SC-R-65-888

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CONTAMINATION CONTROL CONSIDERATIONS FOR DESIGNERS AND MANUFACTURING ENGINEERS

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by

Manufacturing Research Division - 2564

APRIL 1965

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Presented at: Third Annual Technical Meeting
American Association for Contamination Control
Los Angeles, California, May 1964, under the
title, "Contamination Control in Industry."
Paper prepared and presented by
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Issued by
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ABSTRACT

Much of our technology and production talent has become geared to the design and production of high-reliability components and systems for nuclear or space applications. These products must work right the first (and often the only) time they are used. Unfortunately, experience has taught us that contamination is one of the major stumbling blocks in assuring reliable operation of super-critical components.

This paper is an attempt to put a fence around the entire field of contamination control as related to designers and manufacturing engineers. The answers to many of our contamination problems are subtle and complex. There is no panacea for solving all our contamination problems, such as putting all operations within a clean room, even a laminar-flow clean room.

Key Words: Contamination control, product design,
cleaning, manufacturing processes,
impurities, storage

ACKNOWLEDGMENT

The author is indebted to the following members of the Contamination Control Project Group of the Advanced Manufacturing Development Division for their support in compiling the extensive checklist portion of the paper:

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CONTAMINATION CONTROL CONSIDERATIONS FOR DESIGNERS
AND MANUFACTURING ENGINEERS

What is Contamination?

Contamination has been defined in many ways, but for the purpose of this report, it is defined as follows:

"Any unwanted material in or on the product of interest. It may be solid, gaseous, or liquid in nature."

Contamination may be gross in nature, clearly visible in large quantities, or may be sub-microscopic in size, defying identification in some instances by even the most advanced analytical methods. It may be a particulate or it may be a film. Often, the presence of a contaminant is only known by indirect effects on the operation of the contaminated product. Perhaps this has best and most vividly been illustrated by the increased electrical contact resistance of components that have been contaminated by what has often been called "invisible" films.

The unwanted material is likely classified as a contaminant in a given situation only because of its location. For example, paint is certainly not a contaminant when it is used on a metal wall for protection and beauty. However, this same paint becomes a serious contaminant if it flakes off onto the metal surface of a precise assembly. Dirt is not a contaminant in the back yard garden, but on the freshly mopped floor it is a constant enemy of every housewife.

Contamination takes many forms. It is the metal chip in the hydraulic valve, the screwdriver in the missile fuel tank or astronaut's space capsule. It may be the germ on the surgeon's knife, or the detergent in the city water supply. The effects of contaminants on the product of interest may vary widely as follows:

Effects of Contaminant on Product

- 1) None Whatsoever
- 2) Slight Degradation
- 3) Intermittent Degradation
- 4) Catastrophic Failure
- 5) Combination of Above Effects

Who is Concerned with Contamination?

To be completely general, we would have to say nearly everyone is concerned with contamination--the doctor, the radiation physicist, the engineer, the housewife. In industry, each individual from the product designer to the assembly technician is concerned. In this discussion we will consider contamination primarily from the viewpoint of reliable component and system production. Therefore, we will not attempt to cover the many other contamination problems of industry such as health hazard to employees, industrial smog problems, etc. Our approach will be to discuss where and how contamination must be controlled throughout the life of the high reliability product, from design to use.

To assure that a given product will function reliably during the end use period of its life, contamination control must be considered along with all other requirements during each stage of the product life. Figure 1 outlines the typical processes or stages through which any product must pass from birth to death. Each stage in the life of the product should be considered from a contamination viewpoint to assure that adequate provisions are incorporated. The degree of consideration given contamination control during each of the four stages must vary from product to product as illustrated in Figure 2. Products A and B require the same contamination control efforts during the manufacture stage but widely differing efforts during design, storage and use stages.

PRODUCT LIFE
BIRTH ↔ DEATH

Figure 1. Outline of the stages through which a product passes between the time of its creation and demise.

Figure 2. Plot of the contamination-control effort expended on two imaginary products at each of the life stages shown in Figure 1.

Design Stage Considerations

Ideally, the product designer should design his product to tolerate the contamination environment under which it will be manufactured and actually used. This can and is being done but not as often as it should be. What should the product designer consider from the viewpoint of contamination? The following checklist is merely typical of the types of contamination questions to which a good product designer will attempt to find the answers.

A. Materials

1. What are the purity requirements of the materials themselves?
 - a. Electrical characteristics, such as dielectric constant.
 - b. Mechanical characteristics, such as strength.

2. Are the materials a potential contamination source themselves?
 - a. Flaking or shedding materials.
 - b. Reaction of materials with fuels, oils, etc.
 - c. Poor wear characteristics.
 - d. Outgassing of organics.
3. Can the materials be worked satisfactorily?
 - a. Burr-free finishes.
 - b. Flashings on castings.
4. Will the combination of the materials produce contamination?
 - a. Ability to clean dissimilar materials.
 - b. Galvanic corrosion.

B. Configuration or Geometry

1. Can individual parts be adequately cleaned?
 - a. Accessibility of critical surfaces for cleaning.
 - b. Blind holes and capillary traps.
2. Can subassemblies and assemblies be adequately cleaned?
 - a. Ability to clean dissimilar mated materials.
 - b. Accessibility of critical surfaces after assembly.
 - c. Protection of clean parts during subsequent assembly operations.
 - d. Generation of contamination during assembly operation (dislodged burrs, solder fluxes, etc.)

