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201-15842A

## ROBUST SUMMARY FOR FLUOROETHANE CATEGORY

### Summary

#### Identification of a structure based category

The fluoroethane category is comprised of test substances composed 2 carbon chains containing attached fluorine and chlorine atoms. The discrete materials vary by the number and positions of fluorine and chlorine atoms that are attached to the chain. Structures of these fluoroethanes are presented below.

| <u>Chemical Name</u>                               | <u>CAS Registry Number</u> | <u>Structure</u>  |
|--|----------------------------|---|
| Ethane, 1,1,2-trichloro-1,2,2-trifluoro (FC-113)   | 76-13-1                    | $\begin{array}{c} \text{F} \quad \text{F} \\   \quad   \\ \text{F}-\text{C}-\text{C}-\text{Cl} \\   \quad   \\ \text{Cl} \quad \text{Cl} \end{array}$ |
| Ethane, 1,1,1-trichloro-2,2,2-trifluoro (FC-113a)  | 354-58-5                   | $\begin{array}{c} \text{F} \quad \text{Cl} \\   \quad   \\ \text{F}-\text{C}-\text{C}-\text{Cl} \\   \quad   \\ \text{F} \quad \text{Cl} \end{array}$ |
| 1,2-Dichloro-1,1,2,2-tetrafluoroethane (FC-114)    | 76-14-2                    | $\begin{array}{c} \text{F} \quad \text{F} \\   \quad   \\ \text{F}-\text{C}-\text{C}-\text{F} \\   \quad   \\ \text{Cl} \quad \text{Cl} \end{array}$  |
| Ethane, 1,1-dichloro-1,2,2,2-tetrafluoro (FC-114a) | 374-07-2                   | $\begin{array}{c} \text{F} \quad \text{F} \\   \quad   \\ \text{F}-\text{C}-\text{C}-\text{Cl} \\   \quad   \\ \text{F} \quad \text{Cl} \end{array}$  |

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Scientific literature was searched and summarized. Data were identified for materials in the category (Table 1). A majority of the SIDS endpoints were covered for the individual materials, as well as the category. Each study on category materials was evaluated for adequacy. Robust summaries were developed for each study addressing specific SIDS endpoints. Summaries were also developed for studies that were either considered inadequate but that provided information of relevance for hazard identification and evaluation, or covered non-SIDS endpoints

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(Appendices A-D). The information presented in these data summaries indicates that these materials share similar physical chemical properties, environmental fate characteristics, ecotoxicity, and mammalian toxicity.

**Table 1: Matrix of Available and Adequate Data for Fluoroethane Category**

|  | FC-113 | FC-113a | FC-114 | FC-114a |
|--|--------|---------|--------|---------|
| <b>PHYSICAL/CHEMICAL CHARACTERISTICS</b>   |        |         |        |         |
| Melting Point  | √      | √       | √      | √       |
| Boiling Point  | √      | √       | √      | √       |
| Vapor Pressure   | √      | √       | √      | √       |
| Partition Coefficient  | √      | √       | √      | √       |
| Water Solubility   | √      | √       | √      | √       |
| <b>ENVIRONMENTAL FATE</b>  |        |         |        |         |
| Photodegradation   | √      | √       | √      | √       |
| Stability in Water   | √      | √       | √      | √       |
| Transport (Fugacity)   | √      | √       | √      | √       |
| Biodegradation   | √      | √       | √      | √       |
| <b>ECOTOXICITY</b>   |        |         |        |         |
| Acute Toxicity to Fish   | √      | √/-     | √/-    | √       |
| Acute Toxicity to Invertebrates  | √      | √/-     | √      | √       |
| Acute Toxicity to Aquatic Plants   | √/-    | √/-     | √/-    | √/-     |
| <b>MAMMALIAN TOXICITY</b>  |        |         |        |         |
| Acute Toxicity   | √      | √       | √      | √       |
| Repeated Dose Toxicity   | √      | √/-     | √      | √/-     |
| Developmental Toxicity   | √      | -       | -      | -       |
| Reproductive Toxicity  | √      | -/*     | -/*    | -/*     |
| Genetic Toxicity Gene Mutations  | √      | -       | √      | -       |
| Genetic Toxicity Chromosomal Aberrations   | -      | -       | -      | -       |
| Genetic Toxicity <i>in vivo</i> Studies (Dominant lethal in mice)  | √      | -       | -      | -       |
| √ = Data are available and considered adequate.<br>√/- = Data are available, but considered inadequate.<br>- = No data available.<br>-/* = No reproductive toxicity studies were available; however, detailed information on the evaluation of reproductive organs is presented in the repeated-dose toxicity studies for these test substances. |        |         |        |         |

