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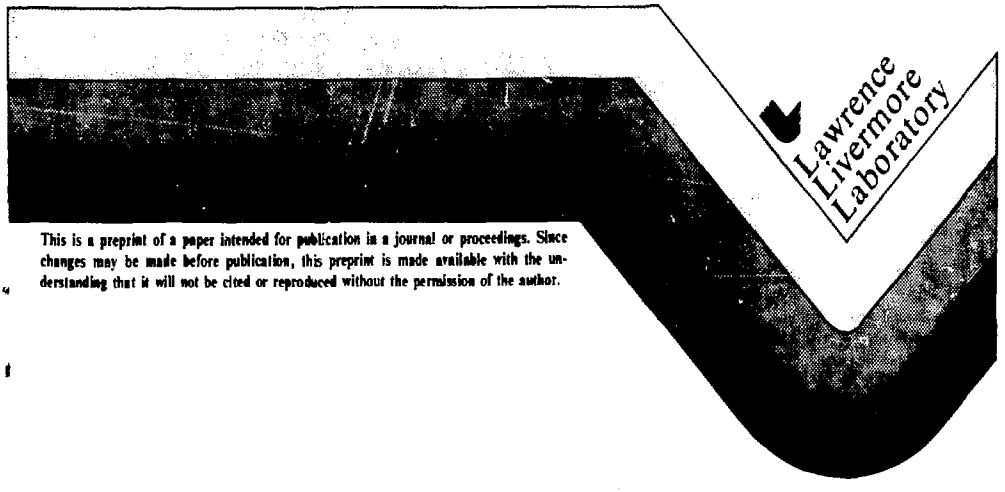

The Need For A Contamination Control Textbook*

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ABSTRACT

Since the authors have become associated with contamination control technology they have repeatedly found themselves searching for technical information that was either never documented and therefore never reached a technical journal or was too specific to appear in a technical article. On countless occasions they have found other workers frustrated over the same lack of concise and up to date information in the relatively broad and interdisciplinary field of surface science, surface cleaning, and clean room operation and design. It is for these reasons that the authors wish to suggest formally that those engineers, chemists, technicians, and surface scientists working in this field collectively create a textbook that they may use as their first reference and teaching book.

The text of this paper suggests a topical outline for a book and gives examples of the kinds of information that it should contain and the types of questions it should address. Included is an extensive bibliography recently collected showing the diversity of disciplines that those working in contamination control must be knowledgeable of and the variety of publications and journals in which these reports and articles are generally found.

A textbook as proposed could be produced by a committee of authors skilled in each of the necessary disciplines working together under the auspices of the Institute of Environmental Sciences or other sponsoring organization.

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Introduction

Because of the diversity of disciplines that those working in contamination control must be aware of no single periodical or publication has emerged to represent this broad spectrum of interest. Although the subject area is not new, dating back to the 1940's and the era of precision mechanical gyroscopes, it is a subject area that has evolved through individual research applied to a specific problem area. Results, if published at all have appeared in technical journals, corporate reports, and at a few conferences devoted specifically to contamination control. A new worker entering the field of contamination control is therefore faced with having to read all the journals and conference proceedings published over the past thirty years. Then he must digest the information and arrive at a series of conclusions based upon his interpretation of these papers. This is an excellent way for a graduate student to begin a new research project, but not an efficient method for a production manager, manufacturing engineer, or technician to quickly learn about the subject area. What is needed is a textbook of senior college level that not only states the fundamental principals and assumptions but describes the equipment, facilities, standards, and operating procedures that could be used to achieve and maintain a stated contaminate level.

Supporting Evidence

To support our contention of how difficult it is to obtain documentation, we performed a computer assisted survey of the existing literature. We searched for abstracts containing the key words 'contamination', 'surface', 'control', 'clean', 'clean room', and 'detergent'. After deleting many closely associated but unnecessary key words such as 'engine', 'weld', 'sewage', 'sediment', 'medical', 'bacteria', etc. the list reduced to 1494 citations. These were manually searched to remove duplicates and obviously inconsequential citations finally arriving at the 160 citation bibliography in Appendix A. Out of these were five citations that could be called textbooks in contamination control technology. They are listed in Table I in chronological order. Note that all were written over only an eight year span and the newest is now eight years old.

