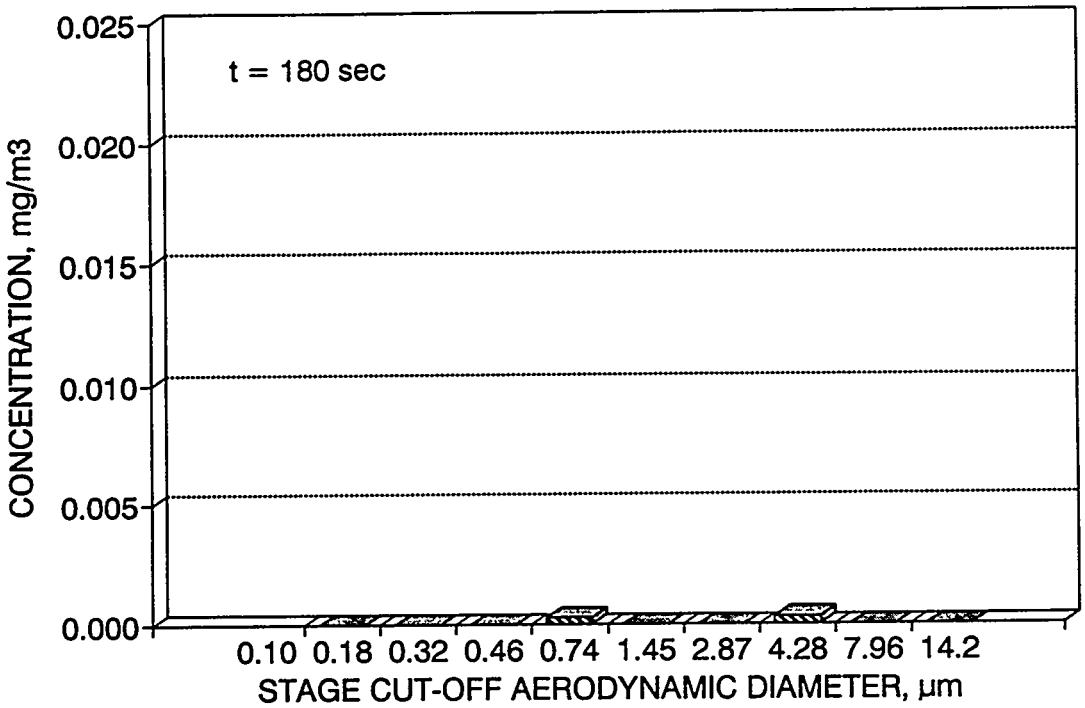


Figure C.7 Initial locations of personnel and area filters during LMC #7 measurement (total hip replacement).

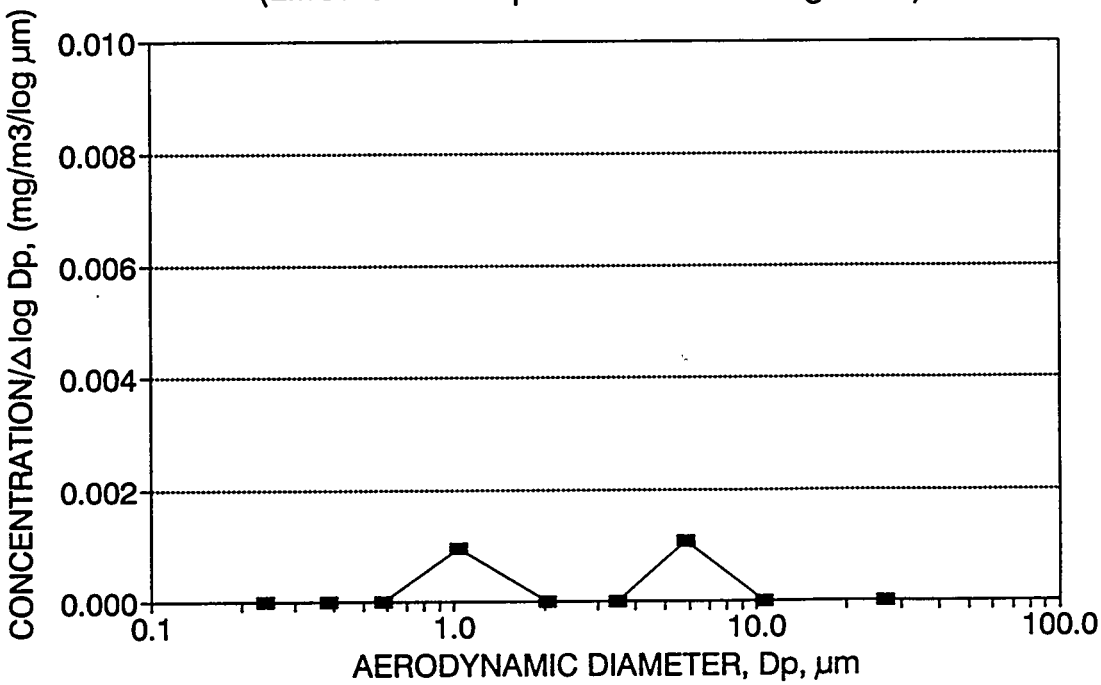
LMC7-0 Total Hip: OR5 Room Background (t = 180 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00028	0.74	-0.128	0.290	0.001	1.04	0.4912	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.491
2.00	0.00000	2.87	0.457	0.174	0.000	3.50	0.0000	0.491
3.00	0.00029	4.28	0.632	0.269	0.001	5.84	0.5088	0.491
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00057						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-0 Total Hip: OR5 Room Background)



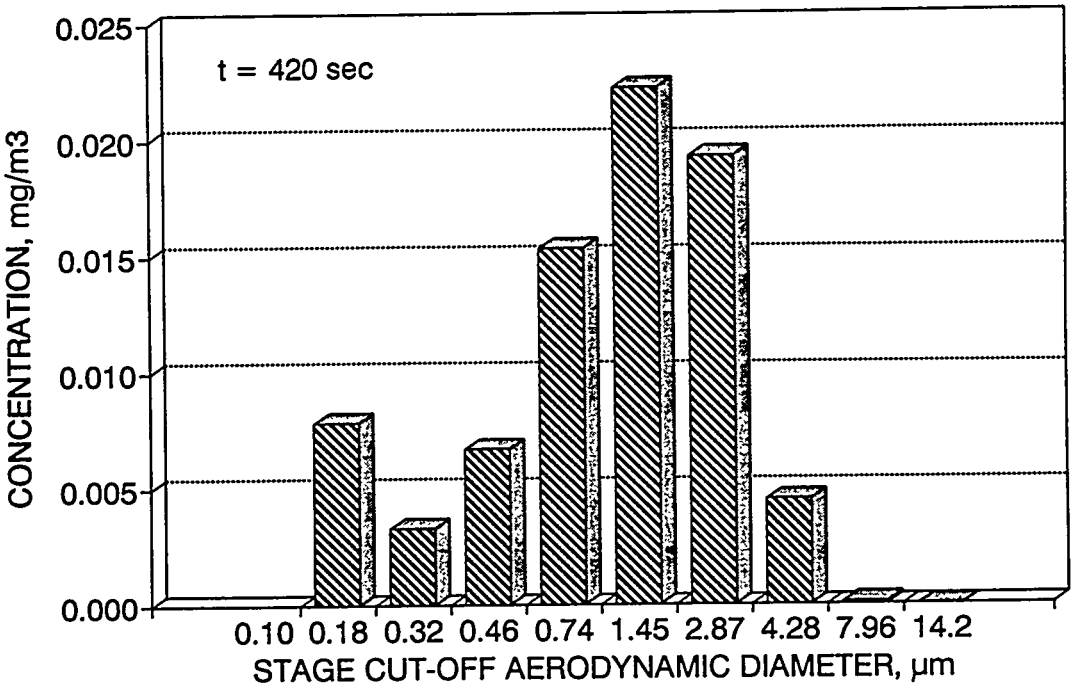
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-0 Total Hip: OR5 Room Background)



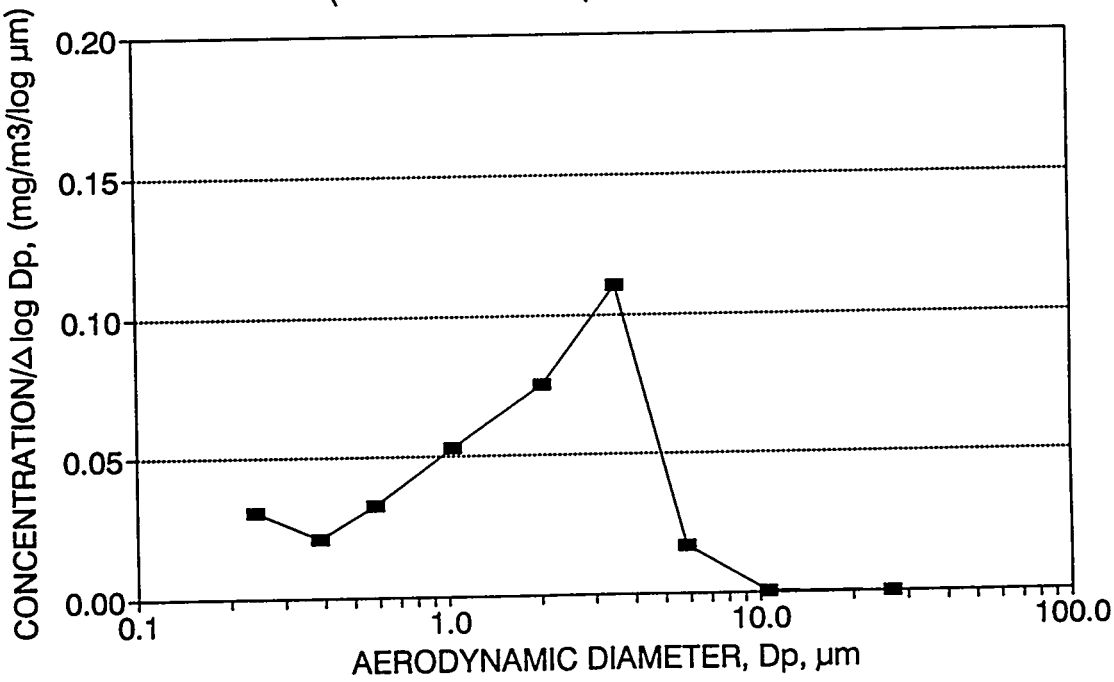
LMC7-1 Total Hip: EC/Cut/IRR (t = 420 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00786	0.18	-0.749	0.257	0.031	0.24	0.0990	0.000
0.20	0.00329	0.32	-0.492	0.157	0.021	0.39	0.0414	0.099
0.30	0.00675	0.46	-0.335	0.206	0.033	0.59	0.0850	0.140
0.50	0.01536	0.74	-0.128	0.290	0.053	1.04	0.1934	0.225
1.00	0.02225	1.45	0.162	0.296	0.075	2.04	0.2802	0.419
2.00	0.01928	2.87	0.457	0.174	0.111	3.50	0.2428	0.699
3.00	0.00453	4.28	0.632	0.269	0.017	5.84	0.0570	0.942
5.60	0.00009	7.96	0.901	0.251	0.000	10.62	0.0012	0.999
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.07941						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-1 Total Hip:EC/Cut, IRR)



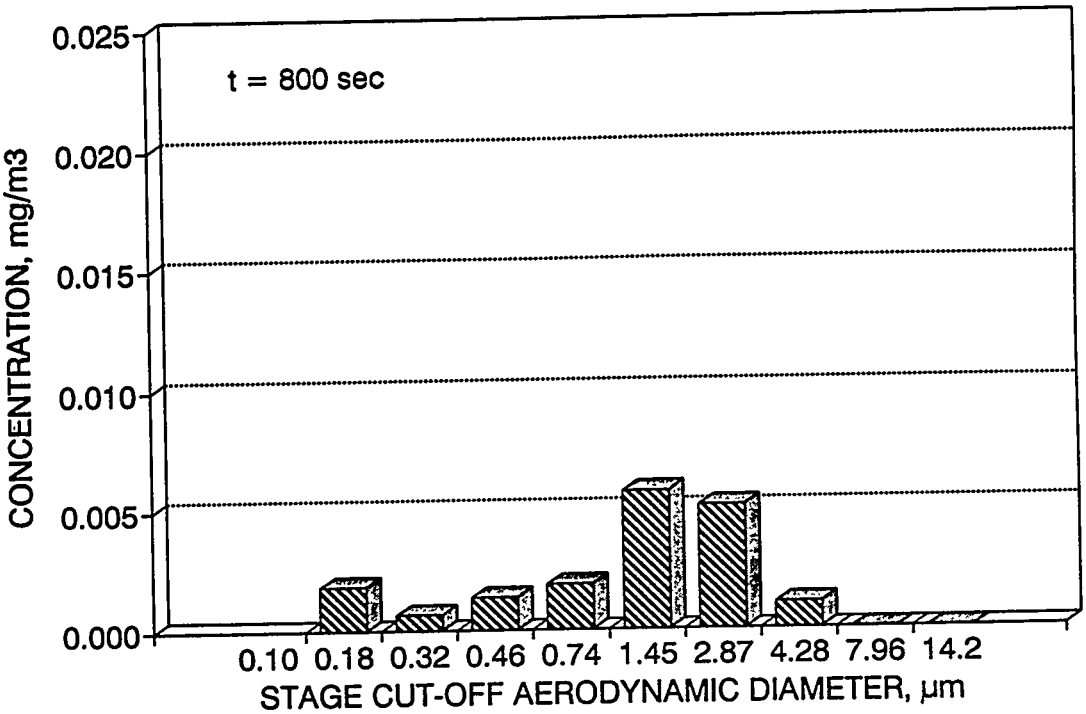
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-1 Total Hip: EC/Cut, IRR)



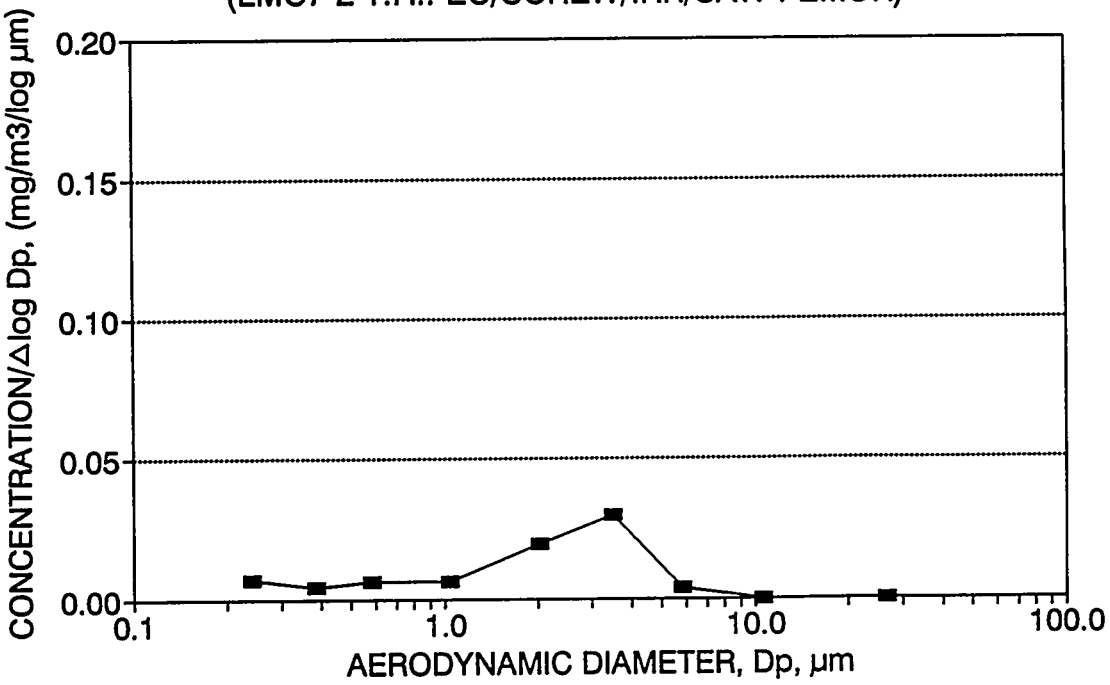
LMC7-2 Total Hip: EC/SCREW/IRR/SAW FEMUR (t = 800 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00182	0.18	-0.749	0.257	0.007	0.24	0.1032	0.000
0.20	0.00064	0.32	-0.492	0.157	0.004	0.39	0.0363	0.103
0.30	0.00133	0.46	-0.335	0.206	0.006	0.59	0.0754	0.140
0.50	0.00186	0.74	-0.128	0.290	0.006	1.04	0.1055	0.215
1.00	0.00576	1.45	0.162	0.296	0.019	2.04	0.3267	0.320
2.00	0.00517	2.87	0.457	0.174	0.030	3.50	0.2933	0.647
3.00	0.00105	4.28	0.632	0.269	0.004	5.84	0.0596	0.940
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.01763						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-2 T.H.: EC/SCREW/IRR/SAW FEMUR)



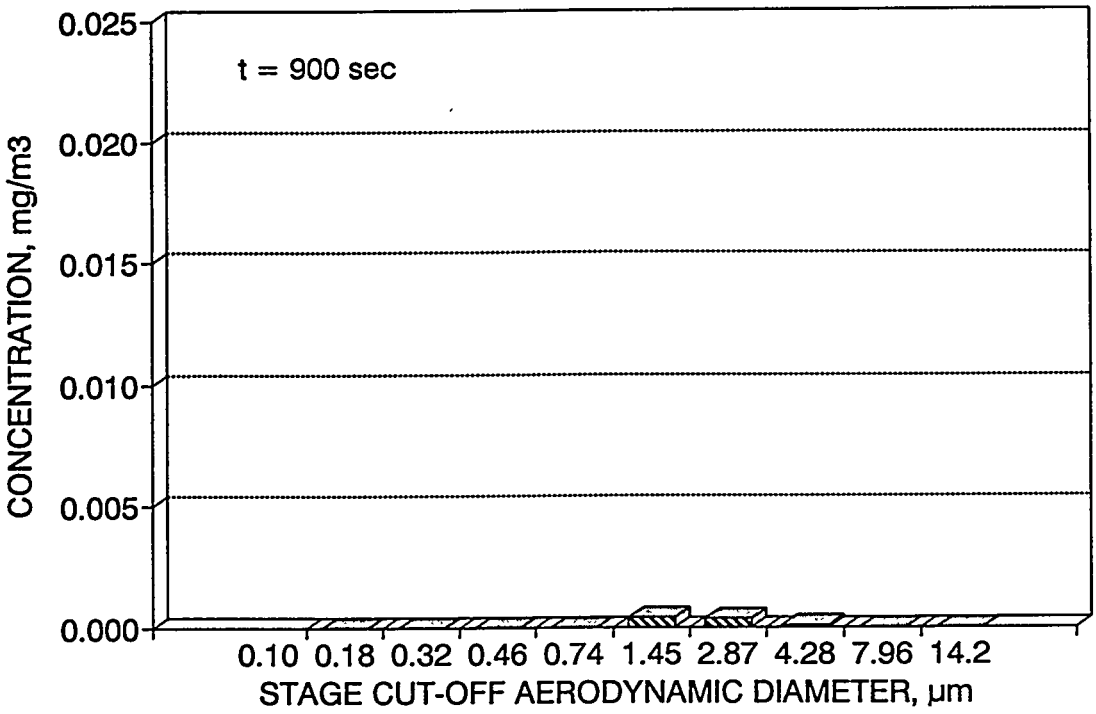
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-2 T.H.: EC/SCREW/IRR/SAW FEMUR)



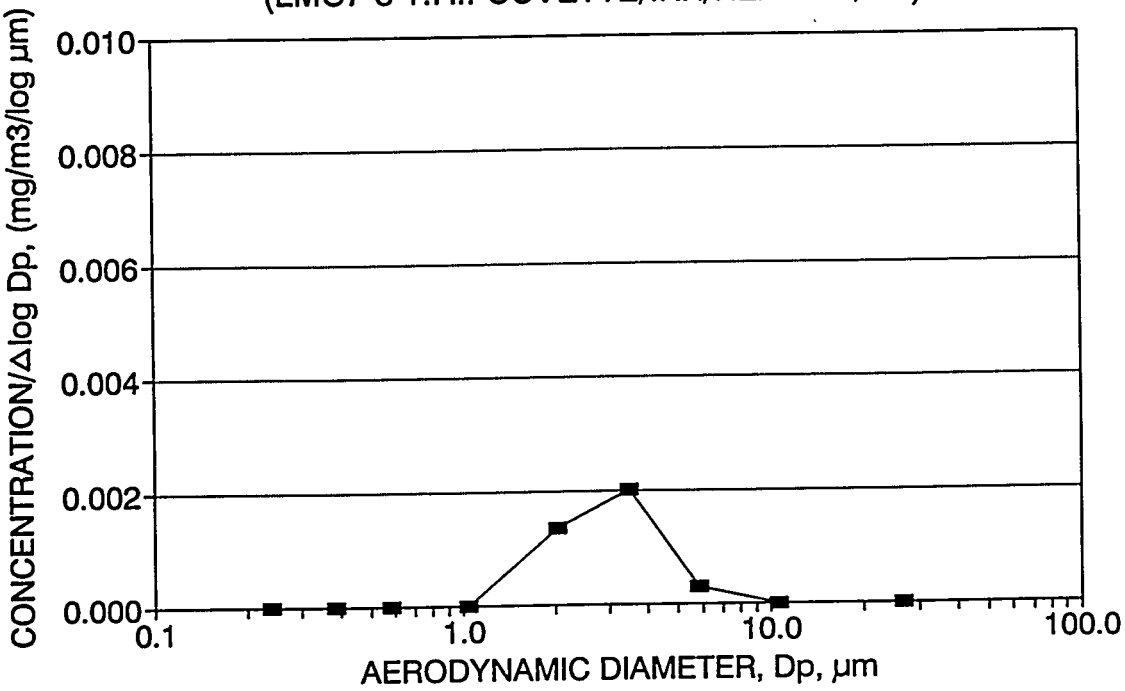
LMC7-3 Total Hip: CUVETTE/IRR/REAMER/EC (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00040	1.45	0.162	0.296	0.001	2.04	0.4819	0.000
2.00	0.00035	2.87	0.457	0.174	0.002	3.50	0.4217	0.482
3.00	0.00008	4.28	0.632	0.269	0.000	5.84	0.0964	0.904
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00083						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-3 T.H.:CUVETTE/IRR/REAMER/EC)



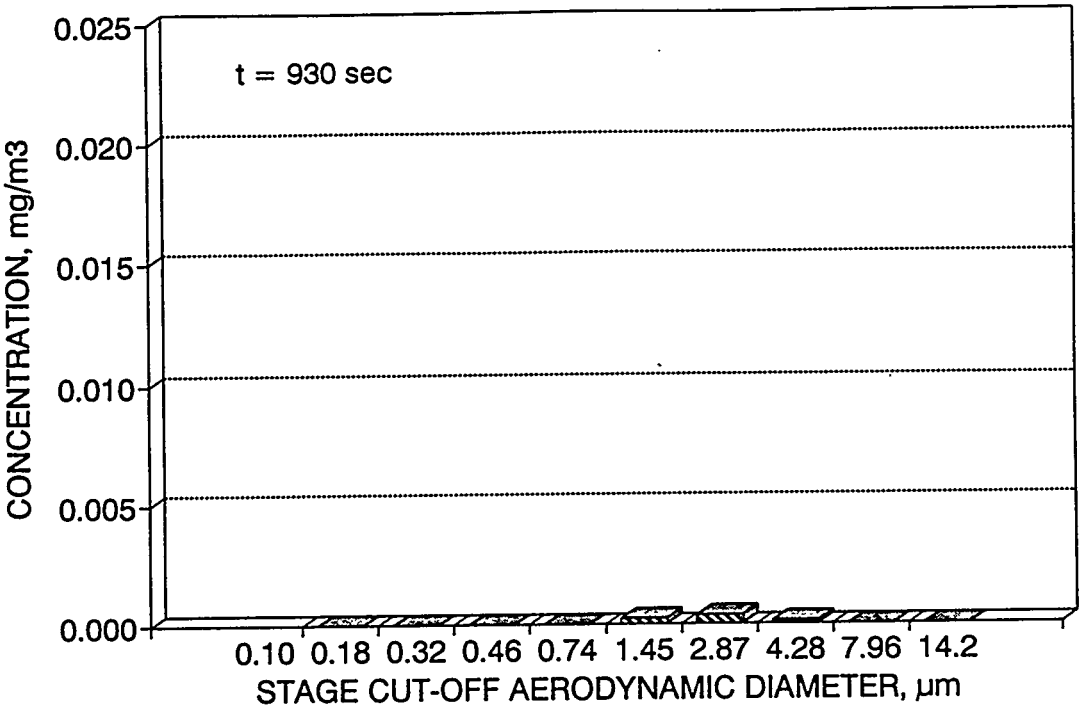
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-3 T.H.: CUVETTE/IRR/REAMER/EC)



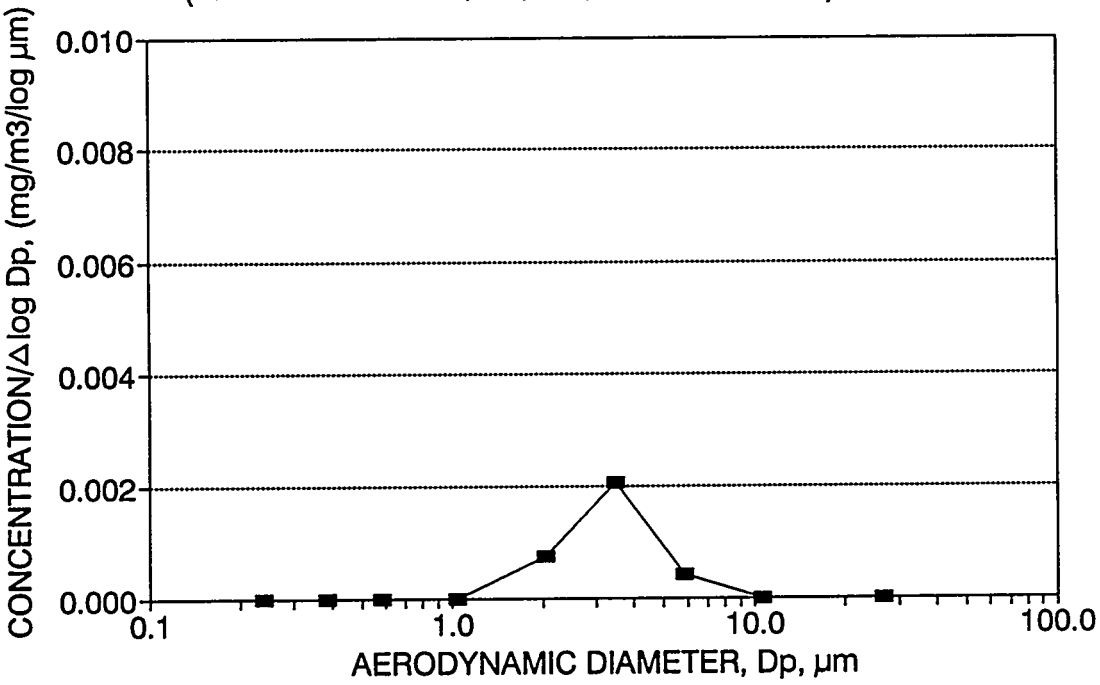
LMC7-4 Total Hip: Hammer/Drill/Irrigation/File/Cuvette (t = 930 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00022	1.45	0.162	0.296	0.001	2.04	0.3188	0.000
2.00	0.00036	2.87	0.457	0.174	0.002	3.50	0.5217	0.319
3.00	0.00011	4.28	0.632	0.269	0.000	5.84	0.1594	0.841
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.2	1.152	0.547	0.000	26.63	0.0000	1.000
		50.0	1.699					1.000
Sum	0.00069						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-4 T.H.: HAM/DR/IRR/FILE/CUVETTE)



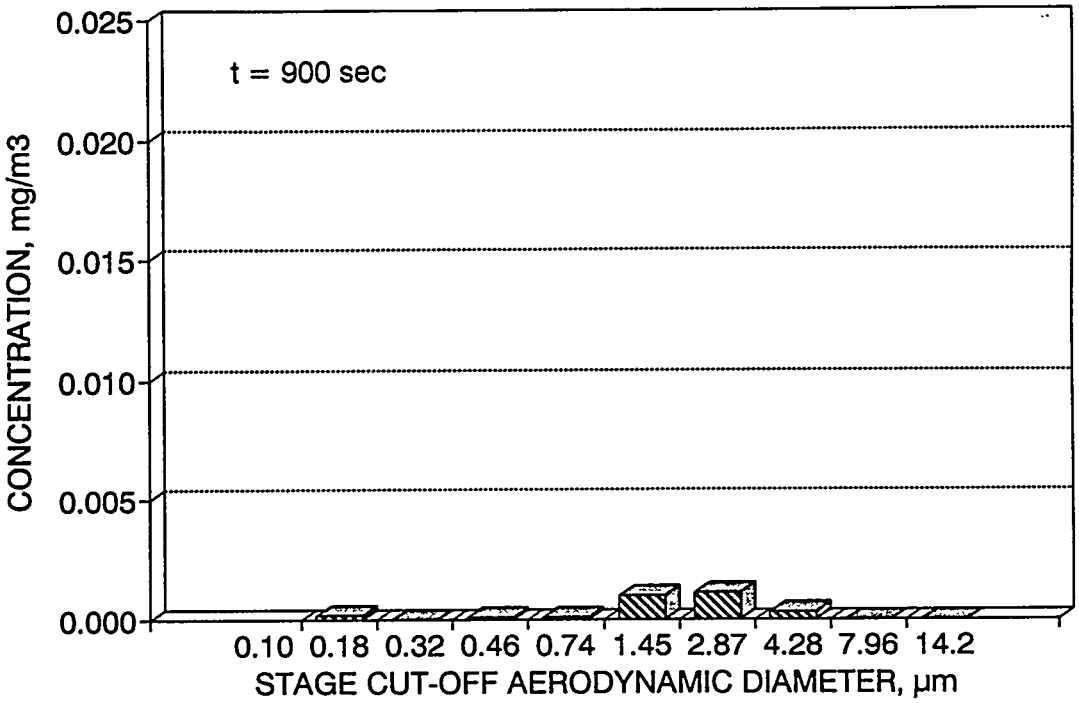
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-4 T.H.:HAM/DR/IRR/FILE/CUVETTE)



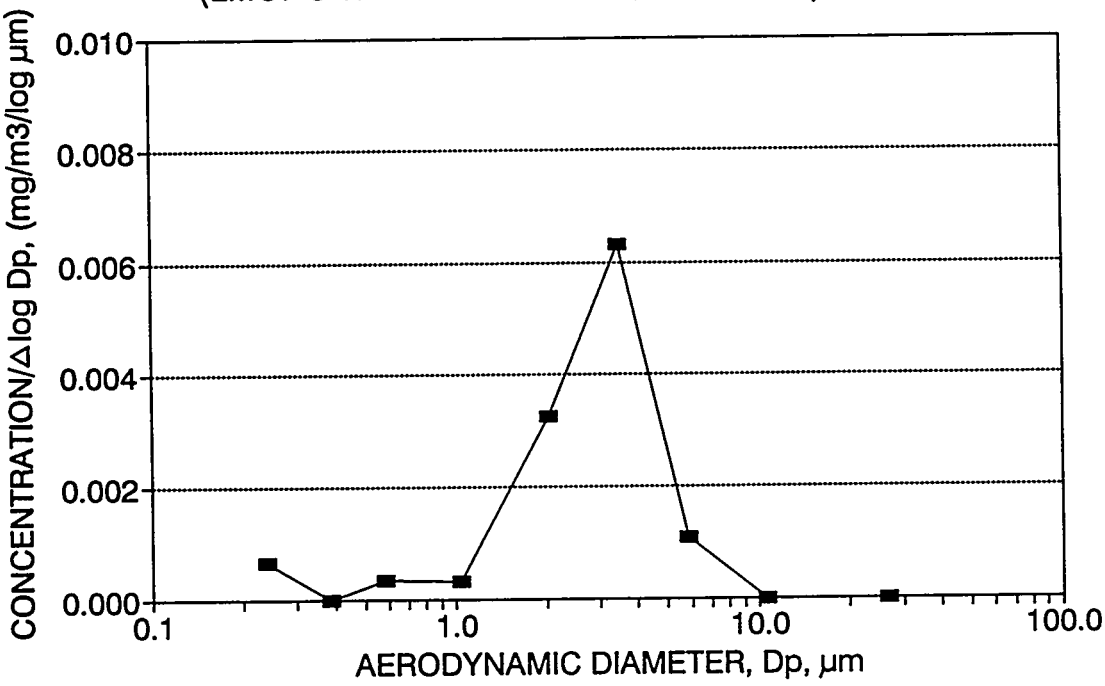
LMC7-5 Total Hip: Fit Prothesis/Irrigation/File (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00017	0.18	-0.749	0.257	0.001	0.24	0.0634	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.063
0.30	0.00007	0.46	-0.335	0.206	0.000	0.59	0.0261	0.063
0.50	0.00009	0.74	-0.128	0.290	0.000	1.04	0.0336	0.090
1.00	0.00096	1.45	0.162	0.296	0.003	2.04	0.3582	0.123
2.00	0.00110	2.87	0.457	0.174	0.006	3.50	0.4104	0.481
3.00	0.00029	4.28	0.632	0.269	0.001	5.84	0.1082	0.892
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00268						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-5 T.H.: FIT PROTHESIS/IRR/H FILE)



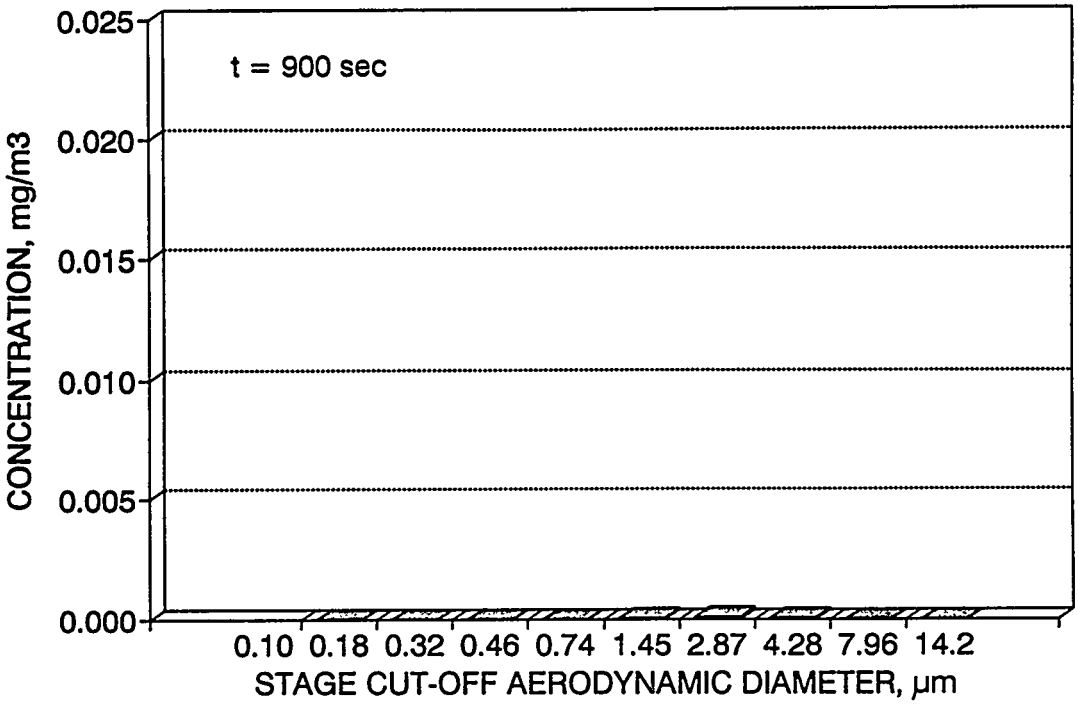
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-5 T.H.: F PROTHESIS/IRR/H FILE)



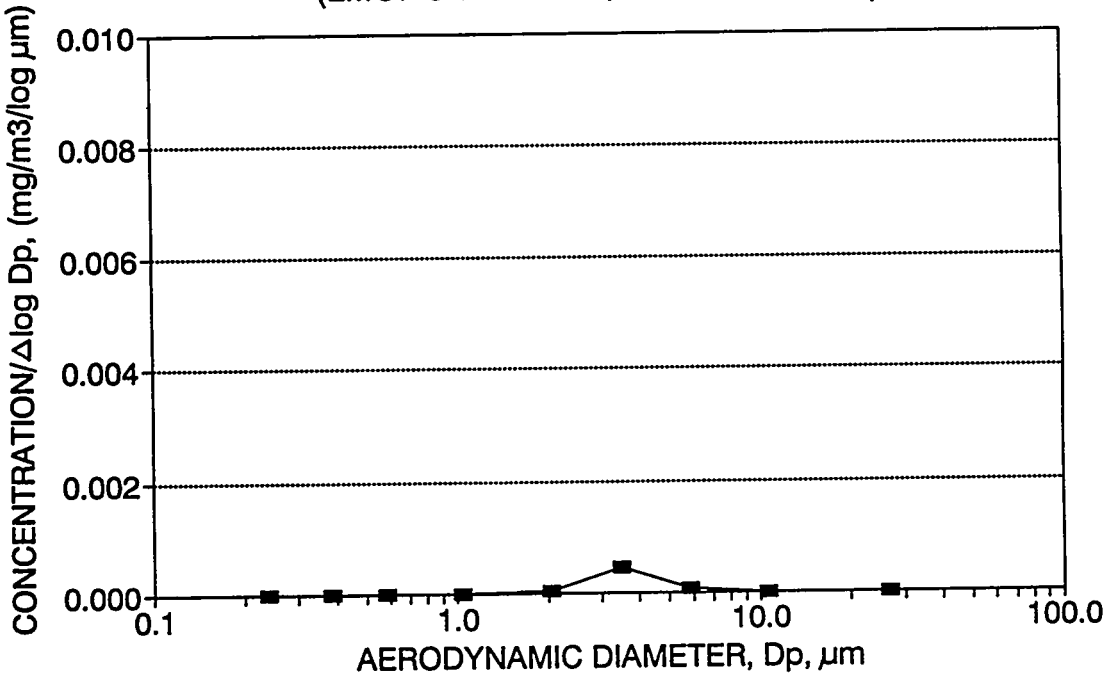
LMC7-6 Total Hip: Cement/Install Prothesis/Irrigation (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.0909	0.000
2.00	0.00008	2.87	0.457	0.174	0.000	3.50	0.7273	0.091
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.1818	0.818
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00011						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-6 T.H.: CEM/PROTHESIS/IRR)



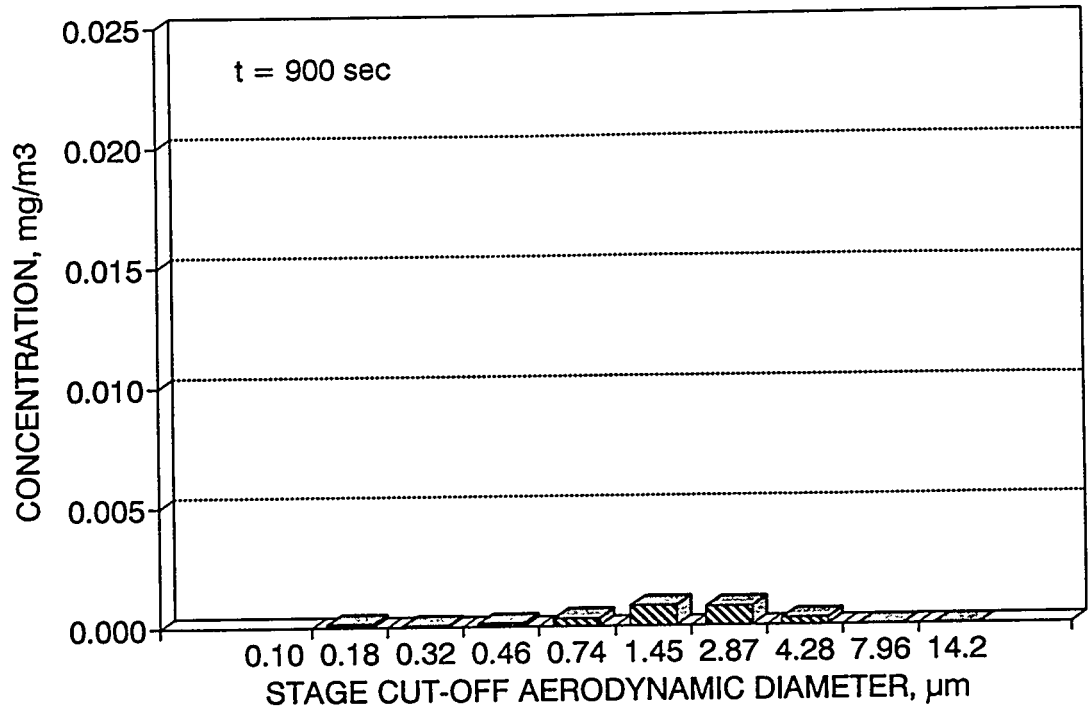
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-6 T.H.: CEM/PROTHESIS/IRR)



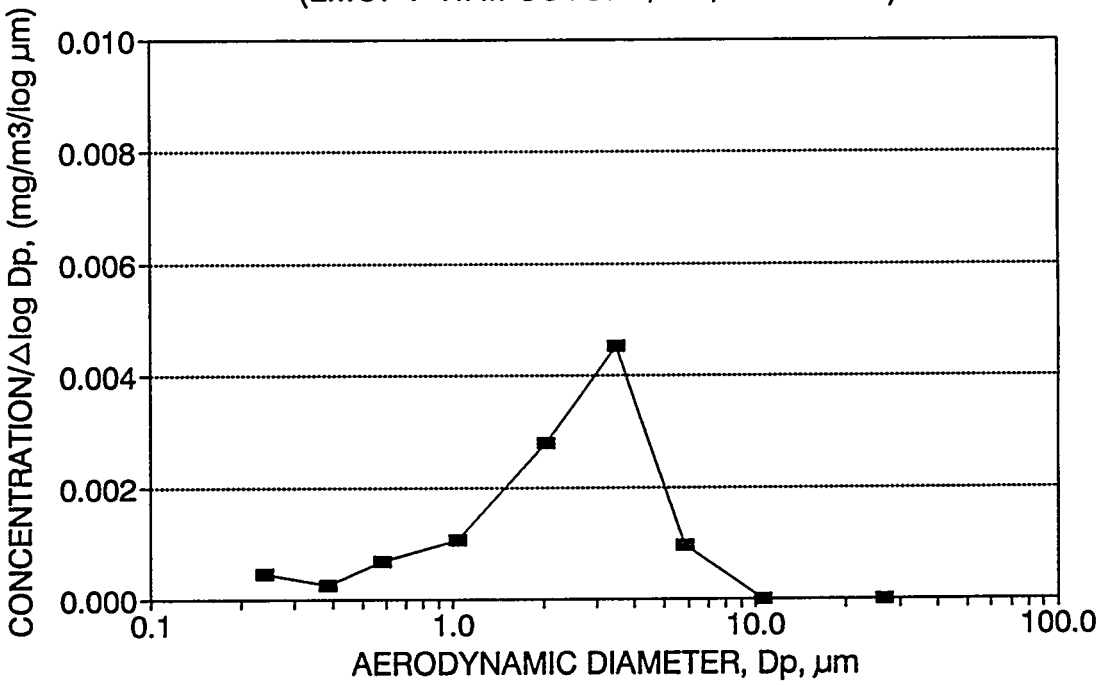
LMC7-7 Total Hip: Suture/Irrigation/Minor EC (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00012	0.18	-0.749	0.257	0.000	0.24	0.0482	0.000
0.20	0.00004	0.32	-0.492	0.157	0.000	0.39	0.0161	0.048
0.30	0.00014	0.46	-0.335	0.206	0.001	0.59	0.0562	0.064
0.50	0.00031	0.74	-0.128	0.290	0.001	1.04	0.1245	0.120
1.00	0.00083	1.45	0.162	0.296	0.003	2.04	0.3333	0.245
2.00	0.00079	2.87	0.457	0.174	0.005	3.50	0.3173	0.578
3.00	0.00026	4.28	0.632	0.269	0.001	5.84	0.1044	0.896
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00249						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-7 T.H.: SUTURE/IRR/MINOR EC)



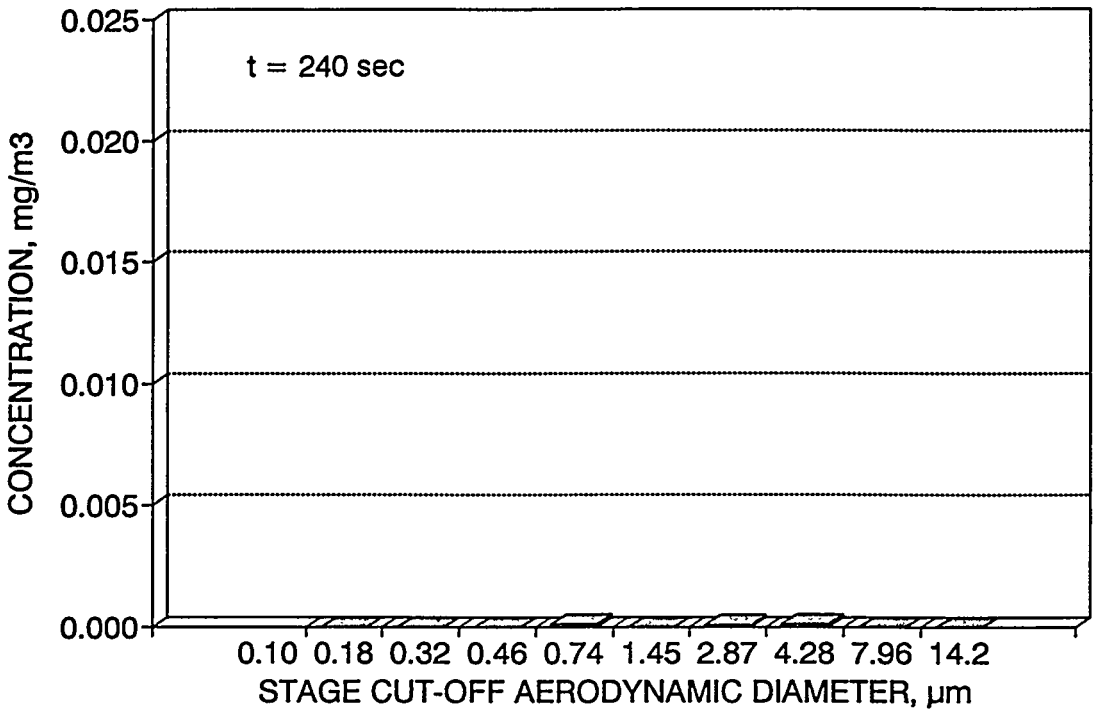
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-7 T.H.: SUTURE/IRR/MINOR EC)



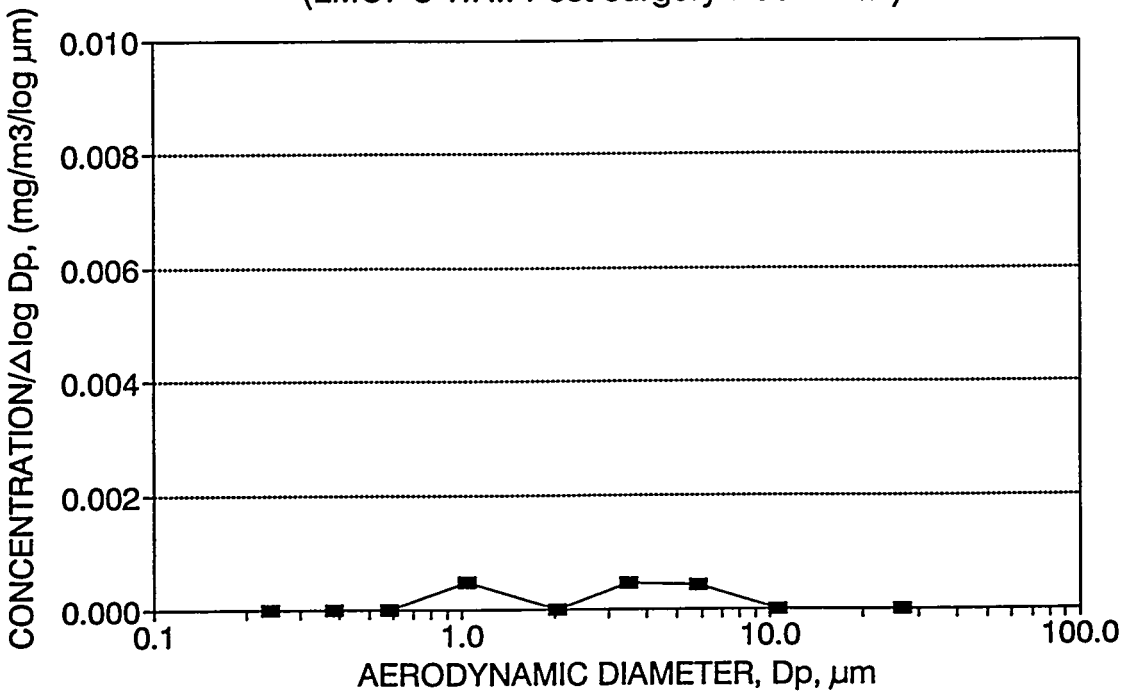
LMC7-8 Total Hip: Post-surgery Room Background (t = 240 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00014	0.74	-0.128	0.290	0.000	1.04	0.4242	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.424
2.00	0.00008	2.87	0.457	0.174	0.000	3.50	0.2424	0.424
3.00	0.00011	4.28	0.632	0.269	0.000	5.84	0.3333	0.667
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00033						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-8 T.H.: Post-surgery Room Bak)



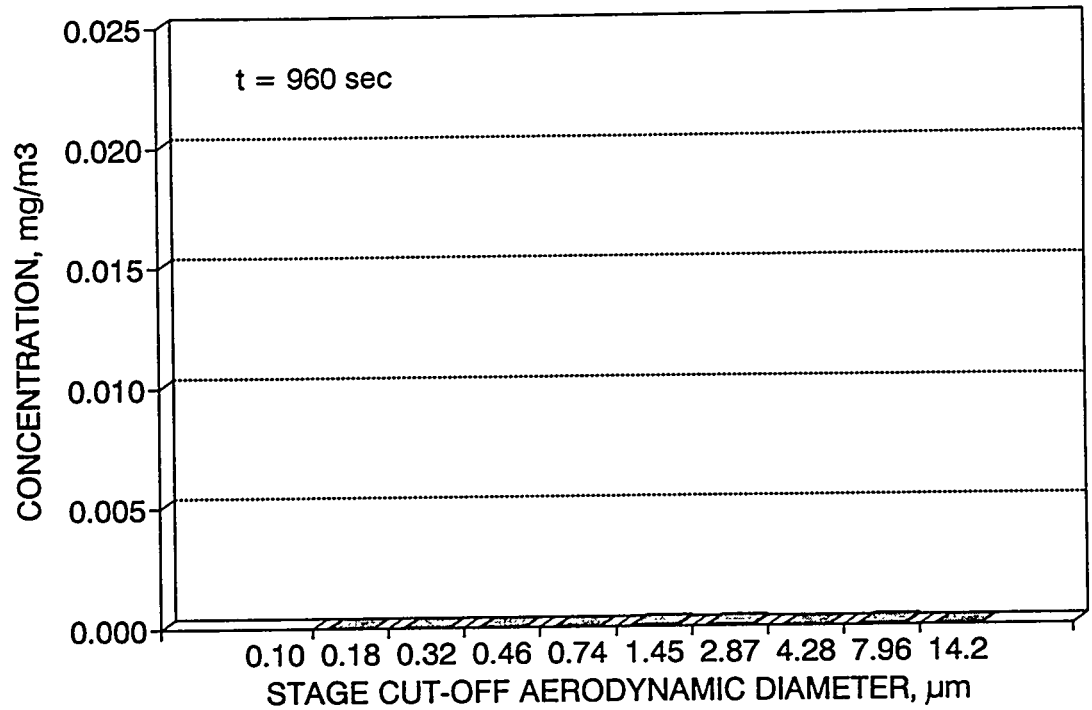
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-8 T.H.: Post-surgery Room Bak)