**Evaluation of Data Matrix Patterns**

The available adequate data were broken out by discipline (physical chemical, environmental fate, ecotoxicology, and mammalian toxicology). These comparisons were conducted to determine if a pattern existed among the materials and to determine if additional testing needed to be conducted to complete the data set for the category. In general, the most striking pattern across the group of materials is their low mammalian toxicity.

All four fluoroethanes have roughly equivalent physical chemical properties as a result of structural similarity. FC-113 and FC-113a are clear, colorless liquids with a slight ethereal odor, neutral pH, and molecular weight of 187.4. FC-114 is a colorless gas and FC-114a is colorless to clear liquefied gas, both containing a slight ethereal odor and molecular weight of 170.9. Melting points range from -94°C to 14.2°C at 760 mm Hg. Boiling points of FC-113 and FC-113a are 47.7 and 46.1°C at 760 mm Hg, respectively. Boiling points of FC-114 and FC-114a are 3.8 and 4°C at 760 mm Hg, respectively. Vapor pressures of FC-113 and FC-113a are 362.5 and 360 mm Hg at 25°C respectively. Vapor pressures of FC-114 and FC-114a are 2014 and 1653 mm Hg at 25°C respectively. **No additional testing is recommended for physical and chemical characteristics.**

**Table 2: Physical and Chemical Characteristics**

|  | <b>FC-113</b>                                       | <b>FC-113a</b>                                      | <b>FC-114</b>                             | <b>FC-114a</b>   |
|--|---|---|---|--|
| <b>Physical Appearance</b>             | Clear, colorless liquid with a slight ethereal odor | Clear, colorless liquid with a slight ethereal odor | Colorless gas with a slight ethereal odor | Colorless to clear liquefied gas with a slight ethereal odor |
| <b>Molecular Weight</b>                | 187.4   | 187.4   | 170.9                                     | 170.9  |
| <b>Water Solubility</b>                | 170 mg/L @ 25°C *                                   | 20.9 mg/L @ 25°C                                    | 130 mg/L @ 25°C                           | 137 mg/L @ 25°C  |
| <b>Melting Point</b>                   | -35°C @ 760 mm Hg                                   | 14.2°C @ 760 mm Hg                                  | -94°C @ 760 mm Hg                         | -56.6°C (pressure not reported)                              |
| <b>Boiling Point</b>                   | 47.7°C @ 760 mm Hg                                  | 46.1°C @ 760 mm Hg                                  | 3.8°C @ 760 mm Hg                         | 4°C @ 760 mm Hg  |
| <b>Vapor Pressure</b>                  | 362.5 mm Hg @ 25°C                                  | 360 mm Hg @ 25°C                                    | 2014 mm Hg @ 25°C                         | 1635 mm Hg @ 25°C  |
| <b>Density</b>                         | 1.56 @ 25°/4°C                                      | 1.58 @ 20°/4°C                                      | 1.46 @ 25°C                               | 1.46 @ 25°/4°C   |
| <b>Partition Coefficient (log Kow)</b> | 3.16  | 3.09*   | 2.82                                      | 2.78*  |
| * Estimated value.                     |   |   |   |  |