Table I Currently available textbooks generally covering contamination control technology

1966 Dwyer, J. L., Contamination Analysis and Control

1969 Sivinski, H.D., Contamination Control Handbook, NASA SP-5076

1970 Austin, P. R., Design and Operation of Clean Rooms

1971-1972 Department of Defense, Contamination Control Technology Mil-Hndb-406, 407

1973 Morrison, P. W., Environmental Control in Electronic Manufacturing

The government publications listed in Table I are handbooks and not really textbooks. They are tabulated lists of facts loosely held together with text. Reading them is akin to reading the Handbook of Chemistry and Physics and they are not representative of the textbook we are proposing. The books by Dwyer and Austin each represent the work of one man. The book by Morrison comes closest to that which we propose and was written by several authors at Western Electric Corp.

It is felt by many that the majority of the research and publication in contamination control took place during the aerospace era of the 1960's and 1970's and that little has occured since. The recent literature survey indicates, to the contrary, that more articles have appeared in the past five years than appeared in the preceding fifteen years. This is shown graphically in Figure 1 and indicates that interest in contamination control is not declining but steadily increasing.

Although a modest amount of literature is available it appears in so many publications that the casual reader is apt to miss the great majority. For instance, only 35% of the articles found were in periodicals and books that might be maintained in a good technical library. The remaining 65% of the citations were from corporate, governmental and other obscure technical sources. Table II lists the sources of the citations appearing in the bibliography. How many of these are you apt to have searched or read during the past year?

Table II List of publishers, publications, and corporations creating the articles in Appendix A Numbers after entries refer to occurences.

Aerojet General
Aerosol Science
Aerospace Corp
Amer Laboratory
Anal Chem
App Optics
Army (5)
Arnold Engr Dev Cntr
AEC
AIChE
Bendix (2)
Boeing Aerospace
Business News
Butterworth
Chapman and Hall Ltd
Chem Publ
Chemical Engr
Cornell U
CRC Press
DuPont
Electron Microsc
Finish Ind
General Dynamics
Halsted Press
Health Physics
Hughes
Int J Air Pollution (4)
Interscience Publ
IES (8)
J Amer Indus Hygiene (3)
J Chem Educ
J. Colloid - Interface Sci
J. Electrochem Soc
J. Hazard Materl
J. Met Finish
J Phys
J Van Sci Tech
John Wiley (2)
JES
JPL
Lincoln Labs
Lockeed
LASL
MacMillan Co.
Marcel Dekker (2)
Nature
Naval Dental Sch
Naval Weapons Center
Nuclear Technology
NASA (27)
NBS Spec Publ
NRL (3)
NTIS (2)
Opt Eng
Pergamon (8)
Plat Surf Finish (2)
Plenum Press
Reinhold (2)
Res Discl
Rockwell
Sandia (10)
Stanford
Surf Technol
SME Tech Paper
Syracuse Inst
Tellus (2)
Thin Solid Films
Water Resources Sci Cntr

The authors hope that readers of this article will come to the conclusion that a working textbook in this subject area is genuinely needed and would greatly benefit those working in the field.

Sponsorship

We are proposing that those working in this field who have a similar interest in the creation of a textbook be brought together under the auspices of a sponsoring or supporting institution to begin drafting an outline. The sponsoring institution might appropriately be the Institute of Environmental Sciences, the larger International Committee of Contamination Control Societies, some governmental body such as the Department of Energy, NASA, the National Bureau of Standards, or possibly an industrial group. Industrial participation should be encouraged as there are many benefits that would result if they were to actively participate in the creation of this text. Although the participation of those companies that manufacture products used in the contamination control field would not be discouraged from participation it is certainly hoped that the resultant text would represent an unbiased opinion in so far as that is possible. In fact, participation by manufacturer should be encouraged because a useful result of such a text would be the direct technical comparions of competing products.