C. Use--How does the ultimate use of the product affect the contamination control requirements?

1. Continuous use
 - a. Long life materials.
 - b. Good wear characteristics.
 - c. Servicing provisions.
2. Intermittent use
 - a. Storage effects.
 - b. Life characteristics.
3. Single operation (one-shot) use
 - a. Storage effects.
 - b. End use environment (temperature, shock, vibration, temperature cycling).

Manufacturing Stage Considerations

What should the manufacturing or process engineer consider from the viewpoint of product contamination?

A. Materials

1. What purity requirements must be met?
2. Does the process have any effect?
 - a. Plastic curing--(shedding).
 - b. Metal tempering.
3. Are preservatives used?
 - a. Rust inhibitors on metals.
 - b. Surfactants.

4. What health hazards are present in the production of materials?
- B. Forming Processes--How may the forming processes contribute to contamination?
1. Process Agents
 - a. Casting sand.
 - b. Mold release compounds.
 - c. Machining oils.
 2. Process By-products
 - a. Flashings and irregularities.
 - b. Burrs and chips.
- C. Finishing Processes--How may the finishing processes contribute to contamination?
1. Process Agents
 - a. Machining oils.
 - b. Grinding and polishing compounds.
 - c. Plating and etching chemical residues.
 2. Process By-products
 - a. Chips and dusts.
 - b. Oxides.
- D. Assembly Processes--How may assembly procedures contribute to contamination?
1. Process Agents
 - a. Solder fluxes.
 - b. Lubricating oils.
 2. Process By-products
 - a. Solder spatters and oxides.
 - b. Screw thread burrs and shavings.
- E. Assembly Procedures--How may assembly procedures contribute to contamination?
1. Tools--Fixtures--Jigs
 - a. Surface dirt and oils.
 - b. Abrasion products.
 2. Personnel Contamination
 - a. Skin flakes, oils.
 - b. Hair.
 - c. Clothing fibers, etc.
 3. Environment
 - a. Airborne dirt.
 - b. Gases.
- F. Testing Procedures--How may in-process testing contribute to contamination?
1. Introduced Contamination
 - a. Handling
 - 1) Skin flakes, oils, hair.
 - 2) Clothing fibers.
 - b. Test Jigs and Fixtures
 - 1) Surface dirt, oils, etc.
 - 2) Abrasive products.

2. Test Agents or By-products
 - a. Chemical tests (dyes, etc.).
 - b. Released gases or operating fluids.
3. Self-Generated Contamination During Test Wear Products

Storage Stage Considerations

What must be considered in storing the product to prevent contamination?

A. Between Manufacturing Processes

1. What type of containers should be used?
 - a. Covered or sealed.
 - b. Bags or jars.
2. What type of fixtures, jigs, and racks should be used?

B. Finished Product Prior to Use

1. What type of containers?
 - a. Temporary.
 - b. Permanent.
 - c. Sealed.
2. What type of packing materials?
 - a. Shock proofing.
 - b. Desiccants.
 - c. Cocooning materials.
3. What effect will the storage environment have?
 - a. Temperature.
 - b. Humidity.
 - c. Dust conditions.

C. Testing Procedures and By-products

Use Stage Considerations

What contamination control considerations are necessary during the use period of the product?

A. Self-Generated Contamination

1. Are wear particles produced?
2. Do parts outgas?
3. Can condensation occur due to temperature changes?
4. Do materials age causing oxides or chalking surfaces?

B. Induced Contamination

1. Are critical parts sealed during use?
2. Must product be periodically inspected or repaired?

C. External Actuating or Servicing Materials (Maintenance Induced)

1. Must product be periodically lubricated?
2. Are fuels used that can cause contamination?
3. Are pneumatic air supplies or hydraulic fluids used?

D. Testing Procedures and Their By-products

E. End Use Environment

Contamination Control Procedures

Contamination is controlled in many different ways and in many different places. I would like to repeat that the ideal situation is to design the product so that contamination has the least effect possible. However, the contamination that is harmful must be controlled. The following outline points out the principal ways by which contamination is controlled.

Surface Contamination Control

A. Products

1. Cleaning processes
 - a. Wiping with cloth.
 - b. Immersion in cleaning solution.
 - c. Vapor degreasing.
 - d. Spraying or flushing.
 - e. Heating or firing.
 - f. Electrolytic and discharge.

B. Production Facilities--(Maintenance of)

1. Work surfaces.
2. Tool and fixtures.
3. General housekeeping.

Liquid Contamination Control

A. Cleaning Solutions

1. Distillation.
2. Filtration.
3. Deionization (water).
4. Control of containers.

B. Actuating Fluids

1. Hydraulics.
2. Fuels.
3. Compressed gases.

Airborne Contamination Control

A. Clean Rooms

B. Clean Work Stations

Conclusions

There are no simple foolproof solutions to contamination problems. Each problem must be evaluated in the light of the particular circumstances dictated by design, manufacturing, storage and use requirements. In addition, serious consideration must be given the possible impact of remedial actions, applied during one stage, on the subsequent stages of the product life. After satisfactory controls are developed and imposed, they must be continually monitored to ensure consistent processing from unit to unit.

It is hoped this broad survey of contamination control considerations has helped to place the problem in its proper perspective and that it will serve as a catalyst in encouraging the designer and manufacturing engineer to draw their own "fences" around their unique contamination problems.