Environmental fate data are essentially equivalent for the category members (Table 3). The environmental fate data indicate all materials are not readily biodegradable and estimated BCF's indicate that these substances have low potential to bioaccumulate. Fugacity model predictions for the fluoroethanes indicate these materials will act similarly in regard to partitioning in the environment. Modeled data shows that all 4 test materials are essentially the same in terms of partitioning, with the majority of the material partitioning to the air and water, with virtually none going to soil or sediment. If released to air, vapor pressures indicates that FC-113 and FC-113a will exist solely as a vapor, and FC-114 and FC-114a will exist solely in the gas phase in the ambient atmosphere. Chlorofluorocarbons are expected to be persistent. These test substances do not react with photochemically produced hydroxyl radicals, ozone molecules, and/or nitrate radicals in the troposphere. FC-113 and FC-114 will gradually diffuse into the stratosphere above the ozone layer where they will slowly degrade due to direct photolysis from UV-C radiation and contribute to the catalytic removal of stratospheric ozone. In the stratosphere, FC-114a will slowly photolyze, releasing chlorine atoms that in turn are responsible for removing ozone. Calculated stratospheric lifetimes for other completely halogenated fluorochloroethanes are generally hundreds of years. Volatilization from moist soil surfaces is expected to be an important fate process based upon estimated Henry's Law constants. If released into water, these test substances may adsorb to suspended solids and sediment based upon estimated Koc values, however, volatilization from water surfaces is expected to be an important fate process based upon the test substances' estimated Henry's Law constants. Estimated volatilization half-lives for FC-113 and FC-113a using a model river and model lake are 4 hours and 5 days, respectively. Estimated volatilization half-lives for FC-114 and FC-114a using a model river and model lake are 1-1.3 hours and 5 days, respectively. **No additional testing is recommended for environmental fate endpoints.**

**Table 3: Environmental Fate**

|                            | <b>FC-113</b>   | <b>FC-113a</b>  | <b>FC-114</b>  | <b>FC-114a</b>   |
|----------------------------|---|---|--|--|
| <b>Stability in Water*</b> | Rapidly volatilize  | Rapidly volatilize  | Rapidly volatilize   | Rapidly volatilize                                     |
| <b>Bioaccumulation</b>     | Low<br>BCF = 11-33<br>@ 0.19 mg/L<br>and 14-86 @<br>0.01 mg/L | Low<br>BCF = 48.2*  | Low<br>BCF = 16-32<br>@ 400 mg/L<br>and 15-28 @<br>40 mg/L | Low<br>BCF = 30*                                       |
| <b>Biodegradation</b>      | Not readily biodegradable                                     | Not readily biodegradable*                                  | Not readily biodegradable*                                 | Not readily biodegradable*                             |
| <b>Fugacity*</b>           | Air 49.3%<br>Water 47.3%<br>Soil 1.66%<br>Sediment<br>1.74%   | Air 47.5%<br>Water 48.4%<br>Soil 2.38%<br>Sediment<br>1.72% | Air 50.4%<br>Water 48.3%<br>Soil 0.5%<br>Sediment 0.8%     | Air 50.5%<br>Water 48.3%<br>Soil 0.5%<br>Sediment 0.7% |
| * Modeled data.            |   |   |  |  |

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Actual and estimated data on ecotoxicology support a category approach for these chemicals. A limited number of ecotoxicological studies have been conducted with these fluoroethane chemicals. Modeling of physical-chemical parameters (i.e.,  $K_{ow}$ ) and aquatic toxicity was conducted to help provide insight into the behavior in the environment and the aquatic toxicity of FC-113, FC-113a, FC-114, and FC-114a (Table 4). Syracuse Research Corporation models for estimating physical-chemical properties were used to estimate  $\log_{10} K_{ow}$  (Meylan and Howard, 1995) for subsequent use in the ECOSAR program (Table 1). ECOSAR (Meylan and Howard, 1999) was used to estimate the missing aquatic toxicity data for the 4 fluoroethane chemicals to green algae, daphnids (planktonic freshwater crustaceans), and fish, if necessary.