Timeliness

Existing texts have adequately reduced a large portion of the technical information available to the authors to useful and concise fundamental statements. Much of this information has unfortunately become dated soon after being published. Although many of the texts have been reprinted with corrections and updates none have undergone any significant change since their original writing. The authors propose that this new textbook be published in loose-leaf notebook format that could and should be periodically updated. An example of such a text is the book entitled An Introduction to Microcomputers by Adam Osborne Associates. This text, developed by an independent consulting firm, serves the continuing need of the microcomputer industry by the publication of timely updates paid for by yearly subscription. As new integrated circuits are introduced subsections and chapters are released fully describing their functions. In a similar fashion it should be possible to produce a text that conceivably would never go out of date. As new products are released or techniques developed they could not only be published in a technical journal, but the author could be requested to write a chapter or subsection that added their technical findings to the already coherent package of information within the textbook. As chapters or sections become outdated they could be entirely rewritten and redistributed to the current subscribers. Since the creation or update of chapters may actually become a profitable venture once the initial text has been created, it is felt that the sponsoring organization would

have no difficulty in finding paid volunteers to write new sections.

Certainly additions, corrections, and style should be under the review and approval of an editorial committee but this should create no obstacle to the inclusion of new and timely information. The majority of the committees work should address maintaining a consistent and coherent document that adequately references existing sections.

Content

Assuming that such a textbook was created, what topics could be expected? Appendix B contains a relatively lengthy outline representing the authors suggestion for subjects that should be included in the textbook. Although many of the section titles have appeared in previous texts, the purpose and emphasis will be somewhat different because the overall purpose of the book is teaching fundamental principals and applications. The following describes the kinds and level of information that could be found under each of the subject headings. Many topics may have inadvertently been neglected and the authors would appreciate any and all suggestions concerning subject content.

Textbook Outline

The suggested textbook outline in Appendix B is divided into twenty-two sections. Each section represents a major subject area or discipline and will require a significant technical contribution. Please refer to Appendix B while reading the following section descriptions.

Note that the broad areas of radioactive contamination and biological contamination have been relegated for future volumes.

1) Overview of Contamination Control

The history of contamination control and the major technical achievements should be documented. This includes a detailed description of what contaminants are and where they originate. How contaminants lead to product failure will require considerable explanation and although only introduced in this section is considered in greater detail in Sections 15 and 16.

Standards and specifications may more correctly require a separate section but as a minimum they should be described briefly and indexed by content so that they can be easily located and referenced. Standards should not be reproduced at length but it might be possible to summarize their purpose in a table or chart. There should also be some history of the evolution of standards and who currently uses them.

2) Clean Room and Operating Theater Design

This lengthy and detailed chapter concerns the fundamental principals of environmental control and the purpose of clean rooms. It

should be sufficiently detailed to teach how to evaluate the needs and requirements for a clean room, how to select the correct type, and how to layout a floor plan. This includes all the considerations necessary to select equipment, construction materials, and specify construction details. Sufficient information should be included to teach preliminary air handling calculations, fan sizing, duct sizing, and construction cost estimating. Details of equipment arrangement to achieve maximum functionality with respect to air filter location is necessary as well as reasons for the recommendations.

After reading this chapter an engineer should be able to intelligently converse with an architect and specify in detail how a clean room could be designed and costed.

3) Filters

Filtration theory is fundamental to contamination control technology. The mechanisms by which particles are captured by filters is not generally understood and therefore leads to confusion in filter selection. The influence of fluid viscosity, velocity, and filter pore size on efficiency needs explanation along with a description of particle capturing mechanisms. A poor understanding of these effects leads to incorrect filter type selection and lack of an appreciation for filter testing. For instance, the reason that there is a difference between liquid and gaseous filtration efficiency for a given filter type should be explained.

Descriptive information should make clear the logical selection of types and brands of filters. Comparisons between competing brands of high efficiency particle air (HEPA) filters would lead to a

better understanding of vendor consistencies and inconsistencies. Filter installation and testing procedures should be described in sufficient detail (with examples of alternative testing equipment and challenge materials) to allow readers to quickly and confidently select and carry out a testing procedure.

4) Clean Room Garments and Related Equipment

There are few subjects less controversial than the need for and extent of clean room garments. How effective are presently available garments? How much bodily coverage is really needed in a laminar flow room? How clean should the garments be and how should they be laundered and tested? What garment types and what materials are currently available? How often should garment to changed? What alternative glove, face mask, and shoe cover types are there to choose from and how clean are they? Each clean room repeatedly faces these questions and yet there is no source of comparative information being published. In fact, there is virtually no advertising medium from which to obtain a list of manufacturers other than the Thomas Register.