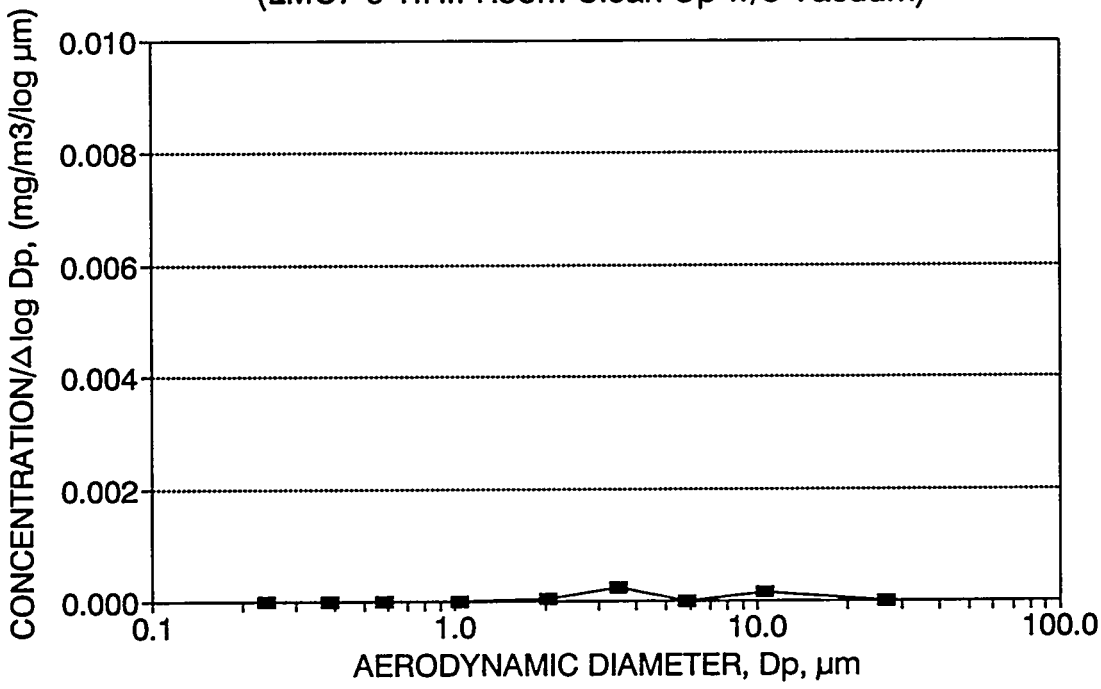
LMC7-9 Total Hip: Room Clean Up without Vacuum (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.1111	0.000
2.00	0.00004	2.87	0.457	0.174	0.000	3.50	0.4444	0.111
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.556
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.4444	0.556
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	9E-05						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC7-9 T.H.: Room Clean Up w/o Vacuum)



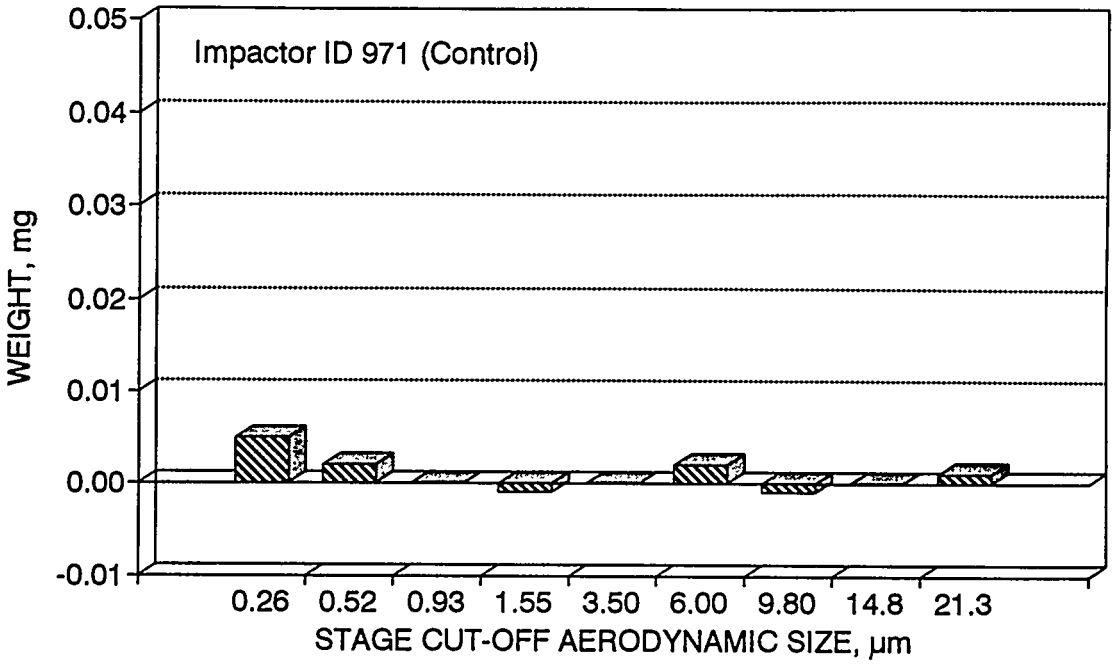
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC7-9 T.H.: Room Clean Up w/o Vacuum)



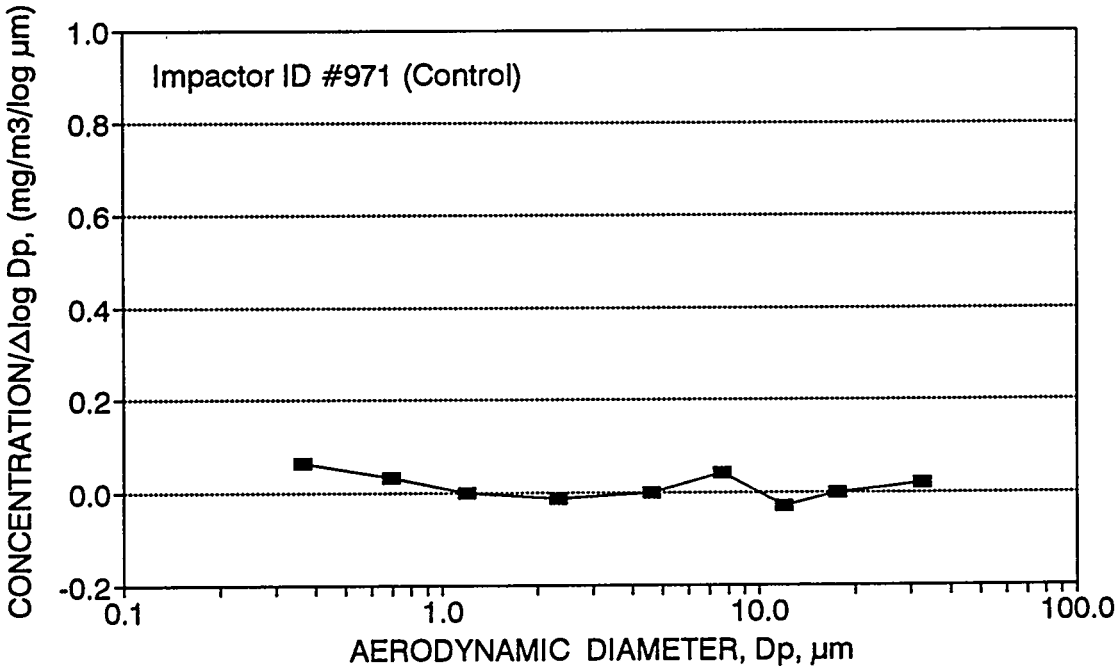
LMC7 Total Hip: Marple Personal Impactor Data (ID No. 971: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.005	1	0.256	0.020	-0.585	0.301	0.065	0.37	0.564	0.000
8	0.52	0.002	0.99	0.256	0.008	-0.284	0.252	0.031	0.70	0.228	0.564
7	0.93	0.000	0.97	0.256	0.000	-0.032	0.222	0.000	1.20	0.000	0.792
6	1.55	-0.001	0.96	0.256	-0.004	0.190	0.354	-0.012	2.33	-0.117	0.792
5	3.50	0.000	0.95	0.256	0.000	0.544	0.234	0.000	4.58	0.000	0.674
4	6.00	0.002	0.89	0.256	0.009	0.778	0.213	0.041	7.67	0.253	0.674
3	9.80	-0.001	0.78	0.256	-0.005	0.991	0.179	-0.028	12.04	-0.145	0.928
2	14.80	0.000	0.61	0.256	0.000	1.170	0.158	0.000	17.75	0.000	0.783
1	21.30	0.001	0.52	0.256	0.008	1.328	0.371	0.020	32.63	0.217	0.783
	50.00					1.699					
Sum		0.008			0.035					1.000	

Marple Personal Impactor Data
LMC7: Total Left Hip Replacement



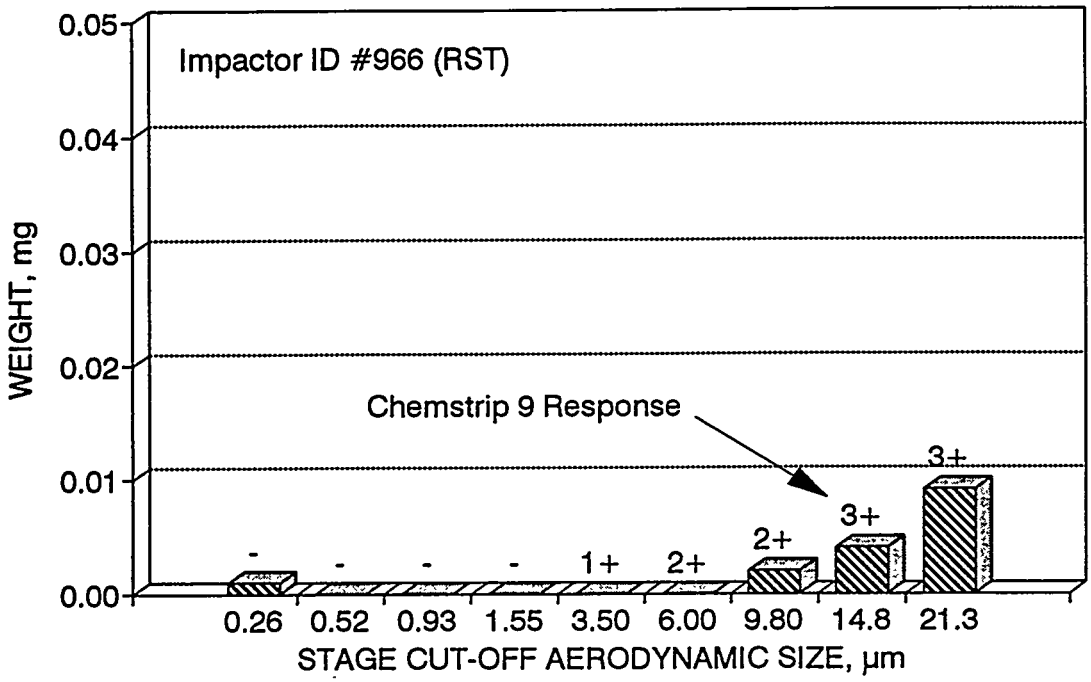
Size distribution by Marple Impactor
LMC7: Total Left Hip Replacement



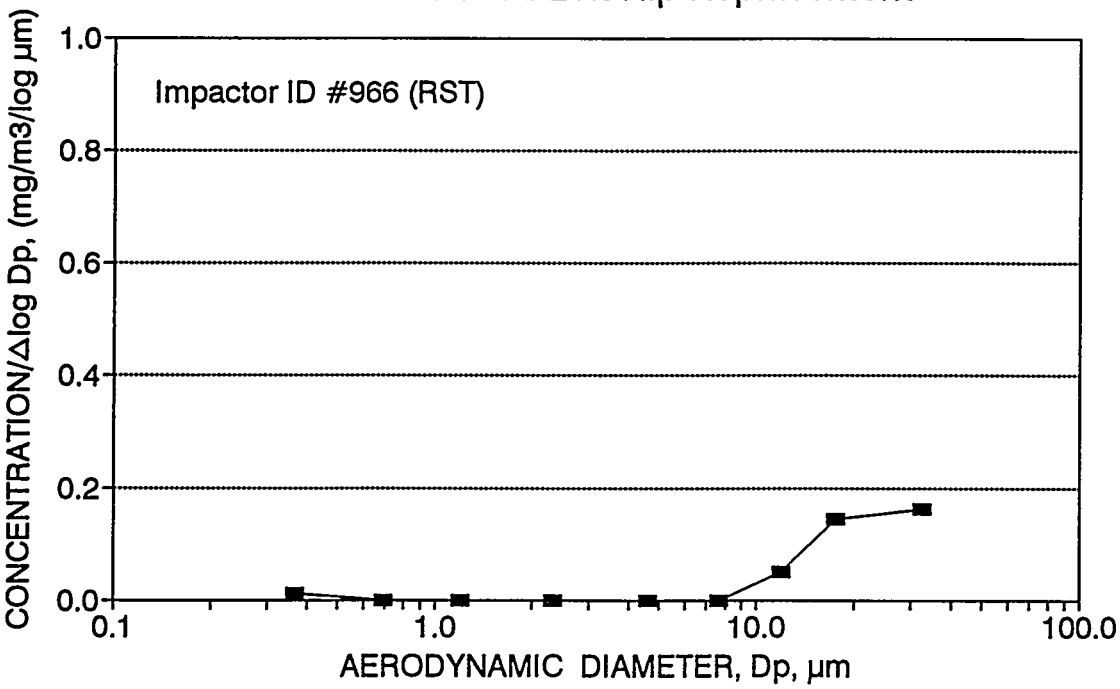
LMC7 Total Hip: Marple Personal Impactor Data (ID No. 966: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.001	1	0.288	0.003	-0.585	0.301	0.012	0.37	0.036	0.000	-
8	0.52	0.000	0.99	0.288	0.000	-0.284	0.252	0.000	0.70	0.000	0.036	-
7	0.93	0.000	0.97	0.288	0.000	-0.032	0.222	0.000	1.20	0.000	0.036	-
6	1.55	0.000	0.96	0.288	0.000	0.190	0.354	0.000	2.33	0.000	0.036	-
5	3.50	0.000	0.95	0.288	0.000	0.544	0.234	0.000	4.58	0.000	0.036	1+
4	6.00	0.000	0.89	0.288	0.000	0.778	0.213	0.000	7.67	0.000	0.036	2+
3	9.80	0.002	0.78	0.288	0.009	0.991	0.179	0.050	12.04	0.093	0.036	2+
2	14.80	0.004	0.61	0.288	0.023	1.170	0.158	0.144	17.75	0.239	0.130	3+
1	21.30	0.009	0.52	0.288	0.060	1.328	0.371	0.162	32.63	0.631	0.369	3+
	50.00					1.699						
Sum		0.016			0.095					1.000		

Marple Personal Impactor Data
LMC7: Total Left Hip Replacement



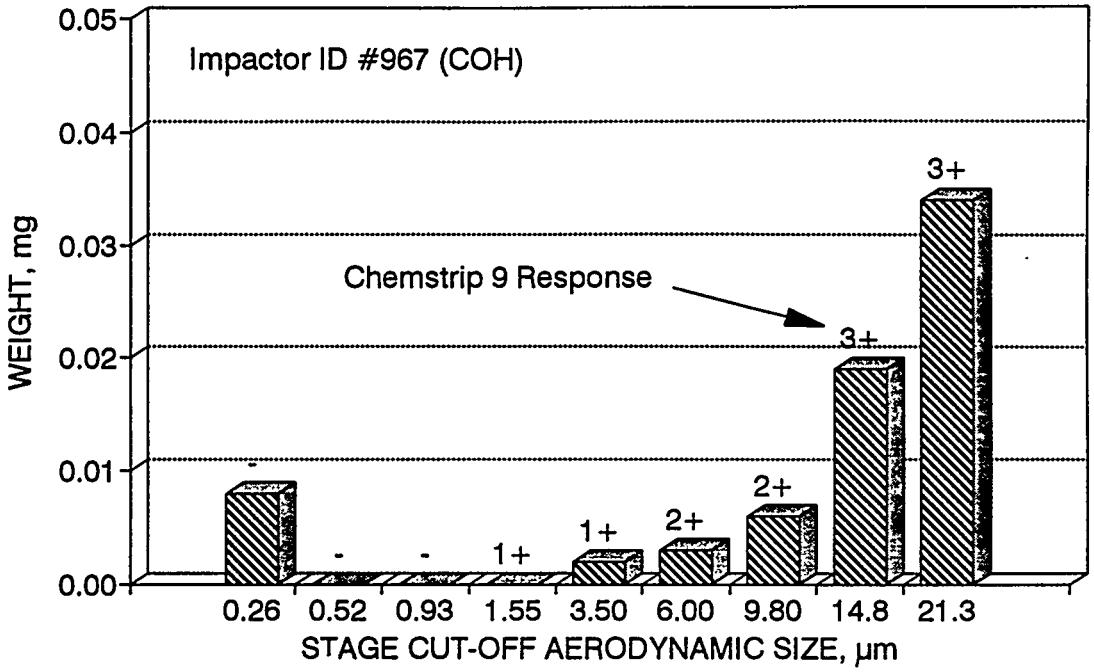
Size distribution by Marple Impactor
LMC7: Total Left Hip Replacement



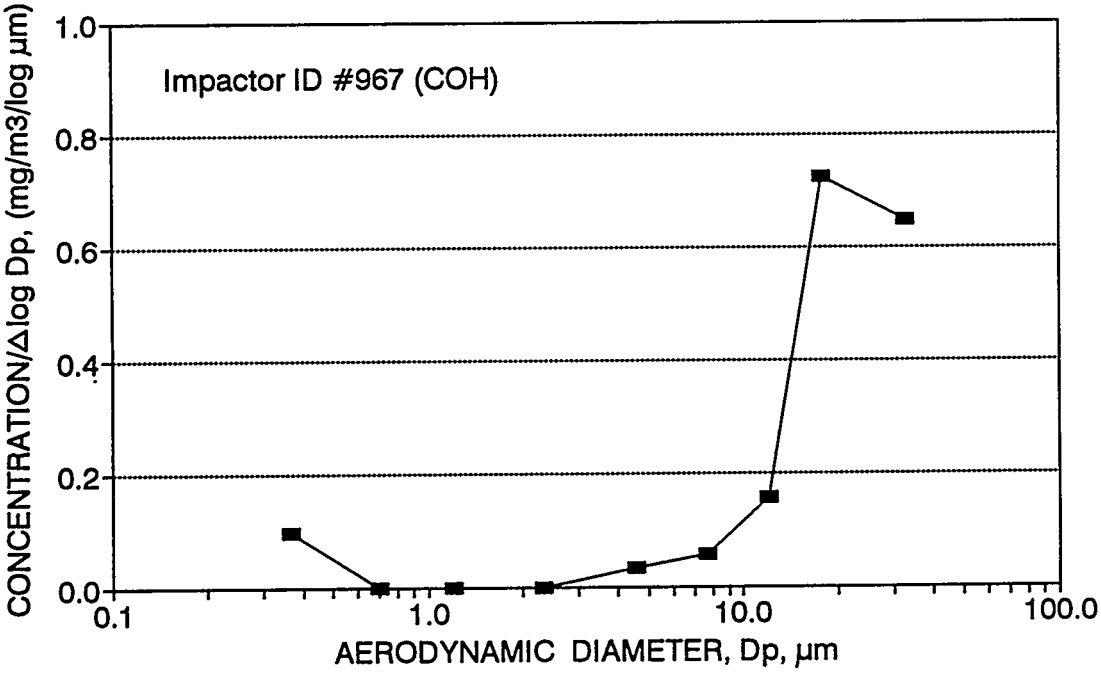
LMC7 Total Hip: Marple Personal Impactor Data (ID No. 967: COH)

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD	M Chem.9
F	0.26	0.008	1	0.272	0.029	-0.585	0.301	0.098	0.37	0.068	0.000	-
8	0.52	0.000	0.99	0.272	0.000	-0.284	0.252	0.000	0.70	0.000	0.068	-
7	0.93	0.000	0.97	0.272	0.000	-0.032	0.222	0.000	1.20	0.000	0.068	-
6	1.55	0.000	0.96	0.272	0.000	0.190	0.354	0.000	2.33	0.000	0.068	1+
5	3.50	0.002	0.95	0.272	0.008	0.544	0.234	0.033	4.58	0.018	0.068	1+
4	6.00	0.003	0.89	0.272	0.012	0.778	0.213	0.058	7.67	0.029	0.086	2+
3	9.80	0.006	0.78	0.272	0.028	0.991	0.179	0.158	12.04	0.065	0.114	2+
2	14.80	0.019	0.61	0.272	0.115	1.170	0.158	0.724	17.75	0.265	0.180	3+
1	21.30	0.034	0.52	0.272	0.240	1.328	0.371	0.649	32.63	0.556	0.444	3+
	50.00					1.699						
Sum		0.072			0.433					1.000		

Marple Personal Impactor Data
LMC7: Total Left Hip Replacement



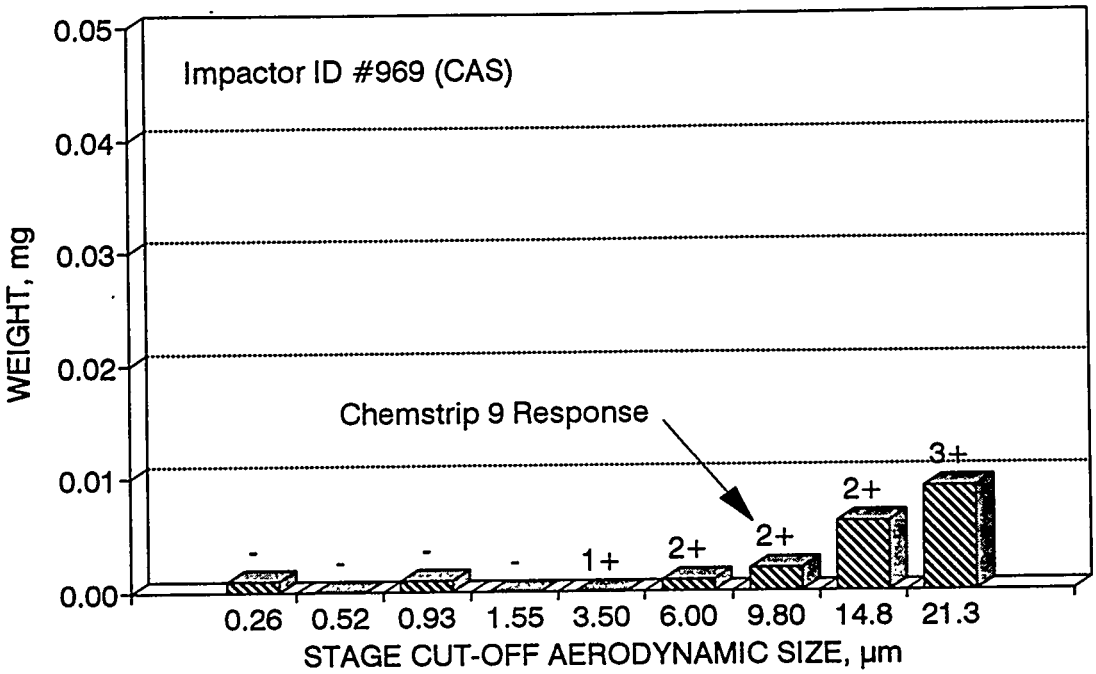
Size distribution by Marple Impactor
LMC7: Total Left Hip Replacement



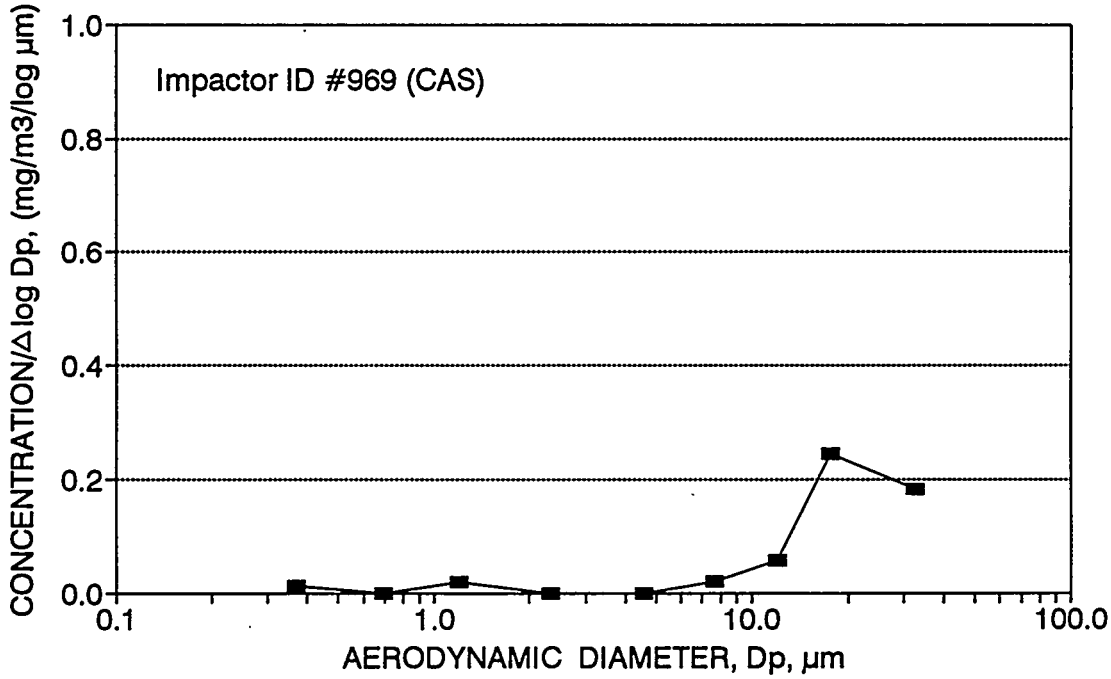
LMC7 Total Hip: Marple Personal Impactor Data (ID No. 969: CAS)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.001	1	0.254	0.004	-0.585	0.301	0.013	0.37	0.030	0.000	-
8	0.52	0.000	0.99	0.254	0.000	-0.284	0.252	0.000	0.70	0.000	0.030	-
7	0.93	0.001	0.97	0.254	0.004	-0.032	0.222	0.018	1.20	0.031	0.030	-
6	1.55	0.000	0.96	0.254	0.000	0.190	0.354	0.000	2.33	0.000	0.062	-
5	3.50	0.000	0.95	0.254	0.000	0.544	0.234	0.000	4.58	0.000	0.062	1+
4	6.00	0.001	0.89	0.254	0.004	0.778	0.213	0.021	7.67	0.034	0.062	2+
3	9.80	0.002	0.78	0.254	0.010	0.991	0.179	0.056	12.04	0.078	0.096	2+
2	14.80	0.006	0.61	0.254	0.039	1.170	0.158	0.245	17.75	0.299	0.174	2+
1	21.30	0.009	0.52	0.254	0.068	1.328	0.371	0.184	32.63	0.527	0.473	3+
	50.00					1.699						
Sum		0.020			0.129					1.000		

Marple Personal Impactor Data
LMC7: Total Left Hip Replacement



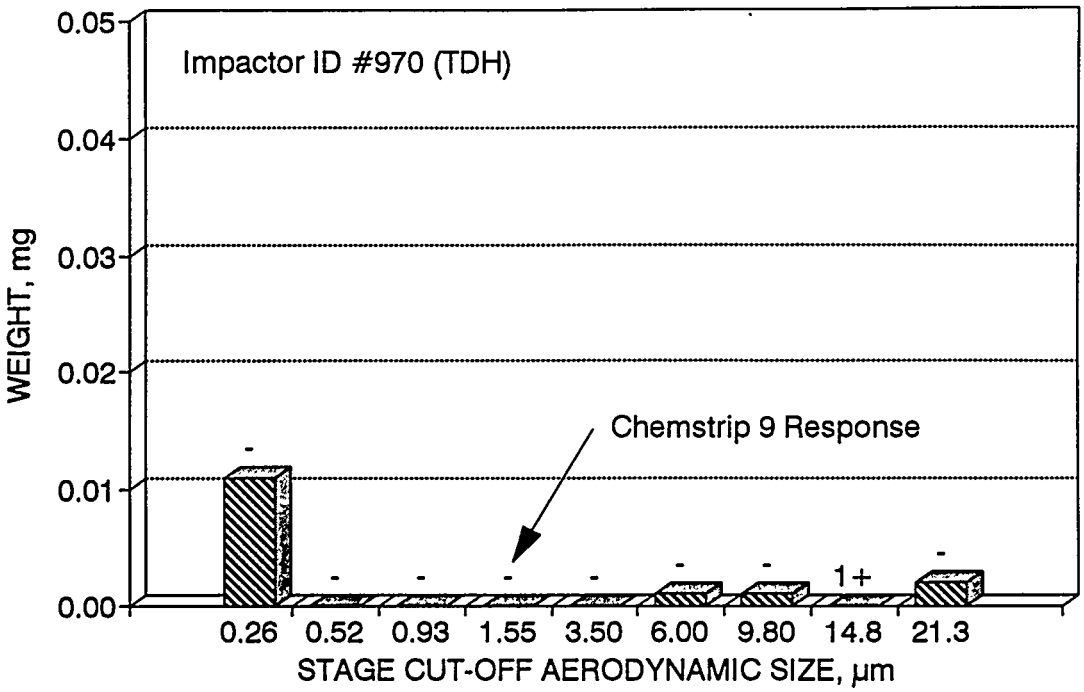
Size distribution by Marple Impactor
LMC7: Total Left Hip Replacement



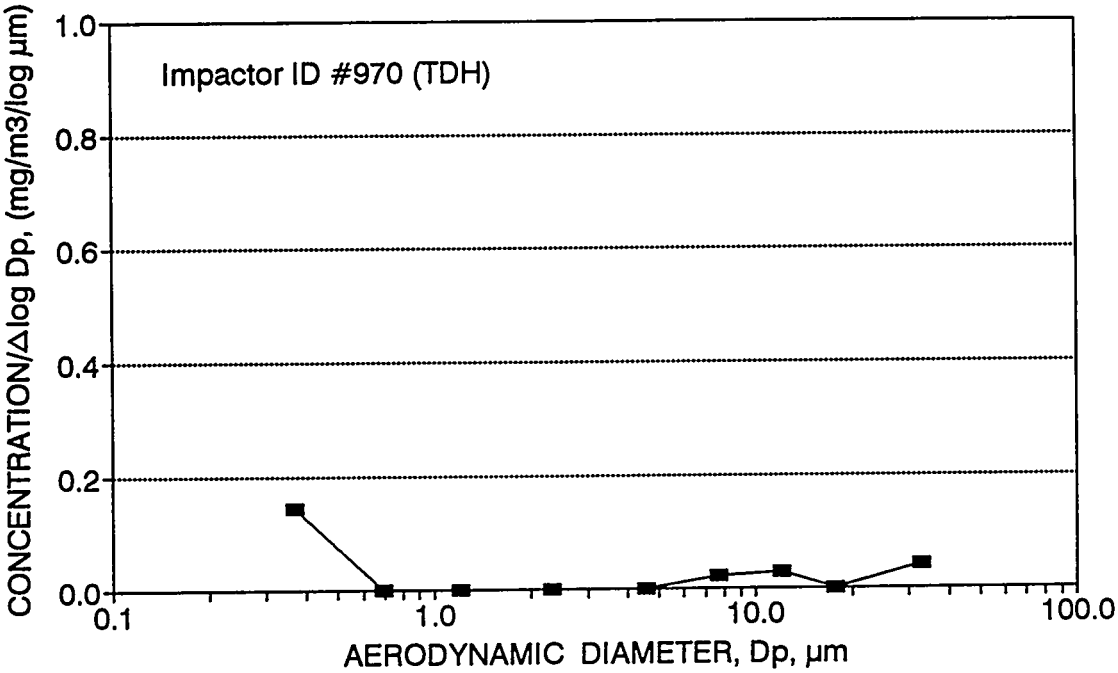
LMC7 Total Hip: Marple Personal Impactor Data (ID No. 970: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.011	1	0.256	0.043	-0.585	0.301	0.143	0.37	0.638	0.000	-
8	0.52	0.000	0.99	0.256	0.000	-0.284	0.252	0.000	0.70	0.000	0.638	-
7	0.93	0.000	0.97	0.256	0.000	-0.032	0.222	0.000	1.20	0.000	0.638	-
6	1.55	0.000	0.96	0.256	0.000	0.190	0.354	0.000	2.33	0.000	0.638	-
5	3.50	0.000	0.95	0.256	0.000	0.544	0.234	0.000	4.58	0.000	0.638	-
4	6.00	0.001	0.89	0.256	0.004	0.778	0.213	0.021	7.67	0.065	0.638	-
3	9.80	0.001	0.78	0.256	0.005	0.991	0.179	0.028	12.04	0.074	0.703	-
2	14.80	0.000	0.61	0.256	0.000	1.170	0.158	0.000	17.75	0.000	0.777	1+
1	21.30	0.002	0.52	0.256	0.015	1.328	0.371	0.041	32.63	0.223	0.777	-
	50.00					1.699						
Sum		0.015			0.067					1.000		

Marple Personal Impactor Data
LMC7: Total Left Hip Replacement



Size distribution by Marple Impactor
LMC7: Total Left Hip Replacement



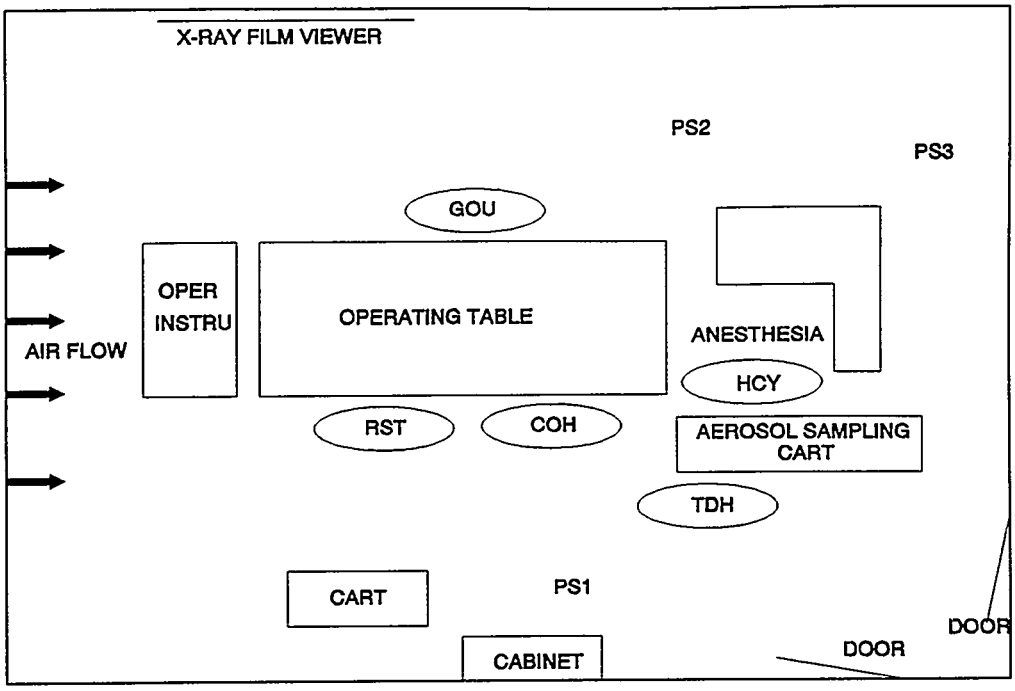
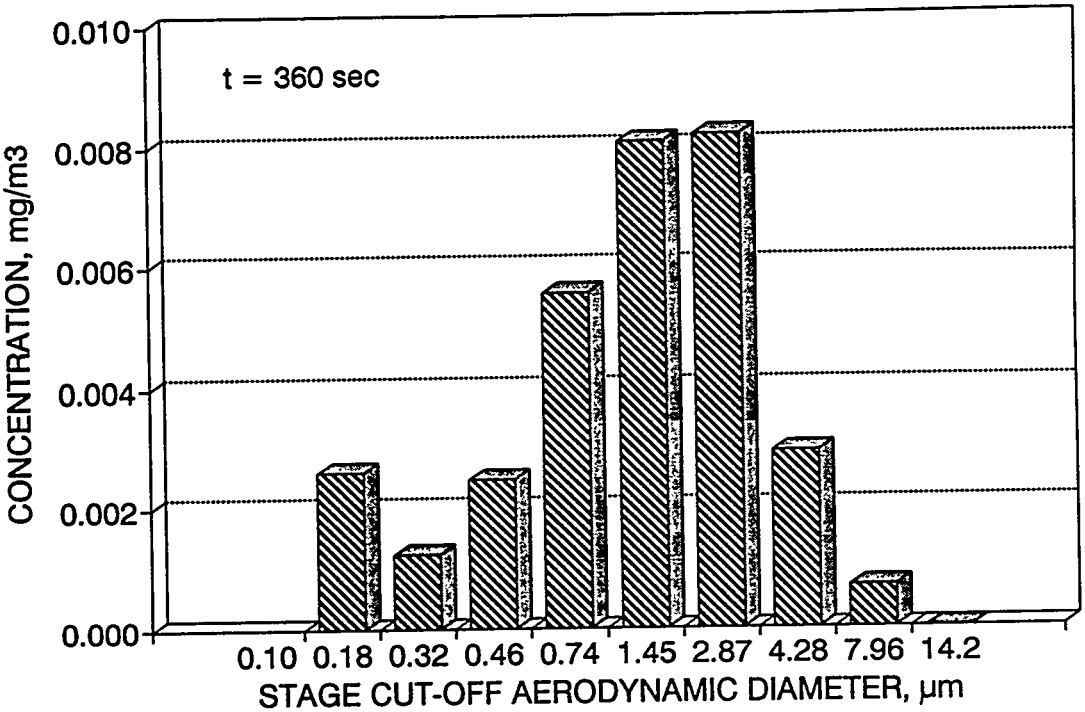


Figure C.8 Initial locations of personnel and area filters during LMC #8 measurement (total hip replacement).

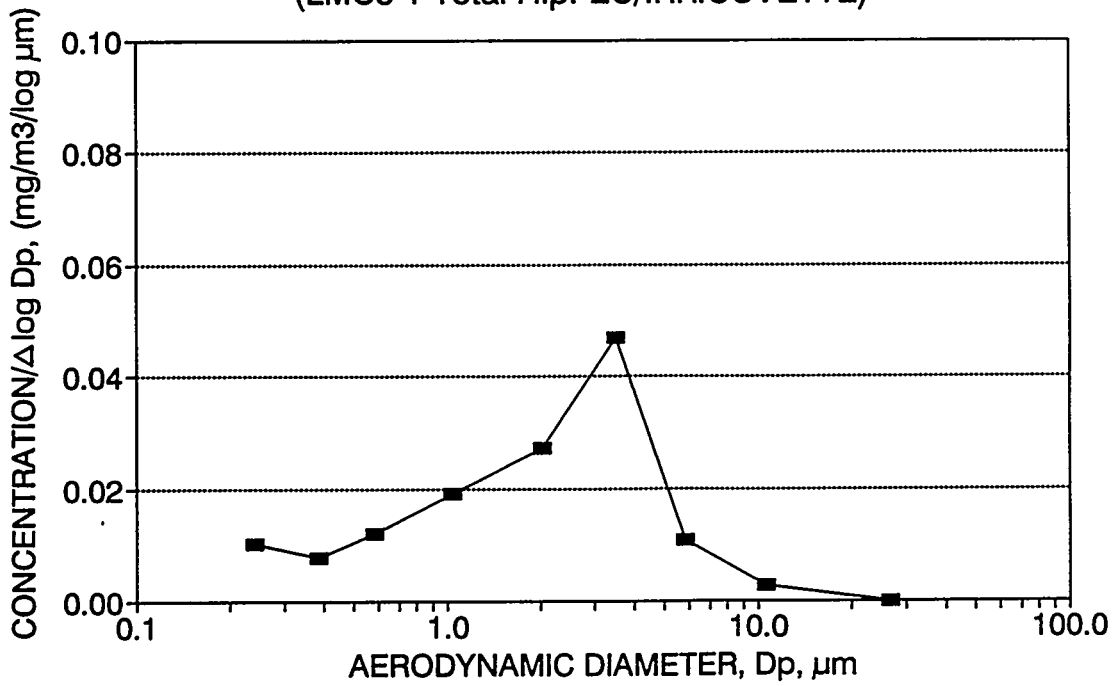
LMC8-1 Total Hip: EC/Irrigulation/Cuvette (t = 360 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00261	0.18	-0.749	0.257	0.010	0.24	0.0823	0.000
0.20	0.00122	0.32	-0.492	0.157	0.008	0.39	0.0385	0.082
0.30	0.00247	0.46	-0.335	0.206	0.012	0.59	0.0779	0.121
0.50	0.00555	0.74	-0.128	0.290	0.019	1.04	0.1750	0.199
1.00	0.00807	1.45	0.162	0.296	0.027	2.04	0.2545	0.374
2.00	0.00819	2.87	0.457	0.174	0.047	3.50	0.2583	0.628
3.00	0.00293	4.28	0.632	0.269	0.011	5.84	0.0924	0.886
5.60	0.00067	7.96	0.901	0.251	0.003	10.62	0.0211	0.979
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.03171						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-1 Total Hip: EC/IRR/CUVETTE)



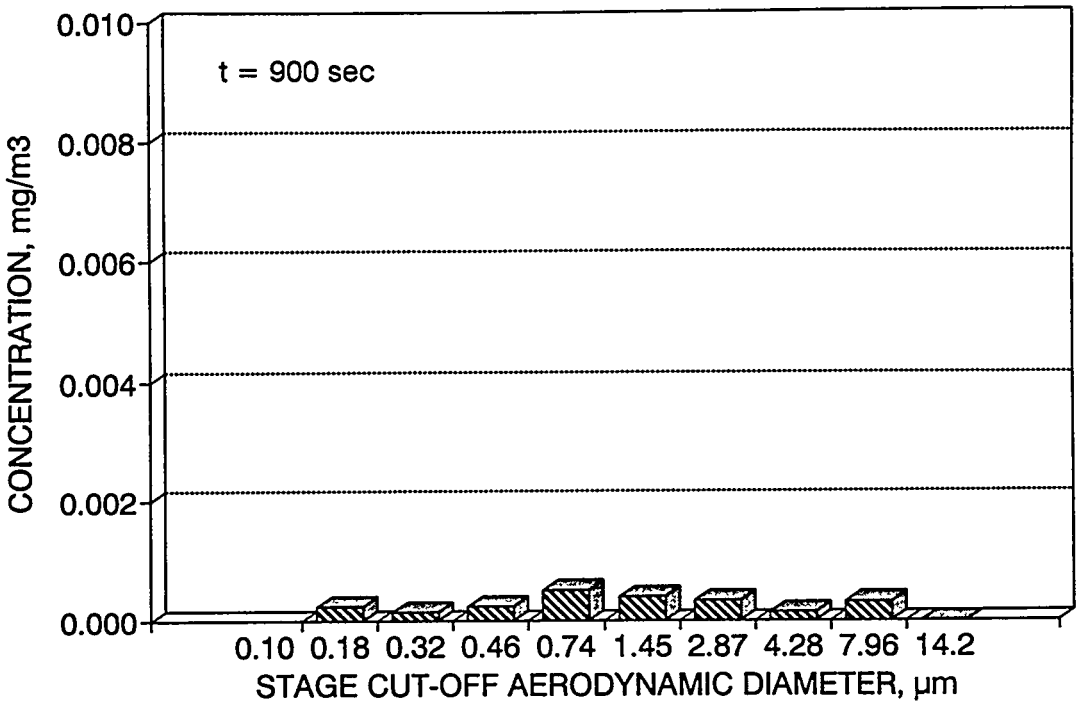
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-1 Total Hip: EC/IRR.CUVETTE)



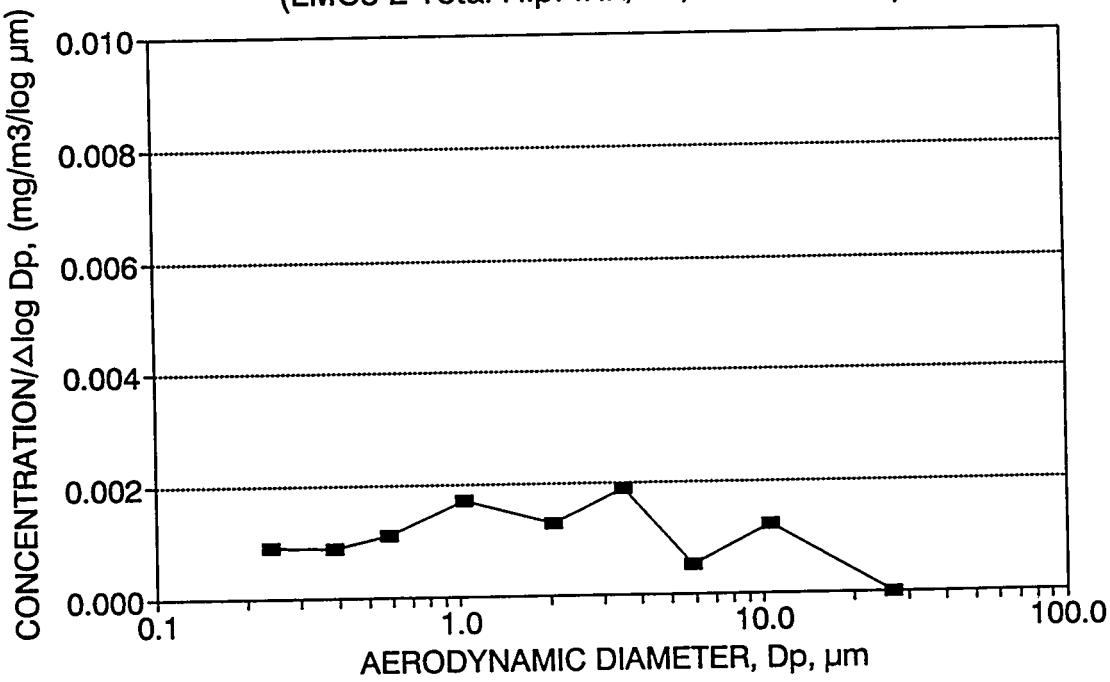
LMC8-2 Total Hip: Irrigation/EC/Saw Femur (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00023	0.18	-0.749	0.257	0.001	0.24	0.1018	0.000
0.20	0.00014	0.32	-0.492	0.157	0.001	0.39	0.0619	0.102
0.30	0.00023	0.46	-0.335	0.206	0.001	0.59	0.1018	0.164
0.50	0.00050	0.74	-0.128	0.290	0.002	1.04	0.2212	0.265
1.00	0.00038	1.45	0.162	0.296	0.001	2.04	0.1681	0.487
2.00	0.00033	2.87	0.457	0.174	0.002	3.50	0.1460	0.655
3.00	0.00014	4.28	0.632	0.269	0.001	5.84	0.0619	0.801
5.60	0.00031	7.96	0.901	0.251	0.001	10.62	0.1372	0.863
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00226						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-2 Total Hip: IRR/EC/SAW FEMUR)



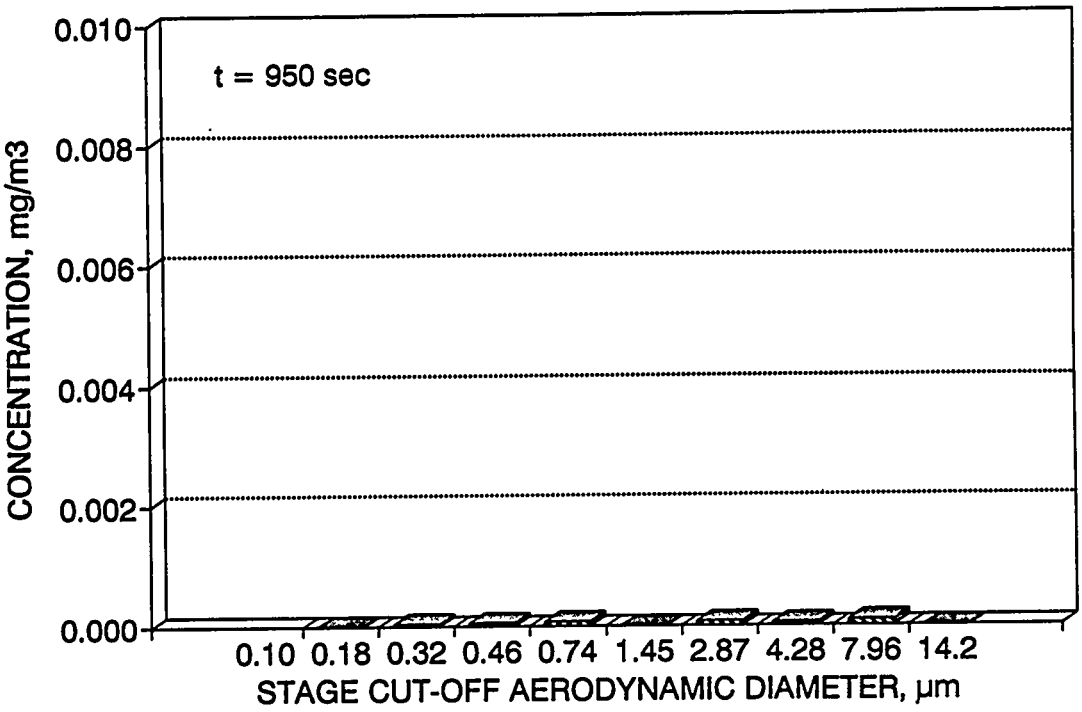
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-2 Total Hip: IRR/EC/SAW FEMUR)



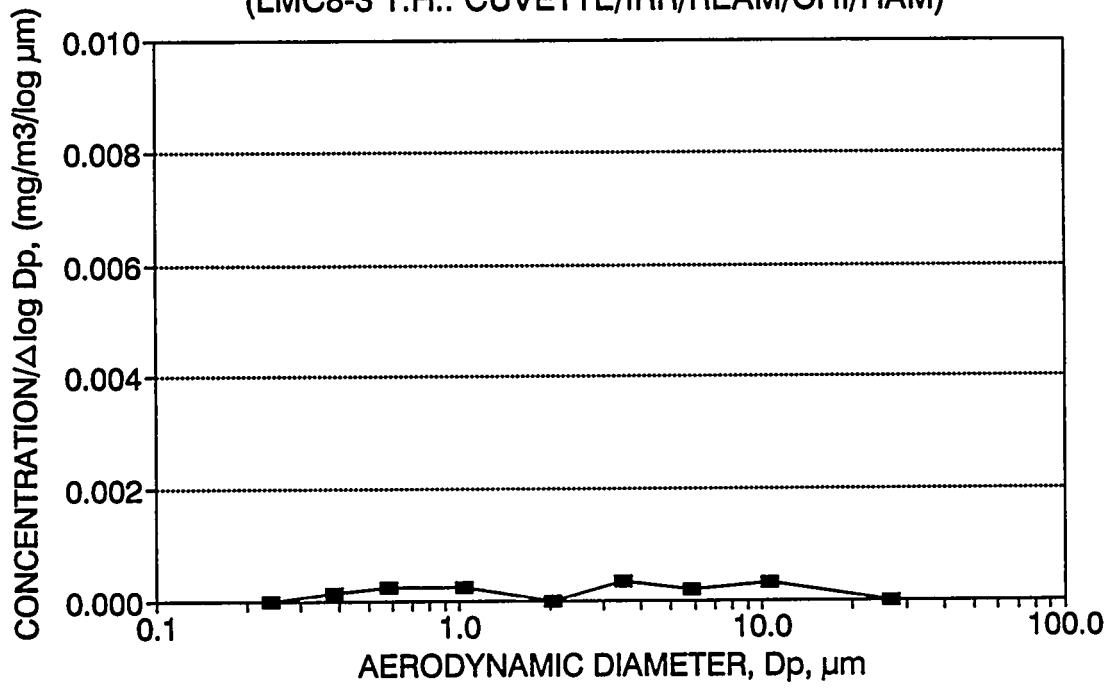
LMC8-3 Total Hip: Cuvette/Irrigation/Reamer/Chisel/Hammer (t = 950 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00002	0.32	-0.492	0.157	0.000	0.39	0.0606	0.000
0.30	0.00005	0.46	-0.335	0.206	0.000	0.59	0.1515	0.061
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.2121	0.212
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.424
2.00	0.00006	2.87	0.457	0.174	0.000	3.50	0.1818	0.424
3.00	0.00005	4.28	0.632	0.269	0.000	5.84	0.1515	0.606
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.2424	0.758
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00033						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-3 T.H.: CUVETTE/IRR/REAM/CHI/HAM)