The existing test data, coupled with ECOSAR predictions, indicate that fluoroethanes possess moderate acute toxicity potential to aquatic organisms. Results of the available aquatic test data with fish and daphnid data indicate that the 96-hour fish  $LC_{50}$  was 7.4-15 mg/L and the 48-hour daphnid  $EC_{50}$  was 38-71 mg/L. The ECOSAR predictions of toxicity to these 2 species are in general agreement with the actual measured values when available. Although no measured data exists for algae, ECOSAR predictions of toxicity are in general agreement with the other species tested. The volatility of these chemicals would necessitate the use of a closed test system for algae testing. This type of testing is difficult with algae. Given the similarity of actual test data and ECOSAR estimated data for other species, and the mode of action of these compounds, no algal testing will be conducted. **Therefore, no additional testing is recommended for ecotoxicity endpoints.**

**Table 4: Ecotoxicity**

|  | <b>FC-113</b>  | <b>FC-113a</b> | <b>FC-114</b>   | <b>FC-114a</b> |
|--|----------------|----------------|---|----------------|
| <b>Toxicity to Fish</b> (96-hour LC <sub>50</sub> value)   | 7.4 mg/L (M)   |                | ca. 2 mg/L (NOEC; 48-hours) <sup>a</sup>                    | 15 mg/L (M)    |
|  | 11.28 mg/L (E) | 13.1 mg/L (E)  | ca. 1.5 mg/L (NOEC; 24-hours) <sup>a</sup><br>21.5 mg/L (E) | 23.4 mg/L (E)  |
| <b>Toxicity to Invertebrates</b> (48-hour EC <sub>50</sub> value)  | 71 mg/L (M)    |                | >100% saturation at 25°C (N; Atlantic oyster embryo)        | 38 mg/L (M)    |
|  | 13.1 mg/L (E)  | 15.2 mg/L (E)  | 10% saturation at 18°C (N; grass shrimp)<br>24.4 mg/L (E)   | 26.5 mg/L (E)  |
| <b>Toxicity to Algae</b> (96-hour EC <sub>50</sub> value)  | 8.75 mg/L (E)  | 10.1 mg/L (E)  | 16.0 mg/L (E)   | 17.3 mg/L (E)  |
| E = estimated value<br>M = measured value<br>N = nominal value<br><sup>a</sup> It was not defined if this value was nominal or measured.<br>The log Kow values used in the ECOSAR model are listed in Table 2. |                |                |   |                |

Acute toxicity data indicates that these chemicals exhibit similar acute toxicity (Table 5) and thus support the category approach. In mammalian species, all 4 fluoroethanes had very low acute inhalation toxicity, with ALC or LC<sub>50</sub> values in rats or mice of >49,500 ppm. FC-113 had very low acute oral toxicity with an LD<sub>50</sub> in rats of 43,000 mg/kg, and FC-114 was at most slightly toxic via the oral route with an ALD in rats of >2250 mg/kg. FC-113 had very low acute dermal toxicity with a dermal ALD of >11,000 mg/kg. FC-113 and FC-114 produced no to mild skin and eye irritation, and FC-113 was reported to have minimal skin sensitizing potential. Both FC-113 and FC-114 were cardiac sensitizers in dogs. The acute data that exists for these chemicals indicates that the chemicals produce similar toxicity profiles for acute toxicity. **No additional testing is recommended for acute toxicity endpoints.**

**Table 5: Acute Mammalian Toxicity**

|   | <b>FC-113</b>                      | <b>FC-113a</b>      | <b>FC-114</b>                  | <b>FC-114a</b>                   |
|---|------------------------------------|---------------------|--------------------------------|----------------------------------|
| <b>Oral LD<sub>50</sub> (rat)</b>       | 43,000 mg/kg                       | No Data             | ALD >2250 mg/kg                | No Data                          |
| <b>Inhalation LC<sub>50</sub> (rat)</b> | 4-hour ALC = 56,000 ppm            | 4-hour > 49,500 ppm | 30-minute = 700,000 ppm (mice) | 5.25-hour ALC $\geq$ 153,000 ppm |
| <b>Cardiac Sensitization</b>            | Sensitizer                         | No Data             | Sensitizer                     | No Data                          |
| <b>Dermal LD<sub>50</sub> (rabbit)</b>  | ALD > 11,000 mg/kg                 | No Data             | No Data                        | No Data                          |
| <b>Dermal Irritation</b>                | No to mild irritation              | No Data             | Mild irritation                | No Data                          |
| <b>Eye Irritation</b>                   | Practically non-irritating         | No Data             | Mild irritation                | No Data                          |
| <b>Dermal Sensitization</b>             | Minimal skin sensitizing potential | No Data             | No Data                        | No Data                          |