A comprehensive evaluation of garments, even if not answering all of the posed questions, would greatly reduce confusion in the technology.

5) Contamination Science

This section explains from the surface scientist's perspective what contaminants are, how they attach themselves to surfaces and how they migrate. The role that surface energy, electrostatic forces and moisture plays in the retention of particles and aerosols should be explained.

But they should be explained in such a way that the process of surface recontamination and surface cleaning could be more readily understood.

This subject area is well covered in the surface science journals but needs translation to be readily applicable to the clean room community.

6) Identifying Contaminants

It is sometimes unappreciated that the identification of contaminants may lead to the discovery of their source and their elimination. This section treats the problem of contaminant identification on surfaces and in fluids.

The spectroscopic techniques could fill several volumes but this level of detail is not necessary. Explanation as to how the techniques work and what their limitations are is most appropriate. If an engineer or technician after reading this section could decide which technique to use, converse with the machine operator and interpret the results, the section will have served its purpose.

Optical microscopic techniques are well suited to rapid particulate evaluation and should be emphasized. Techniques for sizing and counting particles should also be considered as it relates directly to the following section on measuring cleanliness.

7) Cleanliness Testing

Techniques in this section concern themselves with verifying surface or fluid cleanliness before or after cleaning. They specifically neglect identifying what the contaminant is (which is covered in Section 6) in favor of determing how much is present. If only certain types of

contaminants are of concern then both quantitative and qualitative analysis may be necessary.

Many surface inspection techniques have been devised and they should all be discussed. In particular the sensitivity of the technique should be stated in so far as it is known. The types of contaminants detected should be clearly described possibly by using examples (case studies). Since many of the techniques employ only indirect measurement of the contaminants present, this fact should be clearly stated along with some indication of the reliability of the technique. Well illustrated procedures on how to perform each of the tests would be most helpful. The authors, for instance, have yet to see a clearly illustrated water break test.

Direct comparison of manufacturers products such as fluid particle counters would seem very appropriate. Even user comments concerning equipment reliability would be appropriate. Older comments could be discarded with subsequent revisions.

Cleanliness testing deserves considerable attention as the inability to measure cleanliness levels will lead to a total misuse of the clean room environment and excessive operating expense.

8) Cleaning Theory

This section along with Section 5 on Contamination Science should serve to educate people as to where contaminants come from, how they migrate in a clean room, how they attach themselves to surfaces and what techniques and phenomenon are necessary to remove them. A clear explanation of what detergency and solvency are and how they affect

surfaces and particles is necessary as is an explanation of wetting and surface tension.

Many cleaning methods and 'recipes' are currently available. It should be explained why they are performed in a particular sequence. Why can flushing only be continued until the background contaminant level reaches that of the flushing fluid? Why is dry phase cleaning effective for only certain classes of contaminants? How would someone go about selecting and testing a cleaning process? We feel sure that answers to these questions would be welcomed in contamination control. Readers should also be made aware that far too many cleaning processes are being sold as a cure-all with few of their limitations clearly explained.

9) Cleaning Practice

Cleaning seems to be the inevitable function of the clean room. If contamination cannot be prevented and cleanliness is necessary then cleaning will be required. The cleaning methods described in this section make a distinction between gross cleaning and precision cleaning. This distinction is necessary because some precision methods can be applied to grossly contaminated parts but not the opposite.

Detailed procedures explaining how each method is to be performed should include the cleanliness level that can be achieved. Without a quantitative method for evaluating cleaning ability the decision as to which process to use will be incorrectly based on only chemical compatibility, availability, and cost. In many cases the effectiveness of a cleaning method is not known and if this is true it should be so stated. Many authors are guilty of failing to tell their readers

directly that certain facts are not known or not well understood.

10) Protecting Clean Surfaces

Packaging is the art of creating an environment around a component that will impede its recontamination. The effectiveness of any packaging method clearly depends on the level of cleanliness desired. If conventional plastic packaging is considered then the outgassing rate and water vapor diffusion rate should be compared. The effectiveness of anti-static additives should be weighed against the volatility of the anti-static additive. Product comparisons would allow buyers to identify multiple vendors producing comparable products.