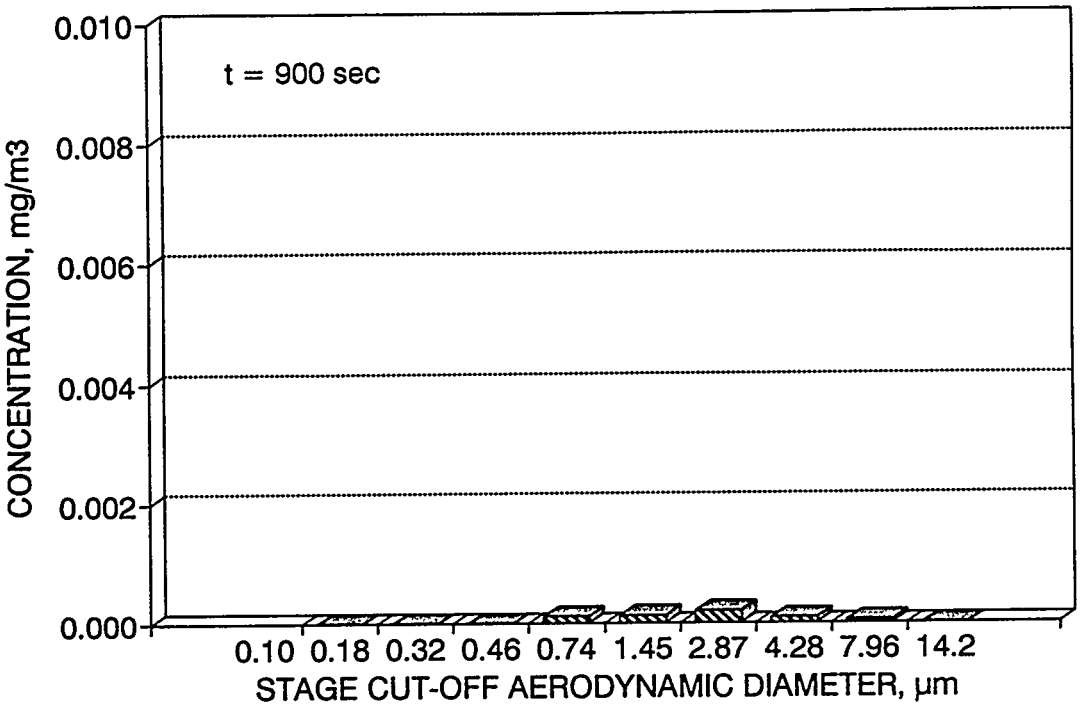
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-3 T.H.: CUVETTE/IRR/REAM/CHI/HAM)



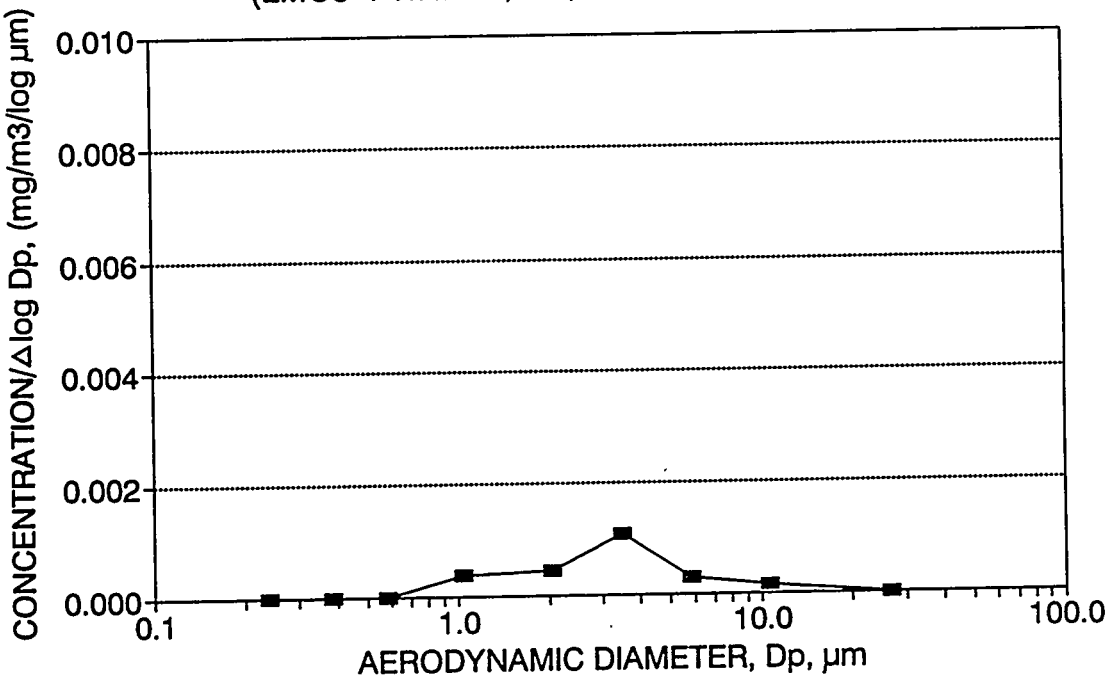
LMC8-4 Total Hip: DR/IRR/CHI/FILE/GRIND/HAM (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00011	0.74	-0.128	0.290	0.000	1.04	0.2000	0.000
1.00	0.00013	1.45	0.162	0.296	0.000	2.04	0.2364	0.200
2.00	0.00019	2.87	0.457	0.174	0.001	3.50	0.3455	0.436
3.00	0.00008	4.28	0.632	0.269	0.000	5.84	0.1455	0.782
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0727	0.927
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00055						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-4 T.H.:DR/IRR/CHI/FILE/GRIND/HAM)



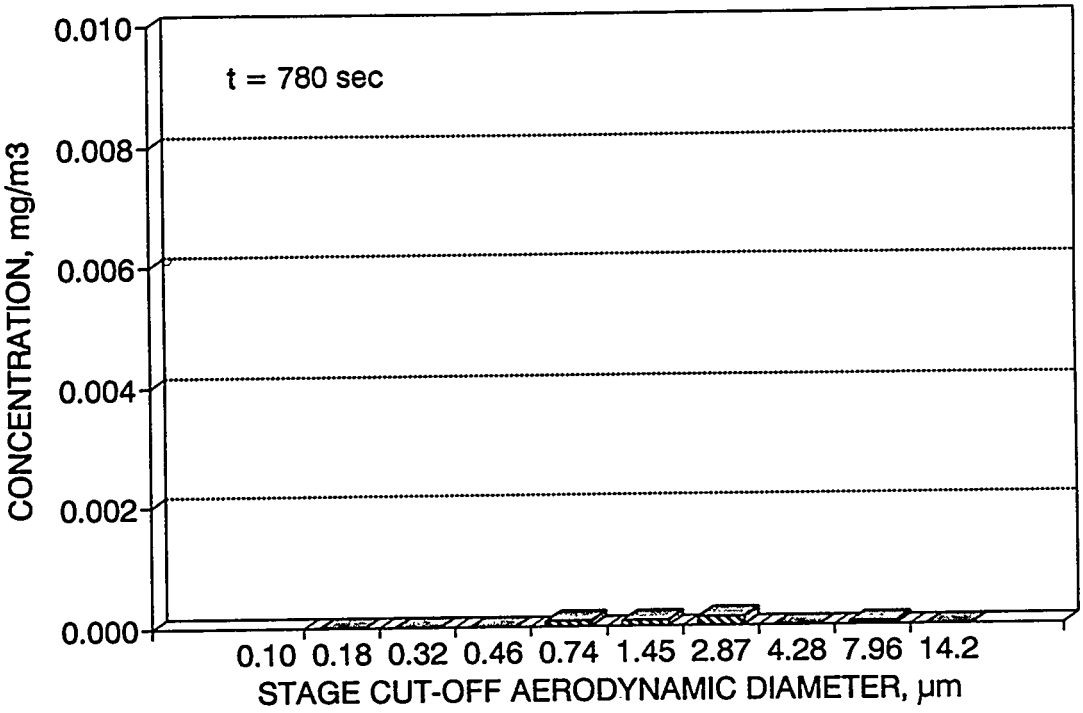
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-4 T.H.:DR/IRR/CHI/FILE/GRIND/HAM)



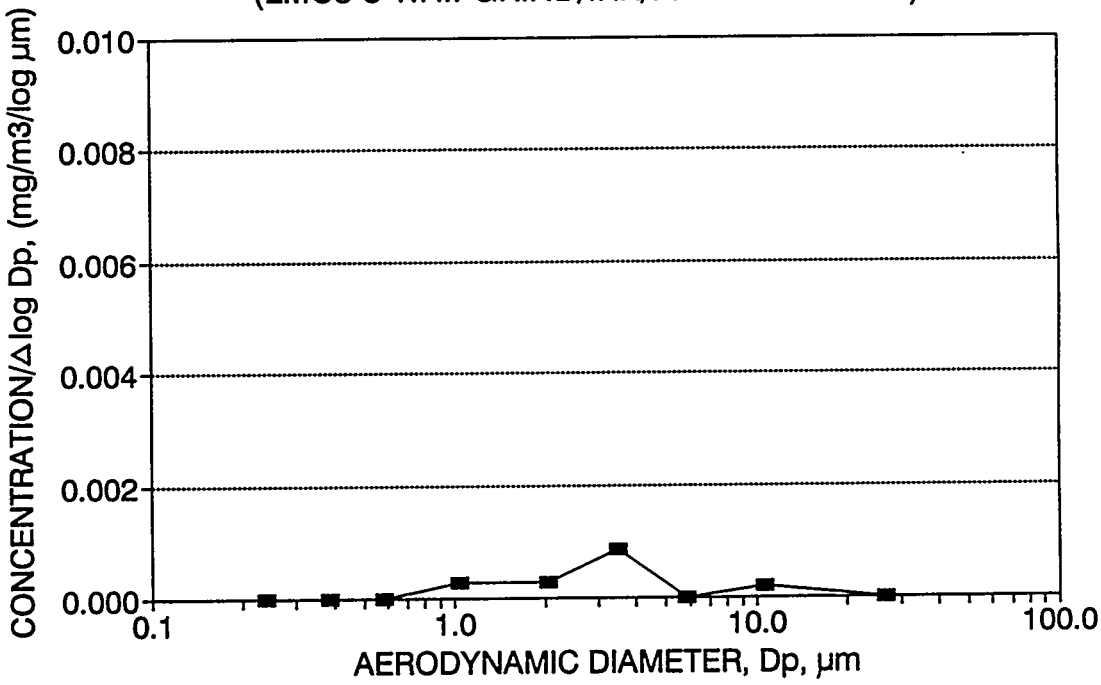
LMC8-5 Total Hip: GRIND/IRR/Fill Bone Chip (t = 780 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00008	0.74	-0.128	0.290	0.000	1.04	0.2222	0.000
1.00	0.00008	1.45	0.162	0.296	0.000	2.04	0.2222	0.222
2.00	0.00015	2.87	0.457	0.174	0.001	3.50	0.4167	0.444
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.861
5.60	0.00005	7.96	0.901	0.251	0.000	10.62	0.1389	0.861
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00036						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-5 T.H.: GRIND/IRR/FILL BONE CHIP)



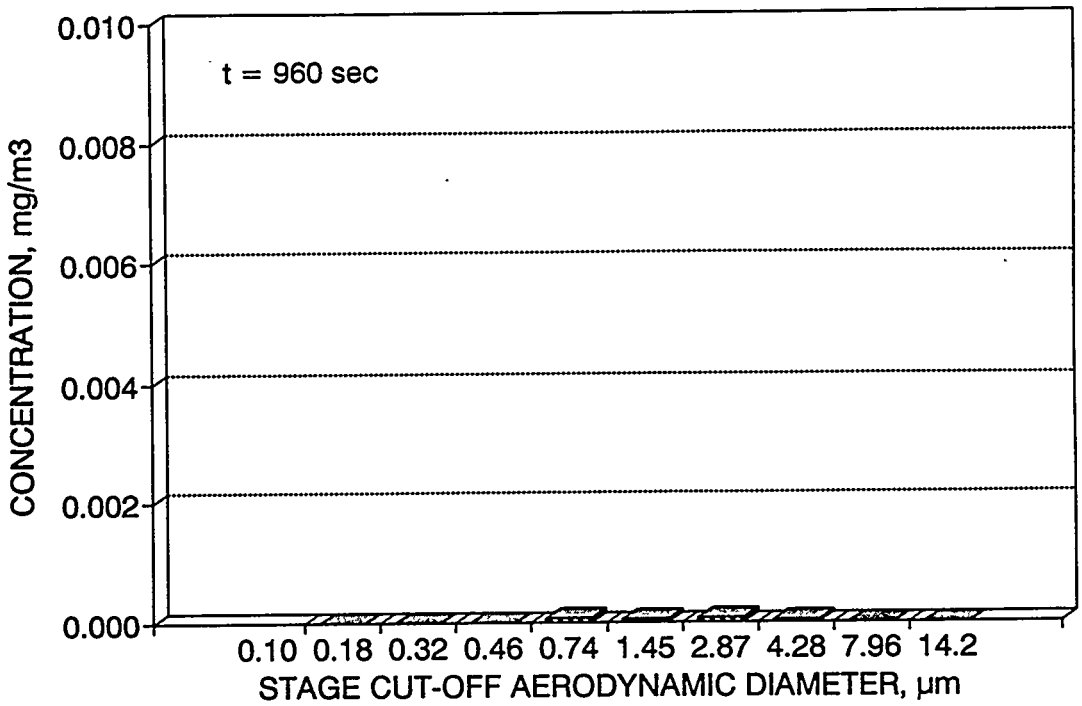
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-5 T.H.: GRIND/IRR/FILL BONE CHIP)



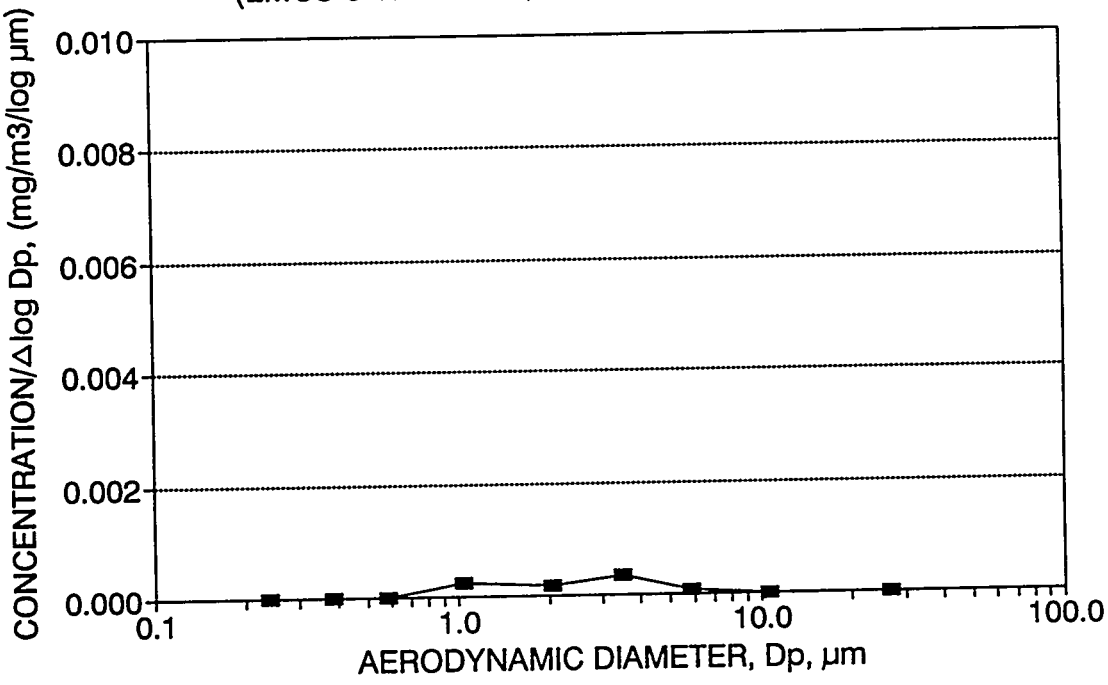
LMC8-6 Total Hip: CEM/PROTHESIS/IRR/SUTURE (t = 960 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.3500	0.000
1.00	0.00005	1.45	0.162	0.296	0.000	2.04	0.2500	0.350
2.00	0.00006	2.87	0.457	0.174	0.000	3.50	0.3000	0.600
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.1000	0.900
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.0002						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-6 T.H.: CEM/PROTHESIS/IRR/SUTURE)



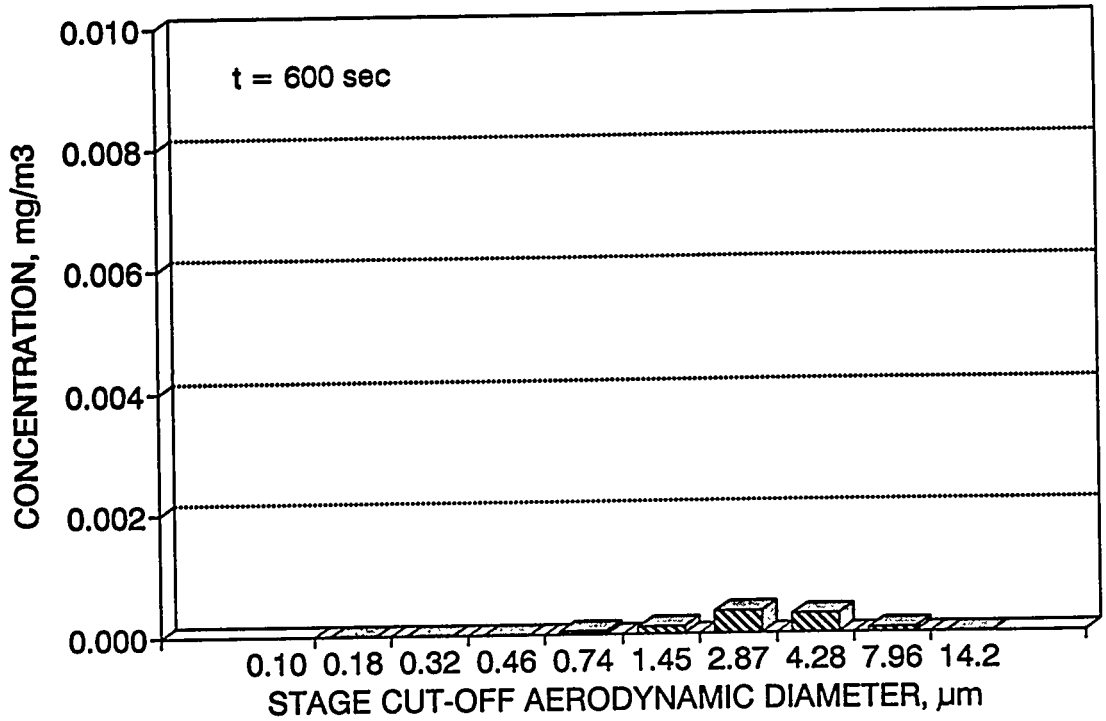
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-6 T.H.: CEM/PROTHESIS/IRR/SUTURE)



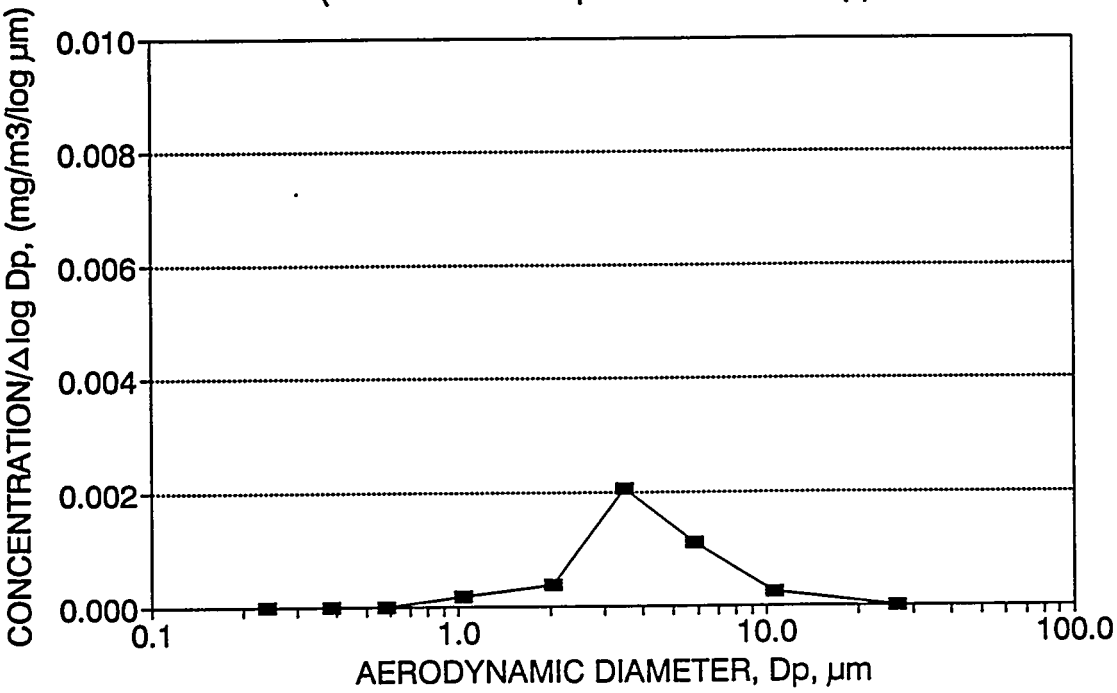
LMC8-7 Total Hip: Room Clean Up (t = 600 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00005	0.74	-0.128	0.290	0.000	1.04	0.0568	0.000
1.00	0.00011	1.45	0.162	0.296	0.000	2.04	0.1250	0.057
2.00	0.00036	2.87	0.457	0.174	0.002	3.50	0.4091	0.182
3.00	0.00030	4.28	0.632	0.269	0.001	5.84	0.3409	0.591
5.60	0.00006	7.96	0.901	0.251	0.000	10.62	0.0682	0.932
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00088						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC8-7 Total Hip: Room Clean Up)



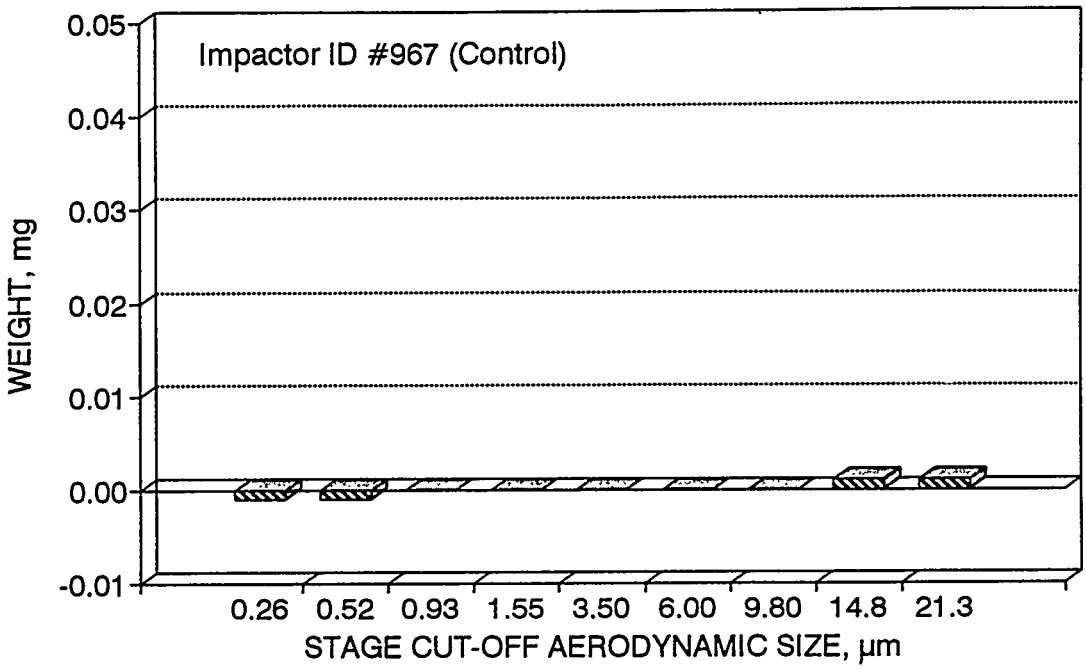
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC8-7 Total Hip: Room Clean Up)



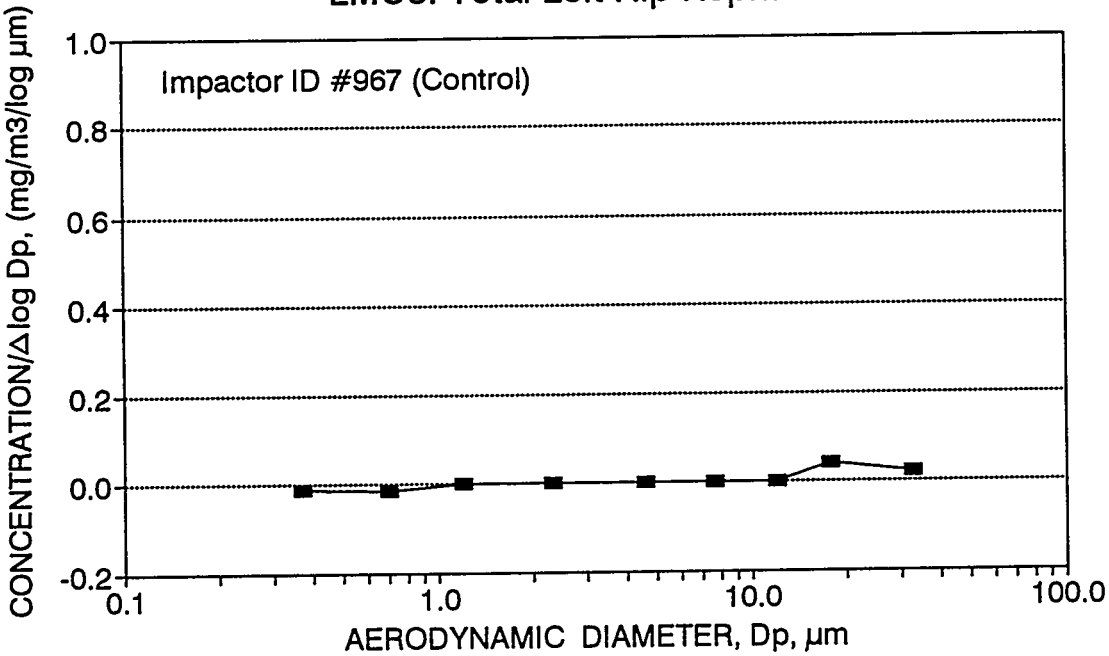
LMC8 Total Hip: Marple Personal Impactor Data (ID No. 967: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	-0.001	1	0.26	-0.004	-0.585	0.301	-0.013	0.37	-0.644	0.000
8	0.52	-0.001	0.99	0.26	-0.004	-0.284	0.252	-0.015	0.70	-0.651	-0.644
7	0.93	0.000	0.97	0.26	0.000	-0.032	0.222	0.000	1.20	0.000	-1.295
6	1.55	0.000	0.96	0.26	0.000	0.190	0.354	0.000	2.33	0.000	-1.295
5	3.50	0.000	0.95	0.26	0.000	0.544	0.234	0.000	4.58	0.000	-1.295
4	6.00	0.000	0.89	0.26	0.000	0.778	0.213	0.000	7.67	0.000	-1.295
3	9.80	0.000	0.78	0.26	0.000	0.991	0.179	0.000	12.04	0.000	-1.295
2	14.80	0.001	0.61	0.26	0.006	1.170	0.158	0.040	17.75	1.056	-1.295
1	21.30	0.001	0.52	0.26	0.007	1.328	0.371	0.020	32.63	1.239	-0.239
	50.00					1.699					
Sum		0.000			0.006					1.000	

Marple Personal Impactor Data
LMC8: Total Left Hip Replacement



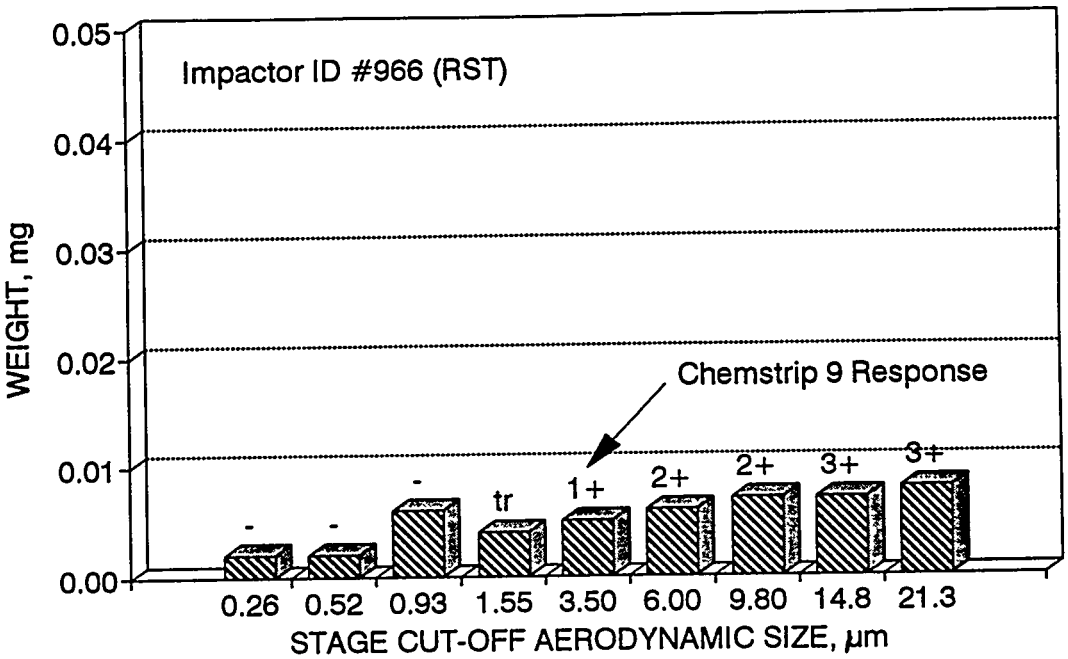
Size distribution by Marple Impactor
LMC8: Total Left Hip Replacement



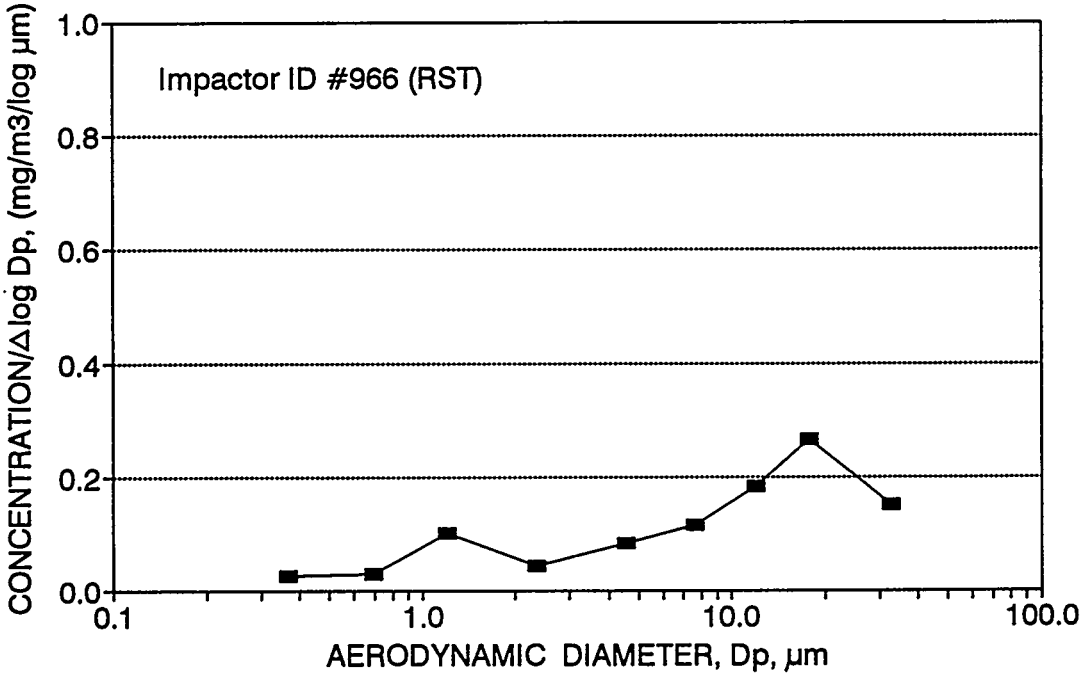
LMC8 Total Hip: Marple Personal Impactor Data (ID No. 966: RST)

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD	M Chem.9
F	0.26	0.002	1	0.274	0.007	-0.585	0.301	0.024	0.37	0.032	0.000	-
8	0.52	0.002	0.99	0.274	0.007	-0.284	0.252	0.029	0.70	0.032	0.032	-
7	0.93	0.006	0.97	0.274	0.023	-0.032	0.222	0.102	1.20	0.099	0.065	-
6	1.55	0.004	0.96	0.274	0.015	0.190	0.354	0.043	2.33	0.067	0.164	tr
5	3.50	0.005	0.95	0.274	0.019	0.544	0.234	0.082	4.58	0.085	0.231	1+
4	6.00	0.006	0.89	0.274	0.025	0.778	0.213	0.115	7.67	0.108	0.316	2+
3	9.80	0.007	0.78	0.274	0.033	0.991	0.179	0.183	12.04	0.144	0.424	2+
2	14.80	0.007	0.61	0.274	0.042	1.170	0.158	0.265	17.75	0.184	0.568	3+
1	21.30	0.008	0.52	0.274	0.056	1.328	0.371	0.152	32.63	0.247	0.753	3+
	50.00					1.699						
Sum		0.047			0.227					1.000		

Marple Personal Impactor Data
LMC8: Total Left Hip Replacement



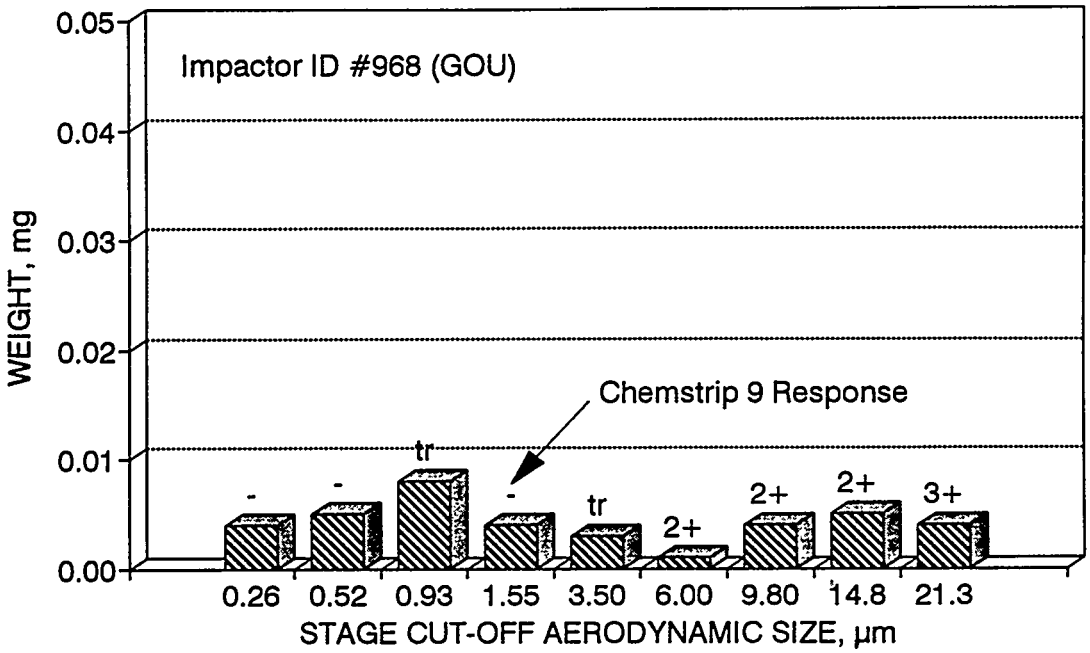
Size distribution by Marple Impactor
LMC8: Total Left Hip Replacement



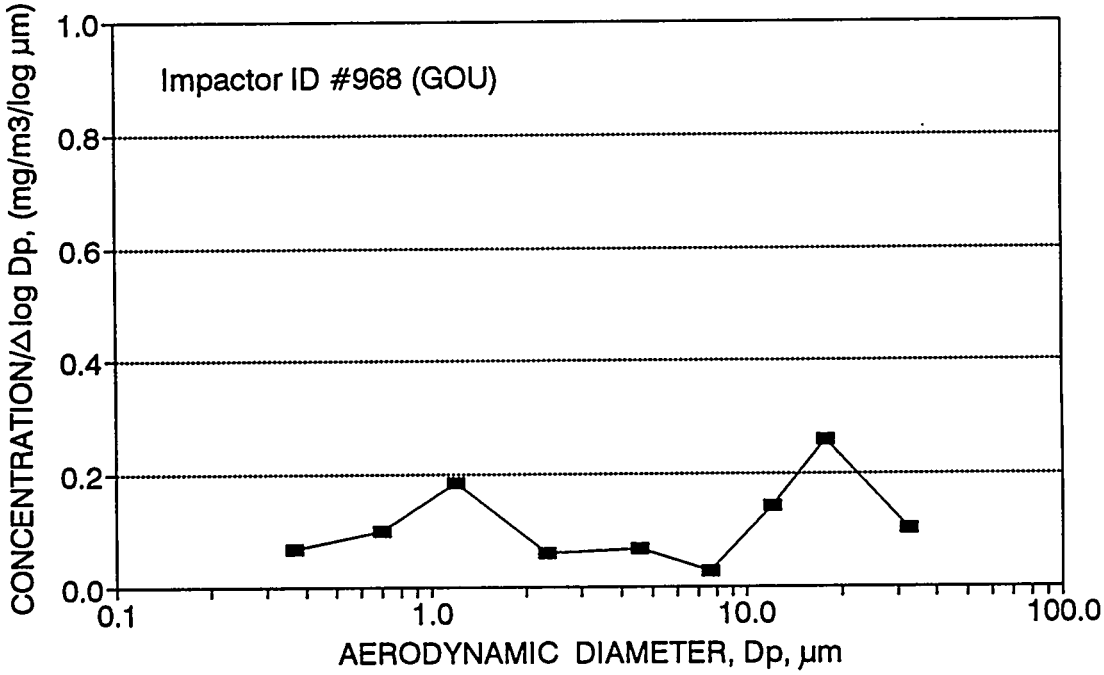
LMC8 Total Hip: Marple Personal Impactor Data (ID No. 968: GOU)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.004	1	0.2	0.020	-0.585	0.301	0.066	0.37	0.086	0.000	-
8	0.52	0.005	0.99	0.2	0.025	-0.284	0.252	0.100	0.70	0.108	0.086	-
7	0.93	0.008	0.97	0.2	0.041	-0.032	0.222	0.186	1.20	0.176	0.194	tr
6	1.55	0.004	0.96	0.2	0.021	0.190	0.354	0.059	2.33	0.089	0.370	-
5	3.50	0.003	0.95	0.2	0.016	0.544	0.234	0.067	4.58	0.068	0.459	tr
4	6.00	0.001	0.89	0.2	0.006	0.778	0.213	0.026	7.67	0.024	0.527	2+
3	9.80	0.004	0.78	0.2	0.026	0.991	0.179	0.143	12.04	0.110	0.551	2+
2	14.80	0.005	0.61	0.2	0.041	1.170	0.158	0.259	17.75	0.175	0.660	2+
1	21.30	0.004	0.52	0.2	0.038	1.328	0.371	0.104	32.63	0.164	0.836	3+
	50.00					1.699						
Sum		0.038			0.234					1.000		

Marple Personal Impactor Data
LMC8: Total Left Hip Replacement



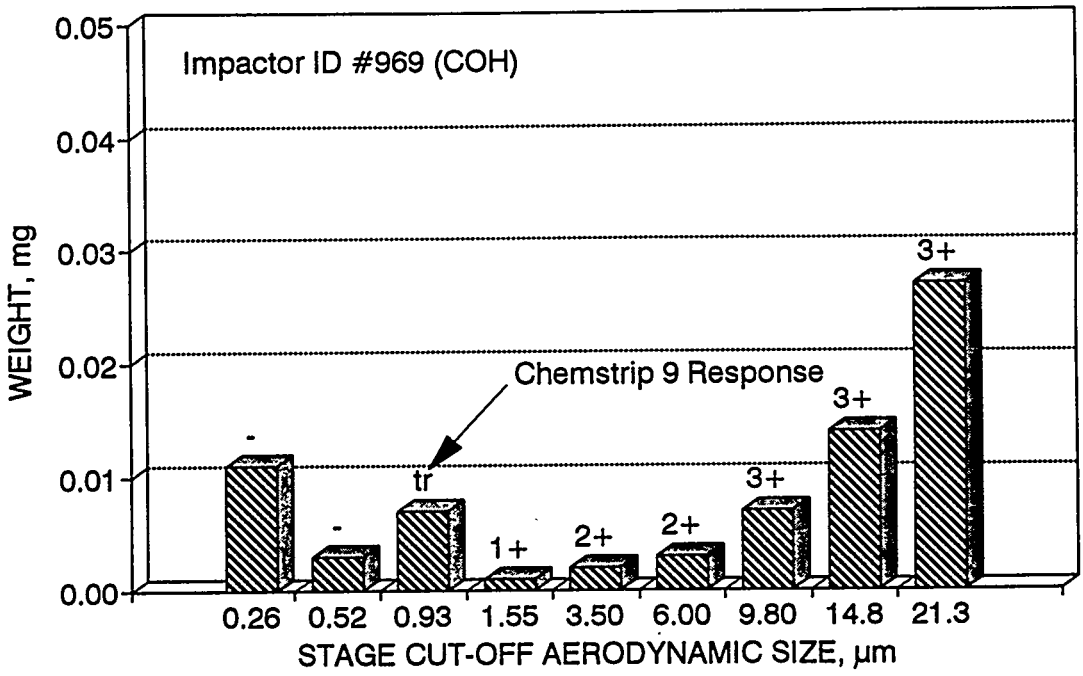
Size distribution by Marple Impactor
LMC8: Total Left Hip Replacement



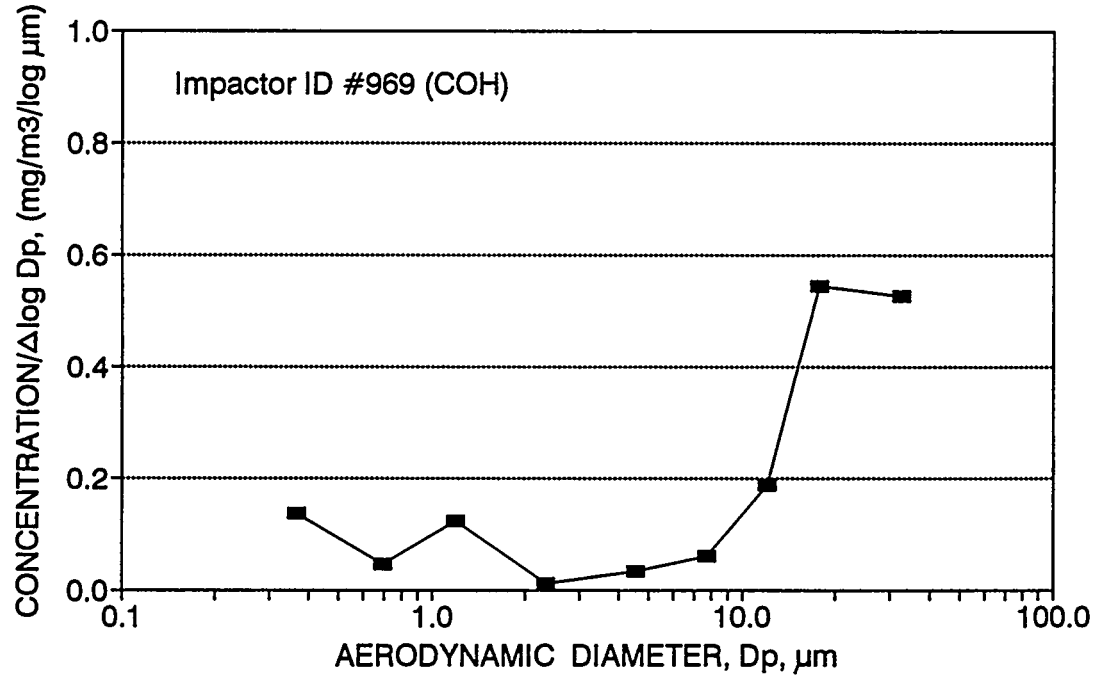
LMC8 Total Hip: Marple Personal Impactor Data (ID No. 969:COH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.011	1	0.266	0.041	-0.585	0.301	0.137	0.37	0.099	0.000	-
8	0.52	0.003	0.99	0.266	0.011	-0.284	0.252	0.045	0.70	0.027	0.099	-
7	0.93	0.007	0.97	0.266	0.027	-0.032	0.222	0.122	1.20	0.065	0.126	tr
6	1.55	0.001	0.96	0.266	0.004	0.190	0.354	0.011	2.33	0.009	0.190	1+
5	3.50	0.002	0.95	0.266	0.008	0.544	0.234	0.034	4.58	0.019	0.200	2+
4	6.00	0.003	0.89	0.266	0.013	0.778	0.213	0.059	7.67	0.030	0.219	2+
3	9.80	0.007	0.78	0.266	0.034	0.991	0.179	0.188	12.04	0.080	0.249	3+
2	14.80	0.014	0.61	0.266	0.086	1.170	0.158	0.546	17.75	0.206	0.329	3+
1	21.30	0.027	0.52	0.266	0.195	1.328	0.371	0.527	32.63	0.465	0.535	3+
	50.00					1.699						
Sum		0.075			0.420					1.000		

Marple Personal Impactor Data
LMC8: Total Left Hip Replacement



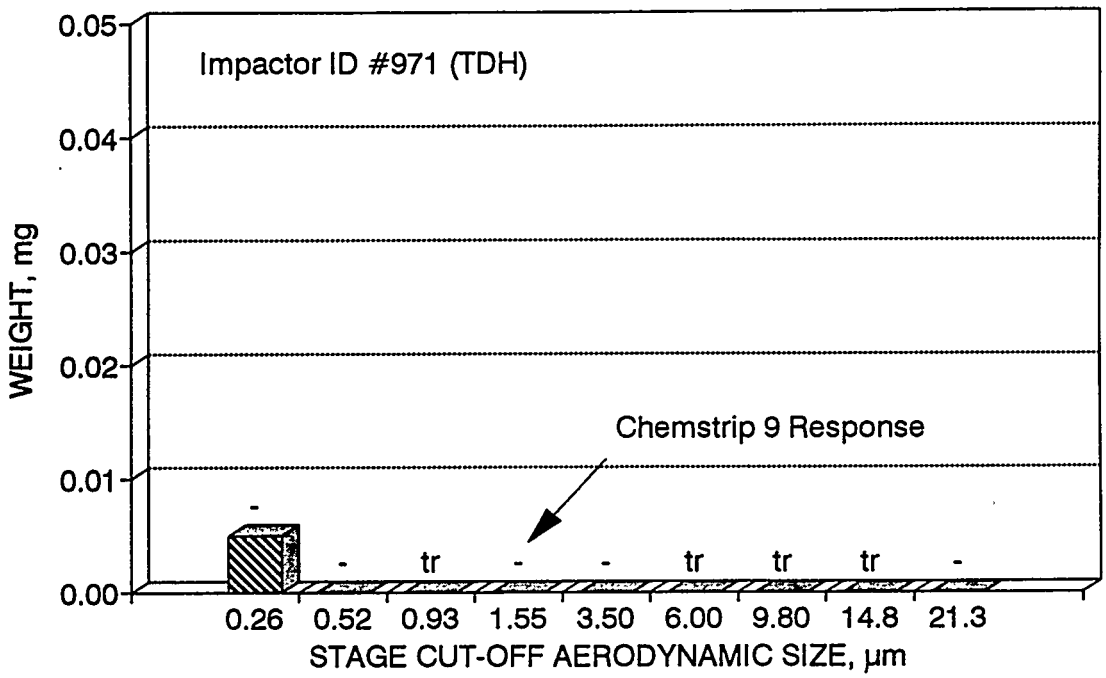
Size distribution by Marple Impactor
LMC8: Total Left Hip Replacement



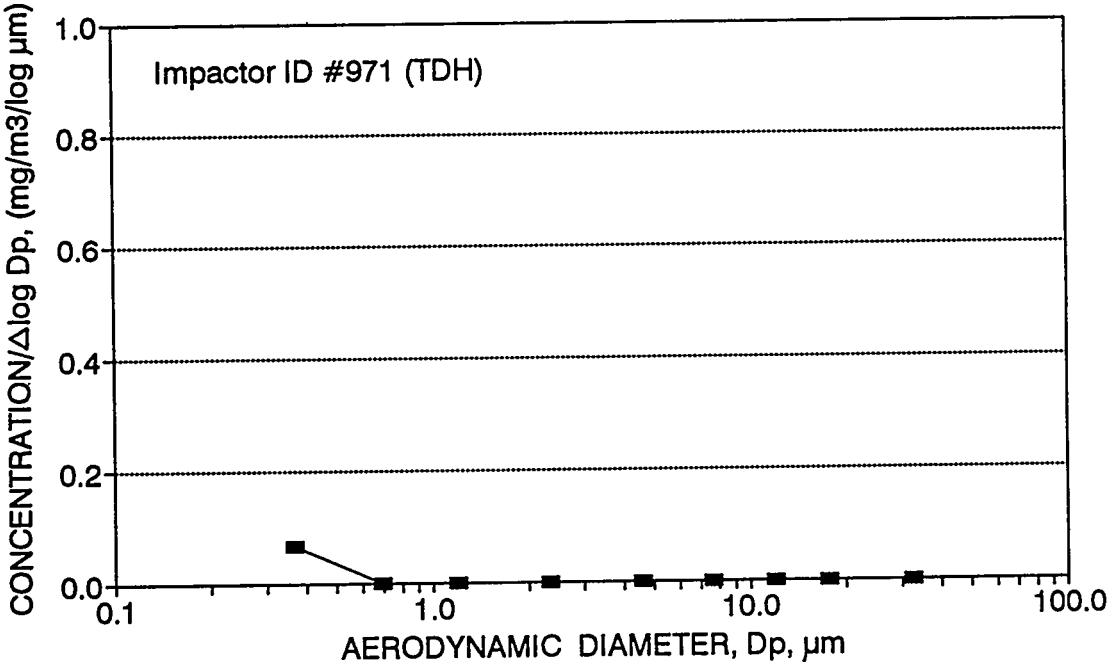
LMC8 Total Hip: Marple Personal Impactor Data (ID No. 971: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.005	1	0.25	0.020	-0.585	0.301	0.066	0.37	1.000	0.000	-
8	0.52	0.000	0.99	0.25	0.000	-0.284	0.252	0.000	0.70	0.000	1.000	-
7	0.93	0.000	0.97	0.25	0.000	-0.032	0.222	0.000	1.20	0.000	1.000	tr
6	1.55	0.000	0.96	0.25	0.000	0.190	0.354	0.000	2.33	0.000	1.000	-
5	3.50	0.000	0.95	0.25	0.000	0.544	0.234	0.000	4.58	0.000	1.000	-
4	6.00	0.000	0.89	0.25	0.000	0.778	0.213	0.000	7.67	0.000	1.000	tr
3	9.80	0.000	0.78	0.25	0.000	0.991	0.179	0.000	12.04	0.000	1.000	tr
2	14.80	0.000	0.61	0.25	0.000	1.170	0.158	0.000	17.75	0.000	1.000	tr
1	21.30	0.000	0.52	0.25	0.000	1.328	0.371	0.000	32.63	0.000	1.000	-
	50.00					1.699						
Sum		0.005			0.020					1.000		

Marple Personal Impactor Data
LMC8: Total Left Hip Replacement



Size distribution by Marple Impactor
LMC8: Total Left Hip Replacement



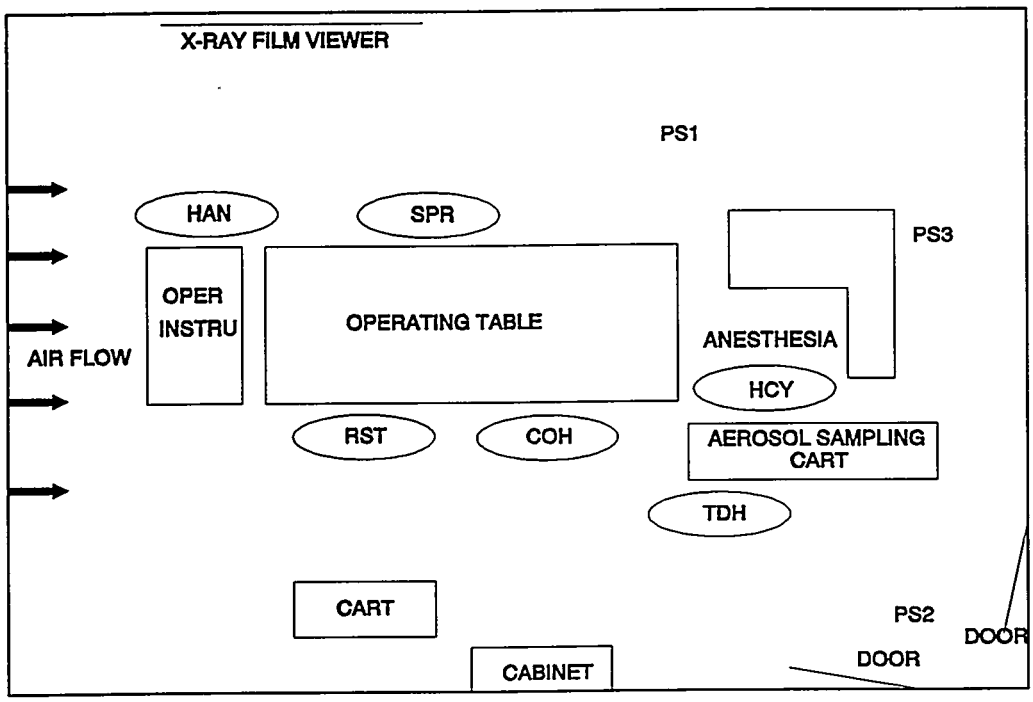
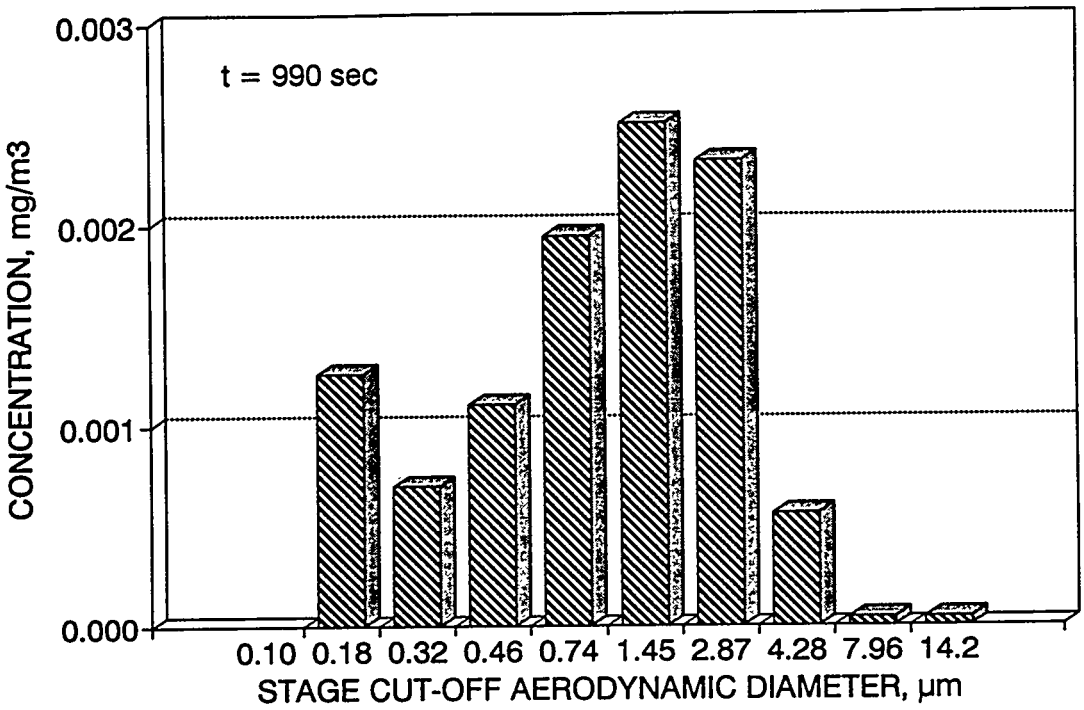


Figure C.9 Personnel and area filter locations during LMC #9 measurement (left hip osteotomy of fusion with interpositional fascia lata orthoplasty).