**Repeated Dose**

Repeated exposure studies in rats and/or dogs with FC-113 (90-day and 2-year rat inhalation), FC-113a (2-week rat inhalation; 21-day rat oral), FC-114 (2-week rat inhalation; 2-month rat and mouse inhalation; 90-day rat and dog oral), and FC-114a (2-week rat inhalation) have indicated a low degree of toxicity.

In a 90-day rat inhalation study with FC-113, significant increases in lung weights were observed in males at 17,500/20,000 ppm. These findings were positively correlated with gross and microscopic evidence of multi-focal granulomatous interstitial pneumonia. Although the granulomatous pneumonia was not considered to be induced by the test substance, exposure to FC-113 may have resulted in a stress-related enhancement of the existing pneumonic conditions, which was accompanied by increases in lung weight in these rats. Long-term exposure to rats (2 years) to FC-113 was not associated with remarkable toxicity. With the exception of a decreased rate of body weight gain among female rats at 1 and 2% and male rats at 2%, and a slight, transient decrease in serum glucose level in male rats at 2%, no test substance-related abnormalities were observed. In addition, FC-113 was not found to be oncogenic.

In a 2-week rat inhalation study with FC-113a, no test substance related effects were observed at exposures of 2000, 10,000, or 20,000 ppm, except for a minimal change in the nasal epithelium in all test substance-exposed groups. This minimal change was reversible after 2 weeks, and was

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not considered biologically significant, and may not have been related to FC-113a exposure. In a 21-day oral gavage study in rats with FC-113a, no differences in final mean body weights, body weight gains, clinical signs of toxicity, organ weights, urinalysis parameters, or microscopic effects in the kidney or liver were observed at doses  $\leq 1.24$  mmol/kg (highest dose tested).

In a 2-week inhalation study with FC-114 in mice and rats, no mortality was observed. Transient weight loss was observed in mice at 200,000 ppm, and hematologic effects were noted at 200,000 ppm. Only the rats exposed to 200,000 ppm showed lesions. These were congestive and exudative phenomena. No structural alterations were observed at the levels of the alveolar and bronchial walls. These changes were reversible and disappeared 15 days after stopping the exposure. In a 2-month inhalation study in rats and mice at 10,000 ppm, there was a slight loss of red blood cells and a slight increase in white blood cells during the 1<sup>st</sup> month of exposure, which were practically non-existent at the end of the 2<sup>nd</sup> month. No changes in blood composition or lung effects were observed. Oral administration of FC-114 to rats and dogs for 90-days at doses of 0.5 and 3% (rats) or 25% (dogs) resulted in no test substance-related effects.

Rats exposed to FC-114a at measured concentrations of up to 41,300 ppm for 2 weeks via inhalation, showed no test substance-related effects. **No additional testing is recommended for repeated dose toxicity.**

#### Developmental

Pregnant female rats were exposed to 5000, 12,500, or 25,000 ppm of FC-113 via inhalation during Days 6-15 of gestation. Maternal toxicity evidenced as test substance-related reduced body weight gain and food consumption, and increased signs of hyperactivity were observed at 25,000 ppm. No toxicological significant test substance-related findings were observed in the dams at  $\leq 12,500$  ppm. No test substance-related effects on the fetuses were observed. Therefore, the test substance was not teratogenic in rats at exposure concentrations  $\leq 25,000$  ppm. Although no developmental toxicity data was available for FC-113a, FC-114, and FC-114a, these test substances, based on acute data, are expected to have similar toxicological properties to that of FC-113. **Therefore, no additional testing is recommended for developmental toxicity.**