A controlled environment using an ultra-violet ozone atmospheres has recently proven quite effective at preventing organic recontamination. A tutorial explaining the process in detail and how recontamination is prevented would be most enlightening.

11) Quality Assurance

This is another large section which includes training personnel and detailed clean room operating procedures. It is well known that many of the problems in contamination control involve people. Assuming that a product cannot be produced without people coming in contact with it what are the acceptable operating procedures?

Quality assurance along with monitoring people is responsible for the environment and the tools. This includes periodic testing of supplies,

chemicals, garments and equipment. But, how often should this be done and using what procedures? What kinds of instruction are most effective and how often should training sessions be held? A consensus of operating procedures as used by a variety of industries would be very helpful to any group starting a clean room.

12) Solvent Purification

A section on solvent purification would aid in understanding trace element contamination. What water and organic solvent purification methods are currently available? What standards do commercial products need to surpass to reach Reagent or Electronic Grade? What containers can solvents be safely and cleanly transported in? How clean do solvents have to be for use in a clean room? How can cleanliness be measured and verified on a continuing basis? These are a few of the questions we have asked ourselves and would like to see answered in this a section.

13) Control of Compressed Gases

This section addresses questions similar to those covered in the preceding section. That is, to what standards are compressed gases produced, how can they be cleaned (filtered) before use, and what precautions should be observed in their use.

14) Health and Safety Planning

This section lists examples of hazards generally found in clean rooms and explains how they can be avoided. Examples include chemical toxicity,

fire protection from flammable chemicals and earthquake safety.

15) Contamination Control Through Product Design

16) Examples of Contamination Control from Selected Technologies

These two sections address contamination control from a more basic viewpoint. What can be done to a product to make it less sensitive to contaminants? Are product designers aware of the final use of the product and are they planning so as to allow it to be easily processed in a clean room. The choice of construction materials which aggravate the problem or make certain cleaning procedures difficult is unwise but done every day.

Many industries have faced contamination problems and have eventually solved them. Examples of the steps taken in the evolution of particular industries would be most helpful to clean room operators. Documentation on some of those procedures that have failed to prove adequate would also be very beneficial.

17) Glossary of Terms, Abbreviations and Nomenclautre

18) List of Manufacturers of Contamination Control Products

Self explanatory

19) Specific Product Descriptions and Technical Product Comparisons

This section could be considered the Consumers Union section of the textbook. Many products are evaluated by private industry but results of these evaluations are rarely published. It would be most helpful to others facing the purchase of competing products, to have these product evaluations available. The timeliness of the updated sections of the

textbook would allow frequent revisions to be made as new products become available.

20) Bibliography of the Last 10 Year Literature

21) List of Active Personnel Working in Contamination Control: Listed by Name and Company

Self explanatory

22) Special Sections to be Added by User Industries

This section will only contain a title page and will allow users to write their own section on procedures or proprietary processes. If the section has general applicability it could be submitted to the publisher for inclusion as a new section. Topics might include high vacuum equipment, optics, biological contaminants, hydraulic equipment or radio active decontamination.

Conclusion

It is hoped that many of the readers will agree with us that the proposed written-by-users contamination control textbook is overdue. We have tried to justify it based upon an extensive literature survey showing that very few textbooks (or handbooks) are currently available. We have also tried to show that the limited amount of technical literature available is not easily obtained. This has lead us to recommend that a textbook be published in loose leaf format that could be perpetually kept up-to-date.

Many volunteers will be needed to begin the creation of such a textbook and any and all help will be appreciated. If you or your organization wish to participate or you simply agree that a textbook is needed please contact one of the authors by phone or letter. If there is sufficient interest and if a sponsoring organization can be located we will be on our way. We look forward to your participation.