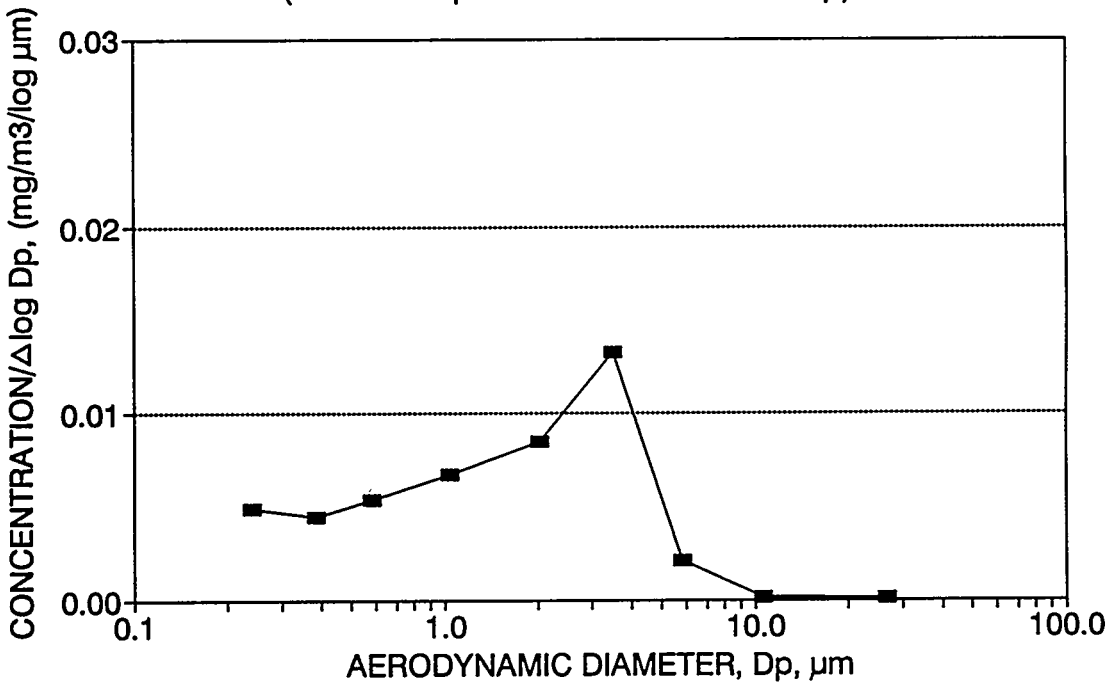
LMC9-1 Hip Reconstruction: EC/IRR/Scrape (t = 990 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00126	0.18	-0.749	0.257	0.005	0.24	0.1201	0.000
0.20	0.00070	0.32	-0.492	0.157	0.004	0.39	0.0667	0.120
0.30	0.00111	0.46	-0.335	0.206	0.005	0.59	0.1058	0.187
0.50	0.00195	0.74	-0.128	0.290	0.007	1.04	0.1859	0.293
1.00	0.00251	1.45	0.162	0.296	0.008	2.04	0.2393	0.479
2.00	0.00232	2.87	0.457	0.174	0.013	3.50	0.2212	0.718
3.00	0.00056	4.28	0.632	0.269	0.002	5.84	0.0534	0.939
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.0038	0.992
10.00	0.00004	14.18	1.152	0.547	0.000	26.63	0.0038	0.996
		50.00	1.699					1.000
Sum	0.01049						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC9-1 Hip Reconst.: EC/IRR/Scrap)



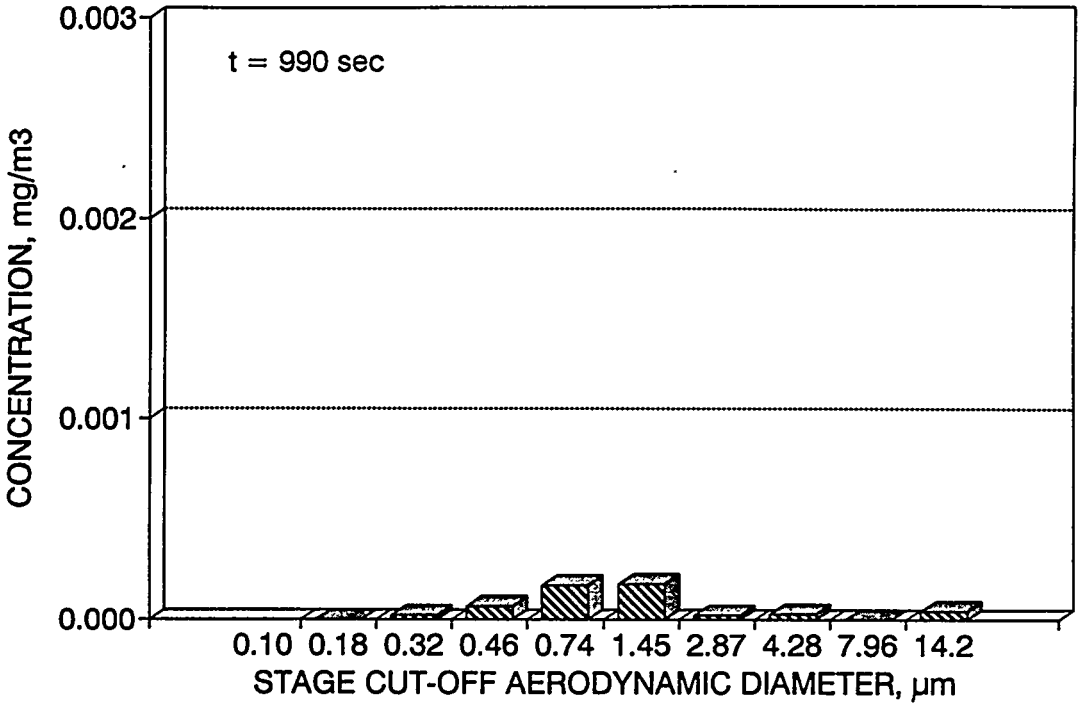
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC9-1 Hip Reconst.: EC/IRR/Scrap)



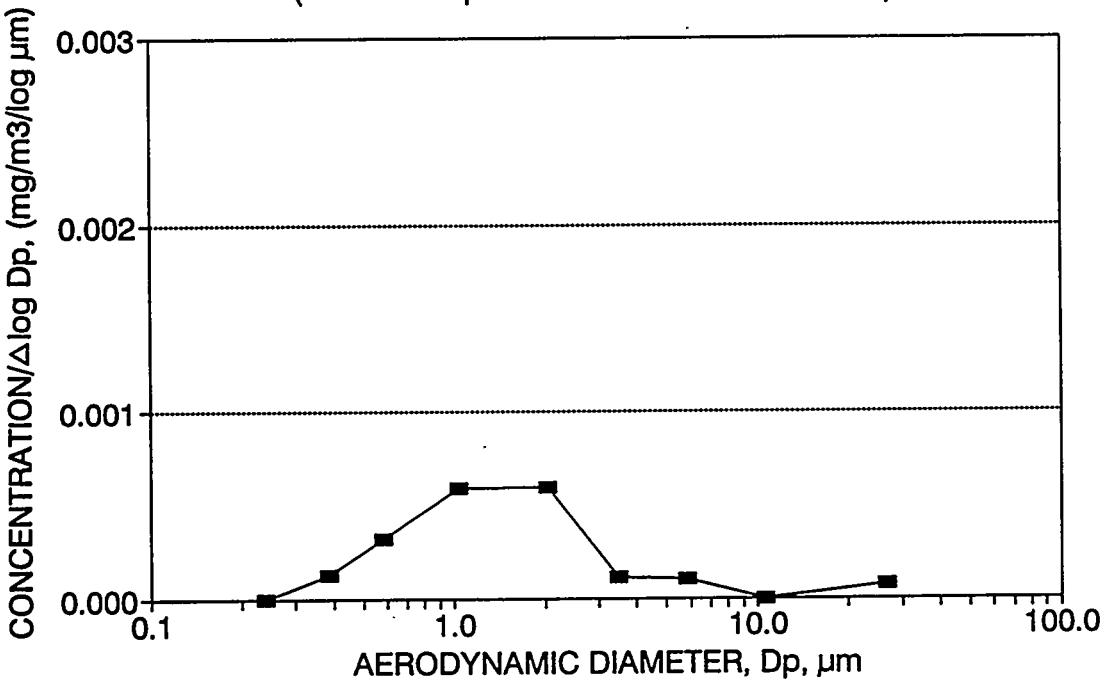
LMC9-2 Hip Reconstruction: EC/IRR/CHISEL (t = 990 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00002	0.32	-0.492	0.157	0.000	0.39	0.0373	0.000
0.30	0.00007	0.46	-0.335	0.206	0.000	0.59	0.1260	0.037
0.50	0.00017	0.74	-0.128	0.290	0.001	1.04	0.3267	0.163
1.00	0.00018	1.45	0.162	0.296	0.001	2.04	0.3384	0.490
2.00	0.00002	2.87	0.457	0.174	0.000	3.50	0.0385	0.828
3.00	0.00003	4.28	0.632	0.269	0.000	5.84	0.0513	0.867
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	0.918
10.00	0.00004	14.18	1.152	0.547	0.000	26.63	0.0817	0.918
		50.00	1.699					1.000
Sum	0.00052						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC9-2 Hip Reconst.: EC/IRR/CHISEL)



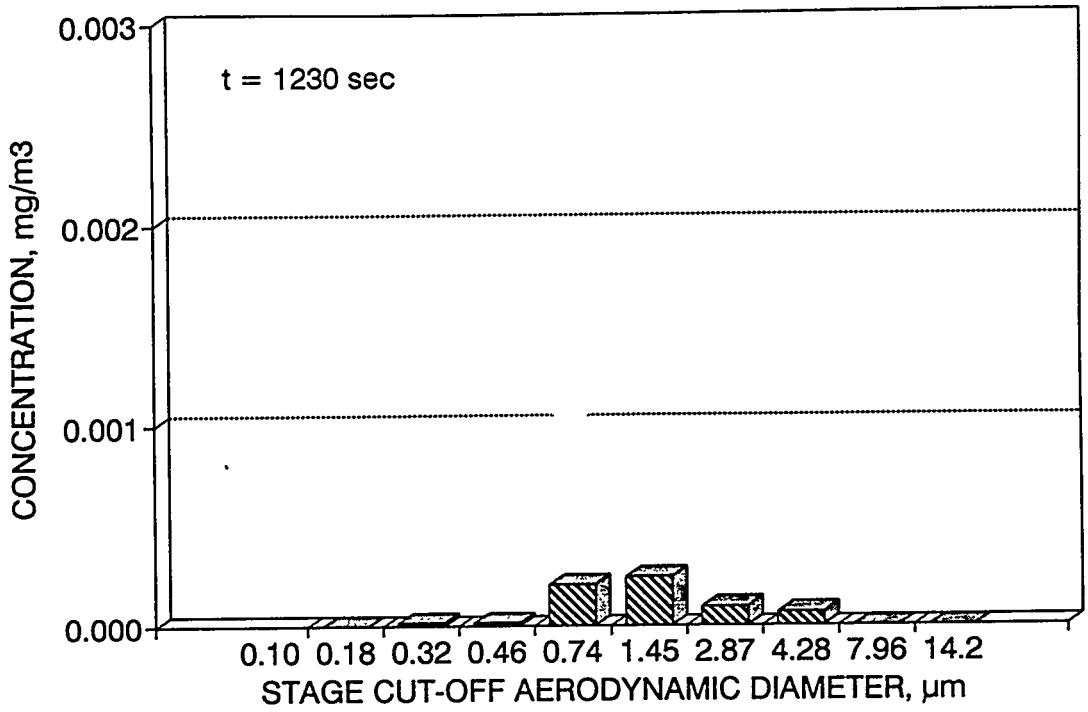
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC9-2 Hip Reconst.: EC/IRR/CHISEL)



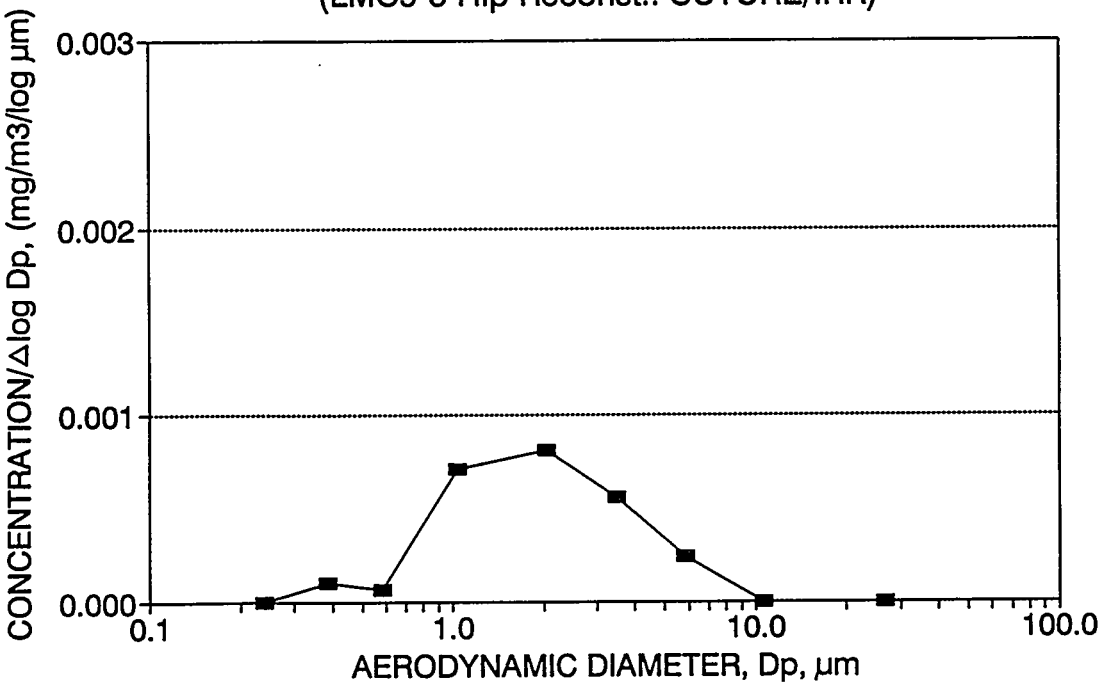
LMC9-3 Hip Reconstruction: SUTURE/IRR (t = 1230 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00002	0.32	-0.492	0.157	0.000	0.39	0.0246	0.000
0.30	0.00001	0.46	-0.335	0.206	0.000	0.59	0.0207	0.025
0.50	0.00020	0.74	-0.128	0.290	0.001	1.04	0.3226	0.045
1.00	0.00024	1.45	0.162	0.296	0.001	2.04	0.3786	0.368
2.00	0.00010	2.87	0.457	0.174	0.001	3.50	0.1521	0.747
3.00	0.00006	4.28	0.632	0.269	0.000	5.84	0.1014	0.899
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00064						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC9-3 Hip Reconst.: SUTURE/IRR)



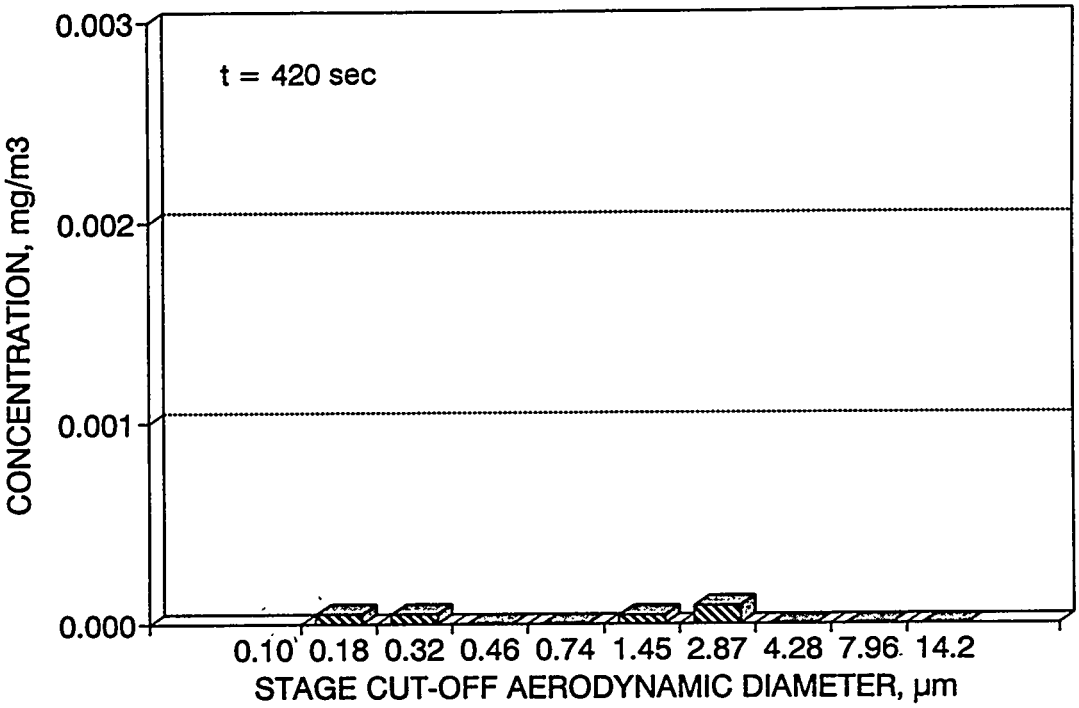
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC9-3 Hip Reconst.: SUTURE/IRR)



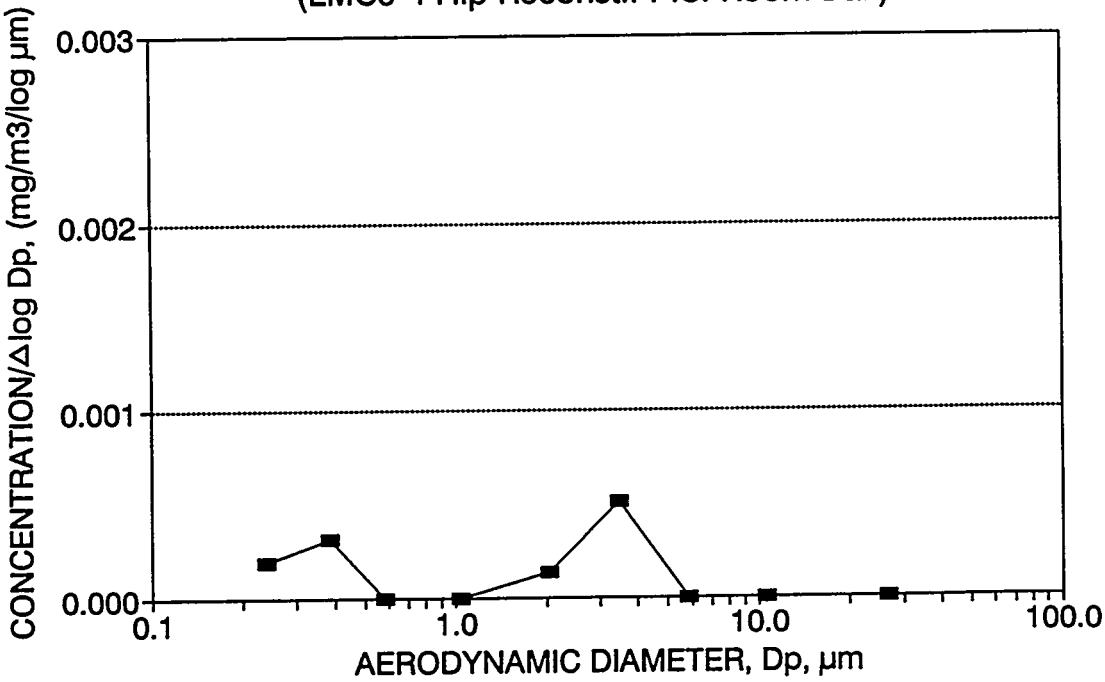
LMC9-4 Hip Reconstruction: Post-surgery Room Background (t = 420 sec)

A	B	C	D	E	F	G	H	I
ECD, μm	C, mg/m3	Dae, μm	log Dp	δlog Dp	(B)/(E)	GMD, μm	m frac	f<Dae
0.05		0.10				0.13		
0.10	0.00005	0.18	-0.749	0.257	0.000	0.24	0.2174	0.000
0.20	0.00005	0.32	-0.492	0.157	0.000	0.39	0.2174	0.217
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.435
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.435
1.00	0.00004	1.45	0.162	0.296	0.000	2.04	0.1739	0.435
2.00	0.00009	2.87	0.457	0.174	0.001	3.50	0.3913	0.609
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	1.000
5.60	0.00000	7.96	0.901	0.251	0.000	10.62	0.0000	1.000
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00023						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC9-4 Hip Reconst.: P. S. Room Bak)



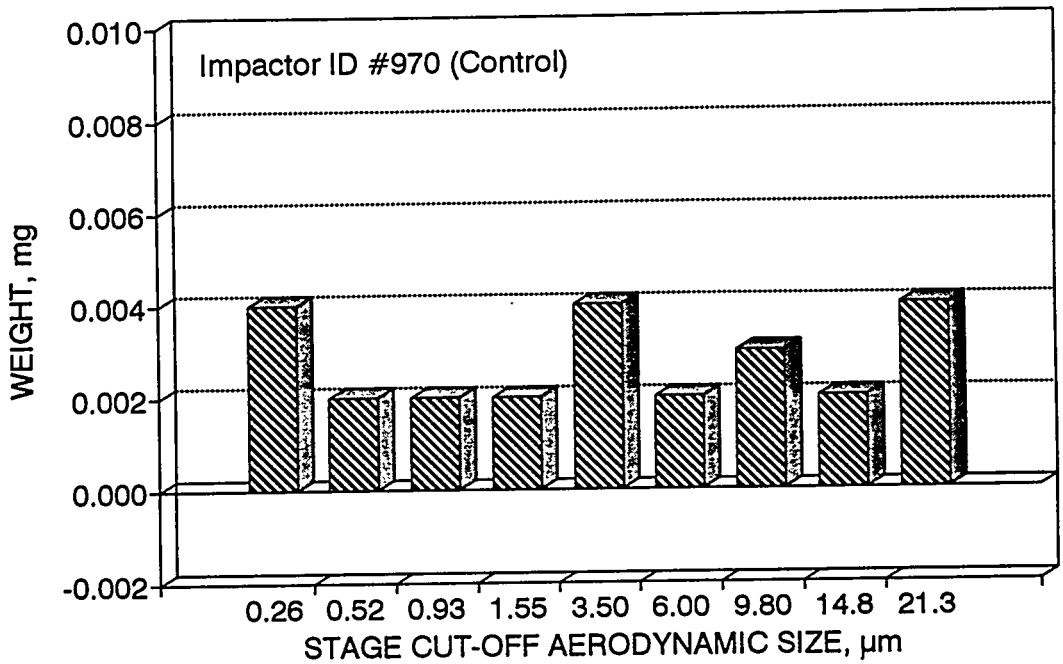
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC9-4 Hip Reconst.: P.S. Room Bak)



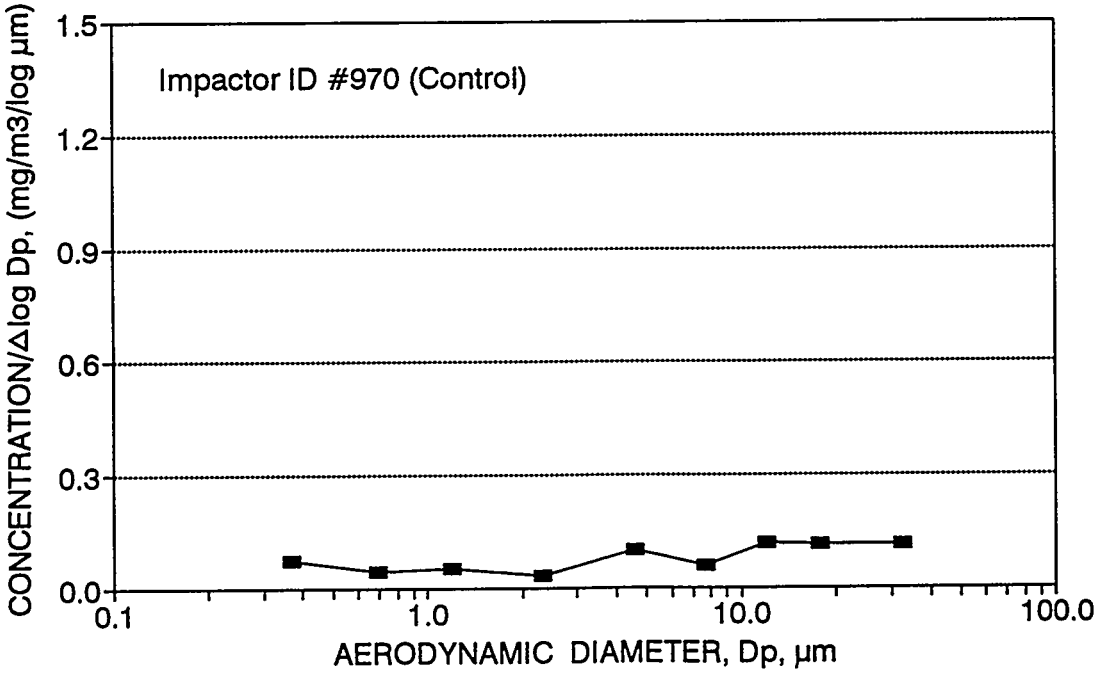
LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 970: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.004	1	0.18	0.022	-0.585	0.301	0.074	0.37	0.127	0.000
8	0.52	0.002	0.99	0.18	0.011	-0.284	0.252	0.044	0.70	0.064	0.127
7	0.93	0.002	0.97	0.18	0.011	-0.032	0.222	0.052	1.20	0.066	0.191
6	1.55	0.002	0.96	0.18	0.012	0.190	0.354	0.033	2.33	0.066	0.257
5	3.50	0.004	0.95	0.18	0.023	0.544	0.234	0.100	4.58	0.134	0.323
4	6.00	0.002	0.89	0.18	0.012	0.778	0.213	0.059	7.67	0.071	0.457
3	9.80	0.003	0.78	0.18	0.021	0.991	0.179	0.119	12.04	0.122	0.529
2	14.80	0.002	0.61	0.18	0.018	1.170	0.158	0.115	17.75	0.104	0.651
1	21.30	0.004	0.52	0.18	0.043	1.328	0.371	0.115	32.63	0.245	0.755
	50.00					1.699					
Sum		0.025			0.175					1.000	

Marple Personal Impactor Data
LMC9: Left Hip Reconstruction



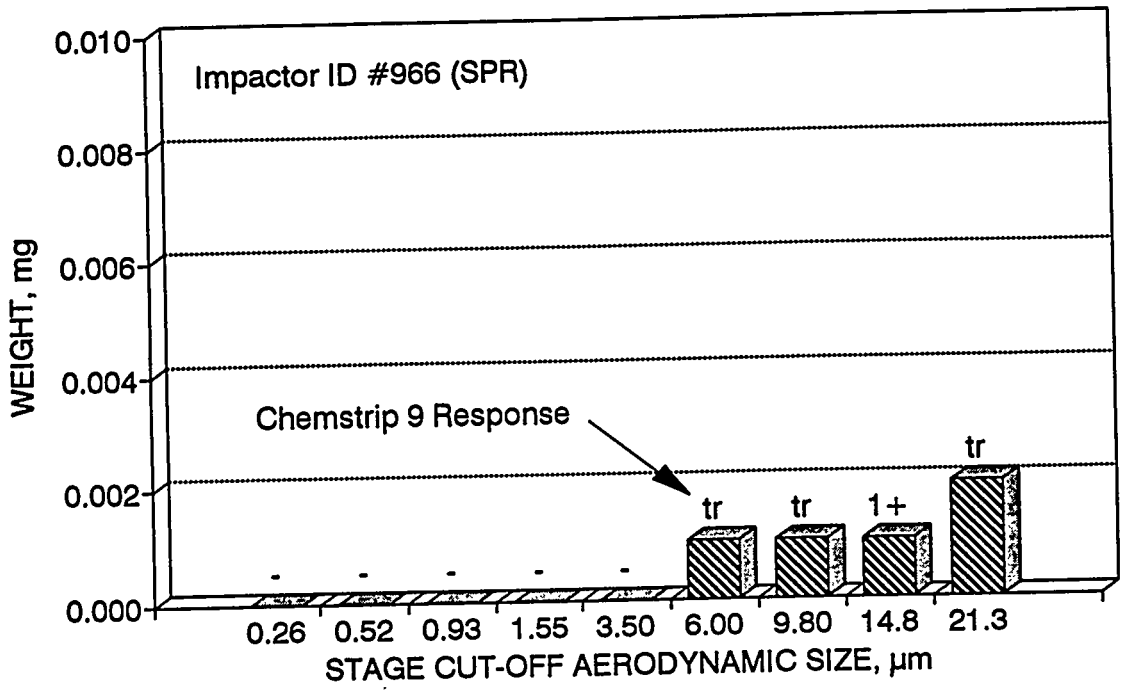
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



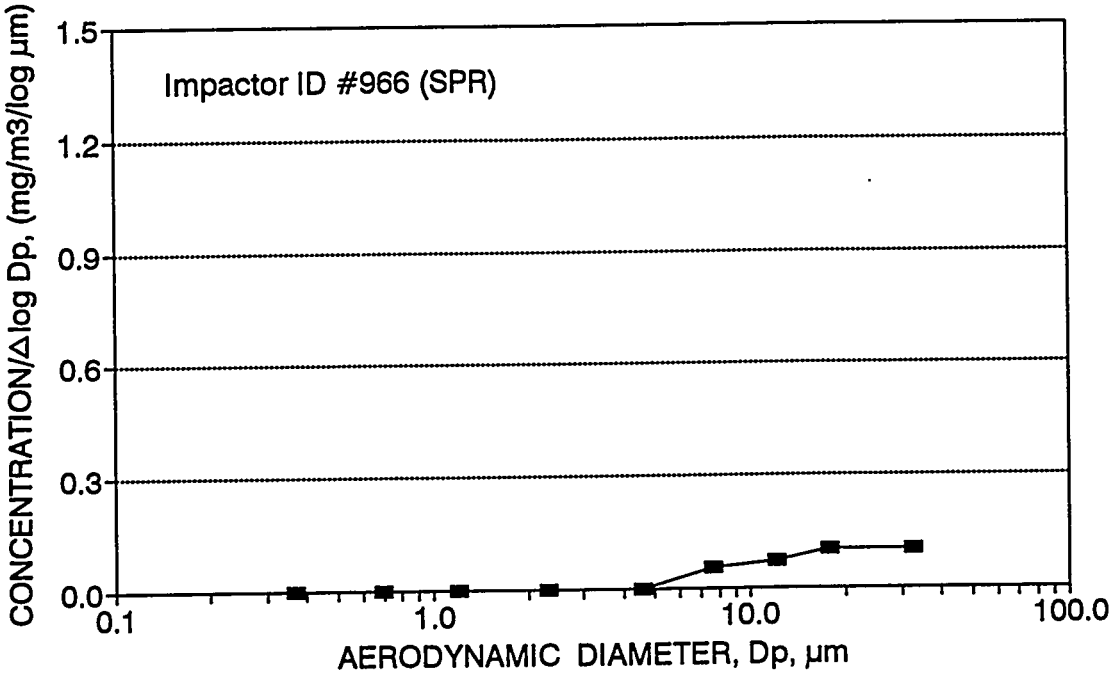
LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 966: SPR)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.1	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	-
8	0.52	0.000	0.99	0.1	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	-
7	0.93	0.000	0.97	0.1	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	-
6	1.55	0.000	0.96	0.1	0.000	0.190	0.354	0.000	2.33	0.000	0.000	-
5	3.50	0.000	0.95	0.1	0.000	0.544	0.234	0.000	4.58	0.000	0.000	-
4	6.00	0.001	0.89	0.1	0.011	0.778	0.213	0.053	7.67	0.142	0.000	tr
3	9.80	0.001	0.78	0.1	0.013	0.991	0.179	0.072	12.04	0.162	0.142	tr
2	14.80	0.001	0.61	0.1	0.016	1.170	0.158	0.104	17.75	0.208	0.305	1+
1	21.30	0.002	0.52	0.1	0.038	1.328	0.371	0.104	32.63	0.487	0.513	tr
	50.00					1.699						
Sum		0.005			0.079					1.000		

Marple Personal Impactor Data
LMC9: Left Hip Reconstruction



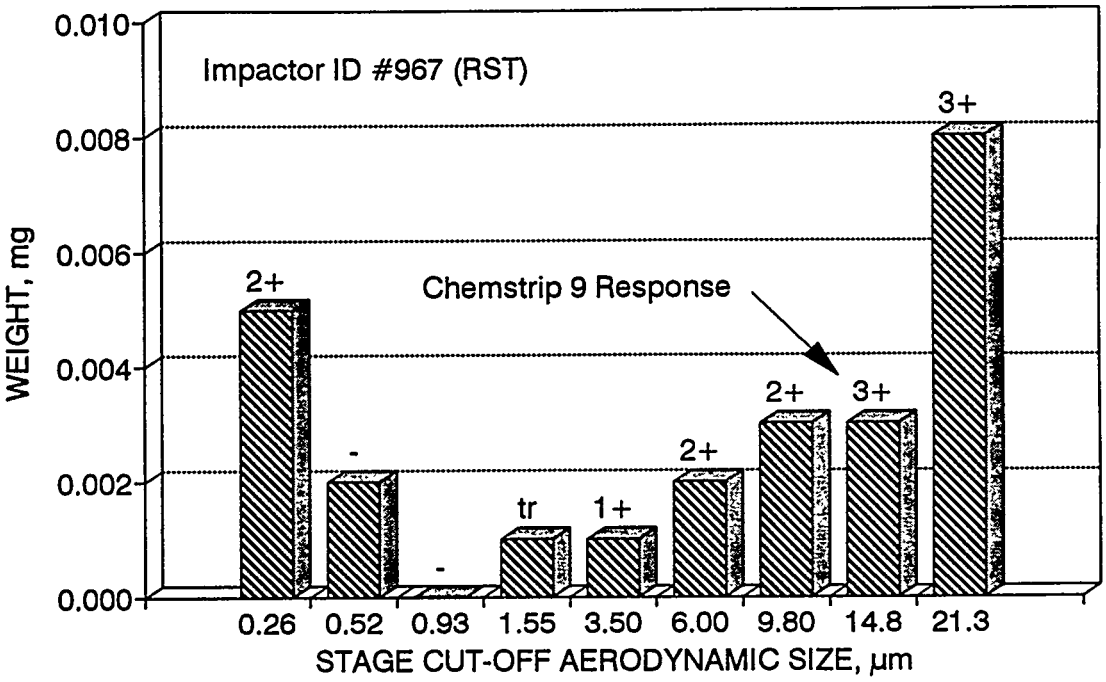
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



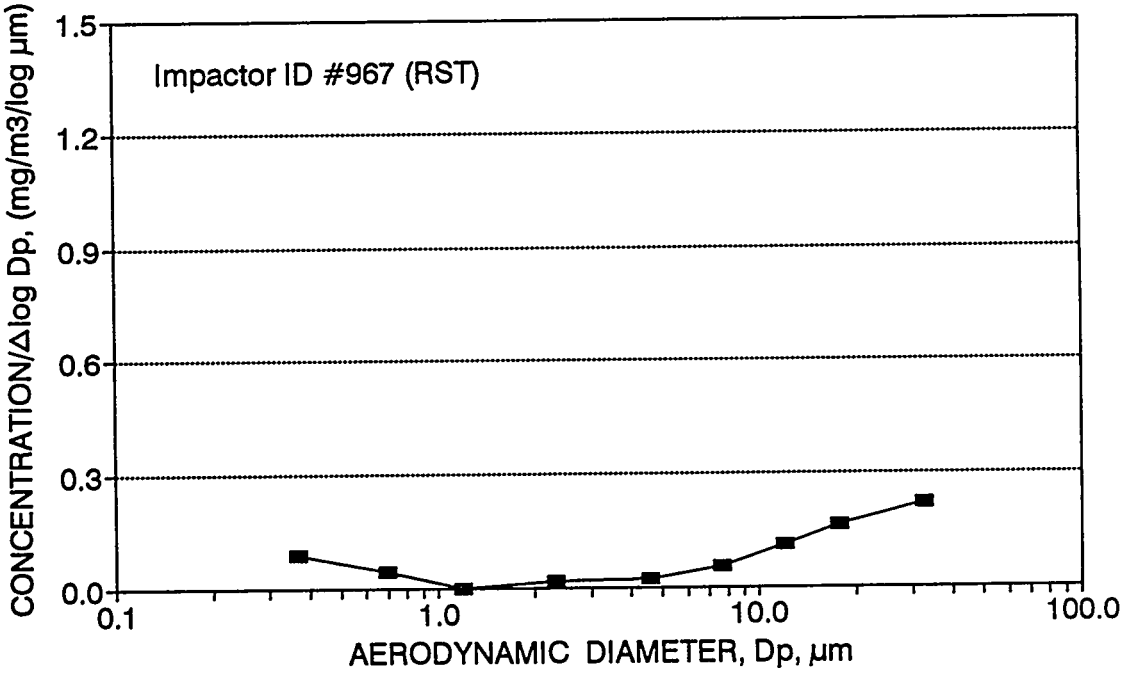
LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 967: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.005	1	0.188	0.027	-0.585	0.301	0.088	0.37	0.141	0.000	2+
8	0.52	0.002	0.99	0.188	0.011	-0.284	0.252	0.043	0.70	0.057	0.141	-
7	0.93	0.000	0.97	0.188	0.000	-0.032	0.222	0.000	1.20	0.000	0.198	-
6	1.55	0.001	0.96	0.188	0.006	0.190	0.354	0.016	2.33	0.029	0.198	tr
5	3.50	0.001	0.95	0.188	0.006	0.544	0.234	0.024	4.58	0.030	0.227	1+
4	6.00	0.002	0.89	0.188	0.012	0.778	0.213	0.056	7.67	0.063	0.257	2+
3	9.80	0.003	0.78	0.188	0.020	0.991	0.179	0.114	12.04	0.108	0.320	2+
2	14.80	0.003	0.61	0.188	0.026	1.170	0.158	0.165	17.75	0.138	0.428	3+
1	21.30	0.008	0.52	0.188	0.082	1.328	0.371	0.221	32.63	0.433	0.567	3+
	50.00					1.699						
Sum		0.025			0.189					1.000		

Marple Personal Impactor Data
LMC9: Left Hip Reconstruction



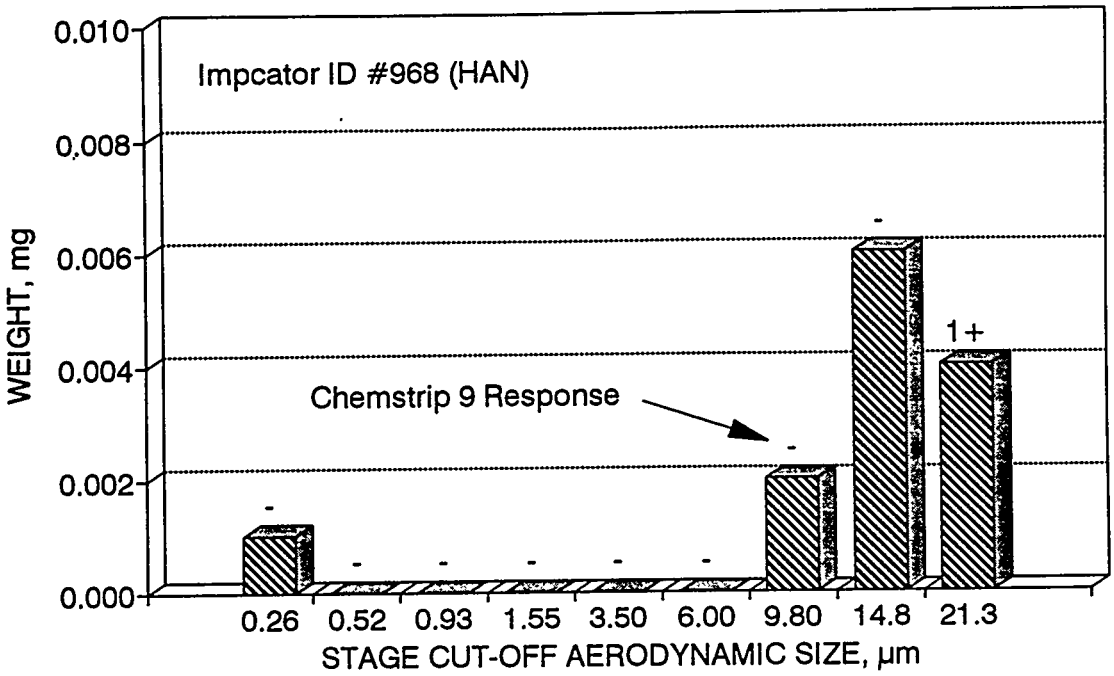
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



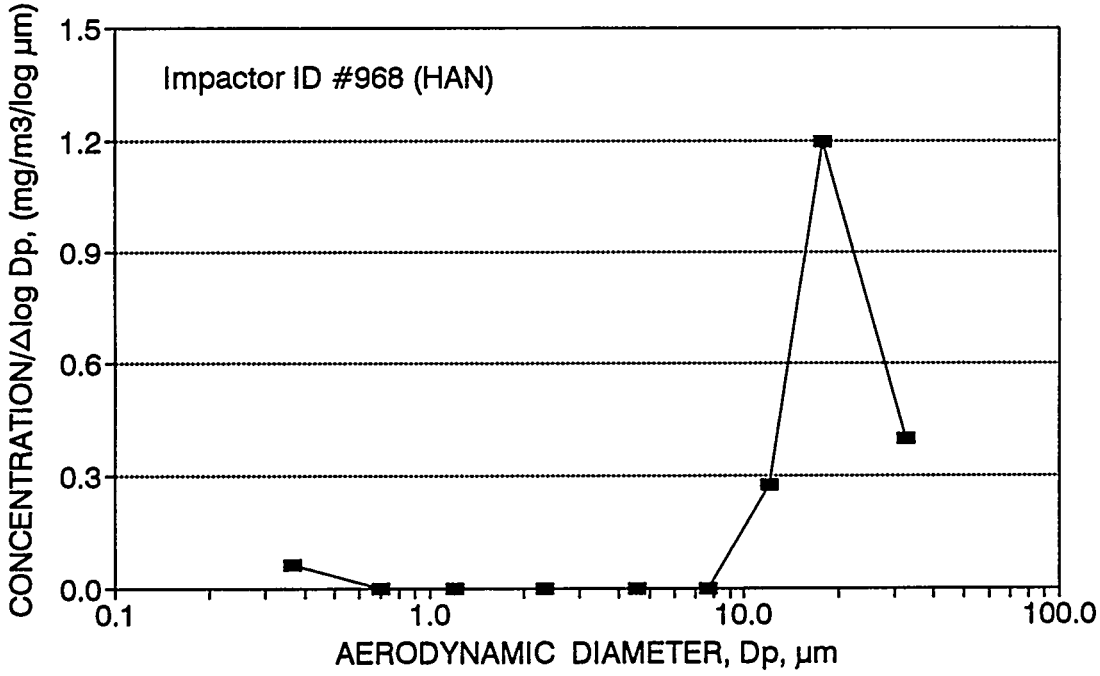
LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 968: HAN)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.001	1	0.052	0.019	-0.585	0.301	0.064	0.37	0.047	0.000	-
8	0.52	0.000	0.99	0.052	0.000	-0.284	0.252	0.000	0.70	0.000	0.047	-
7	0.93	0.000	0.97	0.052	0.000	-0.032	0.222	0.000	1.20	0.000	0.047	-
6	1.55	0.000	0.96	0.052	0.000	0.190	0.354	0.000	2.33	0.000	0.047	-
5	3.50	0.000	0.95	0.052	0.000	0.544	0.234	0.000	4.58	0.000	0.047	-
4	6.00	0.000	0.89	0.052	0.000	0.778	0.213	0.000	7.67	0.000	0.047	-
3	9.80	0.002	0.78	0.052	0.049	0.991	0.179	0.275	12.04	0.122	0.047	-
2	14.80	0.006	0.61	0.052	0.189	1.170	0.158	1.196	17.75	0.466	0.169	-
1	21.30	0.004	0.52	0.052	0.148	1.328	0.371	0.399	32.63	0.365	0.635	1+
	50.00					1.699						
Sum		0.013			0.406					1.000		