#### Reproductive

Male and female rats were exposed to FC-113 at concentrations of 5000 and 12,500 ppm in a reproductive toxicity study. The test substance had no apparent effects on the reproductive parameters examined, with the exception of possible slight effects on pre-coital interval at 5000 and 12,500 ppm, and ovulation at 12,500 ppm. While no formal reproductive toxicity studies have been conducted on FC-113a, FC-114, and FC-114a, pathological examination of the reproductive organs was performed in repeated dose studies for these test substances. No effects on testis or epididymides was observed in repeated dose rat inhalation studies conducted with FC-113a and FC-114a. No test substance-related effects on testis, epididymides, prostate, ovaries, uterus, and/or mammary glands were observed in rat and dog inhalation studies conducted with FC-114. **No additional testing is recommended for reproductive toxicity.**

**Table 6: Repeated Dose, Developmental, and Reproductive Toxicity**

|                               | <b>FC-113</b>  | <b>FC-113a</b>  | <b>FC-114</b>  | <b>FC-114a</b>  |
|-------------------------------|--|---|--|---|
| <b>Repeated Dose Toxicity</b> | <p>90-Day Rat Inhalation: NOAEL = 12,500 ppm</p> <p>2-Year rat inhalation: NOEL = 0.2%</p> <p>5-Day human inhalation: No apparent effect at <math>\leq 1000</math> ppm</p> <p>30-Day human dermal: No adverse effect on the structure and function of skin of scalp and forehead</p> | <p>2-Week Rat Inhalation: NOAEL = 20,000 ppm</p> <p>21-Day rat gavage: NOAEL <math>\geq 1.24</math> mmol/kg</p> | <p>2-Week Rat Inhalation: NOAEL = 100,000 ppm</p> <p>2-Week Mouse Inhalation: NOAEL = 100,000 ppm</p> <p>2-Month Rat Inhalation: NOAEL = 10,000 ppm</p> <p>2-Month Mouse Inhalation: NOAEL = 10,000 ppm</p> <p>90-Day Rat Gavage: NOAEL = 3%</p> <p>90-Day Dog Gavage: NOAEL = 25%</p> | <p>2-Week Rat Inhalation: NOAEL = 41,300 ppm</p>              |
| <b>Developmental Toxicity</b> | Not embryotoxic or teratogenic up to 25,000 ppm in rats  | No Data   | No Data  | No Data   |
| <b>Reproductive Toxicity</b>  | Possible slight effect on pre-coital interval at $\geq 5000$ ppm and ovulation at 12,500 ppm in rats   | No effect on reproductive organs in repeated exposure studies   | No effect on reproductive organs in repeated exposure studies  | No effect on reproductive organs in a repeated exposure study |

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Based on structural similarities and chemical properties, genetic toxicity data can be assumed to be similar between the chemicals (Table 7). Neither FC-113 nor FC-114 were mutagenic in the bacterial reverse mutation assay using *Salmonella typhimurium*. No data were available on the mutagenicity of FC-113a or FC-114a. FC-113 was negative in a dominant lethal study in mice. The negative bacterial reverse mutation assay results for 2 of the 4 compounds, in combination with the negative dominant lethal results, are considered sufficient to exclude any concern about genotoxic effects associated with this chemical category. **Therefore, no additional testing is recommended for genetic toxicity endpoints.**

**Table 7: Genetic Toxicity**

|                       | <b>FC-113</b>                            | <b>FC-113a</b> | <b>FC-114</b> | <b>FC-114a</b> |
|-----------------------|--|----------------|---------------|----------------|
| <b>Mutagenic</b>      | Negative                                 | No Data        | Negative      | No Data        |
| <b>Clastogenic</b>    | No Data                                  | No Data        | No Data       | No Data        |
| <b><i>In Vivo</i></b> | Negative<br>(Dominant<br>Lethal in mice) | No Data        | No Data       | No Data        |

Overall, the toxicology database for fluoroethanes is relatively complete, and the information available does not suggest a high level of concern. As a chemical category can be used for these chemicals, where data are missing for a single test substance, a read across approach is appropriate. As such, **no further testing for the fluoroethanes is recommended.**