Rate of Publications in Contamination Control

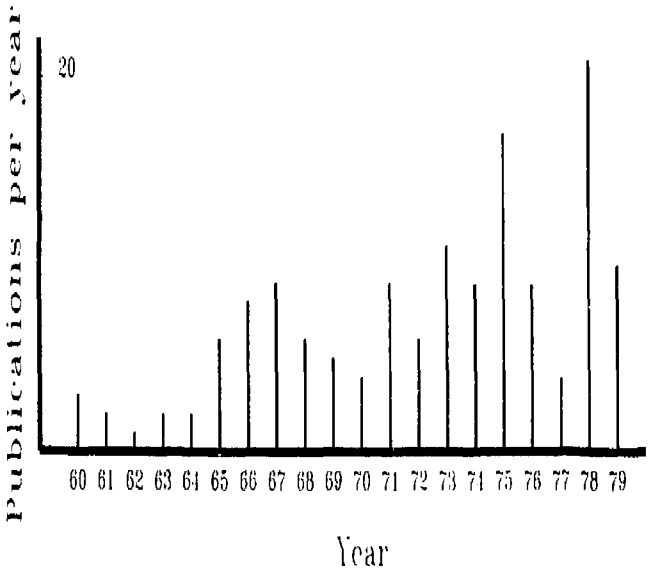

Figure 1

Appendix A

Extended Bibliography on Contamination Control Technology

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Appendix B

Outline for a Contamination Control Textbook

1) Overview of Contamination Control
    - History of contamination control technology
    - Contaminants defined
        - Particles
        - Films
        - Microbiological
        - Radiation
        - Radioactive
    - Sources and types of contaminants
        - Solids, liquids, gases, energy
        - People generated
        - Fabrication generated
        - Cleaning process generated
        - Chemically generated
    - Effects of contaminants on products and patients
    - Defining the necessary cleanliness level
    - Standards, specifications and practices
        - Mil Std
            - 209B, 1246A
        - ASTM, IES, ANSI, NASA
    - The contamination control specialist
2) Clean Room and Operating Theatre Design
    - Fundamentals of environmental control
    - Clean environmental facilities
    - Types of clean rooms
        - Conventional mixed flow
        - Laminar flow
        - Special
        - Work benches and stations
        - Glove boxes

Construction considerations

Temperature, humidity, pressure differentials

Walls, floors and ceiling construction

Furniture, shoe cleaners, air locks

Anterooms and precleaning rooms

Lighting

Sinks, chemical drains, exhaust hoods

Air handling equipment

Ducts and plenums

Fans

Flow calculations

Vibration and noise

Cost

Functional arrangement of equipment

Emergency considerations

Fire, earthquake

Power and equipment failures

3) Filters

Filtration theory

Particle size distributions

Particle diffusion (transport mechanisms)

Collisions, coagulation, agglomoration

Deposition and reentrainment mechanisms

Convective diffusion

Inertial effects

Types and materials of construction

Electrostatic

Cellulosic

Nuclepore

Fiberglass-asbestos

Gas filters

Prefilters

Air conditioning (70% efficiency)

HEPA

Membrane

Flow rate

- Liquid filters
  - Prefilters
  - Membrane
  - Chemical compatibility
  - Velocity and pressure pulsation effects
  - Flow rate
- Cleaning filters
- Testing filters
  - Equipment
    - Photometers
    - Particle counters
    - Radioactive counters (ionization)
  - Standard testing procedures
    - DOP
    - NaCl aerosol
    - Freon aerosol
    - Radioactive particles
  - DOP migration

4) Clean Room Garments and Related Equipment
- Purpose of garments
- Masks
  - Effectiveness
- Smocks
  - Materials
  - Construction details
- Head covering
- Shoe covering
- Wiping materials
  - Linting
  - Nonvolatile residue
  - Absorbtivity
  - Product recommendations
- Gloves
  - Materials
  - Nonvolatile residue
  - Product recommendations
- Tests for cleanliness
- Laundering procedures

5) Contamination Science
    - Contaminant transport mechanisms
    - Surfaces
        - Absorption phenomenon
        - Adsorption phenomenon
        - Binding forces and retention mechanisms
        - Surface energy
    - Gases
    - Liquids

6) Identifying Contaminants
    - Identification of particles
        - Elemental analysis
        - Chemical analysis
    - Identification of films
    - Identification of gases
    - Spectroscopic techniques
        - Mass spectroscopy
        - X-Ray fluorescence
        - AAS (atomic absorption spectroscopy)
        - SIMS (secondary ion mass spectroscopy)
        - ISS (ion scattering spectroscopy)
        - AES (Auger electron spectroscopy)
        - ESCA (electron spectroscopy of chemical analysis)
        - Laser Raman spectroscopy
        - Infra-red and UV absorption spectroscopy
    - Optical microscopy
        - Chemical microscopy
        - Polarized light microscopy
    - Electron and ion microscopy
    - Case histories