Marple Personal Impactor Data
LMC9: Left Hip Reconstruction



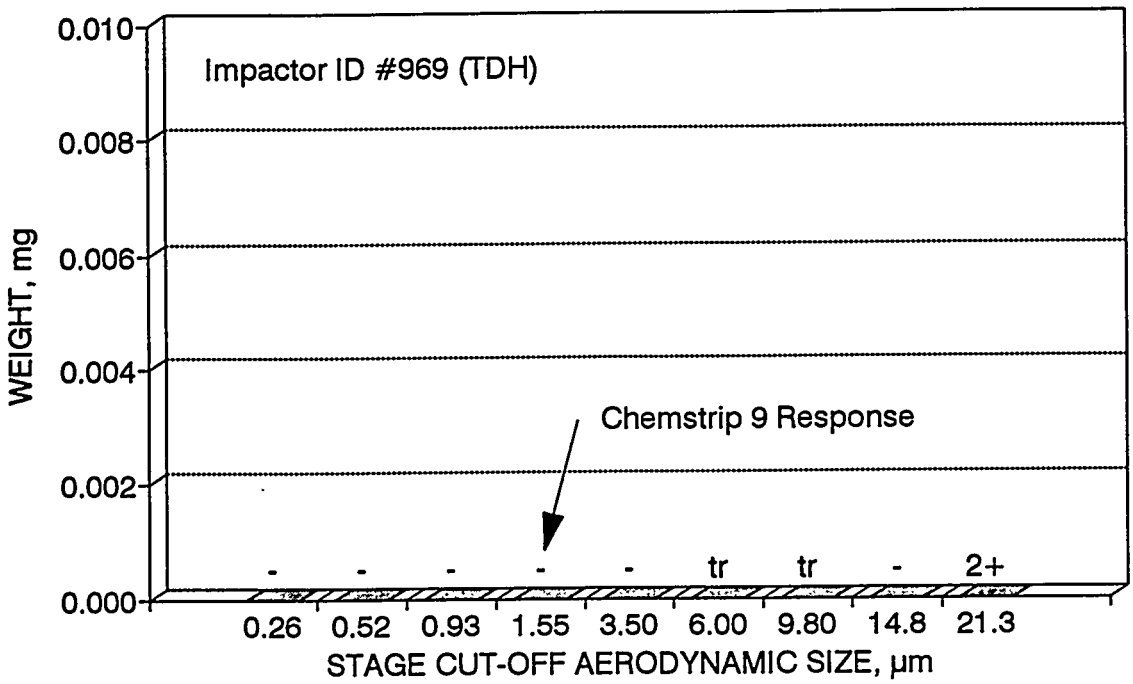
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



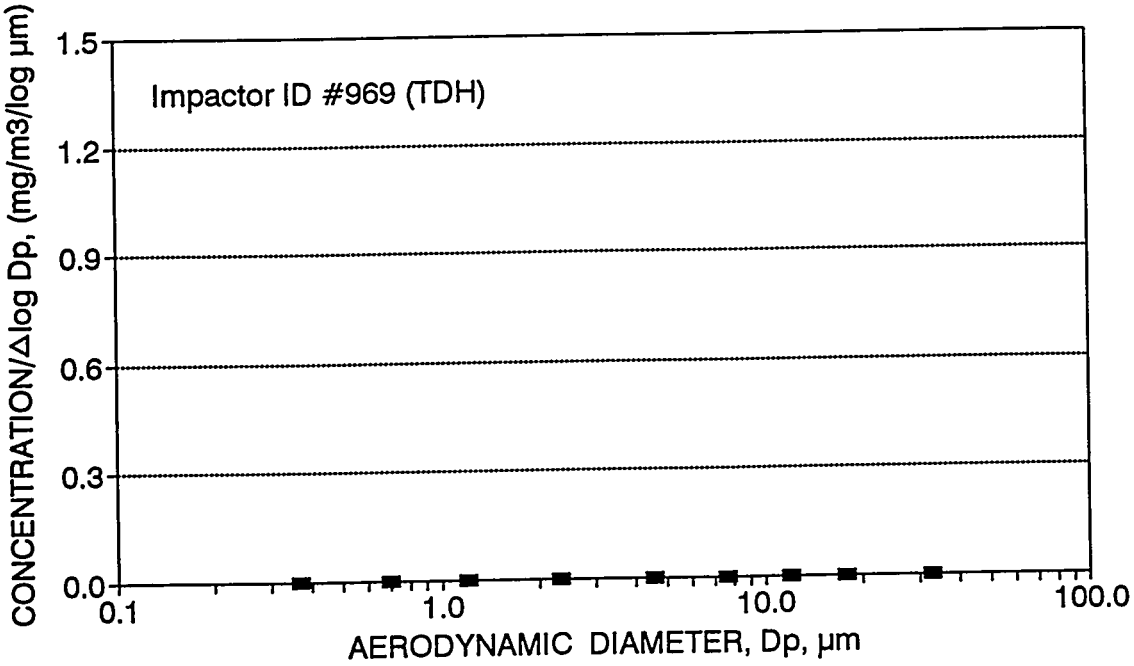
LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 969: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.152	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	-
8	0.52	0.000	0.99	0.152	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	-
7	0.93	0.000	0.97	0.152	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	-
6	1.55	0.000	0.96	0.152	0.000	0.190	0.354	0.000	2.33	0.000	0.000	-
5	3.50	0.000	0.95	0.152	0.000	0.544	0.234	0.000	4.58	0.000	0.000	-
4	6.00	0.000	0.89	0.152	0.000	0.778	0.213	0.000	7.67	0.000	0.000	tr
3	9.80	0.000	0.78	0.152	0.000	0.991	0.179	0.000	12.04	0.000	0.000	tr
2	14.80	0.000	0.61	0.152	0.000	1.170	0.158	0.000	17.75	0.000	0.000	-
1	21.30	0.000	0.52	0.152	0.000	1.328	0.371	0.000	32.63	0.000	0.000	2+
	50.00					1.699						
Sum		0.000			0.000					0.000		

Marple Personal Impactor Data
LMC9: Left Hip Reconstruction

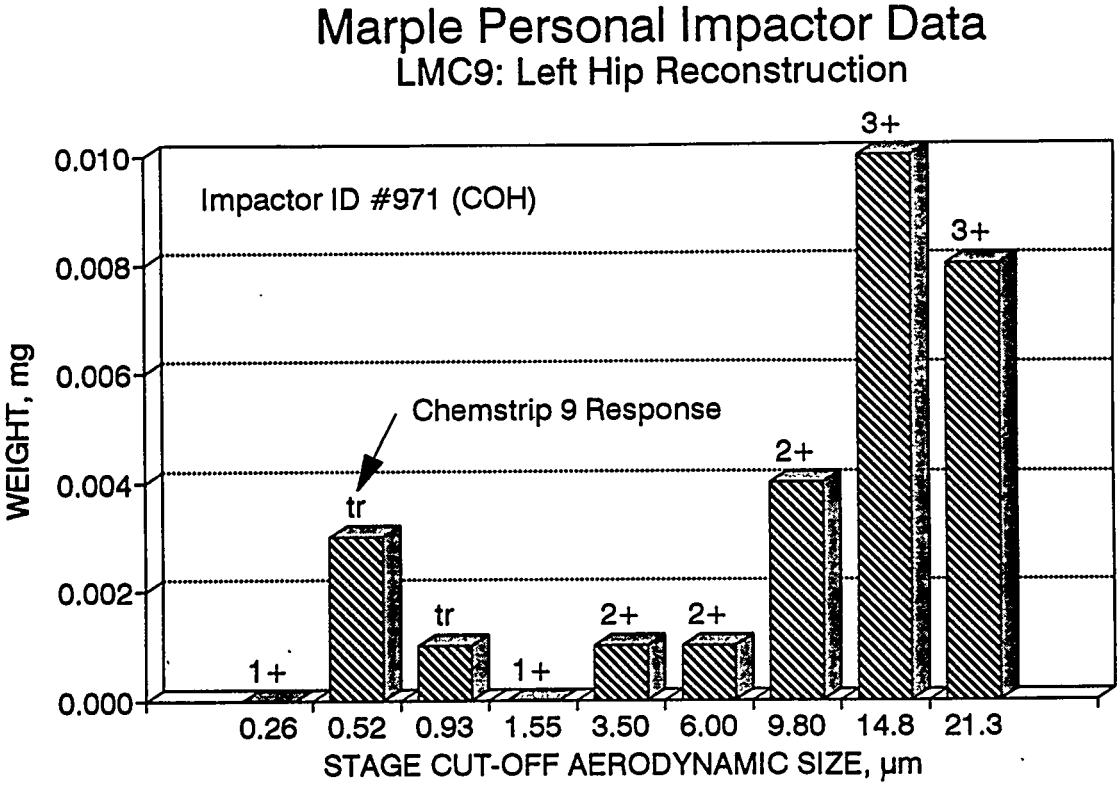


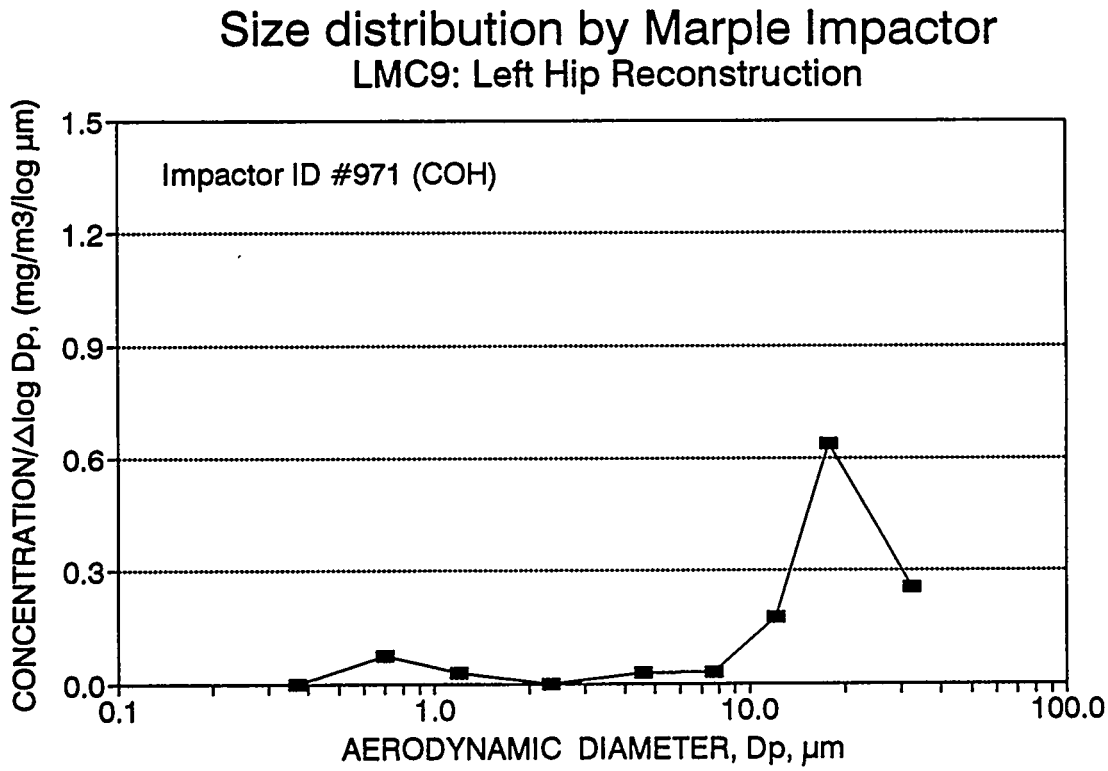
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



LMC9 Hip Reconstruction: Marple Personal Impactor Data (ID No. 971: COH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.162	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	1+
8	0.52	0.003	0.99	0.162	0.019	-0.284	0.252	0.074	0.70	0.070	0.000	tr
7	0.93	0.001	0.97	0.162	0.006	-0.032	0.222	0.029	1.20	0.024	0.070	tr
6	1.55	0.000	0.96	0.162	0.000	0.190	0.354	0.000	2.33	0.000	0.094	1+
5	3.50	0.001	0.95	0.162	0.006	0.544	0.234	0.028	4.58	0.024	0.094	2+
4	6.00	0.001	0.89	0.162	0.007	0.778	0.213	0.033	7.67	0.026	0.119	2+
3	9.80	0.004	0.78	0.162	0.032	0.991	0.179	0.177	12.04	0.119	0.145	2+
2	14.80	0.010	0.61	0.162	0.101	1.170	0.158	0.640	17.75	0.380	0.263	3+
1	21.30	0.008	0.52	0.162	0.095	1.328	0.371	0.256	32.63	0.357	0.643	3+
	50.00					1.699						
Sum		0.028			0.266					1.000		


Marple Personal Impactor Data
LMC9: Left Hip Reconstruction
Impactor ID #971 (COH)
Chemstrip 9 Response
WEIGHT, mg
0.010
0.008
0.006
0.004
0.002
0.000
1+
tr
tr
1+
2+
2+
2+
3+
3+
0.26
0.52
0.93
1.55
3.50
6.00
9.80
14.8
21.3
STAGE CUT-OFF AERODYNAMIC SIZE, µm


Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction
Impactor ID #971 (COH)
CONCENTRATION/Δlog Dp, (mg/m3/log µm)
1.5
1.2
0.9
0.6
0.3
0.0
0.1
1.0
10.0
100.0
AERODYNAMIC DIAMETER, Dp, µm

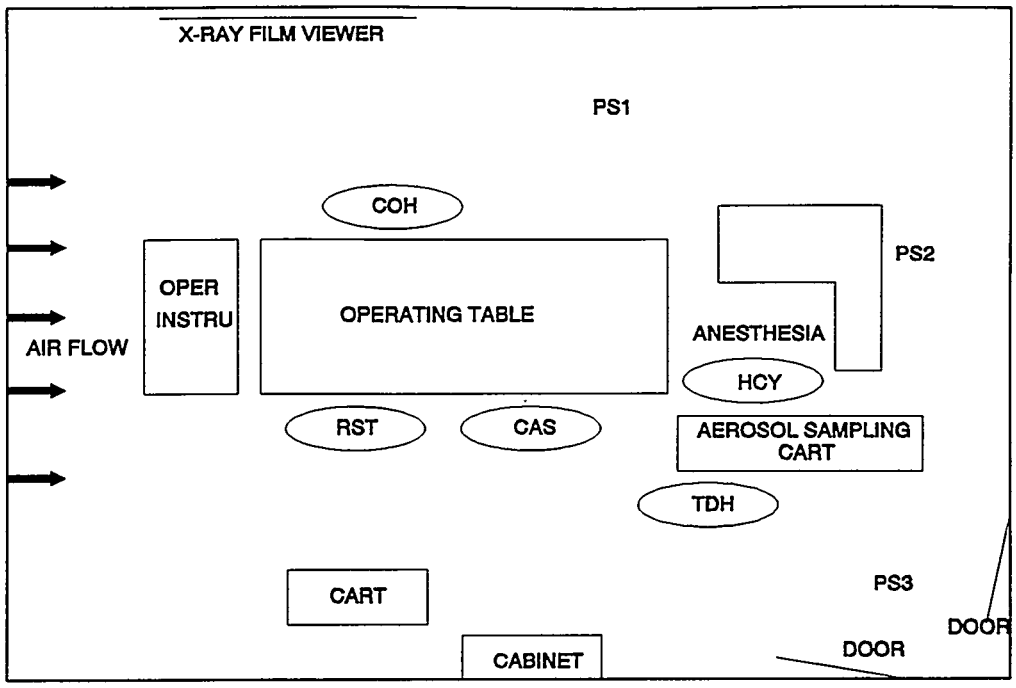
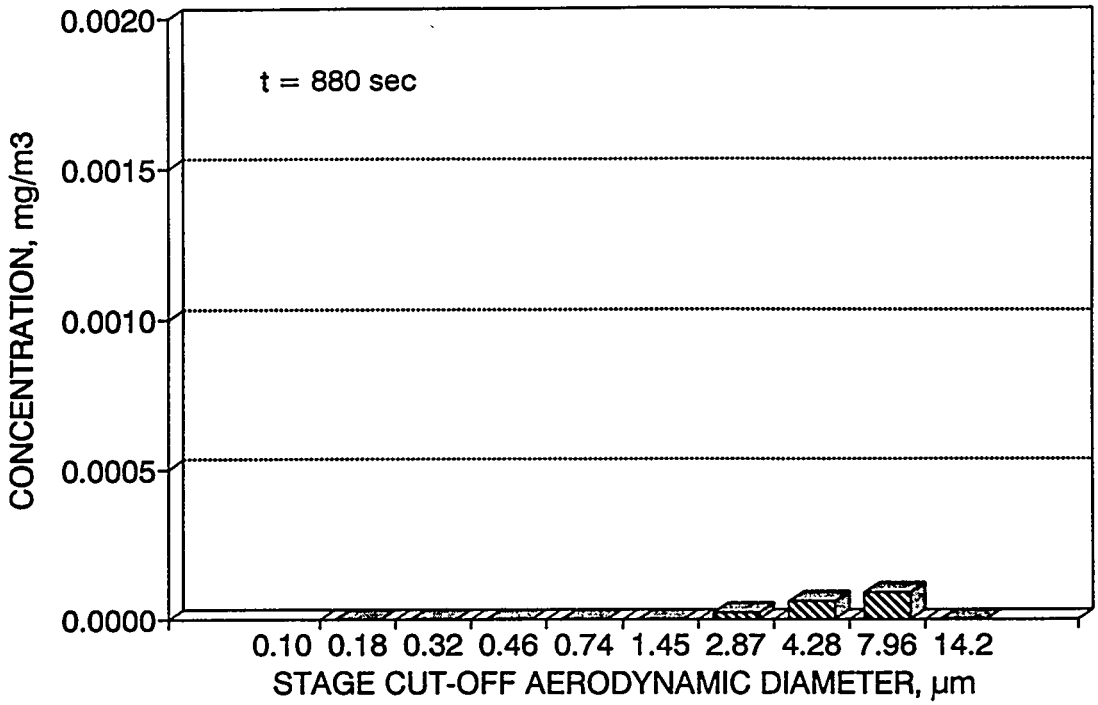


Figure C.10 Personnel and area filter locations during LMC #1 measurement (total knee replacement).

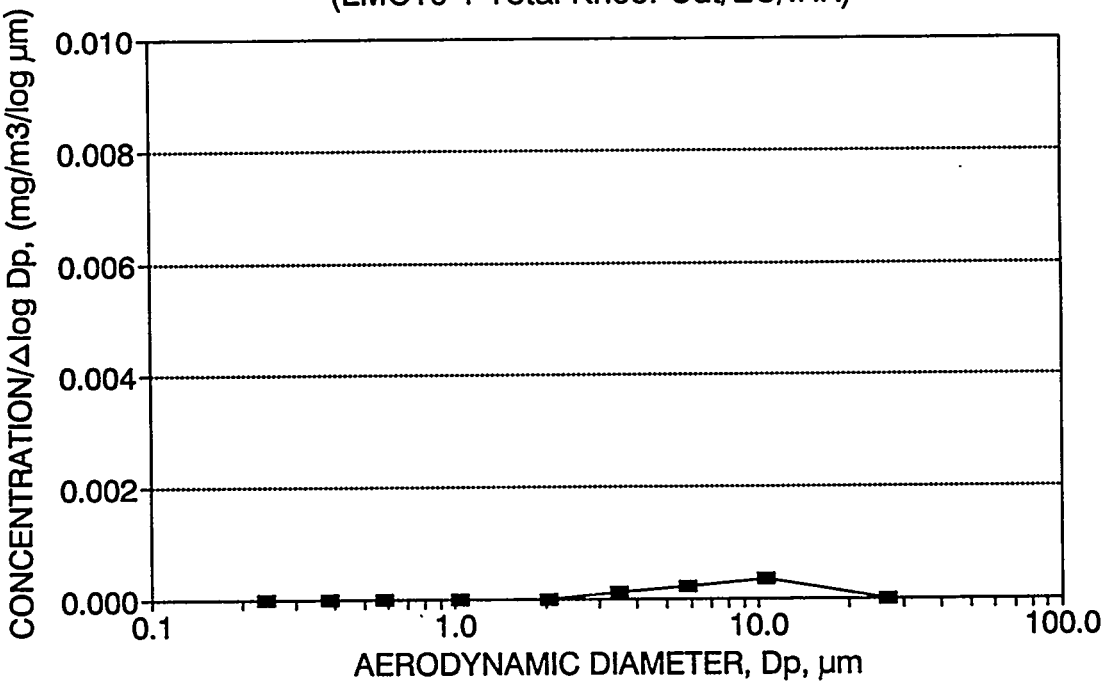
LMC10-1 Total Knee: CUT/EC/IRR (t = 880 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00000	0.74	-0.128	0.290	0.000	1.04	0.0000	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.000
2.00	0.00002	2.87	0.457	0.174	0.000	3.50	0.1176	0.000
3.00	0.00006	4.28	0.632	0.269	0.000	5.84	0.3529	0.118
5.60	0.00009	7.96	0.901	0.251	0.000	10.62	0.5294	0.471
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00017						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-1 Total Knee: Cut/EC/IRR)



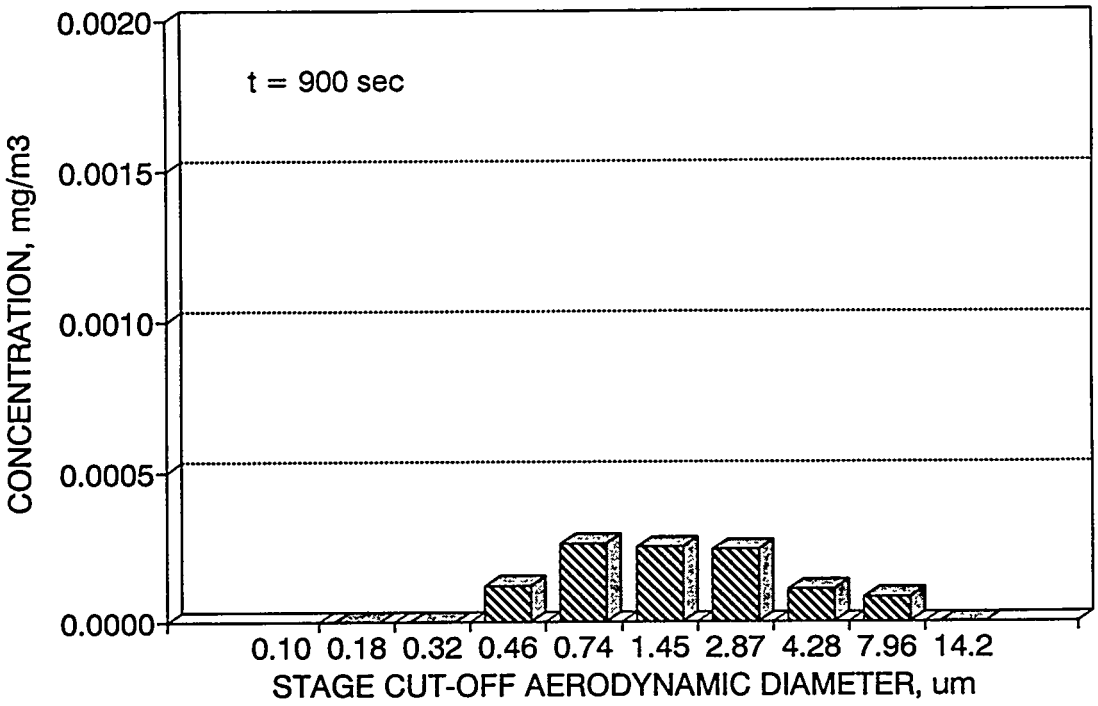
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-1 Total Knee: Cut/EC/IRR)



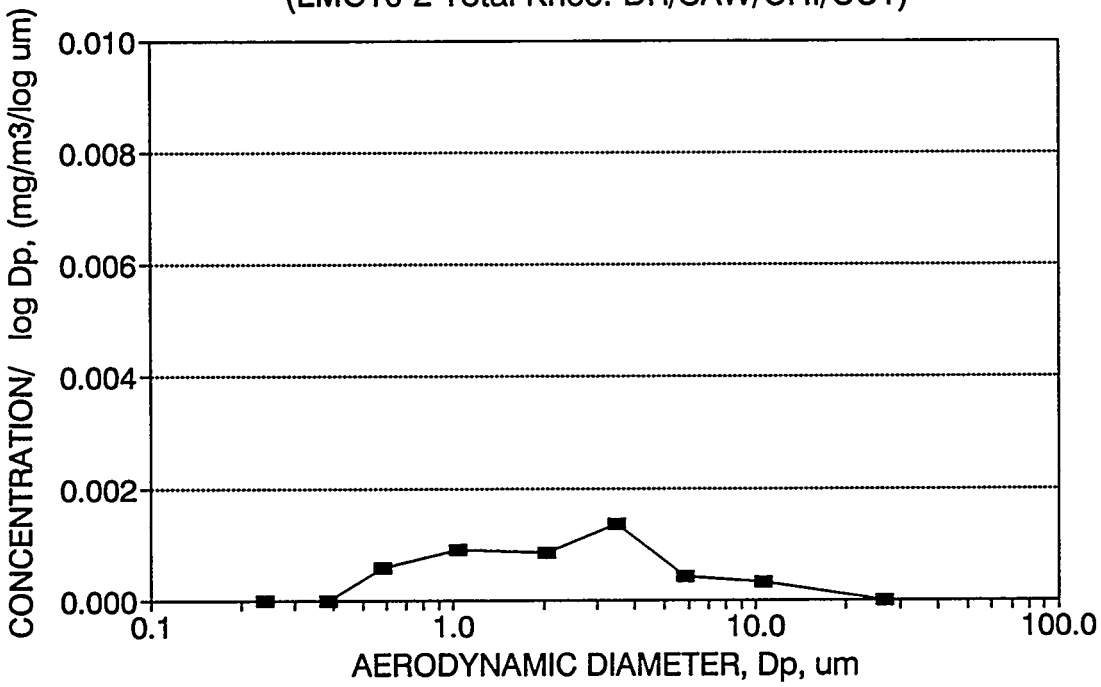
LMC10-2 Total Knee: DR/SAW/CHI/CUT (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00012	0.46	-0.335	0.206	0.001	0.59	0.1132	0.000
0.50	0.00026	0.74	-0.128	0.290	0.001	1.04	0.2453	0.113
1.00	0.00025	1.45	0.162	0.296	0.001	2.04	0.2358	0.358
2.00	0.00024	2.87	0.457	0.174	0.001	3.50	0.2264	0.594
3.00	0.00011	4.28	0.632	0.269	0.000	5.84	0.1038	0.821
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.0755	0.925
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00106						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-2 Total Knee: DR/SAW/CHI/CUT)



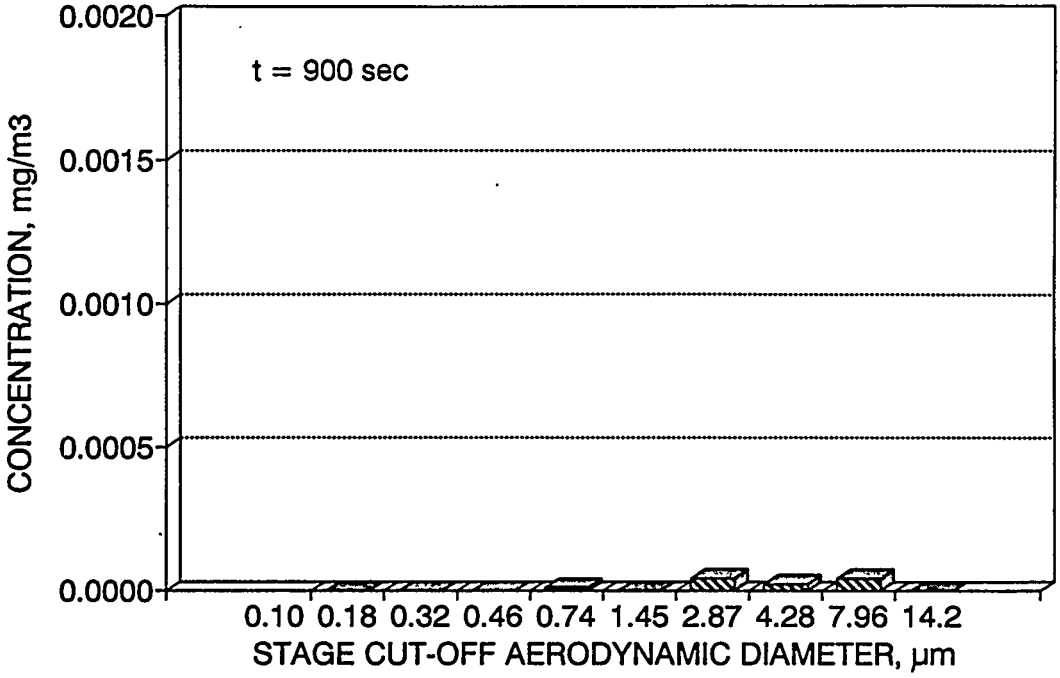
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-2 Total Knee: DR/SAW/CHI/CUT)



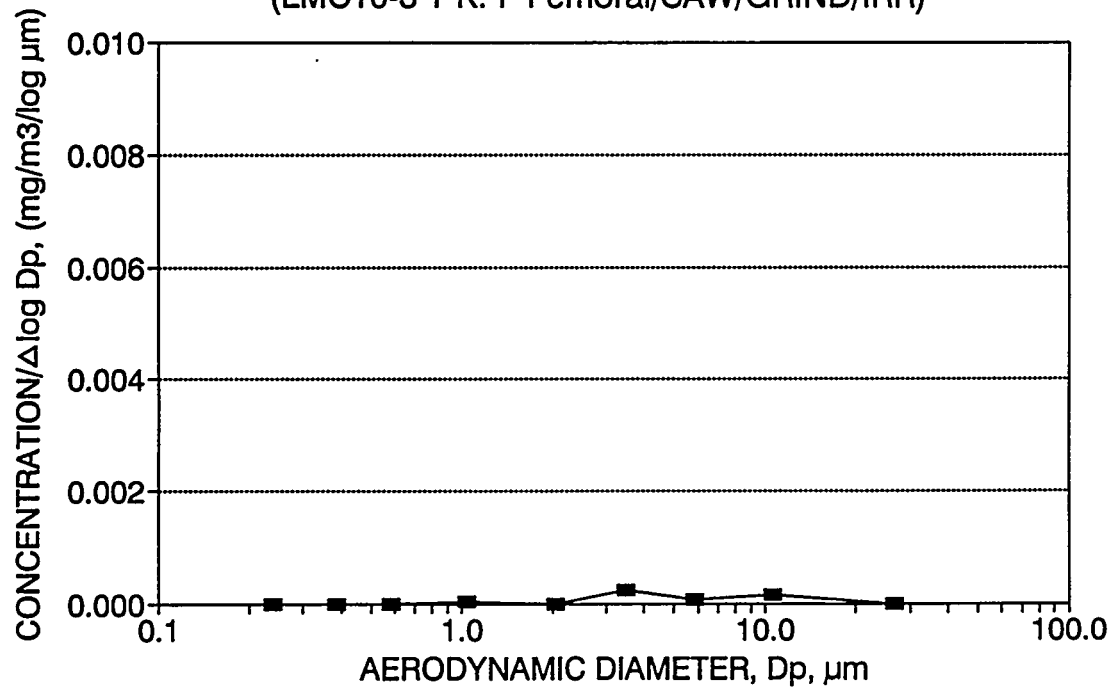
LMC10-3 Total Knee: Fit Femoral/SAW/GRIND/IRR (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00001	0.74	-0.128	0.290	0.000	1.04	0.0909	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.091
2.00	0.00004	2.87	0.457	0.174	0.000	3.50	0.3636	0.091
3.00	0.00002	4.28	0.632	0.269	0.000	5.84	0.1818	0.455
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.3636	0.636
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00011						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-3 T K: F Femoral/SAW/GRIND/IRR)



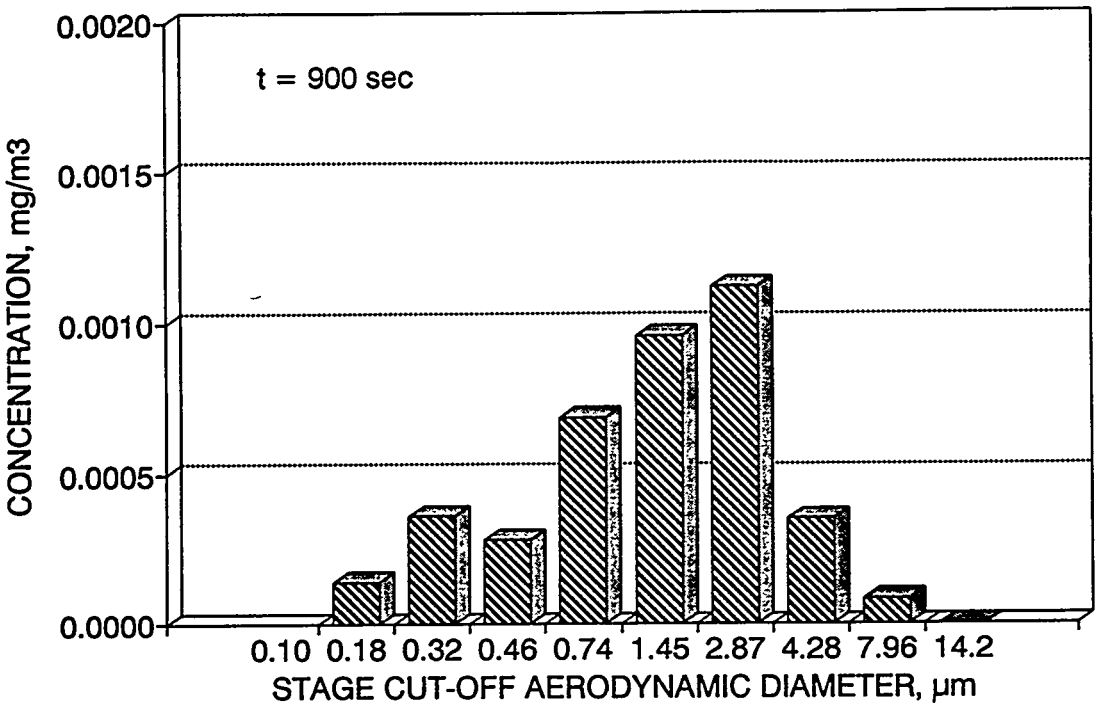
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-3 T K: F Femoral/SAW/GRIND/IRR)



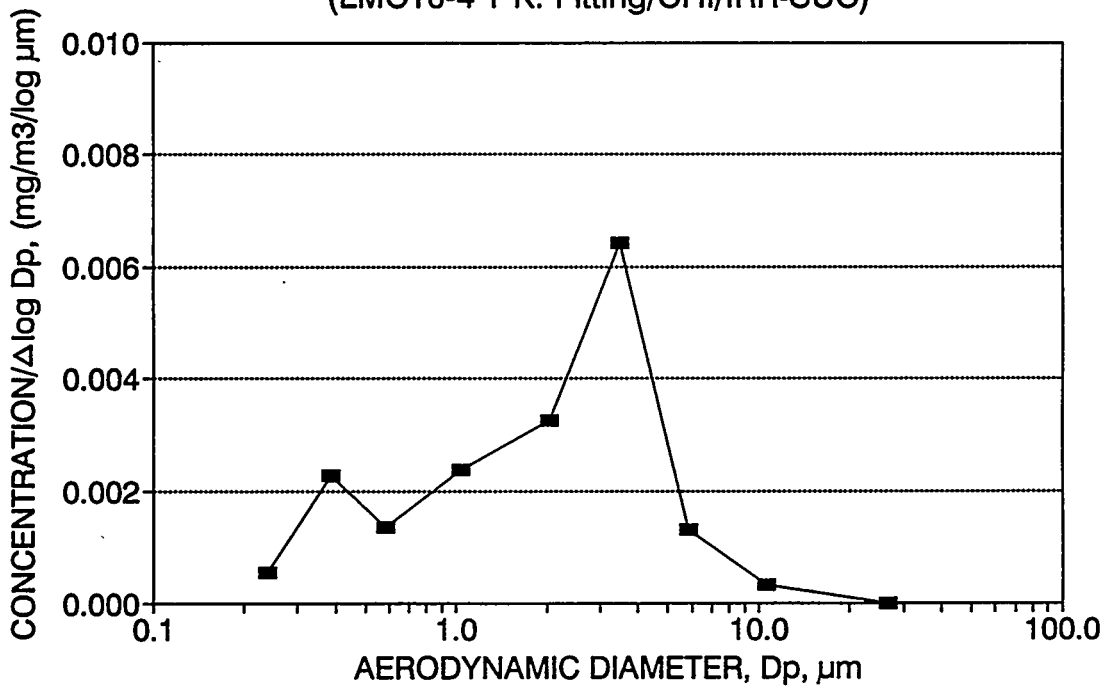
LMC10-4 Total Knee: Fitting/CHI/IRR-SUC (t = 900 sec)

A ECD,μm	B C,mg/m3	C Dae,μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD,μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00014	0.18	-0.749	0.257	0.001	0.24	0.0352	0.000
0.20	0.00036	0.32	-0.492	0.157	0.002	0.39	0.0905	0.035
0.30	0.00028	0.46	-0.335	0.206	0.001	0.59	0.0704	0.126
0.50	0.00069	0.74	-0.128	0.290	0.002	1.04	0.1734	0.196
1.00	0.00096	1.45	0.162	0.296	0.003	2.04	0.2412	0.369
2.00	0.00112	2.87	0.457	0.174	0.006	3.50	0.2814	0.611
3.00	0.00035	4.28	0.632	0.269	0.001	5.84	0.0879	0.892
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.0201	0.980
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00398						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-4 T K: Fitting/CHI/IRR-SUC)



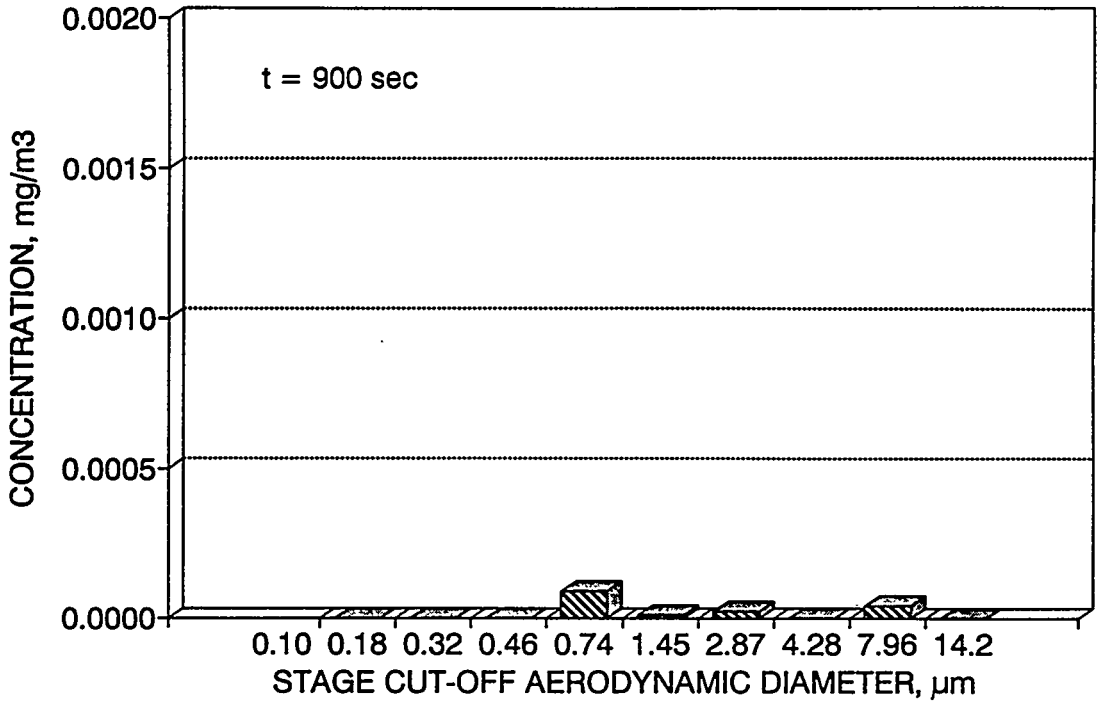
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-4 T K: Fitting/CHI/IRR-SUC)



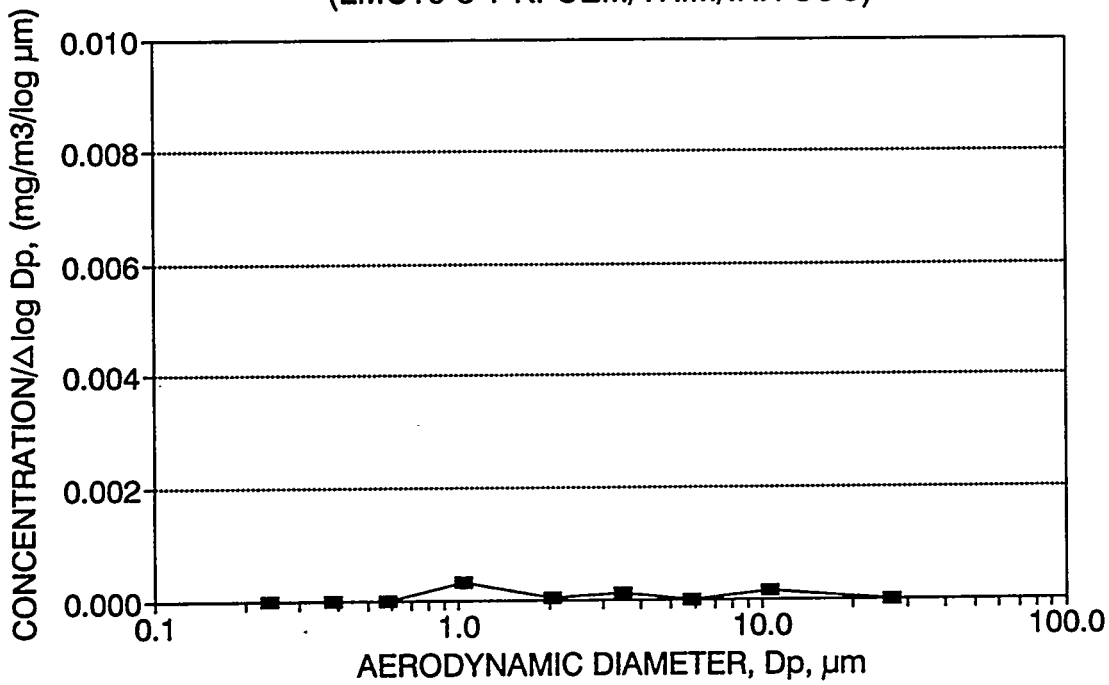
LMC10-5 Total Knee: CEM/TRIM/IRR-SUC (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00009	0.74	-0.128	0.290	0.000	1.04	0.5625	0.000
1.00	0.00001	1.45	0.162	0.296	0.000	2.04	0.0625	0.563
2.00	0.00002	2.87	0.457	0.174	0.000	3.50	0.1250	0.625
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.750
5.60	0.00004	7.96	0.901	0.251	0.000	10.62	0.2500	0.750
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00016						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-5 T K: CEM/TRIM/IRR-SUC)



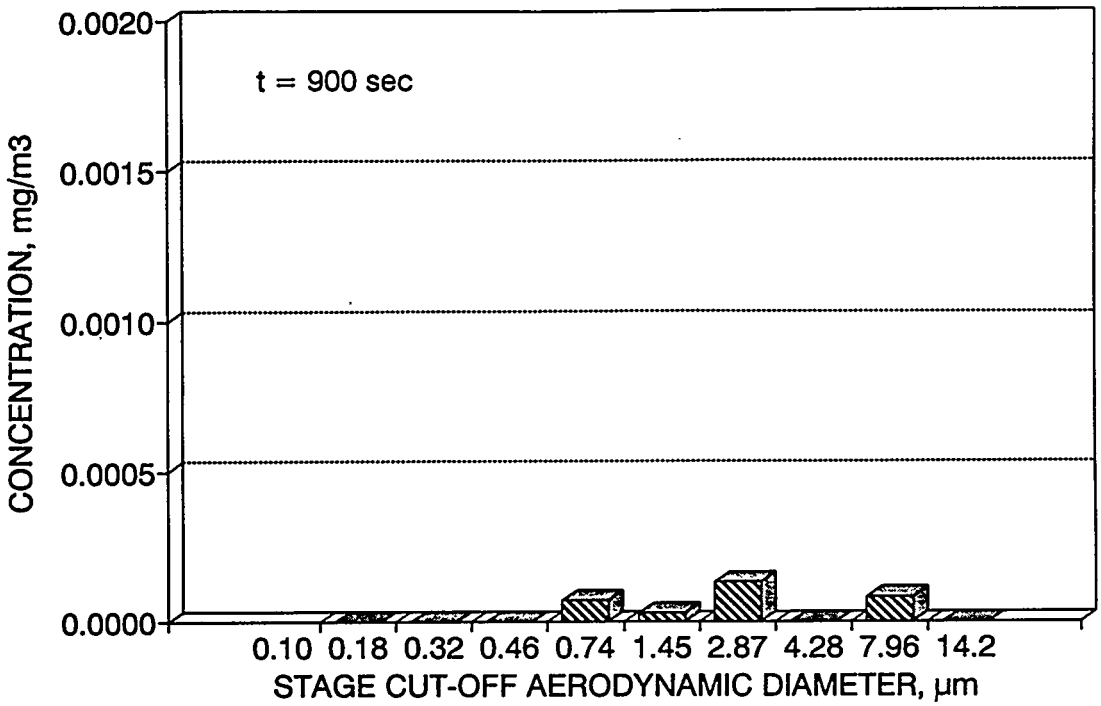
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-5 T K: CEM/TRIM/IRR-SUC)



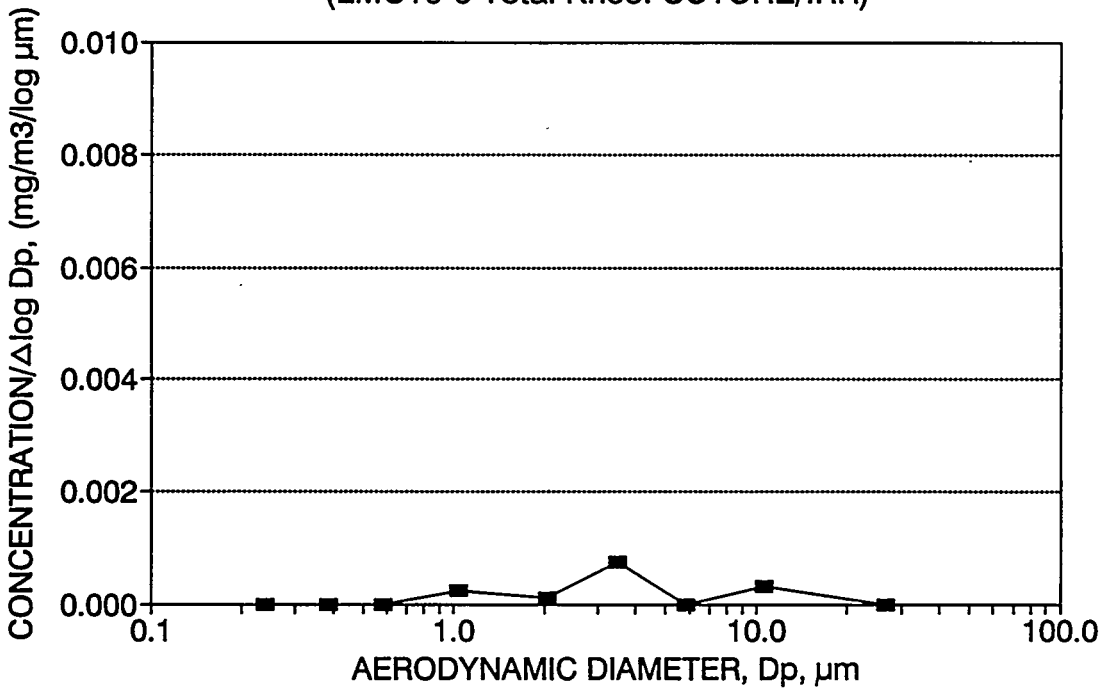
LMC10-6 Total Knee: SUTURE/IRR-SUC (t = 900 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00007	0.74	-0.128	0.290	0.000	1.04	0.2258	0.000
1.00	0.00003	1.45	0.162	0.296	0.000	2.04	0.0968	0.226
2.00	0.00013	2.87	0.457	0.174	0.001	3.50	0.4194	0.323
3.00	0.00000	4.28	0.632	0.269	0.000	5.84	0.0000	0.742
5.60	0.00008	7.96	0.901	0.251	0.000	10.62	0.2581	0.742
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00031						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-6 Total Knee: SUTURE/IRR)



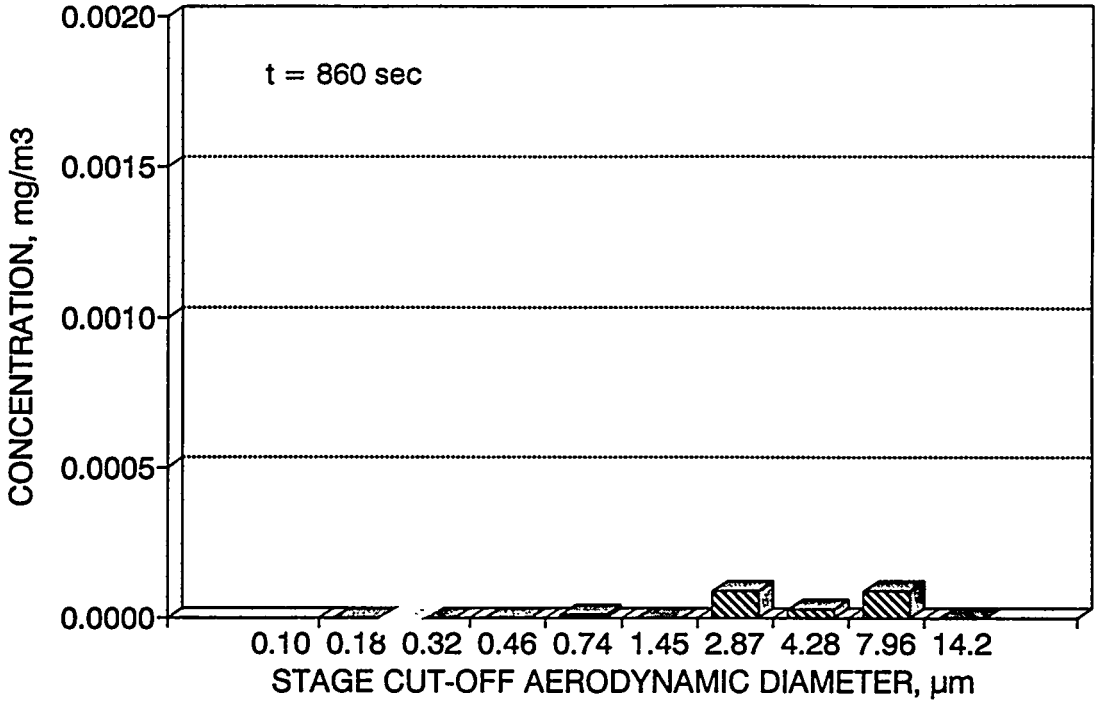
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-6 Total Knee: SUTURE/IRR)



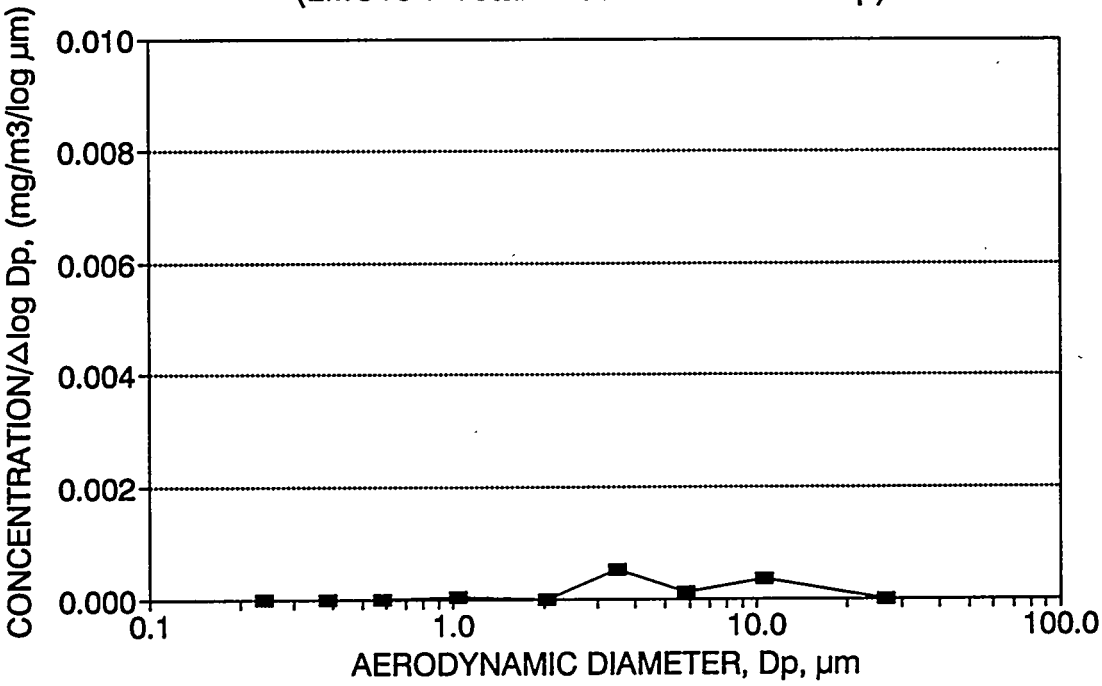
LMC10-7 Total Knee: Room Clean Up (t = 860 sec)