#### Human Exposure

Air concentrations of Freons 113, 113a, 114 and 114a in manufacturing operations are very low (NIOSH, 1978), and except in the case of accidental releases, there is little potential for significant worker exposure. DuPont has no Acceptable Exposure Limit for FC-113 or FC-114. The DuPont Acceptable Exposure Limit for FC-113a and FC-114a are 1000 ppm, 8- and 12-hour TWA. The ACGIH Threshold Limit Value for FC-113 and FC-114 is 1000 ppm, 8-hour TWA (with a STEL for FC-113 of 1250 ppm), and the OSHA Permissible Exposure Level is 1000 ppm, 8-hour TWA.

Reports investigating health effects of occupational exposure to FC-113 were available. In the first of these, Imbus and Adkins (1972) documented exposure to FC-113 among clean room workers at the Kennedy Space Center over a period of approximately 4.5 years, and compared clinical findings between groups of 50 exposed and non-exposed workers. FC-113 concentrations ranged from 46-4750 ppm over the study period, with mean and median concentrations of 669 ppm and 435 ppm, respectively. The average daily exposure duration was 6 hours, and the average duration of employment in the clean rooms was 2.77 years. Exposed and non-exposed workers were compared with respect to general medical history, clinical chemistry, chest x-ray and selected respiratory parameters. With the exception of dry skin in one

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individual, no differences were observed between exposed and non-exposed groups that could be attributed to FC-113 exposure.

A second study of occupational exposure to FC-113 conducted by NIOSH (1980), documented exposure to FC-113 among workers using a vapor degreaser. At the time of the survey, room air concentrations of FC-113 were less than 15% of the current TLV (7600 mg/m<sup>3</sup>). Interviews with employees in this work area did not reveal evidence of health problems associated with FC-113 exposure.

In a third study, a group of 13 workers occupationally exposed to 23-62 ppm FC-113 from a few minutes up to a few hours per day were examined. No adverse effects were observed (Triebig and Burkhardt, 1978).

Several cases of accidental death due to occupational exposure to excessive concentrations of FC-113 have been reported (May and Blotzer, 1984; Yonemitsu et al., 1983; Clark et al., 1985; Lehmann, 1980; Stansbury, 1983; Hoshika et al., 1989; McGee et al., 1990; NIOSH, 1989; Kaufman et al., 1994). In the cases that reported actual concentrations, workers were exposed to concentrations of FC-113 ranging from approximately 5000 ppm to 142,000 ppm, which is approximately 5-142 times the documented TLV value.

Other effects due to occupational exposure to FC-113 have been reported, however, in the majority of the reports the exposure concentration was not reported. Two cases of occupational exposure resulted in cardiac anomalies, including cardiac arrest, arrhythmias, and/or atrial hypertension (Kaufman et al., 1994; Voge, 1996). Two studies reported decreased nerve conduction velocity, however in one case there was improvement after occupational exposure ceased (Campbell et al., 1986). In the second incident involving a refrigeration repair worker, a follow-up study with 27 refrigeration workers and control group of 14 pipefitters resulted in no difference in conduction velocity between the two groups, although the refrigeration workers reported an elevated incidence of "lightheadedness" (Raffi and Violante, 1981; O'Donoghue, 1985). Liver effects were noted in 2 cases where exposure was at high concentrations (actual concentrations not reported) (Lun and Schmidt, 1979).

Additional clinical reports of human exposure or epidemiology studies with FC-113 were reported; however, exposure to other chemicals/solvents also occurred at that time (AT&T, 1991; Boeing, 1992; Esswein, 1993; Neghab et al., 1997; Rasmussen et al., 1988; Rasmussen et al., 1993a; 1993b; 1993c).

Air monitoring results from a product packaging area of a fluorochemical manufacturing plant indicated FC-114 air concentrations ranging from 0.0022-0.2033% during product loading (NIOSH, 1978).

No reports of human occupational exposure to FC-113a or FC-114a were found.

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