7) Cleanliness Testing
    - Surfaces
        - Visual inspection
        - Sampling techniques
            - Surface wiping techniques
            - Vacuuming
        - Solvent monitoring

- Particle counters
- Thin films
- Water break
- Contact angle
- Atomizer test
- Exo-electron emission
- Radiochemistry
  - Evaporative rate analysis (ERA) MESERAN
- Coeffi ient of friction
- Coefficient of adhesion with indium
- Fluorescent dye
- Edge lighting
- Ellipsometry
- Weight loss-gain

Liquids

- Sampling techniques
- Nonvolatile residue
  - Gravimetric
  - Spectrophotometry
  - Chromatography
  - Nephelometer
- Liquid Particle Counters

Gases

- Sampling techniques
- Moisture monitoring
- Particle counters
  - Light scattering
  - Condensation nuclei
  - Cascade impactor
  - Calibration and standards

8) Cleaning Theory

- Theoretical vs technical cleanliness
- Adhesion of contaminants
- Absorption and desorption
- Redispersion
- Permeation and diffusion
- Electrostatic effects

- Liquid phase cleaning
  - Wetting
  - Surface tension
  - Detergency
  - Surfactants
  - Emulsification, saponification, deflocculation
  - Solvent activity
- Organic solvents
  - Grades and types
- Water
- Selective solvents
- Dry phase cleaning
  - Vacuum firing
  - Glow discharge plasma and sputter
  - Electron bombardment

9) Cleaning Practice

- Wiping
- Solvents
  - Solvent compatibility charts
- Gross cleaning
- Precision cleaning
- Chemical cleaning
  - Chemical degradation
- Cleaning Surfaces
  - Specific vs general methods
  - Gross cleaning
    - Barrel tumbling and abrasive methods
  - Cleaning organics
  - Cleaning oxides
  - Optical cleaning
  - Metal cleaning
    - Acid
    - Alkaline
    - Detergent
    - Solvent
    - Electrochemical
    - Mechanical

- Precision cleaning
  - Vapor degreasing
  - Ultra-violet/ozone
  - Glow Discharge
  - Sticky films
  - Low and high pressure spray
  - Ultrasonic
  - Detergent
  - Immersion
  - Cleanliness verification
  - Thermal baking and degassing
- Drying

10) Protecting Clean Surfaces

- Clean packaging defined
- Packaging materials
  - Plastics
  - Non-plastics
  - Diffusion of water vapor
  - Anti-static additives
- Packaging methods
- Sealing
- Ultra-violet/ozone protection

11) Quality Assurance

- Training and Education
  - Courses in-house, nationwide
  - Effectiveness of the buddy system
  - Training manuals, slides and movies
  - Reference literature
    - NASA manuals
    - Mil Hbdb 406, 407
- Personnel restrictions and working procedures
  - Permitted articles
  - Clothing rules
  - Cleaning the work area
  - Protecting clean parts
  - Clean room operating procedures
- Testing clean room supplies

Testing the clean room environment

Air and other gases

Surfaces

Fluids

Janitorial services and facilities maintenance

Janitorial storage area, mop sink and drain

Built-in vacuum systems

12) Solvent Purification

Water

Organic solvents

Distillation

Reverse osmosis

Filtration

Degassing

Sedimentation

Centrifugation

Deionization

13) Control of Compressed Gasses

14) Health and Safety Planning

OSHA regulations

Cleaning agent safety rules

First aid

15) Contamination Control Through Product Design

Awareness of the designer

Material selection

Assembly techniques

Designing for cleanliness

16) Examples of Contamination Control from Selected Technologies

Satellite systems

Semiconductor fabrication

Precision mechanical components

Pharmaceutical manufacture and packaging

Photographic processing

Thin film technology

Optical components

17) Glossery of Terms, Abbreviations, and Nomenclature

18) List of Manufacturers of Contamination Control Products

19) Specific Product Descriptions and Technical Product Comparisons

20) Bibliography of the Last 10 Years Literature

21) List of Active Personnel Working in Contamination Control Listed by Name and by Company

22) Special Sections to be Added by User Industries