A ECD, μm	B C, mg/m3	C Dae, μm	D log Dp	E δlog Dp	F (B)/(E)	G GMD, μm	H m frac	I f<Dae
0.05		0.10				0.13		
0.10	0.00000	0.18	-0.749	0.257	0.000	0.24	0.0000	0.000
0.20	0.00000	0.32	-0.492	0.157	0.000	0.39	0.0000	0.000
0.30	0.00000	0.46	-0.335	0.206	0.000	0.59	0.0000	0.000
0.50	0.00001	0.74	-0.128	0.290	0.000	1.04	0.0455	0.000
1.00	0.00000	1.45	0.162	0.296	0.000	2.04	0.0000	0.045
2.00	0.00009	2.87	0.457	0.174	0.001	3.50	0.4091	0.045
3.00	0.00003	4.28	0.632	0.269	0.000	5.84	0.1364	0.455
5.60	0.00009	7.96	0.901	0.251	0.000	10.62	0.4091	0.591
10.00	0.00000	14.18	1.152	0.547	0.000	26.63	0.0000	1.000
		50.00	1.699					1.000
Sum	0.00022						1.0000	

SIZE HISTOGRAM AS DETERMINED BY QCM
(LMC10-7 Total Knee: Room Clean Up)



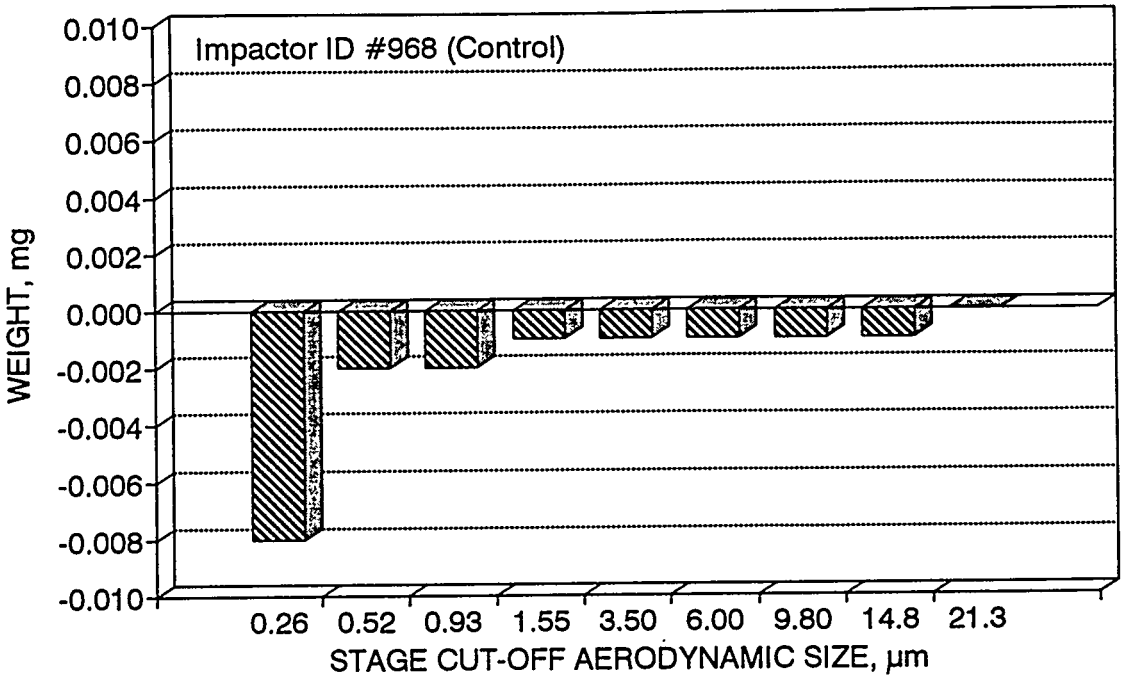
SIZE DISTRIBUTION AS DETERMINED BY QCM
(LMC10-7 Total Knee: Room Clean Up)



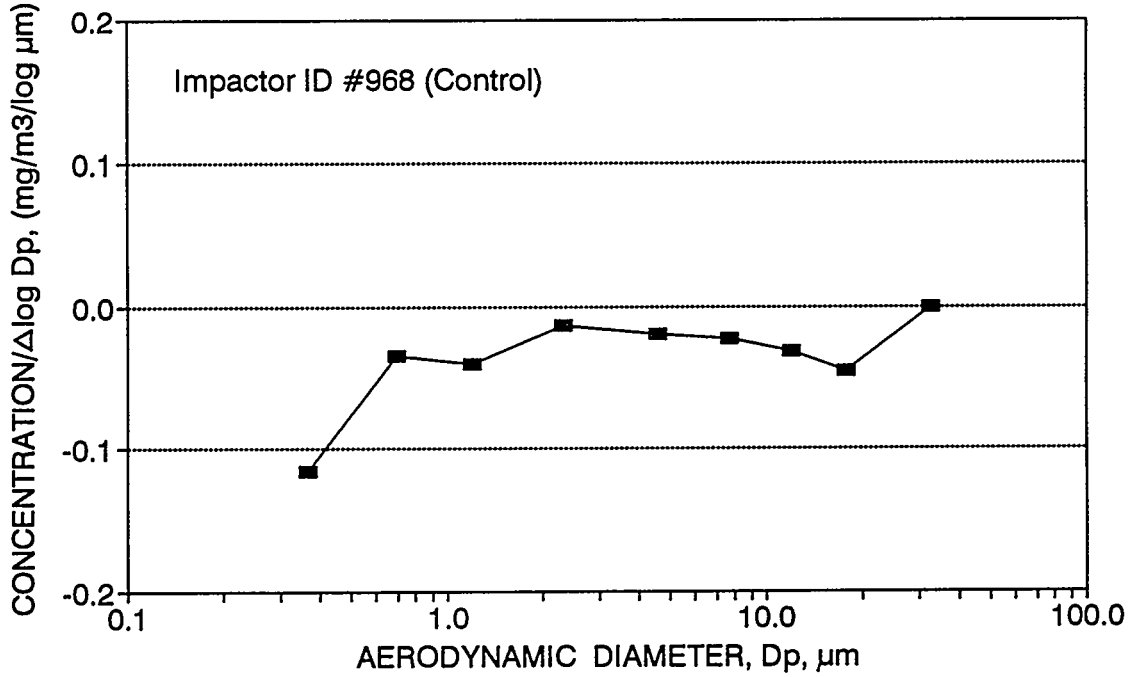
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 968: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	-0.008	1	0.23	-0.035	-0.585	0.301	-0.116	0.37	0.439	0.000
8	0.52	-0.002	0.99	0.23	-0.009	-0.284	0.252	-0.035	0.70	0.111	0.439
7	0.93	-0.002	0.97	0.23	-0.009	-0.032	0.222	-0.040	1.20	0.113	0.550
6	1.55	-0.001	0.96	0.23	-0.005	0.190	0.354	-0.013	2.33	0.057	0.663
5	3.50	-0.001	0.95	0.23	-0.005	0.544	0.234	-0.020	4.58	0.058	0.720
4	6.00	-0.001	0.89	0.23	-0.005	0.778	0.213	-0.023	7.67	0.062	0.778
3	9.80	-0.001	0.78	0.23	-0.006	0.991	0.179	-0.031	12.04	0.070	0.840
2	14.80	-0.001	0.61	0.23	-0.007	1.170	0.158	-0.045	17.75	0.090	0.910
1	21.30	0.000	0.52	0.23	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		-0.017			-0.079					1.000	

Marple Personal Impactor Data
LMC10: Total Left Knee



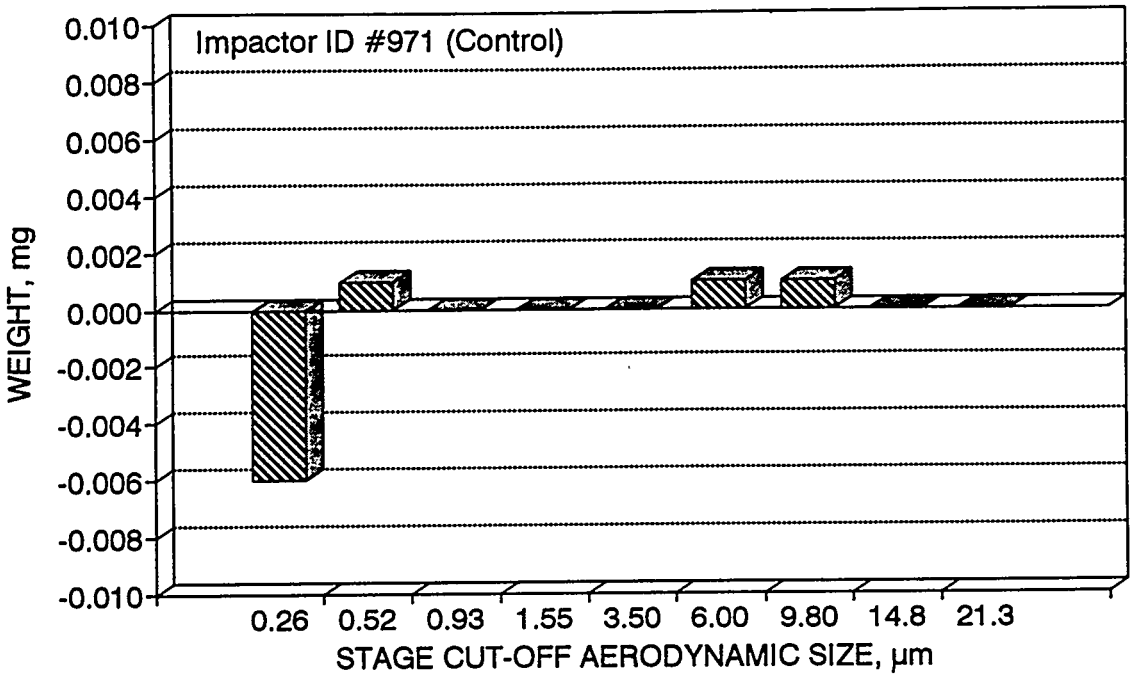
Size distribution by Marple Impactor
LMC10: Total Left Knee



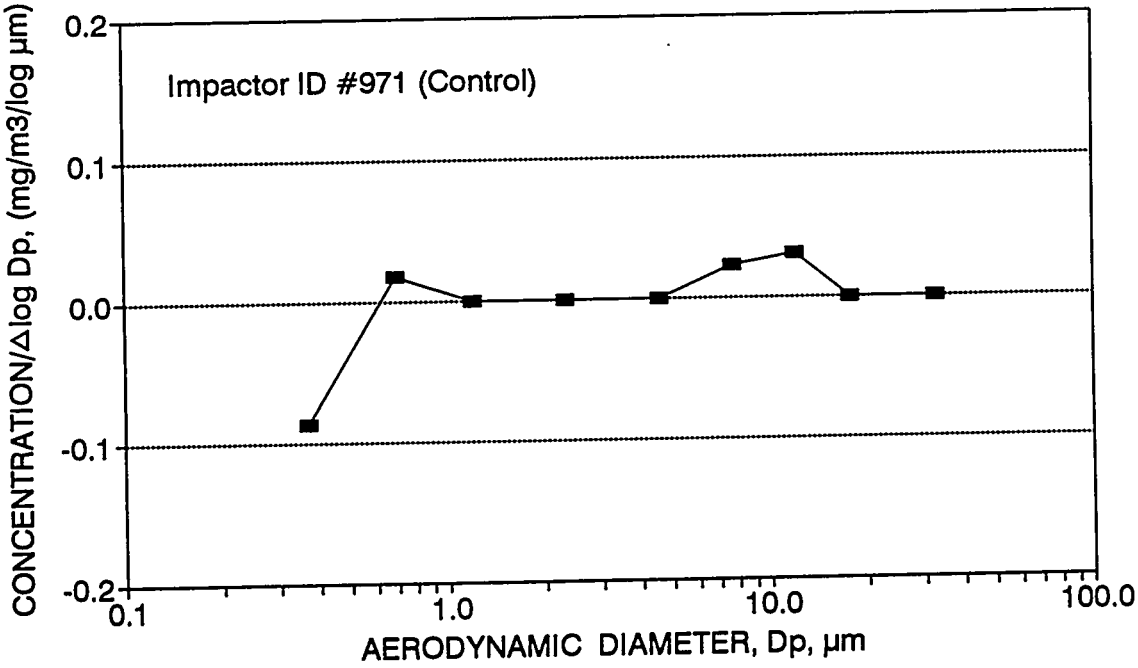
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 971: Control)

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	-0.006	1	0.23	-0.026	-0.585	0.301	-0.087	0.37	2.322	0.000
8	0.52	0.001	0.99	0.23	0.004	-0.284	0.252	0.017	0.70	-0.391	2.322
7	0.93	0.000	0.97	0.23	0.000	-0.032	0.222	0.000	1.20	0.000	1.931
6	1.55	0.000	0.96	0.23	0.000	0.190	0.354	0.000	2.33	0.000	1.931
5	3.50	0.000	0.95	0.23	0.000	0.544	0.234	0.000	4.58	0.000	1.931
4	6.00	0.001	0.89	0.23	0.005	0.778	0.213	0.023	7.67	-0.435	1.931
3	9.80	0.001	0.78	0.23	0.006	0.991	0.179	0.031	12.04	-0.496	1.496
2	14.80	0.000	0.61	0.23	0.000	1.170	0.158	0.000	17.75	0.000	1.000
1	21.30	0.000	0.52	0.23	0.000	1.328	0.371	0.000	32.63	0.000	1.000
	50.00					1.699					
Sum		-0.003			-0.011					1.000	

Marple Personal Impactor Data
LMC10: Total Left Knee



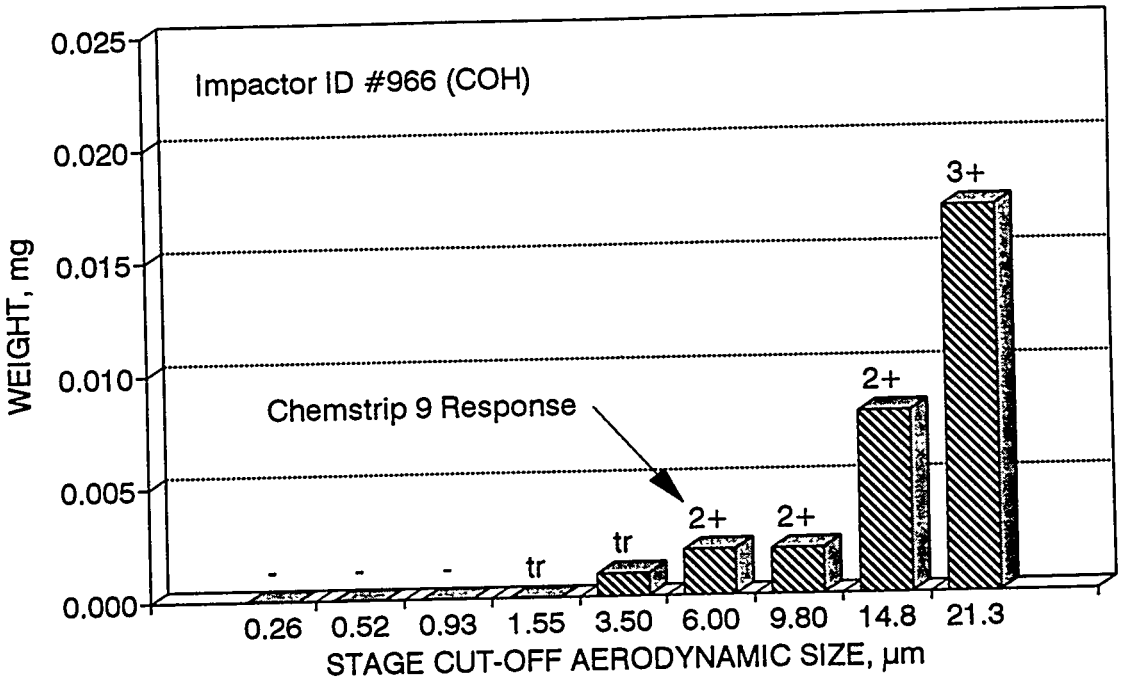
Size distribution by Marple Impactor
LMC10: Total Left Knee



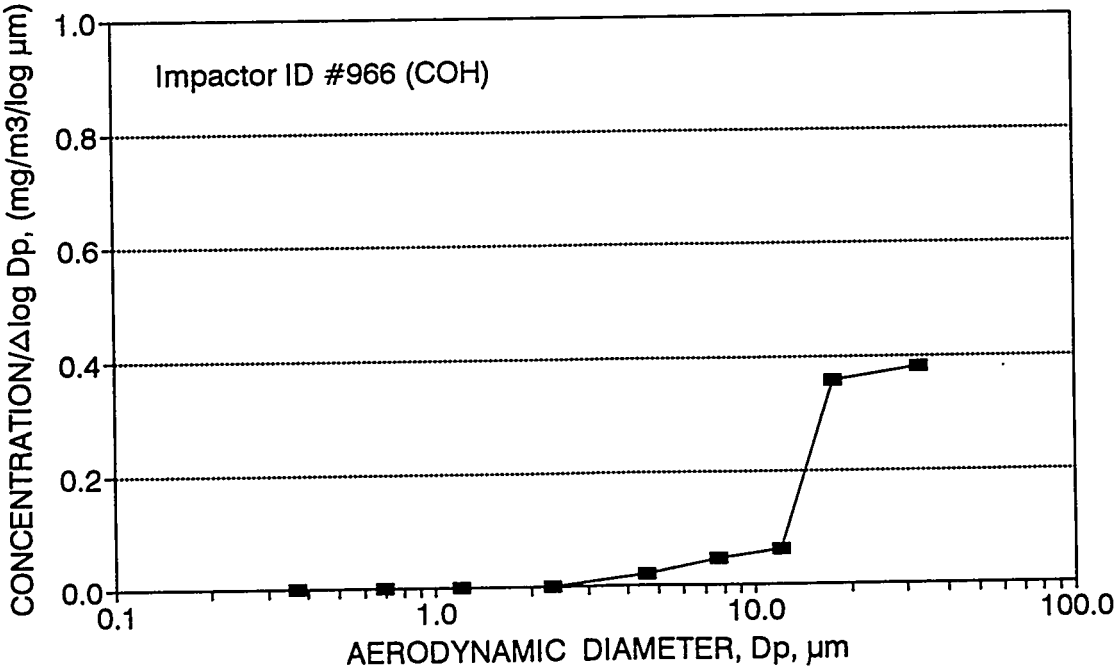
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 966:COH)

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD	M Chem.9
F	0.26	0.000	1	0.232	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	-
8	0.52	0.000	0.99	0.232	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	-
7	0.93	0.000	0.97	0.232	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	-
6	1.55	0.000	0.96	0.232	0.000	0.190	0.354	0.000	2.33	0.000	0.000	tr
5	3.50	0.001	0.95	0.232	0.005	0.544	0.234	0.019	4.58	0.020	0.000	tr
4	6.00	0.002	0.89	0.232	0.010	0.778	0.213	0.045	7.67	0.043	0.020	2+
3	9.80	0.002	0.78	0.232	0.011	0.991	0.179	0.062	12.04	0.050	0.064	2+
2	14.80	0.008	0.61	0.232	0.057	1.170	0.158	0.358	17.75	0.254	0.113	2+
1	21.30	0.017	0.52	0.232	0.141	1.328	0.371	0.380	32.63	0.633	0.367	3+
	50.00					1.699						
Sum		0.030			0.223					1.000		

Marple Personal Impactor Data
LMC10: Total Left Knee



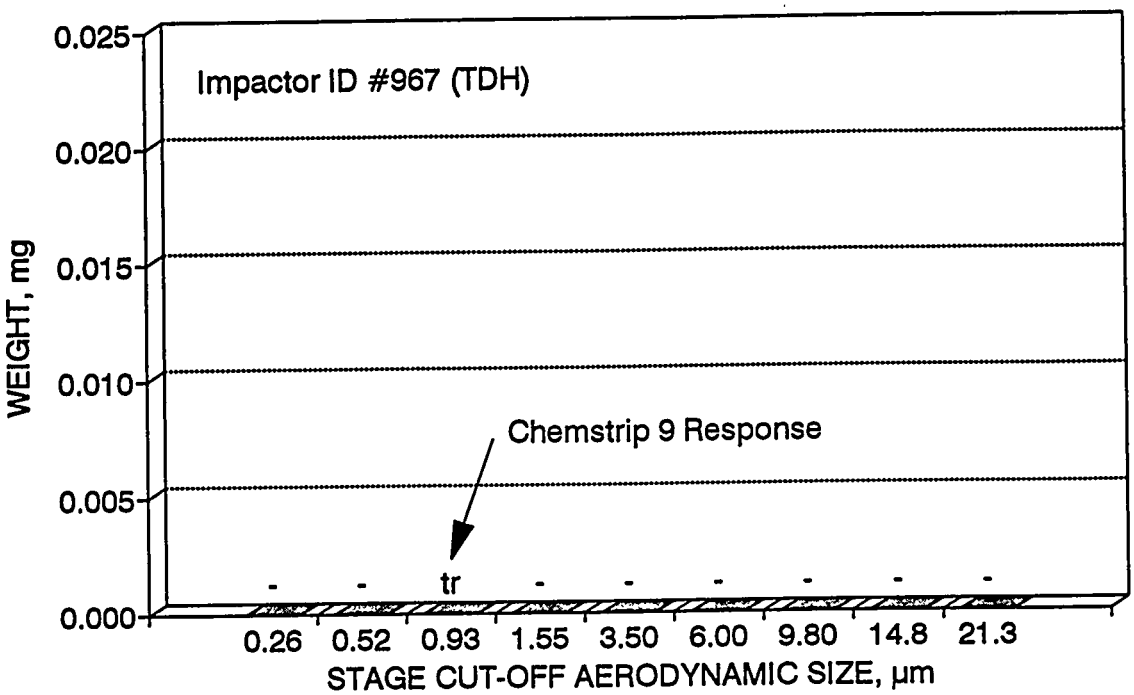
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



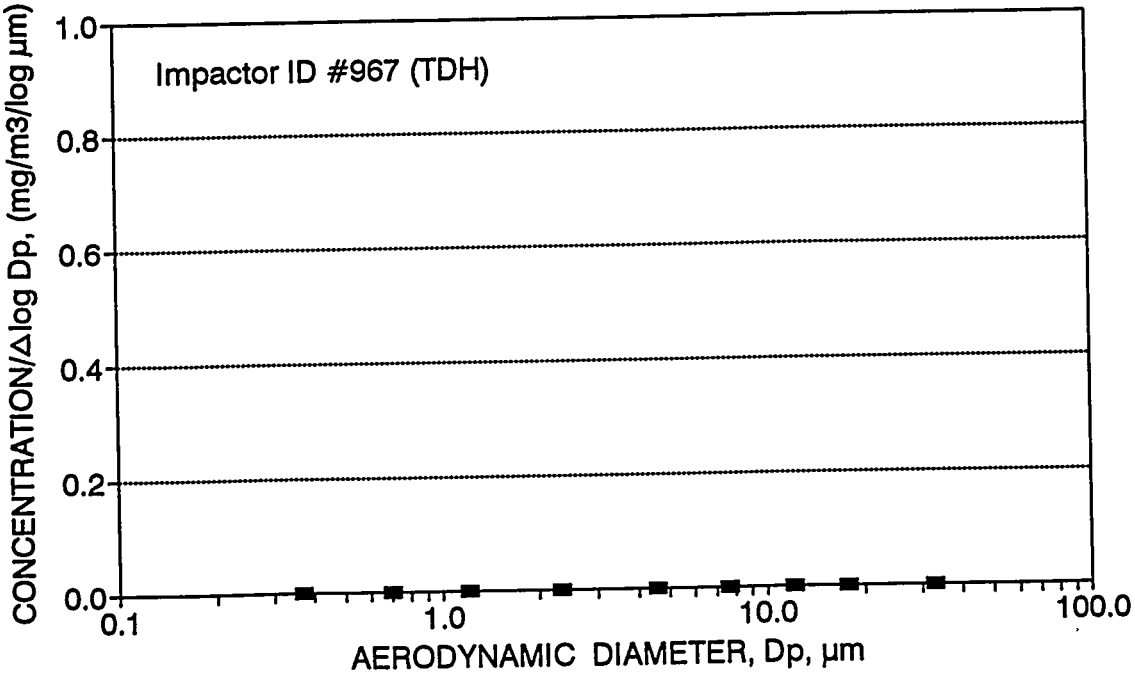
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 967: TDH)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.222	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	-
8	0.52	0.000	0.99	0.222	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	-
7	0.93	0.000	0.97	0.222	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	tr
6	1.55	0.000	0.96	0.222	0.000	0.190	0.354	0.000	2.33	0.000	0.000	-
5	3.50	0.000	0.95	0.222	0.000	0.544	0.234	0.000	4.58	0.000	0.000	-
4	6.00	0.000	0.89	0.222	0.000	0.778	0.213	0.000	7.67	0.000	0.000	-
3	9.80	0.000	0.78	0.222	0.000	0.991	0.179	0.000	12.04	0.000	0.000	-
2	14.80	0.000	0.61	0.222	0.000	1.170	0.158	0.000	17.75	0.000	0.000	-
1	21.30	0.000	0.52	0.222	0.000	1.328	0.371	0.000	32.63	0.000	0.000	-
	50.00					1.699						
Sum		0.000			0.000					0.000		

Marple Personal Impactor Data
LMC10: Total Left Knee



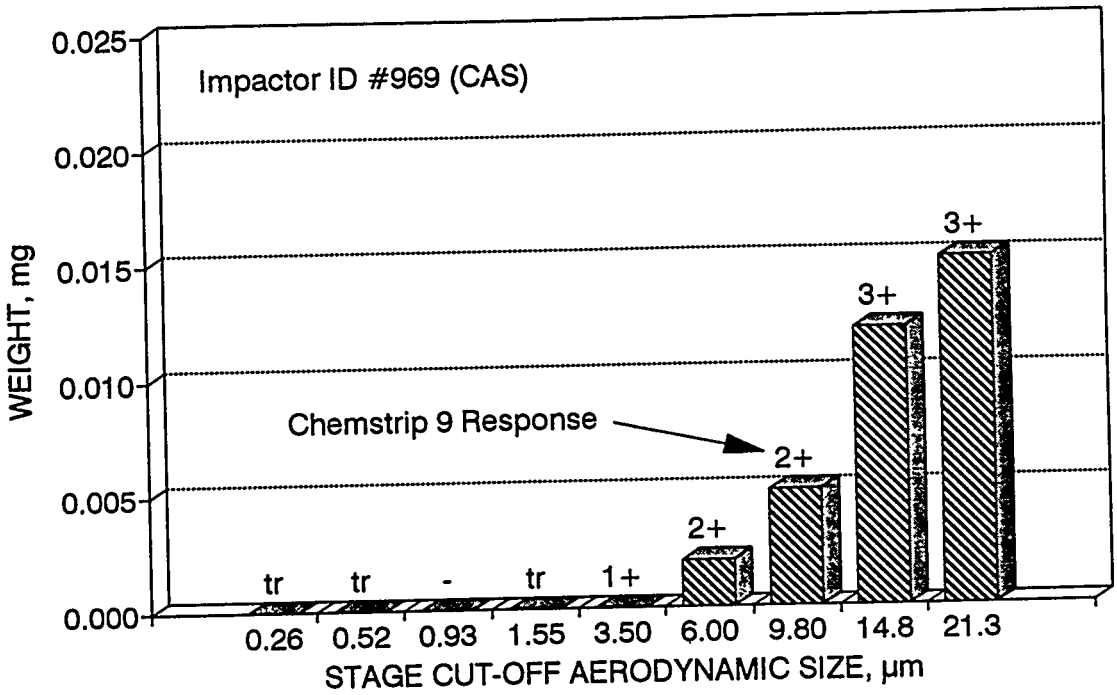
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



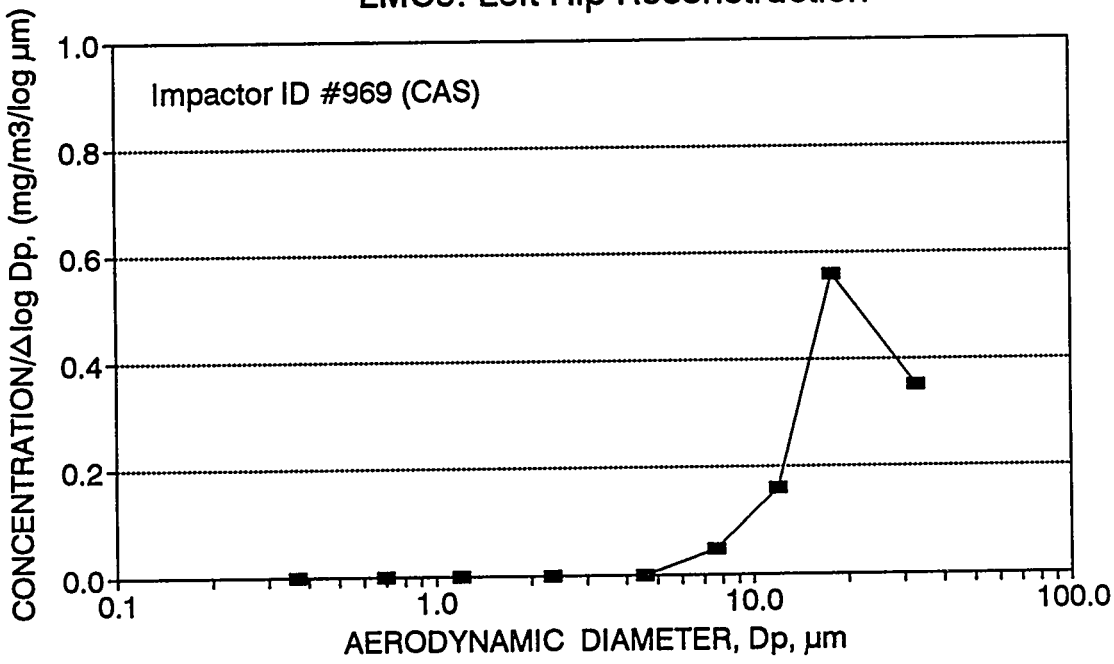
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 969: CAS)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.222	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	tr
8	0.52	0.000	0.99	0.222	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	tr
7	0.93	0.000	0.97	0.222	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	-
6	1.55	0.000	0.96	0.222	0.000	0.190	0.354	0.000	2.33	0.000	0.000	tr
5	3.50	0.000	0.95	0.222	0.000	0.544	0.234	0.000	4.58	0.000	0.000	1+
4	6.00	0.002	0.89	0.222	0.010	0.778	0.213	0.048	7.67	0.039	0.000	2+
3	9.80	0.005	0.78	0.222	0.029	0.991	0.179	0.161	12.04	0.112	0.039	2+
2	14.80	0.012	0.61	0.222	0.089	1.170	0.158	0.560	17.75	0.344	0.151	3+
1	21.30	0.015	0.52	0.222	0.130	1.328	0.371	0.351	32.63	0.505	0.495	3+
	50.00					1.699						
Sum		0.034			0.258					1.000		

Marple Personal Impactor Data
LMC10: Total Left Knee



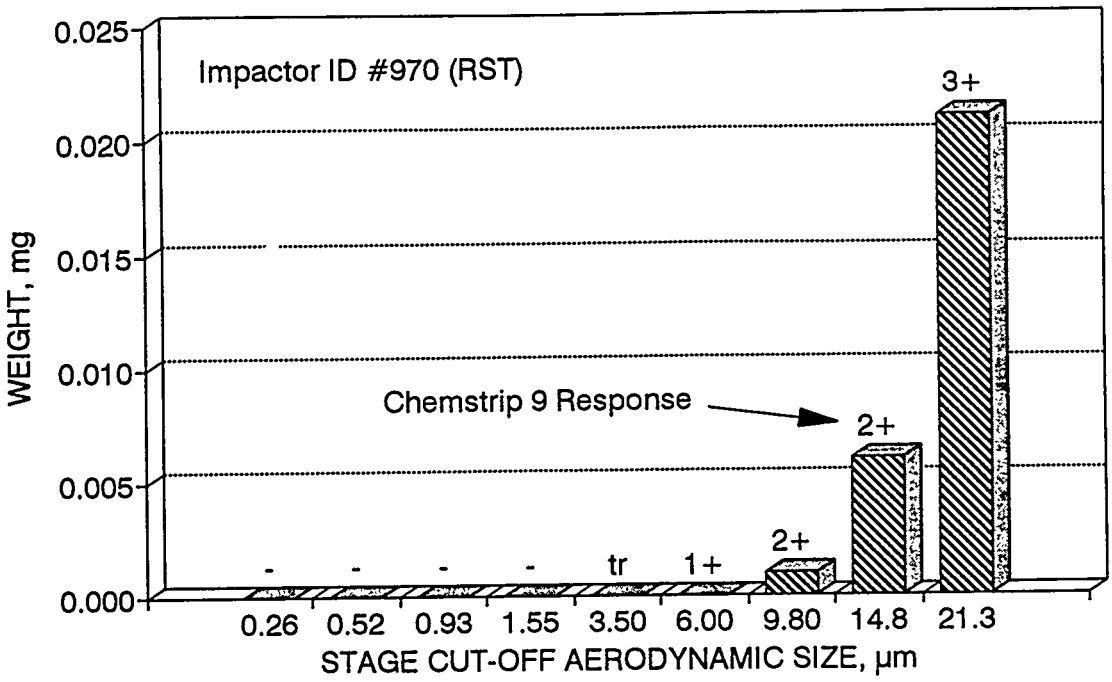
Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



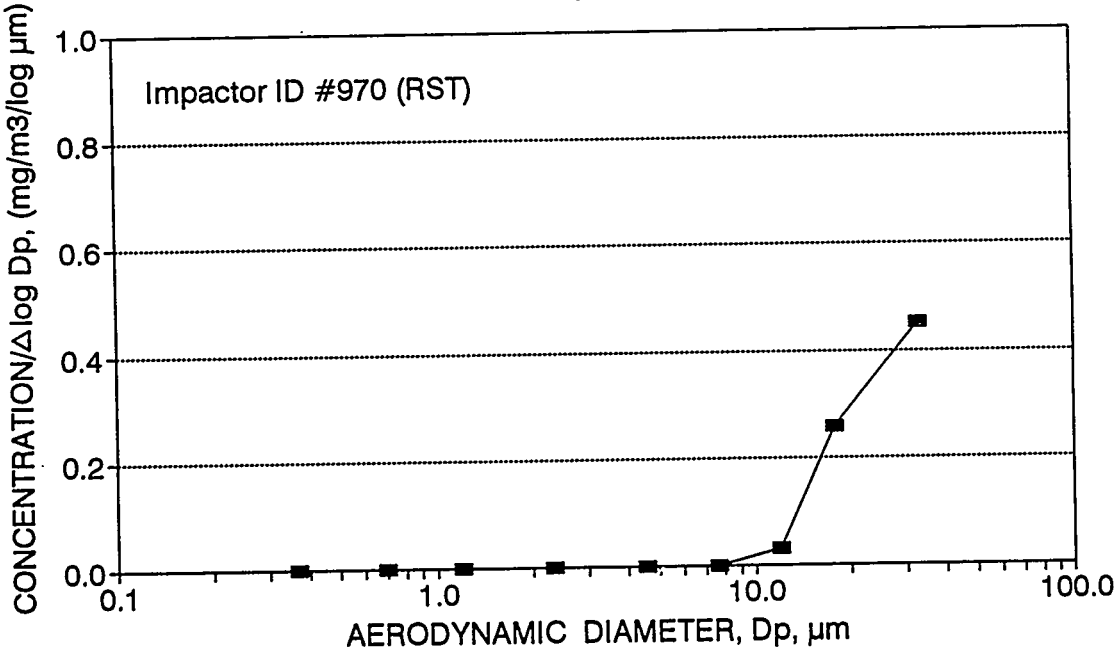
LMC10 Total Knee: Marple Personal Impactor Data (ID No. 970: RST)

A	B	C	D	E	F	G	H	I	J	K	L	M
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD	Chem.9
F	0.26	0.000	1	0.24	0.000	-0.585	0.301	0.000	0.37	0.000	0.000	-
8	0.52	0.000	0.99	0.24	0.000	-0.284	0.252	0.000	0.70	0.000	0.000	-
7	0.93	0.000	0.97	0.24	0.000	-0.032	0.222	0.000	1.20	0.000	0.000	-
6	1.55	0.000	0.96	0.24	0.000	0.190	0.354	0.000	2.33	0.000	0.000	-
5	3.50	0.000	0.95	0.24	0.000	0.544	0.234	0.000	4.58	0.000	0.000	tr
4	6.00	0.000	0.89	0.24	0.000	0.778	0.213	0.000	7.67	0.000	0.000	1+
3	9.80	0.001	0.78	0.24	0.005	0.991	0.179	0.030	12.04	0.025	0.000	2+
2	14.80	0.006	0.61	0.24	0.041	1.170	0.158	0.259	17.75	0.191	0.025	2+
1	21.30	0.021	0.52	0.24	0.168	1.328	0.371	0.454	32.63	0.784	0.216	3+
	50.00					1.699						
Sum		0.028			0.215					1.000		

Marple Personal Impactor Data
LMC10: Total Left Knee



Size distribution by Marple Impactor
LMC9: Left Hip Reconstruction



APPENDIX D

DATA ON Characterization of Aerosols Produced by Total Hip Replacement in Dog Labeled with ^{51}Cr

Abbreviation or Acronyms

A, B, C, ...	column in the table
AJW	assistant
(B)/(E), etc.	column (B) divided by column (E) in the table
BAM	chief surgeon
C	mass concentration, mg/m^3
C.f.	correction factor for sampling efficiency and internal loss
Chem.9	Chemstrip 9 analysis
CPM	count per minute for radioactivity
D_{ae}	aerodynamic diameter, μm
D_p	particle diameter, μm
ECD	effective cut-off diameter, μm
f	fraction
f CPM	fraction of total CPM
f Wt	fraction of total weight or mass
FS1, FS2	filter samples
FSBAK	controlled background filter for counting
GMD	geometric mean diameter, μm
HCY	aerosol staff
LMJ	Lovelace Multi-Jet cascade impactor
MAB	surgeon
RBC	red blood cell
S.D.	standard deviation
TDH	aerosol staff
t	sampling time, sec.
δWt	$= \Delta Wt =$ delta weight

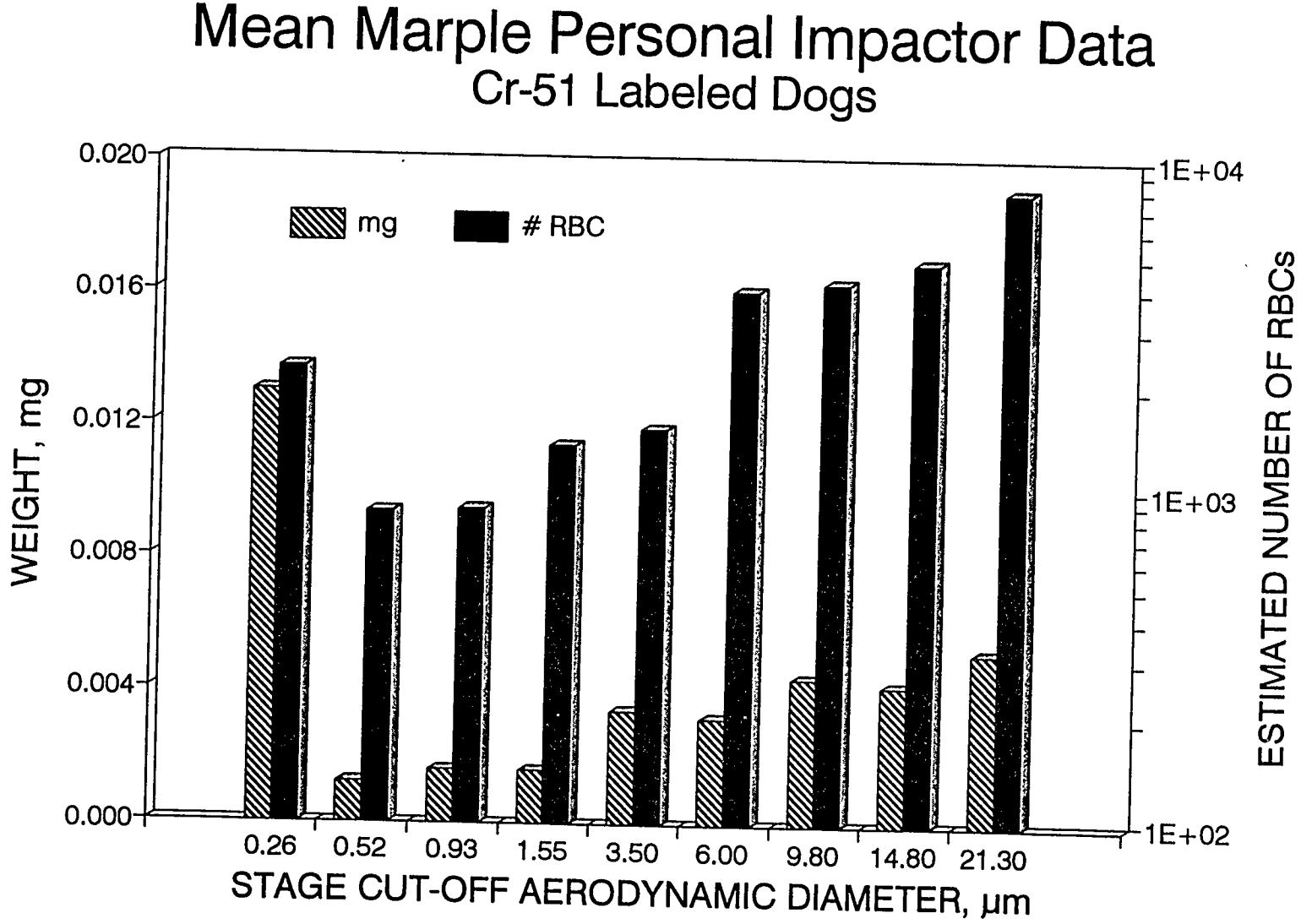
Cr-51 Dogs: Filter Sample Data

Exp ID	F ID	Chem.9	δt, min	δm, mg	C,mg/m3	Ave C,mg/m3	CPM	# RBC	RBC/L	Ave RBC/L
Cr-51_1	FS1	2-3+	30	0.178	0.297	0.179	435.6	104329	174	75
	FS2	2-3+	43	0.083	0.097		22.8	5471	6	
	FSBAK	neg	73	0.000	0.000		0.0	0	0	
Cr-51_2	FS1	1-2+	30	0.115	0.192	0.144	306.5	93067	155	63
	FS2	2+	49	0.112	0.114		22.3	6768	7	
	FSBAK	neg	79	0.000	0.000		0.0	0	0	
Cr-51_3	FS1	2-3+	42	0.073	0.087	0.108	240.3	55296	66	69
	FS2	2+	25	0.072	0.144		158.9	36564	73	
	FSBAK	neg	67	0.000	0.000		0.0		0	
Cr-51_4	FS1	2+	31	0.045	0.073	0.071	85.0	17536	28	20
	FS2	1+	22	0.030	0.068		17.2	3557	8	
	FSBAK	neg	53	0.000	0.000		0.0	0	0	
Cr-51_5	FS1	2+	30	0.121	0.202	0.170	822.3	108262	180	90
	FS2	1-2+	34	0.097	0.143		51.6	6793	10	
	FSBAK	neg	64	0.000	0.000		0.0	0	0	
Average						0.134				63
S.D.						0.040				23
Maximum						0.179				90
Minimum						0.071				20

Cr-51 Dog: Summary of Marple Personal Impactor Data

Stage	ECD, μm	Run 1 δWt, mg	Run 2 δWt, mg	Run 3 δWt, mg	Run 4 δWt, mg	Run 5 δWt, mg	Mean δWt, mg	S.D. δWt, mg	Max. δWt, mg	Min. δWt, mg
F	0.26	0.000	0.011	0.009	0.000	0.045	0.013	0.017	0.045	0.000
8	0.52	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.002	0.001
7	0.93	0.000	0.000	0.001	0.001	0.006	0.002	0.002	0.006	0.000
6	1.55	0.001	0.000	0.002	0.002	0.003	0.002	0.001	0.003	0.000
5	3.50	0.003	0.000	0.004	0.005	0.005	0.003	0.002	0.005	0.000
4	6.00	0.003	0.000	0.004	0.005	0.004	0.003	0.002	0.005	0.000
3	9.80	0.004	0.002	0.005	0.007	0.004	0.004	0.002	0.007	0.002
2	14.80	0.001	0.005	0.003	0.008	0.004	0.004	0.002	0.008	0.001
1	21.30	0.002	0.005	0.011	0.005	0.003	0.005	0.003	0.011	0.002
	50.00									
Sum		0.015	0.024	0.040	0.035	0.075	0.038	0.021	0.075	0.015

Stage	ECD, μm	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC	# RBC
F	0.26	724	4470	973	2418	3189	2355	1396	4470	724
8	0.52	318	2136	292	938	661	869	677	2136	292
7	0.93	175	1995	1	1492	765	886	762	1995	1
6	1.55	695	2576	253	1919	1500	1389	834	2576	253
5	3.50	1654	1	944	3365	1796	1552	1107	3365	1
4	6.00	3062	7939	1355	5156	2789	4060	2288	7939	1355
3	9.80	4351	5783	2568	8608	201	4302	2848	8608	201
2	14.80	5089	8715	2538	8450	74	4973	3348	8715	74
1	21.30	7026	12588	7586	13727	20	8189	4868	13727	20
	50.00									
Sum		23095	46203	16510	46073	10995	28575	14843	46203	10995


Mean Marple Personal Impactor Data
Cr-51 Labeled Dogs
mg
RBC
WEIGHT, mg
0.020
0.016
0.012
0.008
0.004
0.000
ESTIMATED NUMBER OF RBCs
1E+04
1E+03
1E+02
0.26
0.52
0.93
1.55
3.50
6.00
9.80
14.80
21.30
STAGE CUT-OFF AERODYNAMIC DIAMETER, µm

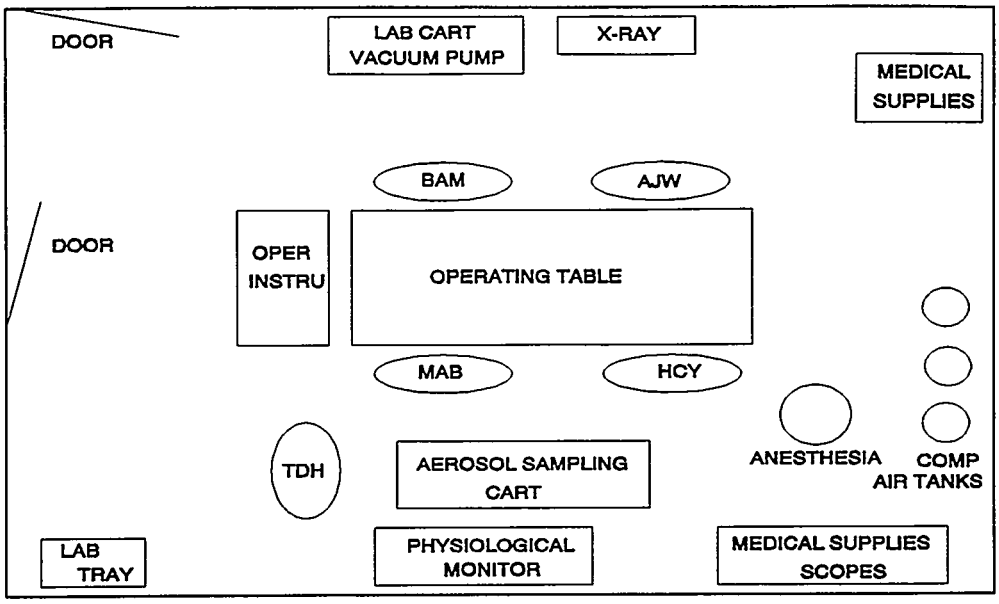


Figure D.1 Personnel locations during ^{51}Cr-labeled dog #1 experiment

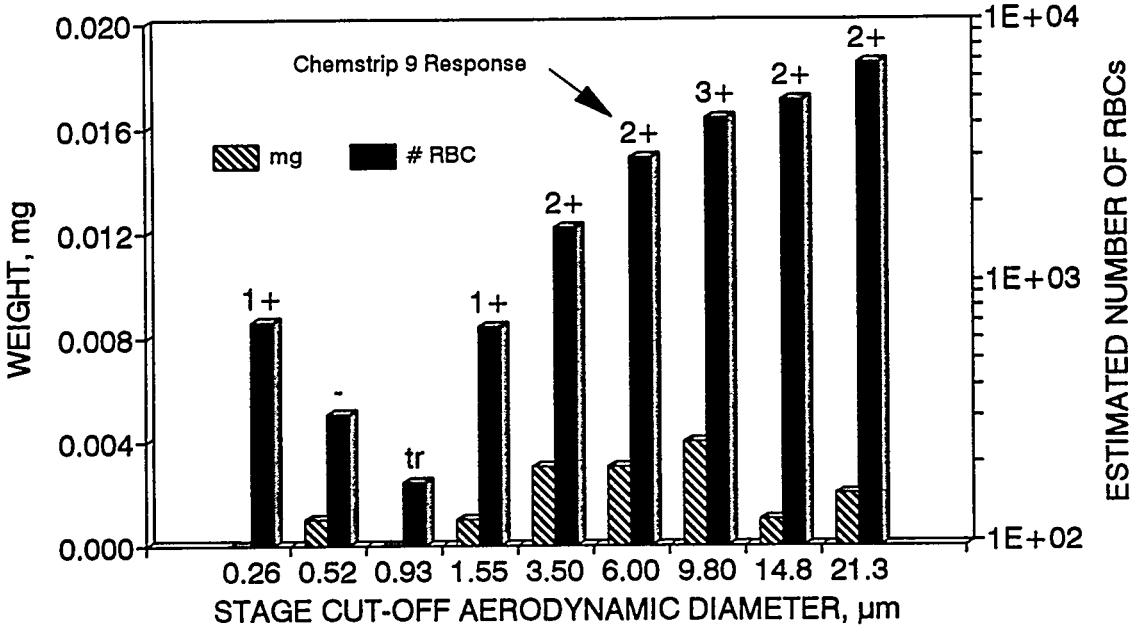
Cr-51 Dog 1: Marple Personal Impactor Data

A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD, μm	δWt, mg	C.f.	S.Vol, m3	C, mg/m3	log Dp	δlog Dp	(F)/(H)	GMD, μm	f Wt	f<ECD
F	0.26	0.000	1	0.15	0.000	-0.585	0.301	0.000	0.37	0.000	0.000
8	0.52	0.001	0.99	0.15	0.007	-0.284	0.252	0.027	0.70	0.053	0.000
7	0.93	0.000	0.97	0.15	0.000	-0.032	0.222	0.000	1.20	0.000	0.053
6	1.55	0.001	0.96	0.15	0.007	0.190	0.354	0.020	2.33	0.054	0.053
5	3.50	0.003	0.95	0.15	0.021	0.544	0.234	0.090	4.58	0.165	0.107
4	6.00	0.003	0.89	0.15	0.022	0.778	0.213	0.105	7.67	0.176	0.271
3	9.80	0.004	0.78	0.15	0.034	0.991	0.179	0.191	12.04	0.267	0.447
2	14.80	0.001	0.61	0.15	0.011	1.170	0.158	0.069	17.75	0.085	0.714
1	21.30	0.002	0.52	0.15	0.026	1.328	0.371	0.069	32.63	0.200	0.800
	50.00					1.699					
Sum		0.015			0.128					1.000	

A	B	M	N	O	P	Q
Stage	ECD, μm	CPM	f CPM	(N)/(H)	# RBC	Chem.9
F	0.26	3.02	0.031	0.104	724	1+
8	0.52	1.33	0.014	0.055	318	-
7	0.93	0.73	0.008	0.034	175	tr
6	1.55	2.9	0.030	0.085	695	1+
5	3.50	6.91	0.072	0.306	1654	2+
4	6.00	12.79	0.133	0.622	3062	2+
3	9.80	18.17	0.188	1.052	4351	3+
2	14.80	21.25	0.220	1.394	5089	2+
1	21.30	29.34	0.304	0.821	7026	2+
	50.00					
Sum		96.44	1.000		23095	

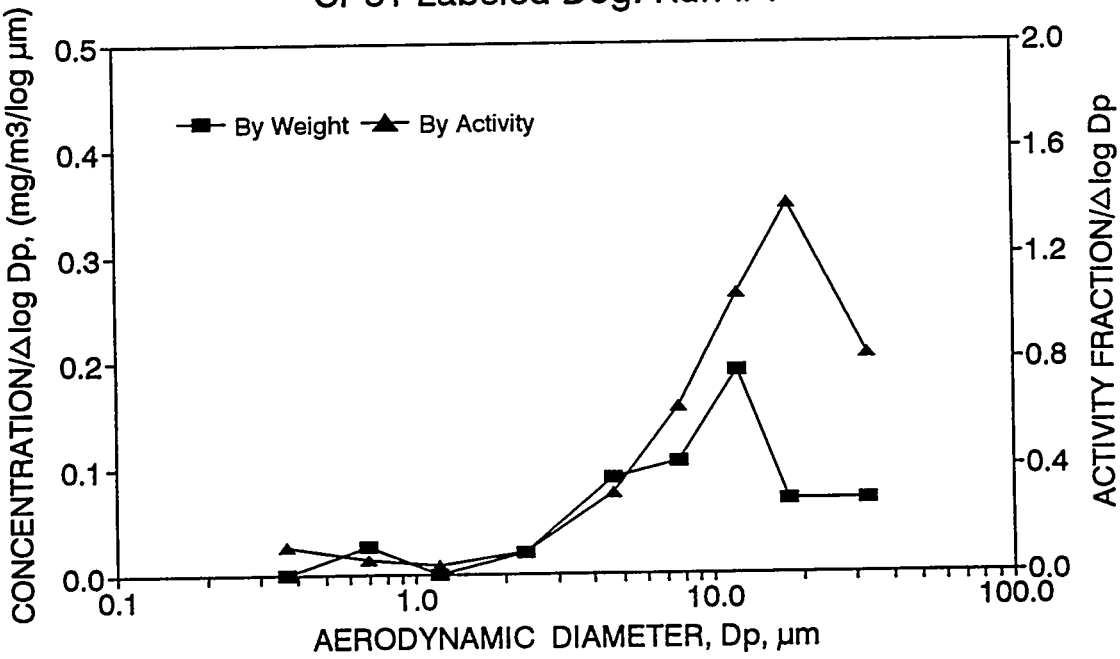
Marple Personal Impactor Data

Cr-51 Labeled Dog: Run #1



Size distribution by Marple Impactor

Cr-51 Labeled Dog: Run #1

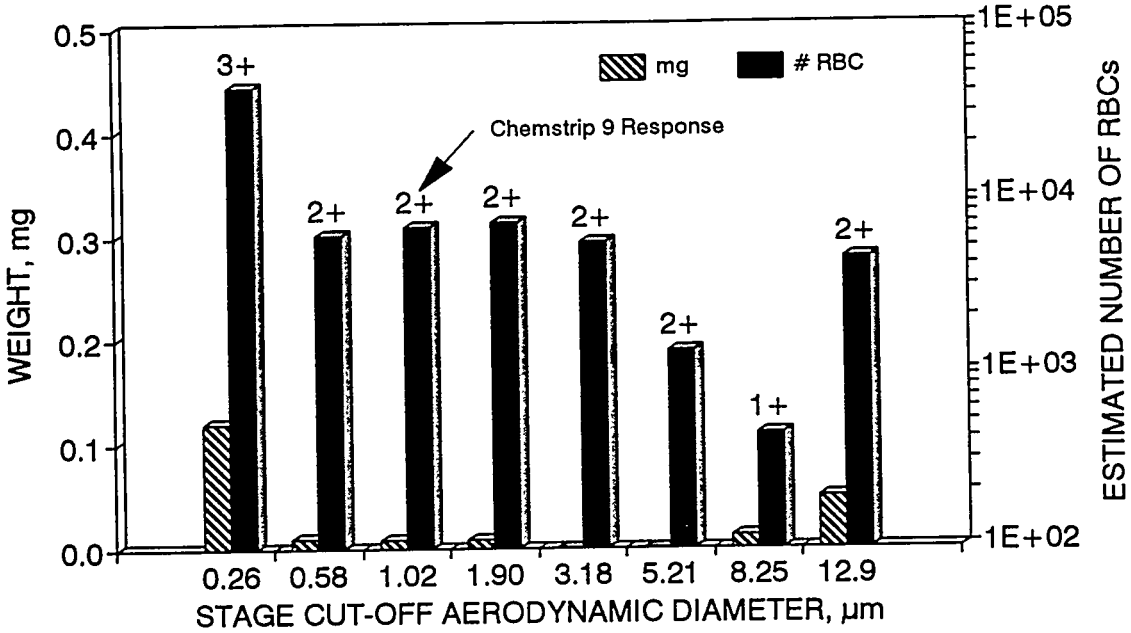


Cr-51 Dog 1: LMJ Impactor Data (ID No. LMJ8106)

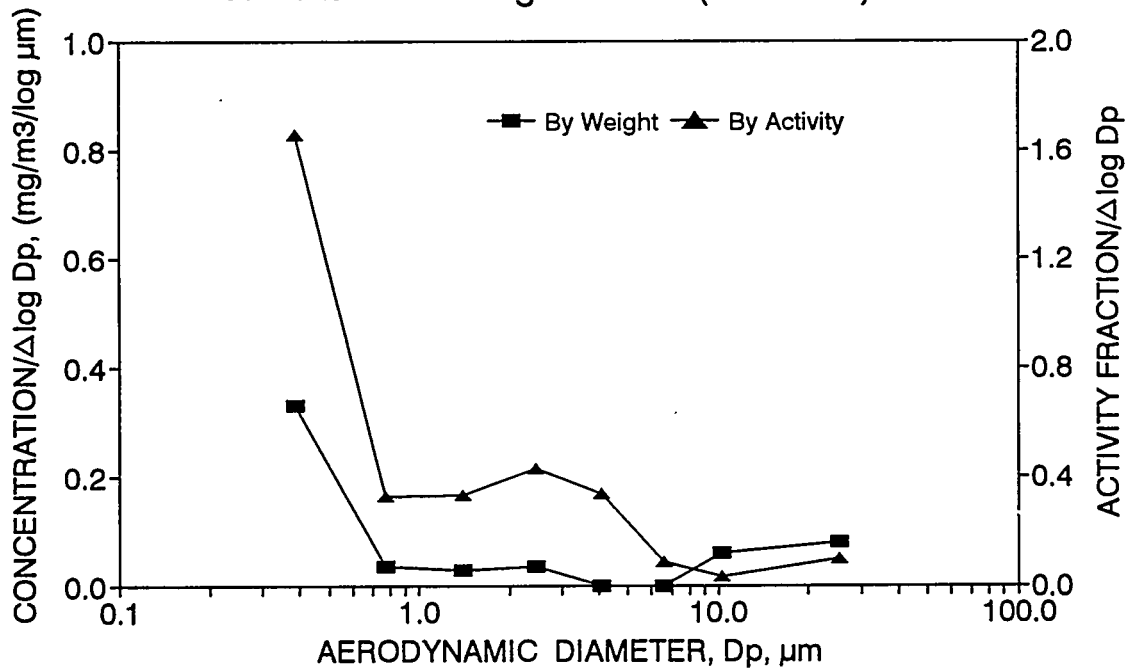
A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD
F	0.26	0.120	1	1.04625	0.115	-0.585	0.348	0.329	0.39	0.583	0.000
7	0.58	0.009	1	1.04625	0.009	-0.237	0.245	0.035	0.77	0.044	0.583
6	1.02	0.008	1	1.04625	0.008	0.009	0.270	0.028	1.39	0.039	0.626
5	1.90	0.008	1	1.04625	0.008	0.279	0.224	0.034	2.46	0.039	0.665
4	3.18	0.000	1	1.04625	0.000	0.502	0.214	0.000	4.07	0.000	0.704
3	5.21	0.000	1	1.04625	0.000	0.717	0.200	0.000	6.56	0.000	0.704
2	8.25	0.012	1	1.04625	0.011	0.916	0.194	0.059	10.31	0.058	0.704
1	12.89	0.049	1	1.04625	0.047	1.110	0.589	0.080	25.39	0.238	0.762
	50.00					1.699					
Sum		0.206			0.197					1.000	

A Stage	B ECD,μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	192.64	0.578	1.659	46139	3+
7	0.58	27.01	0.081	0.331	6468	2+
6	1.02	30.09	0.090	0.334	7207	2+
5	1.90	32.04	0.096	0.430	7674	2+
4	3.18	24.14	0.072	0.338	5781	2+
3	5.21	5.72	0.017	0.086	1369	2+
2	8.25	1.91	0.006	0.030	458	1+
1	12.89	19.73	0.059	0.101	4725	2+
	50.00					
Sum		333.28	1.000		79821	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #1 (LMJ8106)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #1 (LMJ8106)

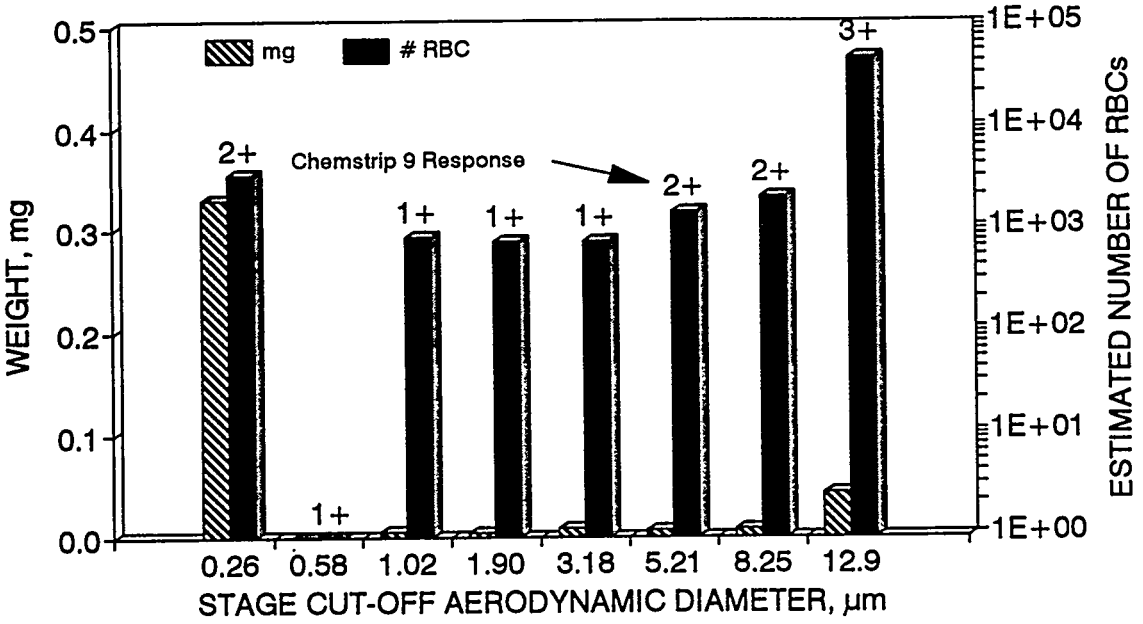


Cr-51 Dog 1: LMJ Impactor Data (ID No. LMJ8380)

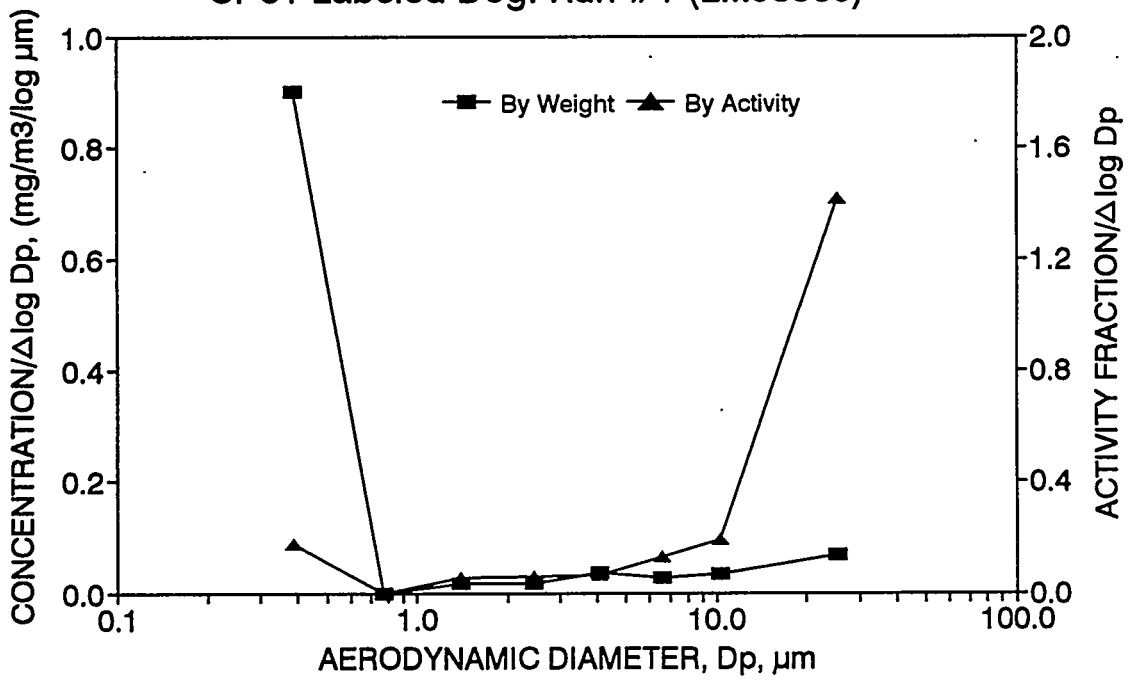
A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD
F	0.26	0.331	1	1.05525	0.314	-0.585	0.348	0.900	0.39	0.819	0.000
7	0.58	0.000	1	1.05525	0.000	-0.237	0.245	0.000	0.77	0.000	0.819
6	1.02	0.005	1	1.05525	0.005	0.009	0.270	0.018	1.39	0.012	0.819
5	1.90	0.004	1	1.05525	0.004	0.279	0.224	0.017	2.46	0.010	0.832
4	3.18	0.008	1	1.05525	0.008	0.502	0.214	0.035	4.07	0.020	0.842
3	5.21	0.006	1	1.05525	0.006	0.717	0.200	0.028	6.56	0.015	0.861
2	8.25	0.007	1	1.05525	0.007	0.916	0.194	0.034	10.31	0.017	0.876
1	12.89	0.043	1	1.05525	0.041	1.110	0.589	0.069	25.39	0.106	0.894
	50.00					1.699					
Sum		0.404			0.383					1.000	

A Stage	B ECD,μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	14.91	0.061	0.175	3570	2+
7	0.58	0.00	0.000	0.000	0	1+
6	1.02	3.65	0.015	0.055	875	1+
5	1.90	3.27	0.013	0.060	784	1+
4	3.18	3.28	0.013	0.062	786	1+
3	5.21	6.37	0.026	0.130	1527	2+
2	8.25	9.00	0.037	0.190	2155	2+
1	12.89	204.45	0.835	1.418	48967	3+
	50.00					
Sum		244.93	1.000		58663	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #1 (LMJ8380)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #1 (LMJ8380)



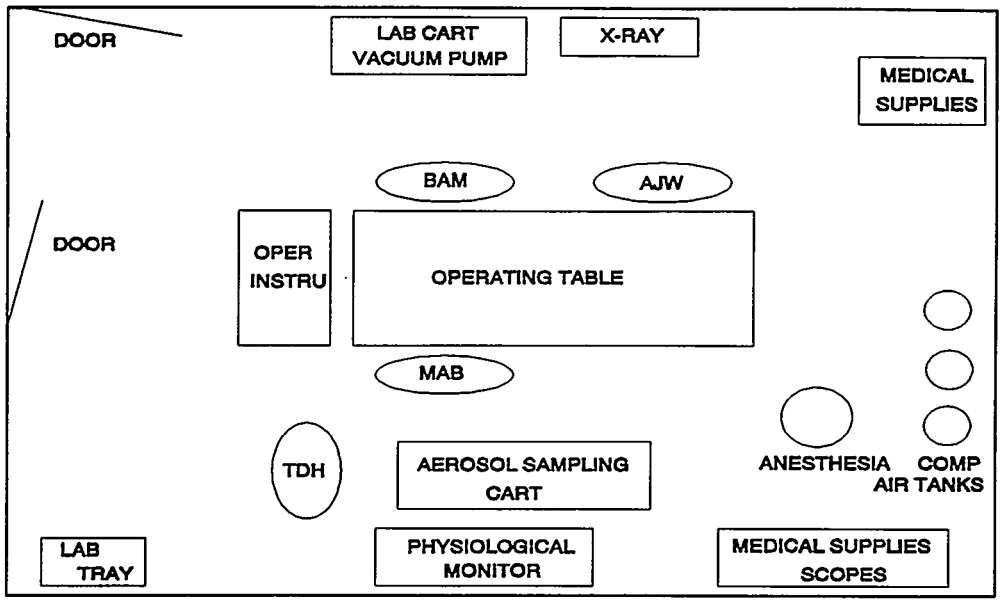


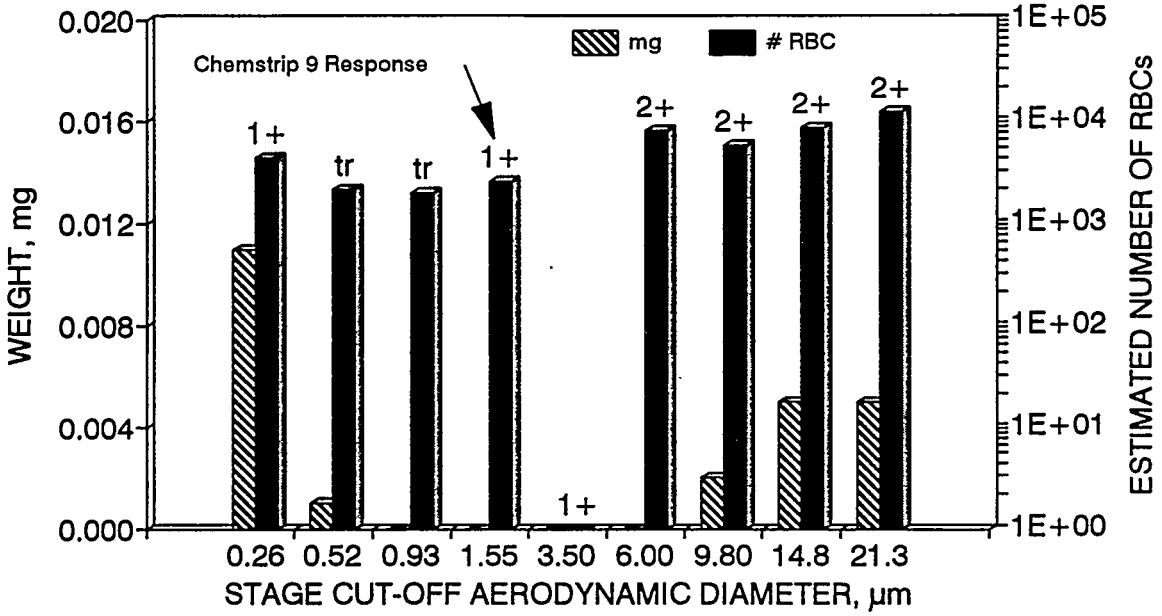
Figure D.2 Personnel locations during ^{51}Cr-labeled dog #2 experiment

Cr-51 Dog 2: Marple Personal Impactor Data

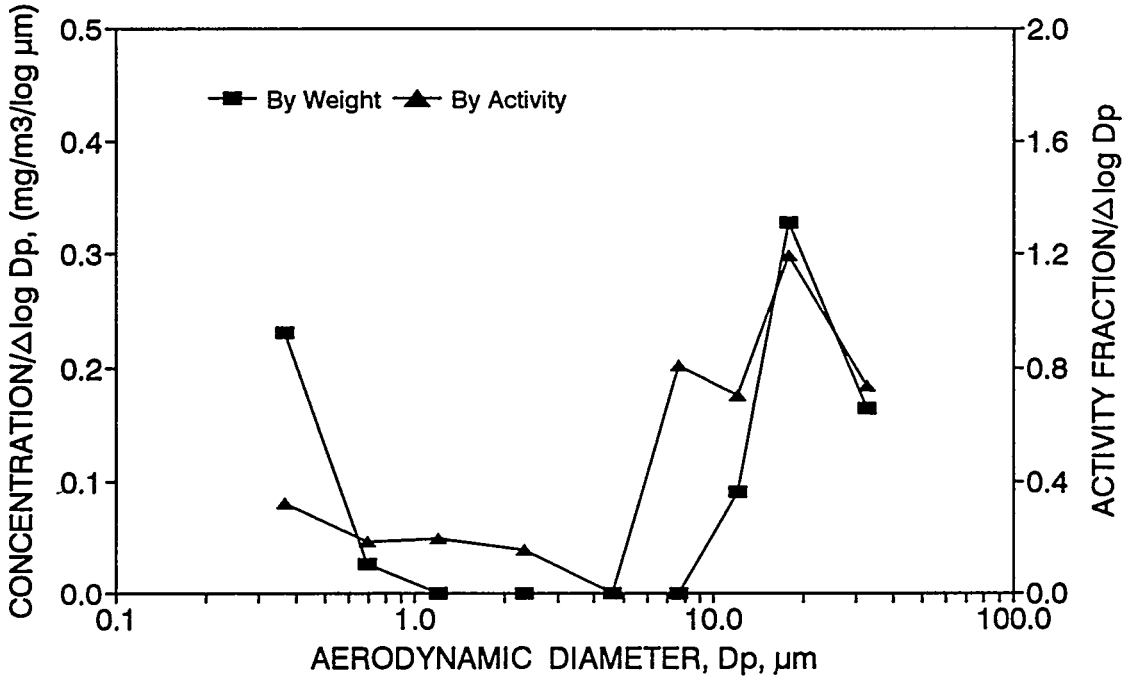
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.011	1	0.158	0.070	-0.585	0.301	0.231	0.37	0.340	0.000
8	0.52	0.001	0.99	0.158	0.006	-0.284	0.252	0.025	0.70	0.031	0.340
7	0.93	0.000	0.97	0.158	0.000	-0.032	0.222	0.000	1.20	0.000	0.371
6	1.55	0.000	0.96	0.158	0.000	0.190	0.354	0.000	2.33	0.000	0.371
5	3.50	0.000	0.95	0.158	0.000	0.544	0.234	0.000	4.58	0.000	0.371
4	6.00	0.000	0.89	0.158	0.000	0.778	0.213	0.000	7.67	0.000	0.371
3	9.80	0.002	0.78	0.158	0.016	0.991	0.179	0.091	12.04	0.079	0.371
2	14.80	0.005	0.61	0.158	0.052	1.170	0.158	0.328	17.75	0.253	0.450
1	21.30	0.005	0.52	0.158	0.061	1.328	0.371	0.164	32.63	0.297	0.703
	50.00					1.699					
Sum		0.024			0.205					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	14.72	0.097	0.321	4470	1+
8	0.52	7.04	0.046	0.183	2136	tr
7	0.93	6.57	0.043	0.195	1995	tr
6	1.55	8.48	0.056	0.158	2576	1+
5	3.50	0	0.000	0.000	0	1+
4	6.00	26.15	0.172	0.806	7939	2+
3	9.80	19.05	0.125	0.699	5783	2+
2	14.80	28.71	0.189	1.193	8715	2+
1	21.30	41.46	0.272	0.735	12588	2+
	50.00					
Sum		152.18	1.000		46202	

Marple Personal Impactor Data
Cr-51 Labeled Dog: Run #2



Size distribution by Marple Impactor
Cr-51 Labeled Dog: Run #2

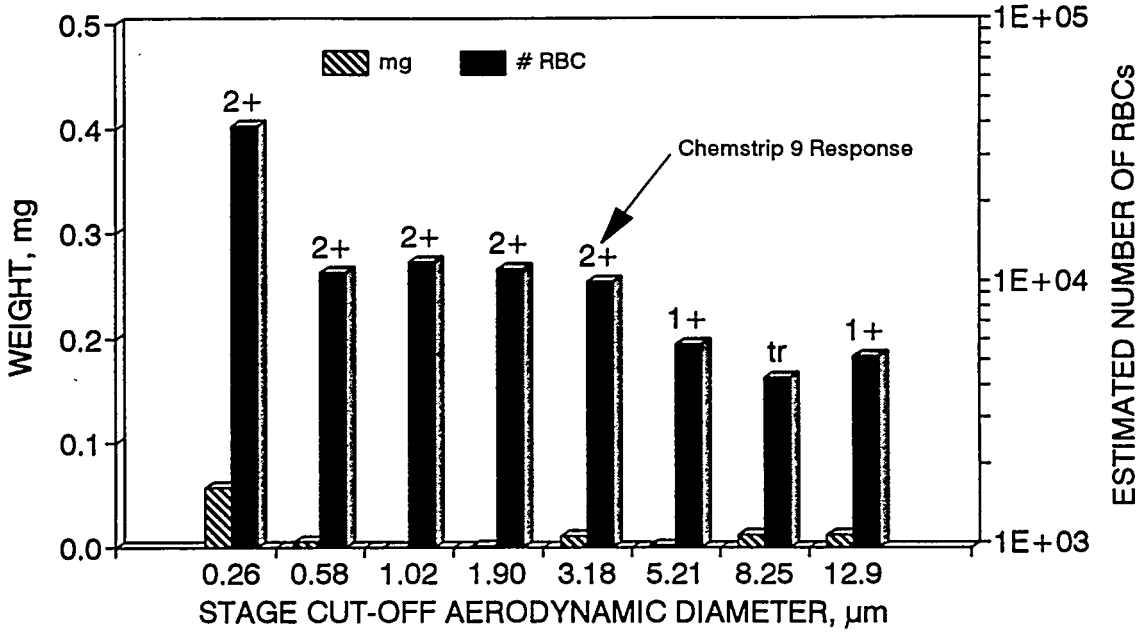


Cr-51 Dog 2: LMJ Impactor Data (ID LMJ8106)

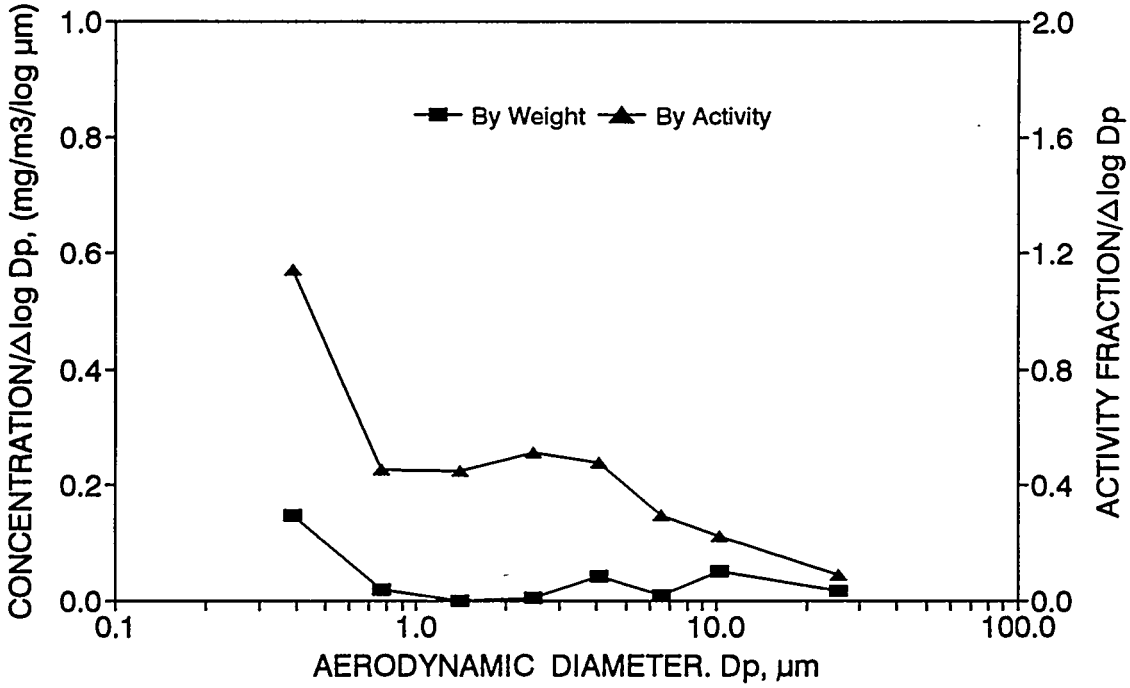
A	B	C	D	E	F	G	H	I	J	K	L
Stage	ECD,μm	δWt,mg	C.f.	S.Vol,m3	C,mg/m3	log Dp	δlog Dp	(F)/(H)	GMD,μm	f Wt	f<ECD
F	0.26	0.057	1	1.10995	0.051	-0.585	0.348	0.147	0.39	0.588	0.000
7	0.58	0.005	1	1.10995	0.005	-0.237	0.245	0.018	0.77	0.052	0.588
6	1.02	0.000	1	1.10995	0.000	0.009	0.270	0.000	1.39	0.000	0.639
5	1.90	0.001	1	1.10995	0.001	0.279	0.224	0.004	2.46	0.010	0.639
4	3.18	0.010	1	1.10995	0.009	0.502	0.214	0.042	4.07	0.103	0.649
3	5.21	0.002	1	1.10995	0.002	0.717	0.200	0.009	6.56	0.021	0.753
2	8.25	0.011	1	1.10995	0.010	0.916	0.194	0.051	10.31	0.113	0.773
1	12.89	0.011	1	1.10995	0.010	1.110	0.589	0.017	25.39	0.113	0.887
	50.00					1.699					
Sum		0.097			0.087					1.000	

A	B	M	N	O	P	Q
Stage	ECD,μm	CPM	f CPM	(N)/(H)	# RBC	Chem.9
F	0.26	133.88	0.398	1.142	40645	2+
7	0.58	37.12	0.110	0.450	11269	2+
6	1.02	40.63	0.121	0.447	12335	2+
5	1.90	38.45	0.114	0.511	11673	2+
4	3.18	34.30	0.102	0.475	10413	2+
3	5.21	19.65	0.058	0.293	5952	1+
2	8.25	14.65	0.044	0.225	4449	tr
1	12.89	17.77	0.053	0.090	5396	1+
	50.00					
Sum		336.45	1.000		102132	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #2 (LMJ8106)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #2 (LMJ8106)

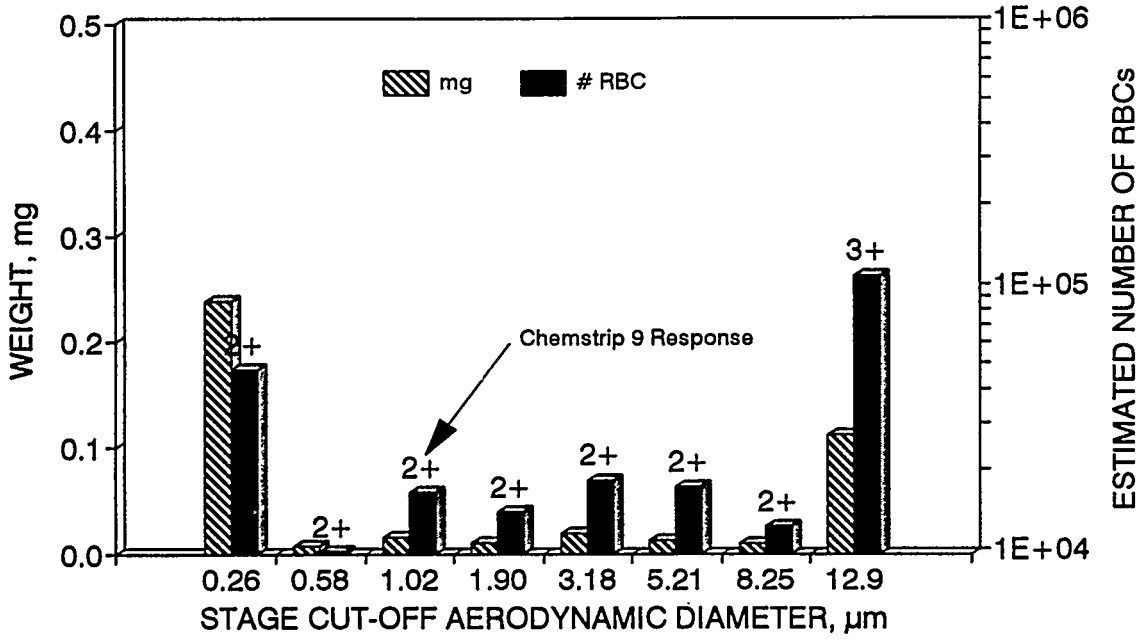


Cr-51 Dog 2: LMJ Impactor Data (ID LMJ8380)

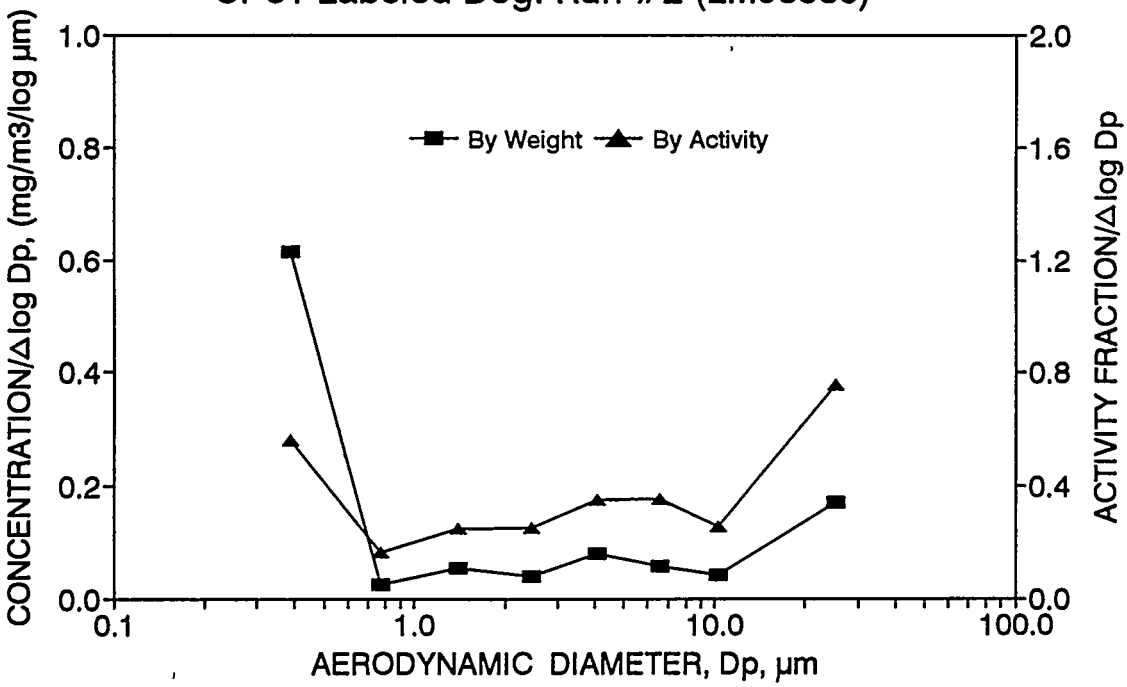
A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD
F	0.26	0.239	1	1.11311	0.215	-0.585	0.348	0.616	0.39	0.562	0.000
7	0.58	0.007	1	1.11311	0.006	-0.237	0.245	0.026	0.77	0.016	0.562
6	1.02	0.016	1	1.11311	0.014	0.009	0.270	0.053	1.39	0.038	0.579
5	1.90	0.010	1	1.11311	0.009	0.279	0.224	0.040	2.46	0.024	0.616
4	3.18	0.019	1	1.11311	0.017	0.502	0.214	0.080	4.07	0.045	0.640
3	5.21	0.013	1	1.11311	0.012	0.717	0.200	0.059	6.56	0.031	0.685
2	8.25	0.009	1	1.11311	0.008	0.916	0.194	0.042	10.31	0.021	0.715
1	12.89	0.112	1	1.11311	0.101	1.110	0.589	0.171	25.39	0.264	0.736
	50.00					1.699					
Sum		0.425			0.382					1.000	

A Stage	B ECD,μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	207.60	0.196	0.561	49722	2+
7	0.58	42.53	0.040	0.163	10186	2+
6	1.02	71.00	0.067	0.248	17005	2+
5	1.90	59.96	0.056	0.252	14360	2+
4	3.18	79.82	0.075	0.351	19117	2+
3	5.21	74.93	0.071	0.354	17946	2+
2	8.25	52.84	0.050	0.257	12655	2+
1	12.89	472.99	0.446	0.757	113266	3+
	50.00					
Sum		1061.67	1.000		254257	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #2 (LMJ8380)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #2 (LMJ8380)



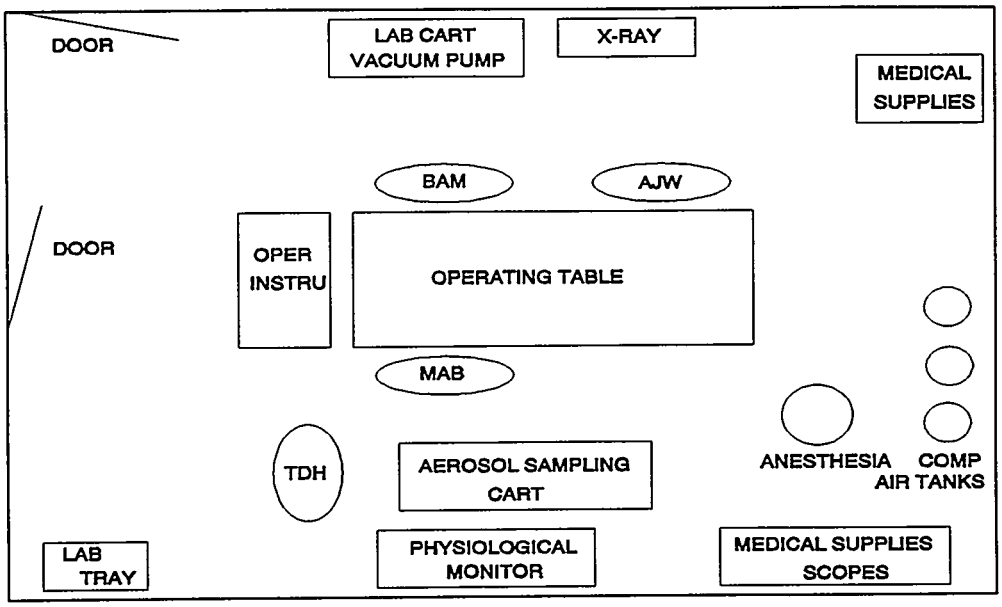


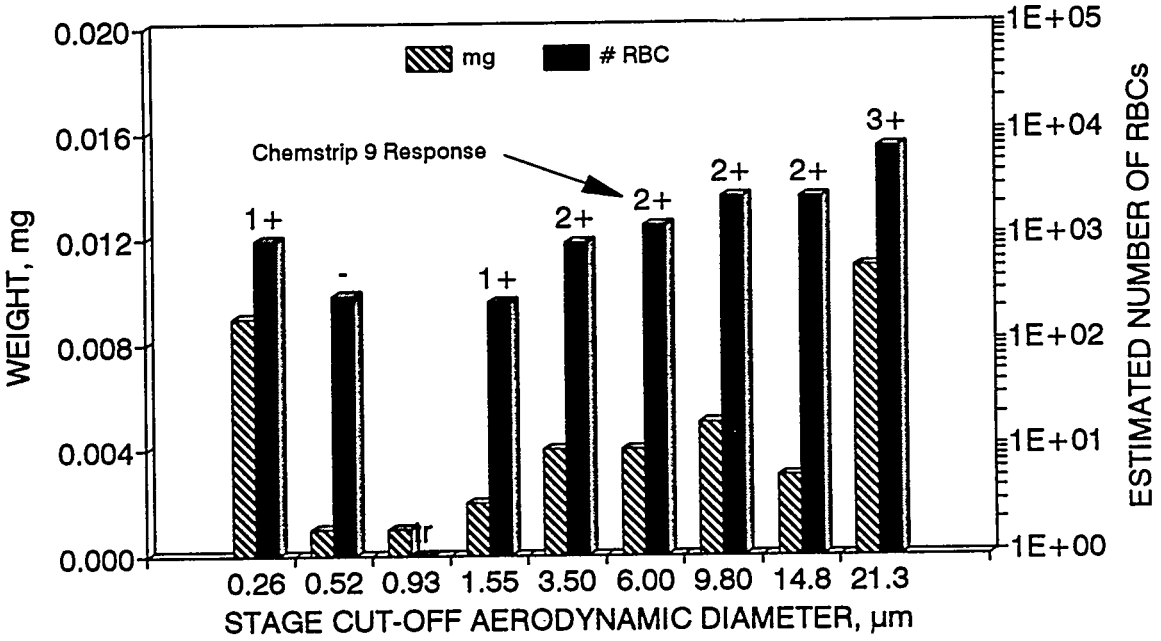
Figure D.3 Personnel locations during ^{51}Cr-labeled dog #3 experiment

Cr-51 Dog 3: Marple Personal Impactor Data

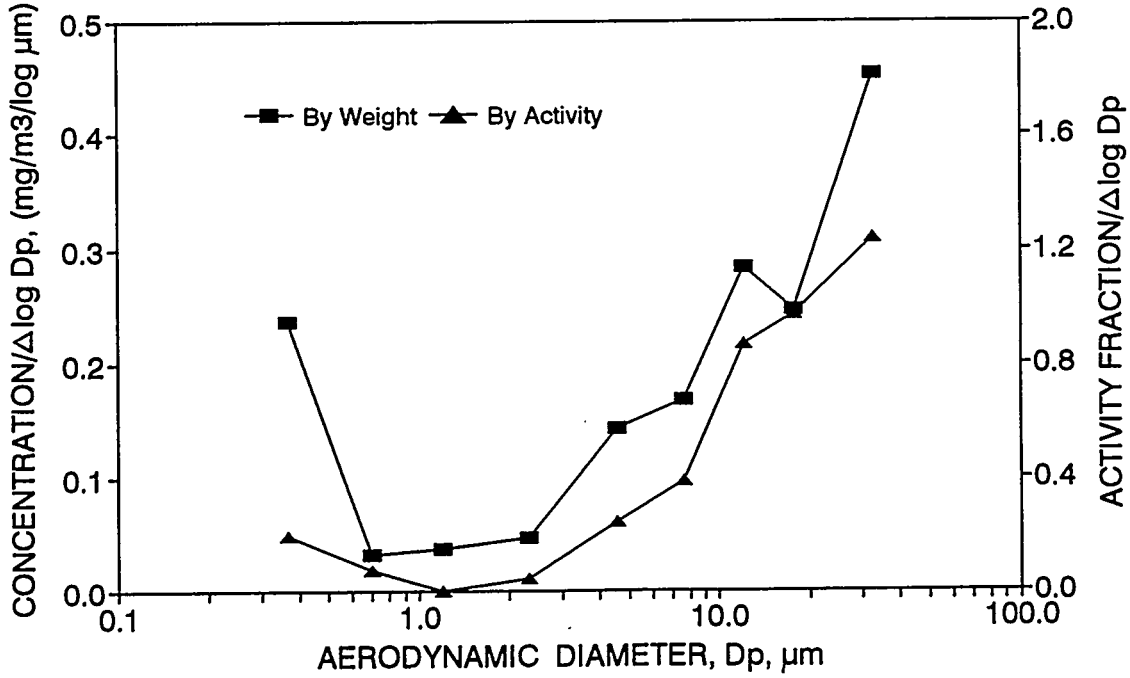
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.009	1	0.126	0.071	-0.585	0.301	0.237	0.37	0.166	0.000
8	0.52	0.001	0.99	0.126	0.008	-0.284	0.252	0.032	0.70	0.019	0.166
7	0.93	0.001	0.97	0.126	0.008	-0.032	0.222	0.037	1.20	0.019	0.184
6	1.55	0.002	0.96	0.126	0.017	0.190	0.354	0.047	2.33	0.038	0.203
5	3.50	0.004	0.95	0.126	0.033	0.544	0.234	0.143	4.58	0.078	0.242
4	6.00	0.004	0.89	0.126	0.036	0.778	0.213	0.167	7.67	0.083	0.319
3	9.80	0.005	0.78	0.126	0.051	0.991	0.179	0.284	12.04	0.118	0.402
2	14.80	0.003	0.61	0.126	0.039	1.170	0.158	0.247	17.75	0.091	0.520
1	21.30	0.011	0.52	0.126	0.168	1.328	0.371	0.453	32.63	0.389	0.611
	50.00					1.699					
Sum		0.040			0.431					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	4.23	0.059	0.196	973	1+
8	0.52	1.27	0.018	0.070	292	-
7	0.93	0	0.000	0.000	0	tr
6	1.55	1.1	0.015	0.043	253	1+
5	3.50	4.1	0.057	0.244	944	2+
4	6.00	5.89	0.082	0.385	1355	2+
3	9.80	11.16	0.156	0.869	2568	2+
2	14.80	11.03	0.154	0.972	2538	2+
1	21.30	32.97	0.460	1.240	7586	3+
	50.00					
Sum		71.75	1.000		16509	

Marple Personal Impactor Data
Cr-51 Labeled Dog: Run #3



Size distribution by Marple Impactor
Cr-51 Labeled Dog: Run #3

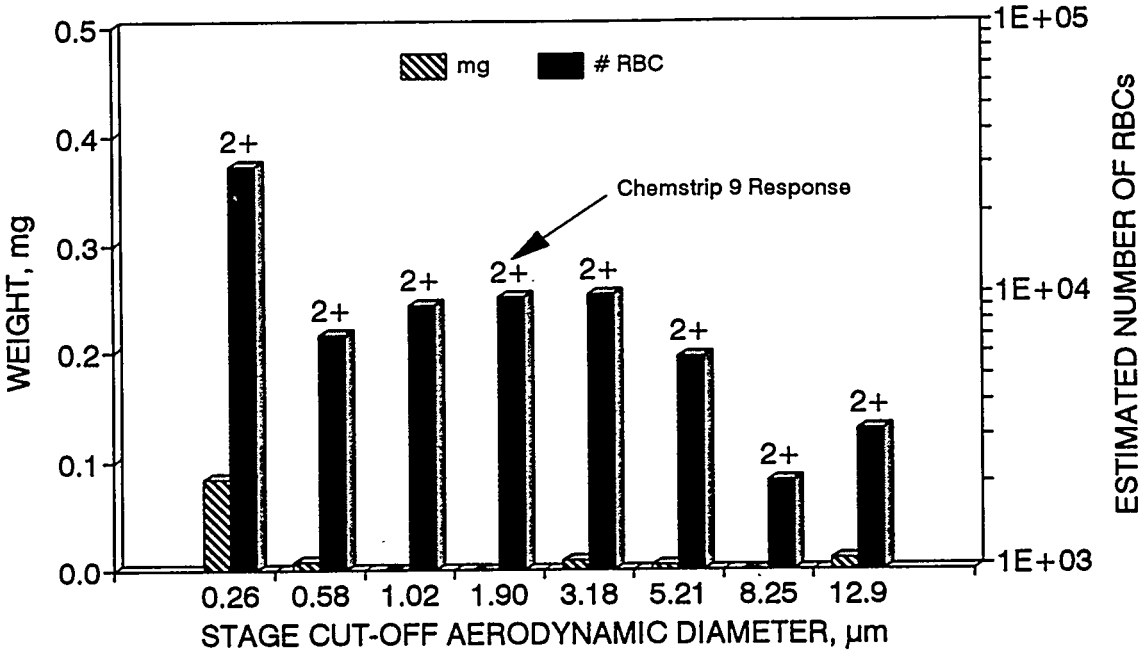


Cr-51 Dog 3: LMJ Impactor Data (ID LMJ8106)

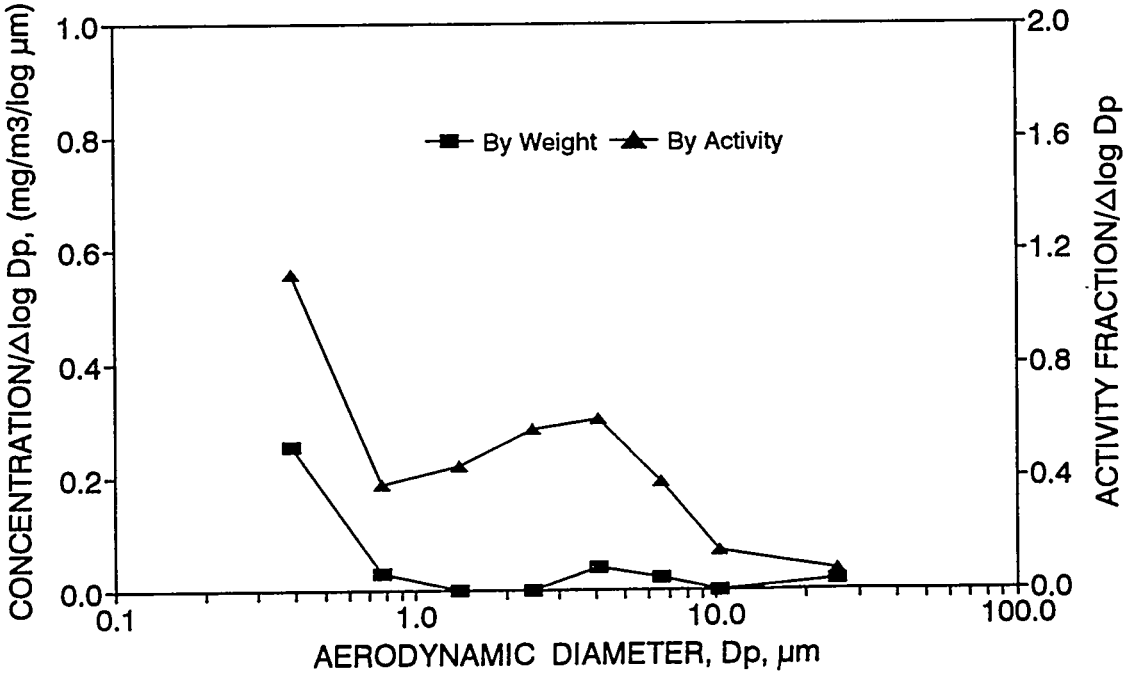
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.084	1	0.9486	0.089	-0.585	0.348	0.254	0.39	0.743	0.000
7	0.58	0.007	1	0.9486	0.007	-0.237	0.245	0.030	0.77	0.062	0.743
6	1.02	0.000	1	0.9486	0.000	0.009	0.270	0.000	1.39	0.000	0.805
5	1.90	0.000	1	0.9486	0.000	0.279	0.224	0.000	2.46	0.000	0.805
4	3.18	0.008	1	0.9486	0.008	0.502	0.214	0.039	4.07	0.071	0.805
3	5.21	0.004	1	0.9486	0.004	0.717	0.200	0.021	6.56	0.035	0.876
2	8.25	0.000	1	0.9486	0.000	0.916	0.194	0.000	10.31	0.000	0.912
1	12.89	0.010	1	0.9486	0.011	1.110	0.589	0.018	25.39	0.088	0.912
	50.00					1.699					
Sum		0.113			0.119					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	134.26	0.389	1.116	30893	2+
7	0.58	31.78	0.092	0.376	7311	2+
6	1.02	40.92	0.119	0.439	9416	2+
5	1.90	43.69	0.127	0.566	10054	2+
4	3.18	44.56	0.129	0.602	10254	2+
3	5.21	26.34	0.076	0.382	6060	2+
2	8.25	9.24	0.027	0.138	2127	2+
1	12.89	14.36	0.042	0.071	3304	2+
	50.00					
Sum		345.15	1.000		79419	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #3 (LMJ8106)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #3 (LMJ8106)

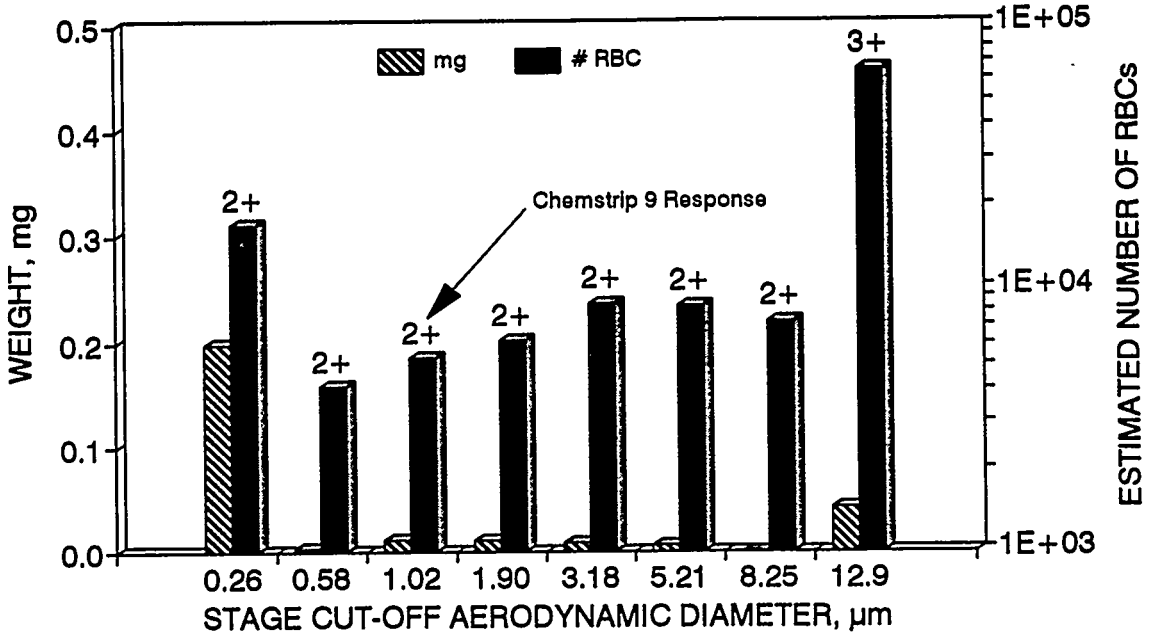


Cr-51 Dog 3: LMJ Impactor Data (ID LMJ8380)

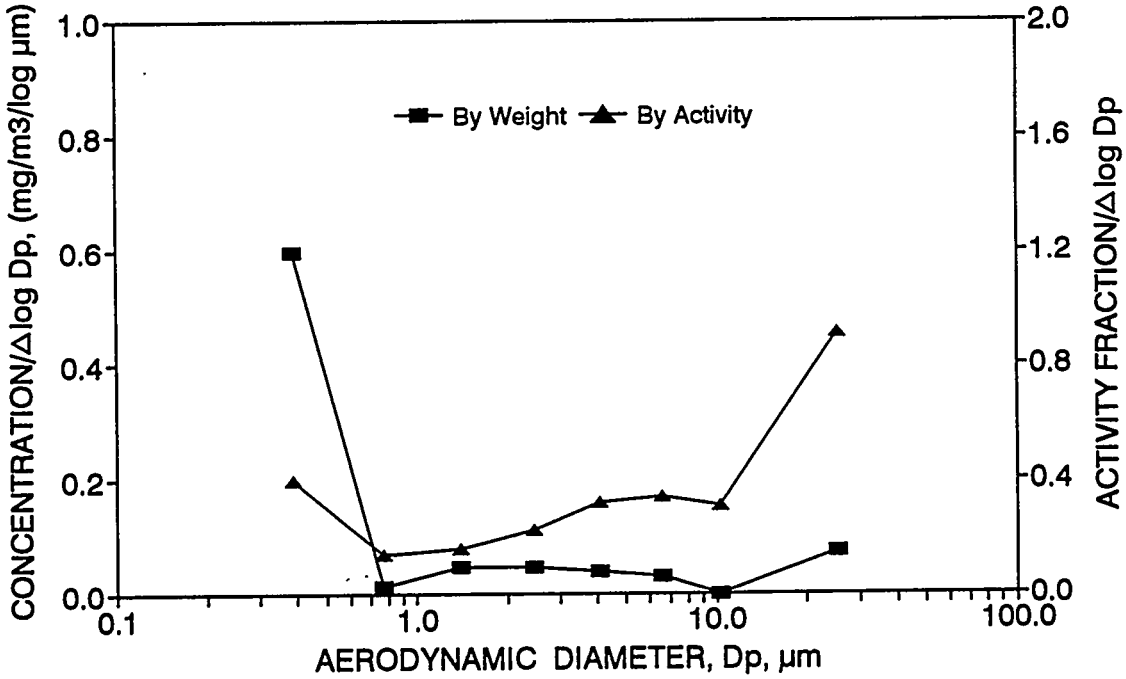
A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD
F	0.26	0.199	1	0.95472	0.208	-0.585	0.348	0.598	0.39	0.711	0.000
7	0.58	0.003	1	0.95472	0.003	-0.237	0.245	0.013	0.77	0.011	0.711
6	1.02	0.012	1	0.95472	0.013	0.009	0.270	0.047	1.39	0.043	0.721
5	1.90	0.010	1	0.95472	0.010	0.279	0.224	0.047	2.46	0.036	0.764
4	3.18	0.008	1	0.95472	0.008	0.502	0.214	0.039	4.07	0.029	0.800
3	5.21	0.006	1	0.95472	0.006	0.717	0.200	0.031	6.56	0.021	0.829
2	8.25	0.000	1	0.95472	0.000	0.916	0.194	0.000	10.31	0.000	0.850
1	12.89	0.042	1	0.95472	0.044	1.110	0.589	0.075	25.39	0.150	0.850
	50.00					1.699					
Sum		0.280			0.293					1.000	

A Stage	B ECD,μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	76.77	0.139	0.398	17666	2+
7	0.58	18.69	0.034	0.138	4301	2+
6	1.02	23.89	0.043	0.160	5496	2+
5	1.90	27.82	0.050	0.225	6402	2+
4	3.18	38.36	0.069	0.323	8827	2+
3	5.21	37.90	0.068	0.343	8722	2+
2	8.25	33.03	0.060	0.308	7600	2+
1	12.89	297.37	0.537	0.912	68426	3+
	50.00					
Sum		553.83	1.000		127440	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #3 (LMJ8380)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #3 (LMJ8380)



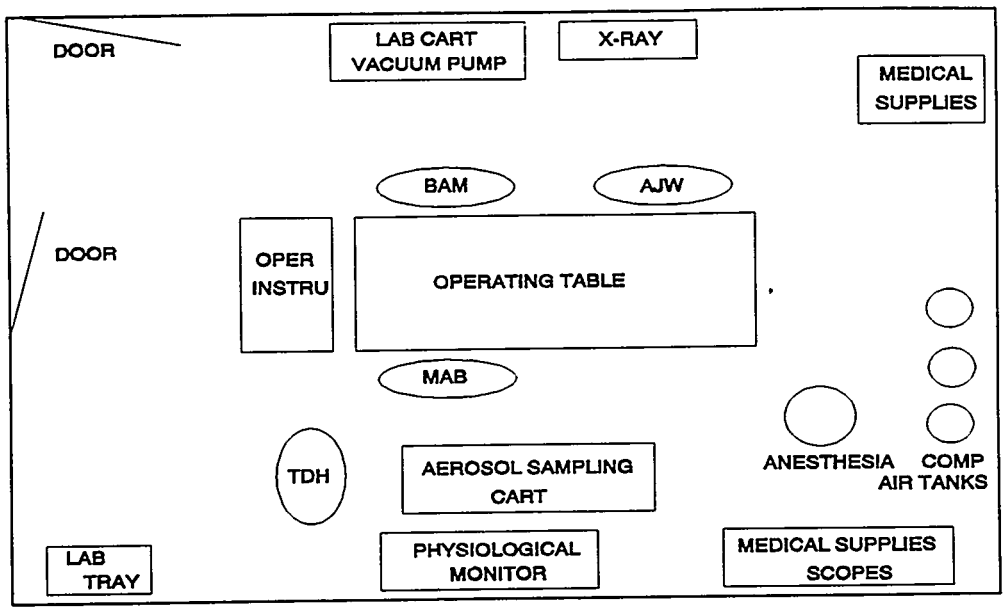


Figure D.4 Personnel locations during ^{51}Cr-labeled dog #4 experiment

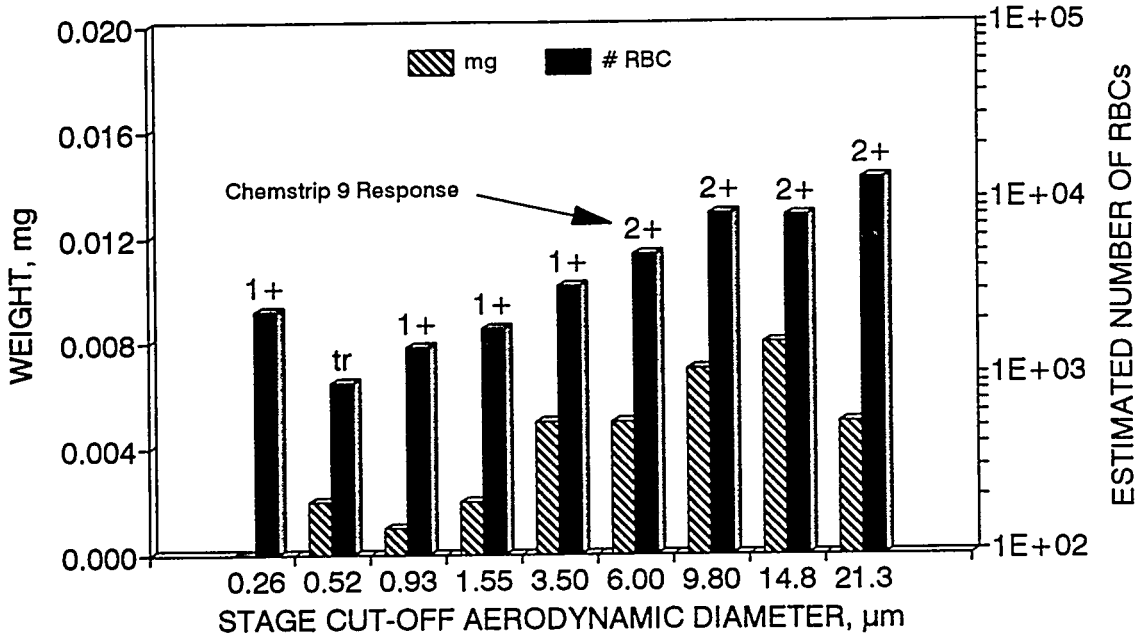
Cr-51 Dog 4: Marple Personal Impactor Data

A Stage	B ECD,μm	C δWt,mg	D C.f.	E S.Vol,m3	F C,mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD,μm	K f Wt	L f<ECD
F	0.26	0.000	1	0.108	0.000	-0.585	0.301	0.000	0.37	0.000	0.000
8	0.52	0.002	0.99	0.108	0.019	-0.284	0.252	0.074	0.70	0.042	0.000
7	0.93	0.001	0.97	0.108	0.010	-0.032	0.222	0.043	1.20	0.022	0.042
6	1.55	0.002	0.96	0.108	0.019	0.190	0.354	0.055	2.33	0.044	0.064
5	3.50	0.005	0.95	0.108	0.049	0.544	0.234	0.208	4.58	0.110	0.108
4	6.00	0.005	0.89	0.108	0.052	0.778	0.213	0.244	7.67	0.118	0.218
3	9.80	0.007	0.78	0.108	0.083	0.991	0.179	0.464	12.04	0.188	0.336
2	14.80	0.008	0.61	0.108	0.121	1.170	0.158	0.768	17.75	0.275	0.524
1	21.30	0.005	0.52	0.108	0.089	1.328	0.371	0.240	32.63	0.201	0.799
	50.00					1.699					
Sum		0.035			0.442					1.000	

A Stage	B ECD,μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	11.72	0.052	0.174	2418	1+
8	0.52	4.55	0.020	0.081	938	tr
7	0.93	7.23	0.032	0.146	1492	1+
6	1.55	9.3	0.042	0.118	1919	1+
5	3.50	16.31	0.073	0.312	3365	1+
4	6.00	24.99	0.112	0.525	5156	2+
3	9.80	41.72	0.187	1.044	8608	2+
2	14.80	40.95	0.183	1.160	8450	2+
1	21.30	66.52	0.298	0.804	13727	2+
	50.00					
Sum		223.29	1.000		46073	

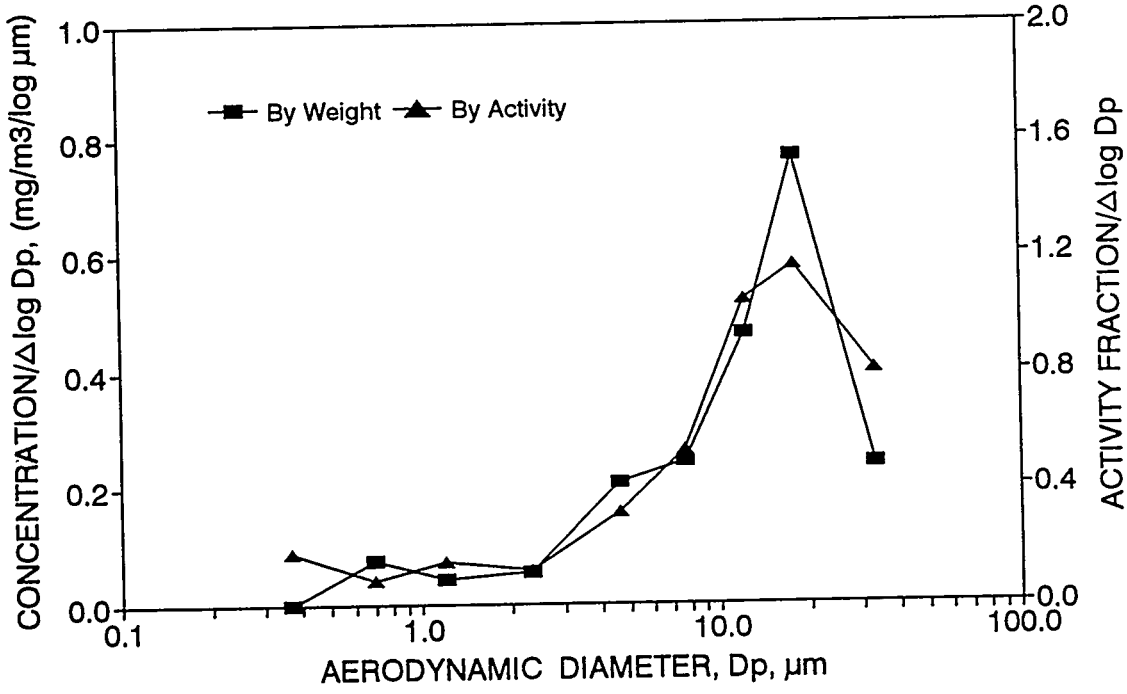
Marple Personal Impactor Data

Cr-51 Labeled Dog: Run #4



Size distribution by Marple Impactor

Cr-51 Labeled Dog: Run #4

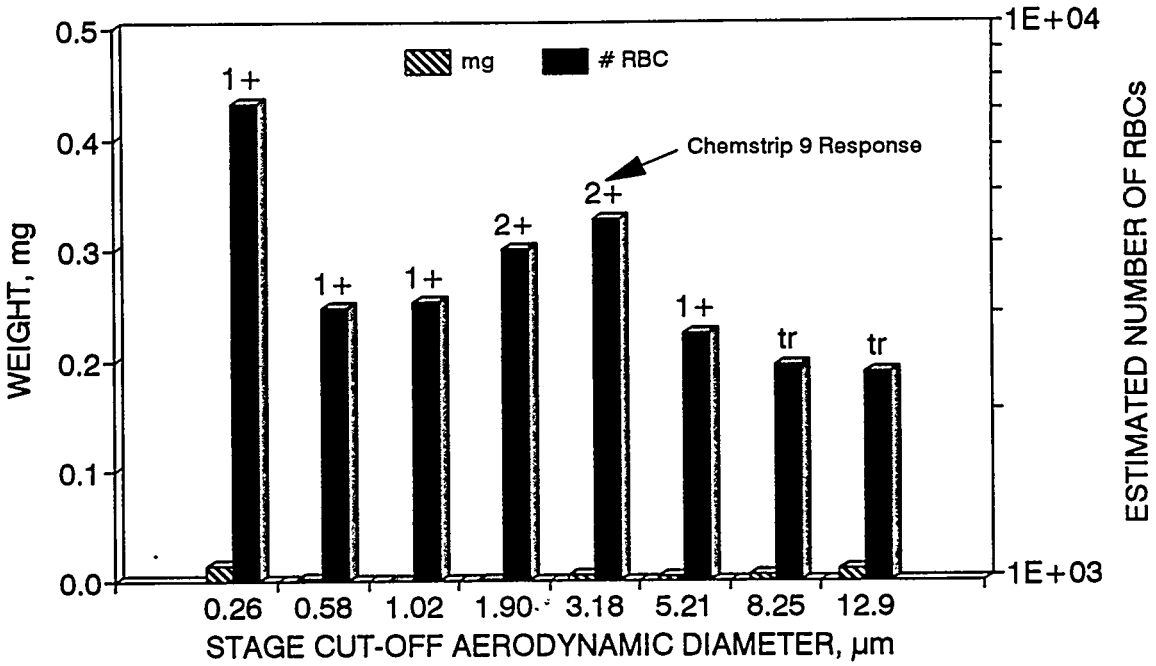


Cr-51 Dog 4: LMJ Impactor Data (ID LMJ8106)

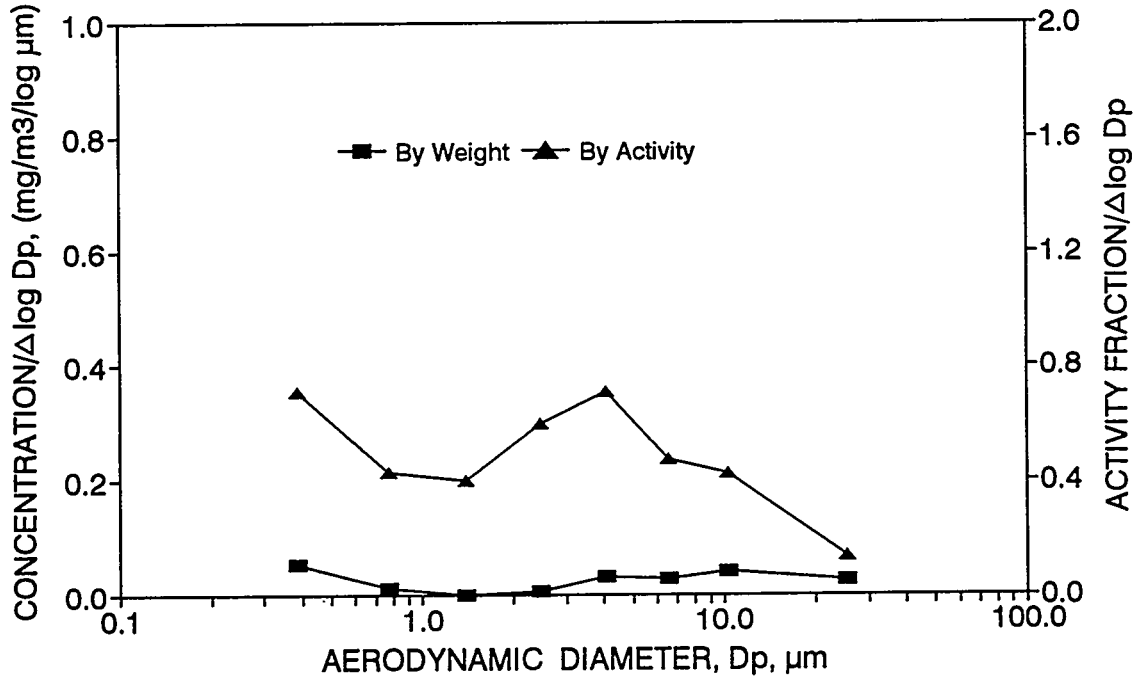
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.014	1	0.75276	0.019	-0.585	0.348	0.053	0.39	0.326	0.000
7	0.58	0.002	1	0.75276	0.003	-0.237	0.245	0.011	0.77	0.047	0.326
6	1.02	0.000	1	0.75276	0.000	0.009	0.270	0.000	1.39	0.000	0.372
5	1.90	0.001	1	0.75276	0.001	0.279	0.224	0.006	2.46	0.023	0.372
4	3.18	0.005	1	0.75276	0.007	0.502	0.214	0.031	4.07	0.116	0.395
3	5.21	0.004	1	0.75276	0.005	0.717	0.200	0.027	6.56	0.093	0.512
2	8.25	0.006	1	0.75276	0.008	0.916	0.194	0.041	10.31	0.140	0.605
1	12.89	0.011	1	0.75276	0.015	1.110	0.589	0.025	25.39	0.256	0.744
	50.00					1.699					
Sum		0.043			0.057					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	35.67	0.246	0.707	7361	1+
7	0.58	15.18	0.105	0.428	3131	1+
6	1.02	15.52	0.107	0.397	3202	1+
5	1.90	19.29	0.133	0.596	3981	2+
4	3.18	22.00	0.152	0.709	4539	2+
3	5.21	13.64	0.094	0.472	2815	1+
2	8.25	11.90	0.082	0.424	2455	tr
1	12.89	11.56	0.080	0.136	2386	tr
	50.00					
Sum		144.76	1.000		29870	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #4 (LMJ8106)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #4 (LMJ8106)



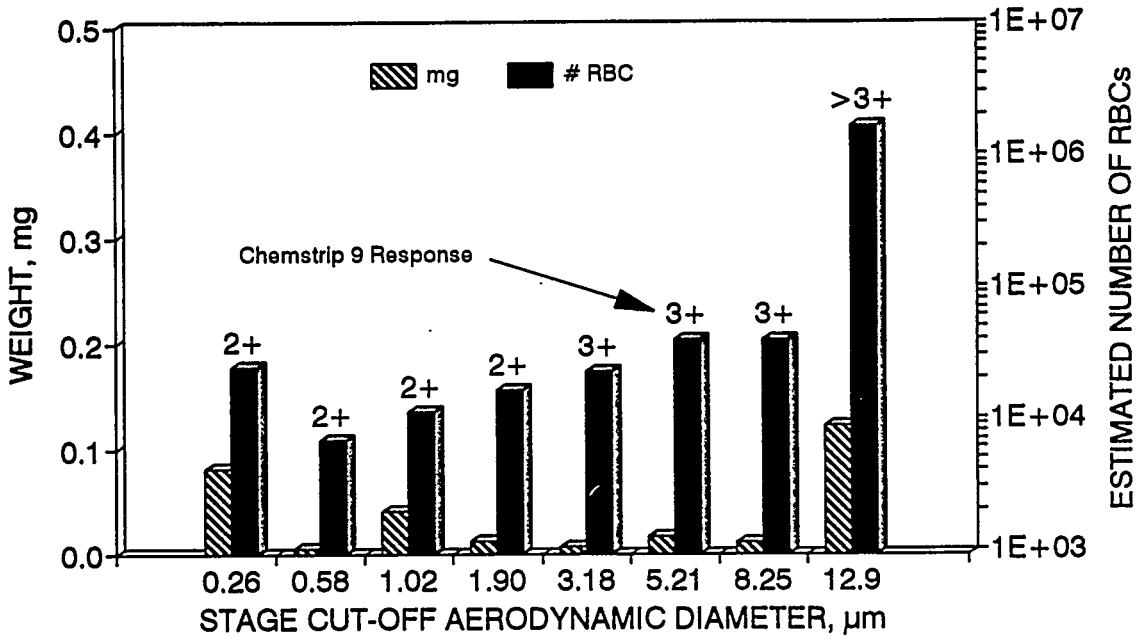
Cr-51 Dog 4: LMJ Impactor Data (ID LMJ8380)

A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.081	1	0.75816	0.107	-0.585	0.348	0.307	0.39	0.273	0.000
7	0.58	0.005	1	0.75816	0.007	-0.237	0.245	0.027	0.77	0.017	0.273
6	1.02	0.041	1	0.75816	0.054	0.009	0.270	0.200	1.39	0.138	0.290
5	1.90	0.012	1	0.75816	0.016	0.279	0.224	0.071	2.46	0.040	0.428
4	3.18	0.007	1	0.75816	0.009	0.502	0.214	0.043	4.07	0.024	0.468
3	5.21	0.017	1	0.75816	0.022	0.717	0.200	0.112	6.56	0.057	0.492
2	8.25	0.011	1	0.75816	0.015	0.916	0.194	0.075	10.31	0.037	0.549
1	12.89	0.123	1	0.75816	0.162	1.110	0.589	0.276	25.39	0.414	0.586
	50.00					1.699					
Sum		0.297			0.392					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	130.07	0.014	0.039	26839	2+
7	0.58	35.40	0.004	0.015	7305	2+
6	1.02	58.46	0.006	0.023	12063	2+
5	1.90	85.60	0.009	0.040	17664	2+
4	3.18	118.51	0.012	0.058	24454	3+
3	5.21	209.33	0.022	0.110	43196	3+
2	8.25	208.10	0.022	0.113	42941	3+
1	12.89	8691.80	0.911	1.548	1793553	>3+
	50.00					
Sum		9537.27	1.000		1968015	

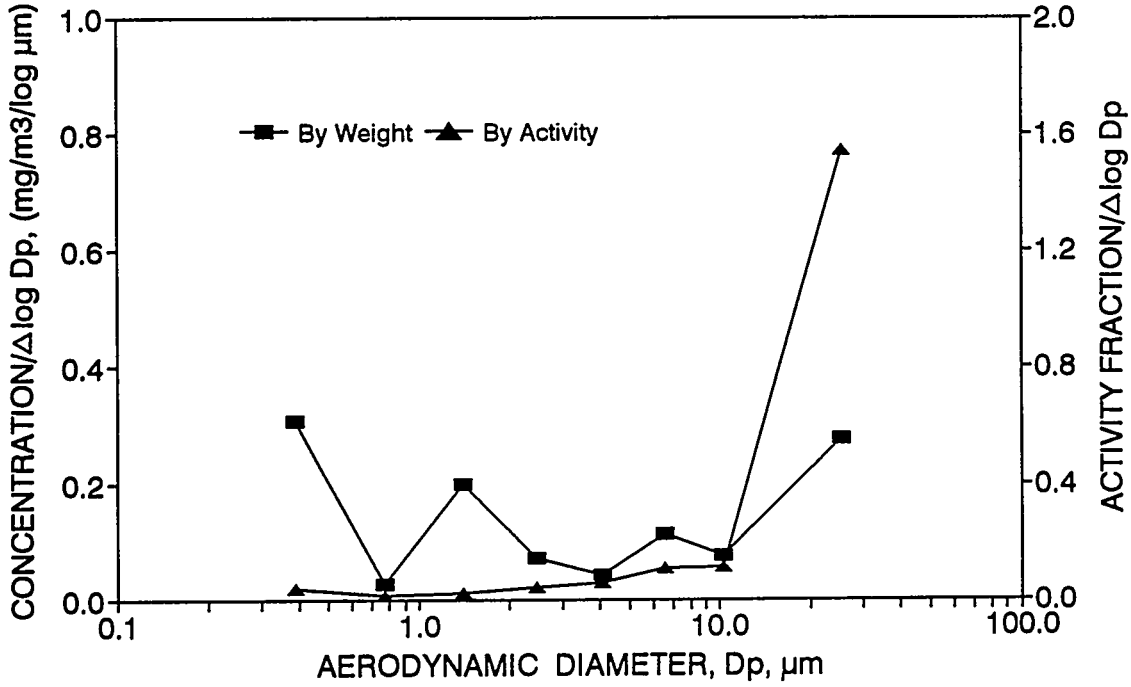
Lovelace Multi-jet Impactor Data

Cr-51 Labeled Dog: Run #4 (LMJ8380)



Size distribution by LMJ Impactor

Cr-51 Labeled Dog: Run #4 (LMJ8380)



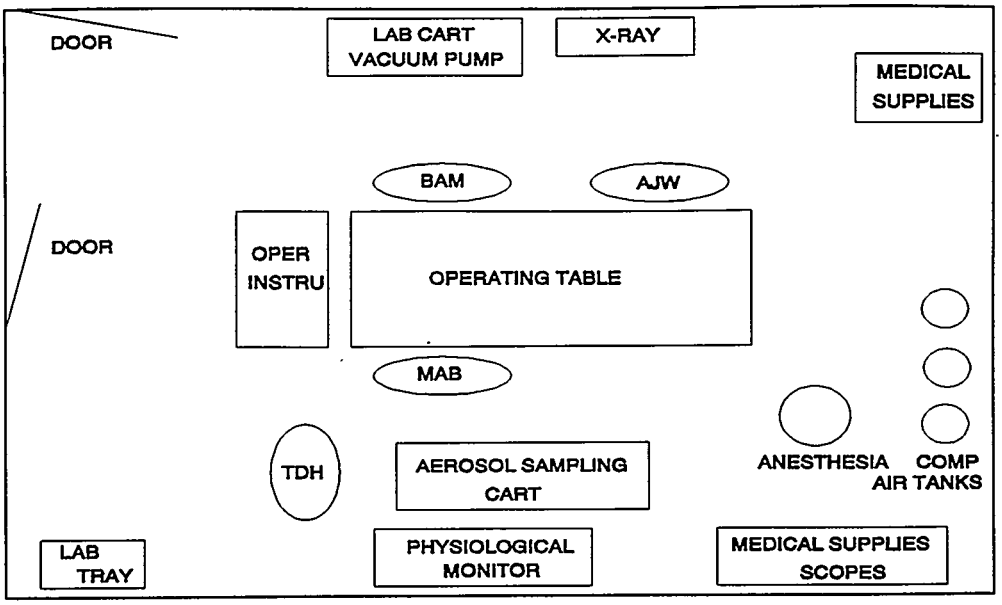


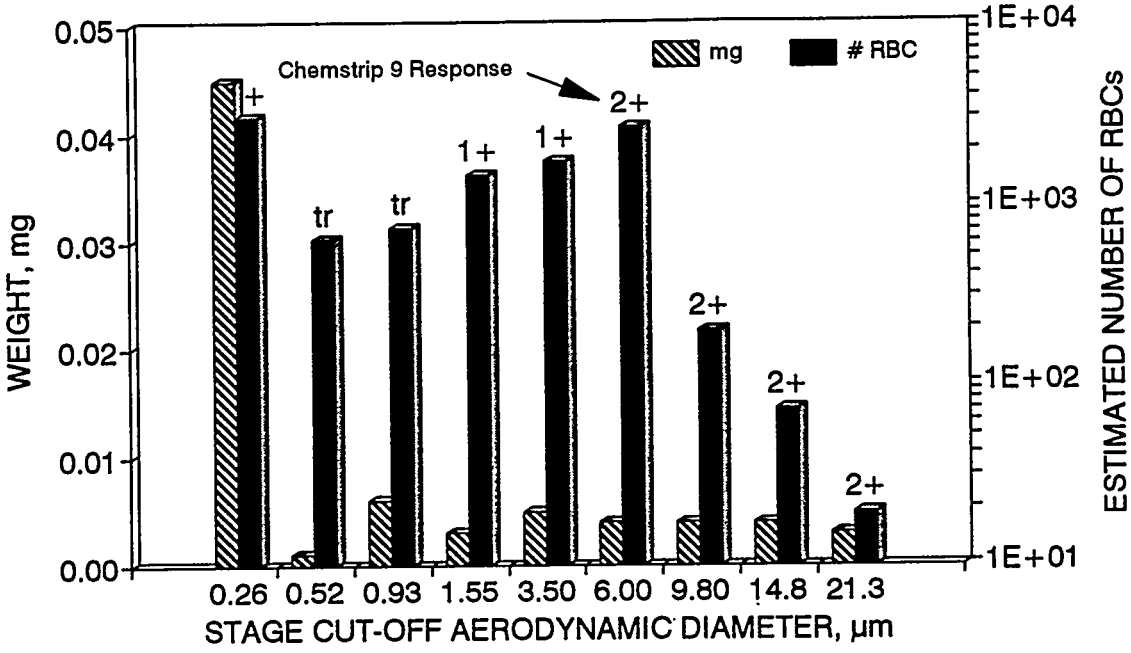
Figure D.5 Personnel locations during ^{51}Cr-labeled dog #5 experiment

Cr-51 Dog 5: Marple Personal Impactor Data

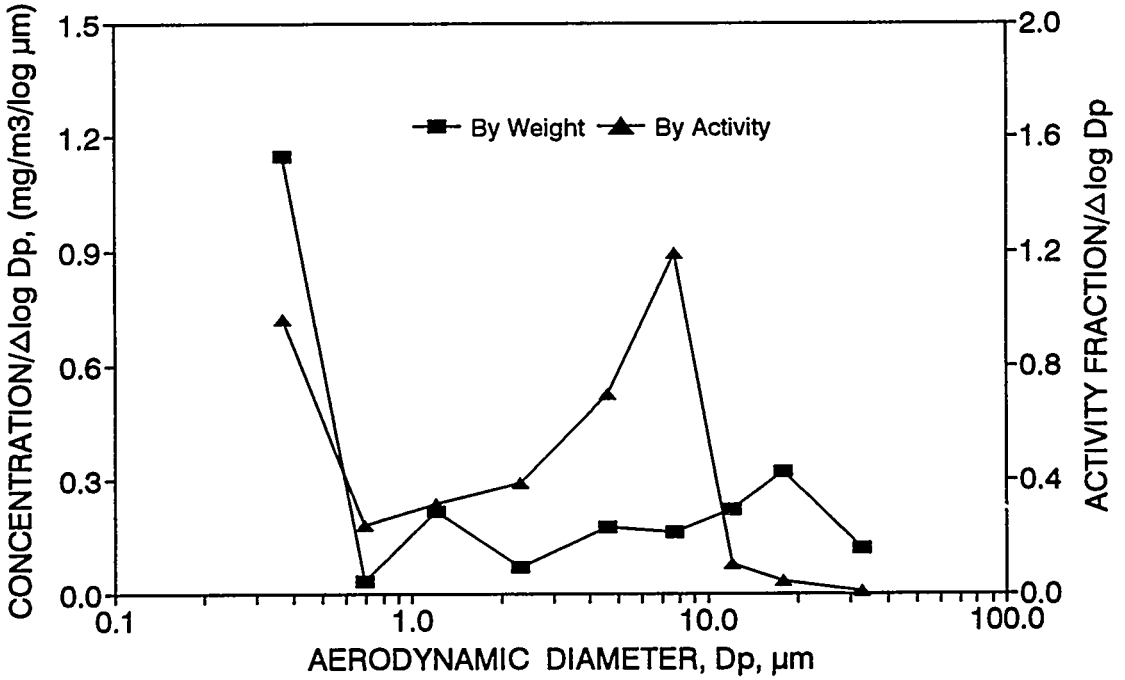
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.045	1	0.13	0.346	-0.585	0.301	1.150	0.37	0.545	0.000
8	0.52	0.001	0.99	0.13	0.008	-0.284	0.252	0.031	0.70	0.012	0.545
7	0.93	0.006	0.97	0.13	0.048	-0.032	0.222	0.214	1.20	0.075	0.557
6	1.55	0.003	0.96	0.13	0.024	0.190	0.354	0.068	2.33	0.038	0.632
5	3.50	0.005	0.95	0.13	0.040	0.544	0.234	0.173	4.58	0.064	0.670
4	6.00	0.004	0.89	0.13	0.035	0.778	0.213	0.162	7.67	0.054	0.734
3	9.80	0.004	0.78	0.13	0.039	0.991	0.179	0.220	12.04	0.062	0.789
2	14.80	0.004	0.61	0.13	0.050	1.170	0.158	0.319	17.75	0.079	0.851
1	21.30	0.003	0.52	0.13	0.044	1.328	0.371	0.120	32.63	0.070	0.930
	50.00					1.699					
Sum		0.075			0.635					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	24.23	0.290	0.964	3189	1+
8	0.52	5.02	0.060	0.238	661	tr
7	0.93	5.81	0.070	0.314	765	tr
6	1.55	11.39	0.136	0.386	1500	1+
5	3.50	13.64	0.163	0.698	1796	1+
4	6.00	21.18	0.254	1.190	2789	2+
3	9.80	1.52	0.018	0.102	201	2+
2	14.80	0.56	0.007	0.042	74	2+
1	21.30	0.15	0.002	0.005	20	2+
	50.00					
Sum		83.50	1.000		10995	

Marple Personal Impactor Data
Cr-51 Labeled Dog: Run #5



Size distribution by Marple Impactor
Cr-51 Labeled Dog: Run #5

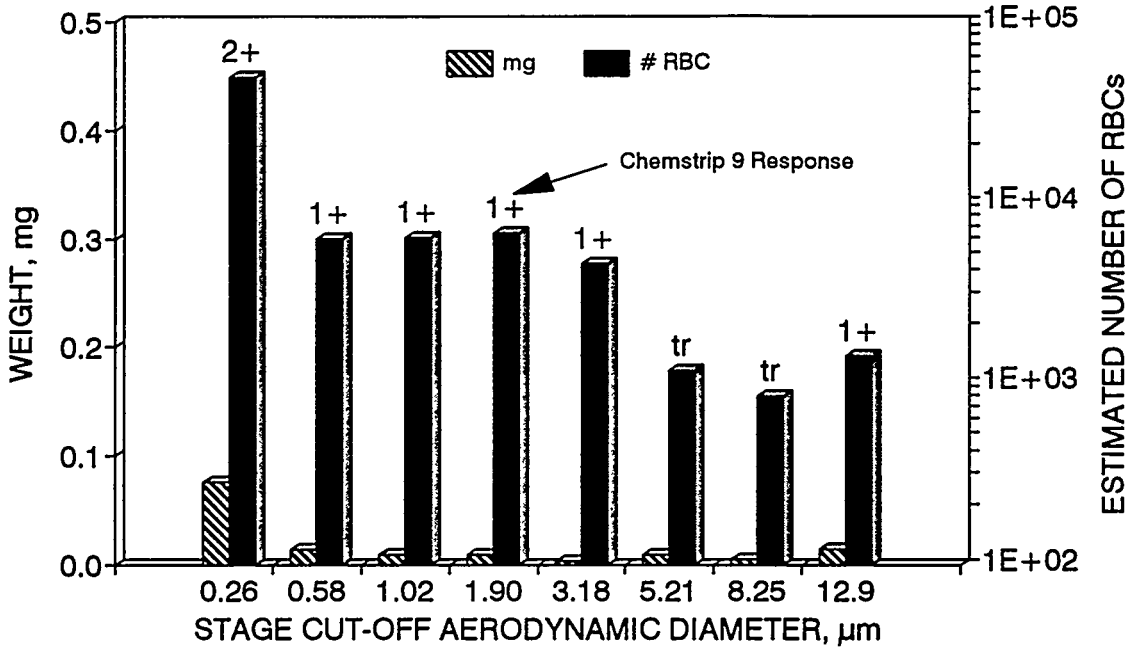


Cr-51 Dog 5: LMJ Impactor Data (ID LMJ8106)

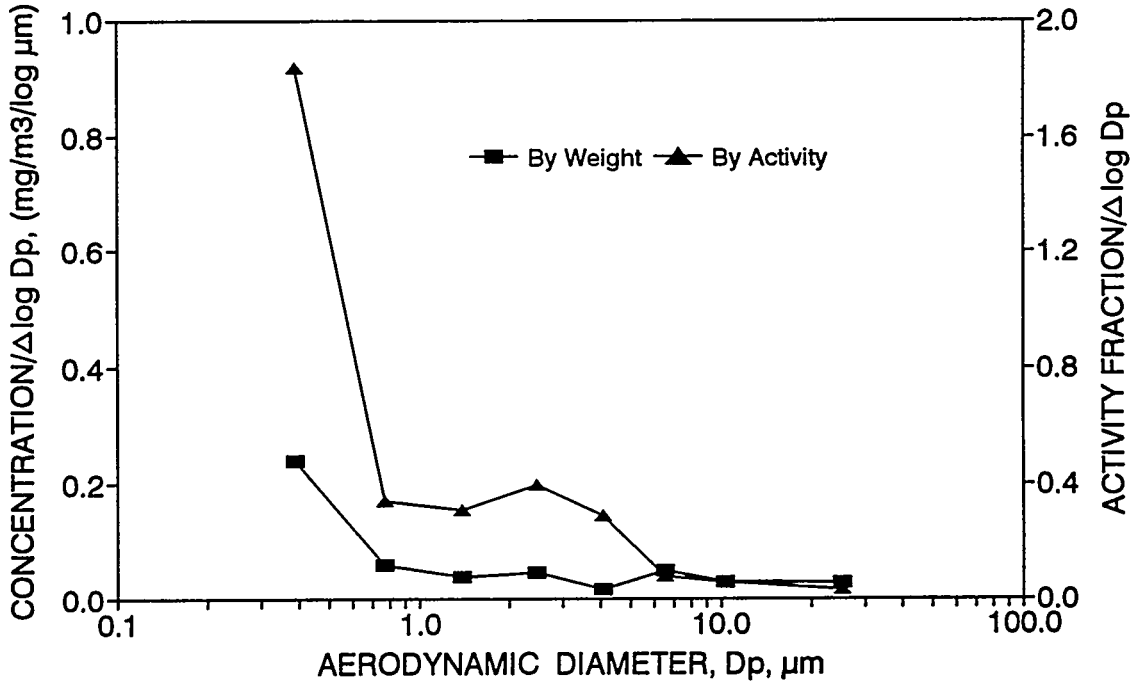
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.076	1	0.91195	0.083	-0.585	0.348	0.239	0.39	0.551	0.000
7	0.58	0.013	1	0.91195	0.014	-0.237	0.245	0.058	0.77	0.094	0.551
6	1.02	0.009	1	0.91195	0.010	0.009	0.270	0.037	1.39	0.065	0.645
5	1.90	0.009	1	0.91195	0.010	0.279	0.224	0.044	2.46	0.065	0.710
4	3.18	0.003	1	0.91195	0.003	0.502	0.214	0.015	4.07	0.022	0.775
3	5.21	0.009	1	0.91195	0.010	0.717	0.200	0.049	6.56	0.065	0.797
2	8.25	0.005	1	0.91195	0.005	0.916	0.194	0.028	10.31	0.036	0.862
1	12.89	0.014	1	0.91195	0.015	1.110	0.589	0.026	25.39	0.101	0.899
	50.00					1.699					
Sum		0.138			0.151					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	377.52	0.640	1.838	49704	2+
7	0.58	48.74	0.083	0.337	6418	1+
6	1.02	48.83	0.083	0.307	6429	1+
5	1.90	52.00	0.088	0.394	6847	1+
4	3.18	36.36	0.062	0.288	4655	1+
3	5.21	8.89	0.015	0.076	1171	tr
2	8.25	6.43	0.011	0.056	847	tr
1	12.89	10.83	0.018	0.031	1426	1+
	50.00					
Sum		589.60	1.000		77497	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #5 (LMJ8106)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #5 (LMJ8106)

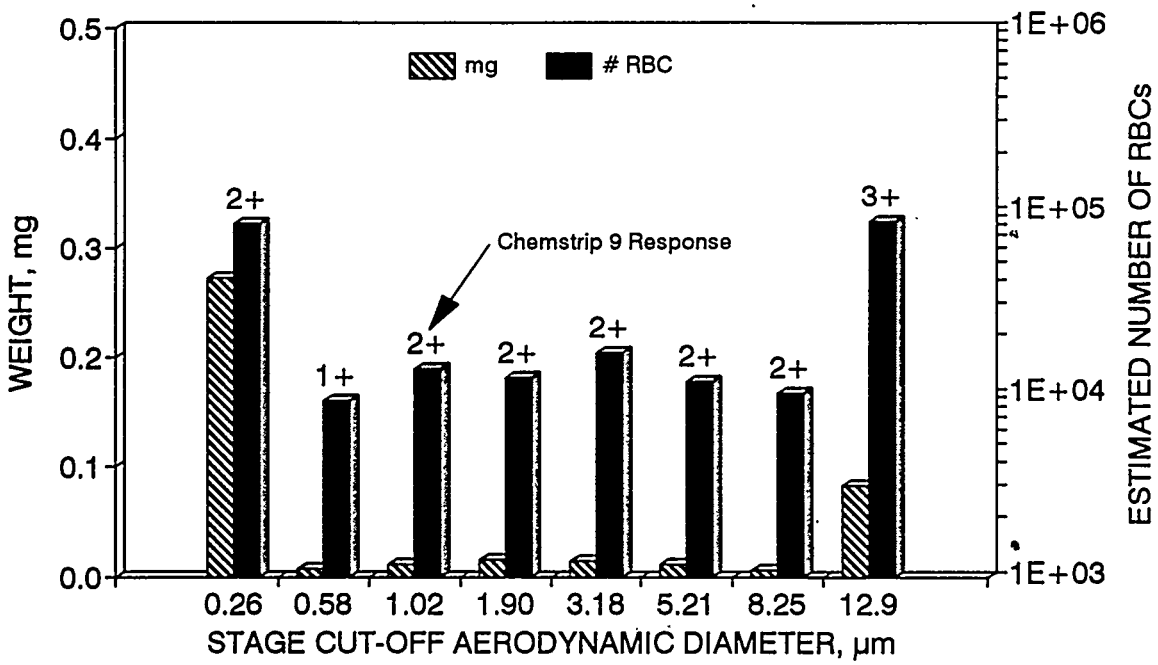


Cr-51 Dog 5: LMJ Impactor Data (ID LMJ8380)

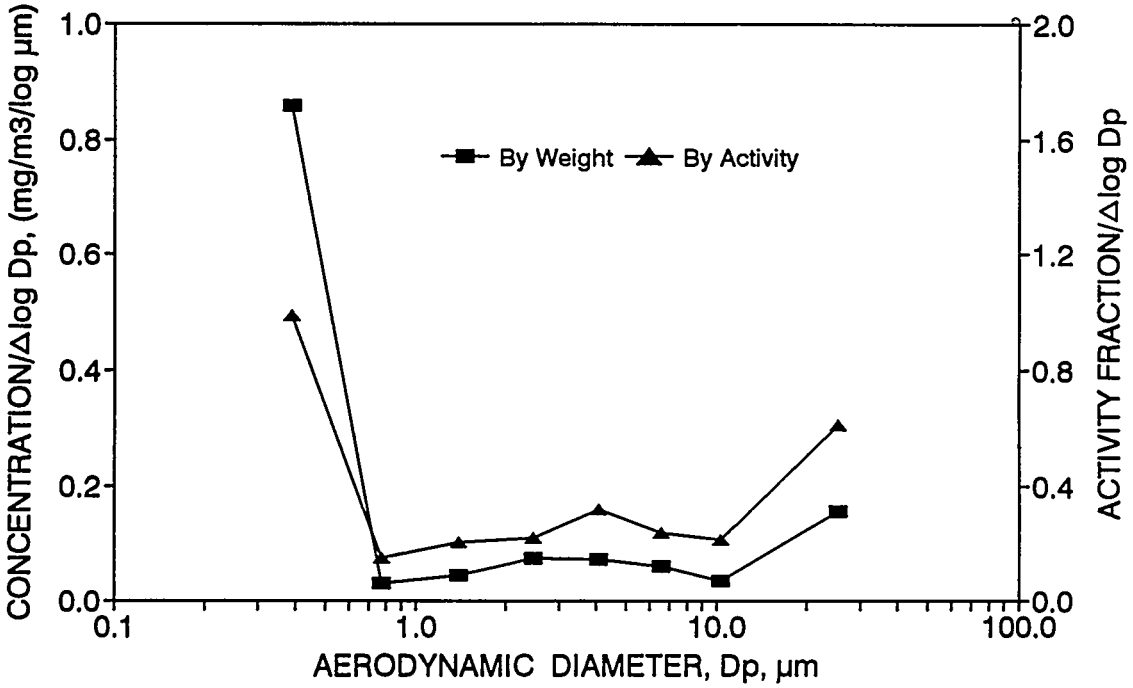
A Stage	B ECD, μm	C δWt, mg	D C.f.	E S.Vol, m3	F C, mg/m3	G log Dp	H δlog Dp	I (F)/(H)	J GMD, μm	K f Wt	L f<ECD
F	0.26	0.273	1	0.9126	0.299	-0.585	0.348	0.858	0.39	0.650	0.000
7	0.58	0.007	1	0.9126	0.008	-0.237	0.245	0.031	0.77	0.017	0.650
6	1.02	0.011	1	0.9126	0.012	0.009	0.270	0.045	1.39	0.026	0.667
5	1.90	0.015	1	0.9126	0.016	0.279	0.224	0.073	2.46	0.036	0.693
4	3.18	0.014	1	0.9126	0.015	0.502	0.214	0.072	4.07	0.033	0.729
3	5.21	0.011	1	0.9126	0.012	0.717	0.200	0.060	6.56	0.026	0.762
2	8.25	0.006	1	0.9126	0.007	0.916	0.194	0.034	10.31	0.014	0.788
1	12.89	0.083	1	0.9126	0.091	1.110	0.589	0.154	25.39	0.198	0.802
	50.00					1.699					
Sum		0.420			0.460					1.000	

A Stage	B ECD, μm	M CPM	N f CPM	O (N)/(H)	P # RBC	Q Chem.9
F	0.26	648.54	0.345	0.990	85387	2+
7	0.58	69.35	0.037	0.150	9131	1+
6	1.02	103.71	0.055	0.204	13655	2+
5	1.90	91.76	0.049	0.218	12081	2+
4	3.18	127.73	0.068	0.317	16817	2+
3	5.21	87.95	0.047	0.234	11580	2+
2	8.25	76.91	0.041	0.211	10126	2+
1	12.89	673.99	0.359	0.609	88658	3+
	50.00					
Sum		1879.94	1.000		247435	

Lovelace Multi-jet Impactor Data
Cr-51 Labeled Dog: Run #5 (LMJ8380)



Size distribution by LMJ Impactor
Cr-51 Labeled Dog: Run #5 (LMJ8380)



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