Selection and safe use of alternatives to CTC

Electrical Applications

gtz PROKLIMA

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1. The Phase-out of CTC

1.1 About CTC

Carbon tetrachloride (CTC) is a solvent and cleaning agent used widely across many industry segments. Its high solvency power, low cost and the fact that it is non-flammable made it popular in many cleaning applications.

Although CTC is very popular, it is an ozone depleting substance (ODS) like chlorofluorocarbons (CFCs). It destroys the stratospheric ozone layer which protects life on our planet from harmful ultraviolet-B (UV-B) rays. It increases the incidence of skin cancer, eye cataract, suppresses the human immune system, reduces crop yields and affects aquatic life. Another adverse impact of CTC is its contribution to global warming. The global warming potential (GWP) of CTC is about 1,400 times higher than that of carbon dioxide (CO_2), the main greenhouse gas.

At the workplace CTC is an occupational health hazard. CTC is very toxic and is absorbed by the skin and also in the gastrointestinal and respiratory systems. CTC affects the central nervous system (CNS) severely, causing headache, weakness, drowsiness, nausea and vomiting. Inhalation of high levels can permanently damage the liver and kidneys. The severity of the effects depends on the route and frequency of exposure. CTC is proven to cause cancer in animals and is a suspected human carcinogen.

1.2 The Montreal Protocol

To protect the ozone layer, India, along with more than 190 countries has signed the Montreal Protocol to phase out production and consumption of CTC and other ozone depleting substances. Under this agreement India has committed to phase-out the use of CTC as a solvent completely by 31st December 2009.

As the phase-out is progressing, CTC supplies in the market are dwindling rapidly. Beyond 31st December 2009 CTC will not be

available for solvent uses. Given the reduction of supply, the price of CTC has risen substantially making it costlier today than most of its alternatives.

1.3 Role of GTZ-Proklima

For enterprises there is an urgent need to substitute CTC now. But finding suitable alternatives, especially safer ones, is not an easy task. There is no single alternative which can replace CTC in all its applications and in the absence of sufficient information enterprises may substitute CTC with an even more hazardous substance such as Trichloroethylene or Benzene.

Within the framework of the Multilateral Fund of the Montreal Protocol, the Governments of Germany and France have mandated GTZ-Proklima to provide technical assistance to CTC consuming industries in the Indian textiles and metal cleaning sectors. In addition World Bank, UNIDO and UNDP (on behalf of the Government of Japan) are assisting the country in specific industry sectors with large usage of CTC. These activities are coordinated under the National CTC Phase-out Plan by the World Bank as the lead implementing agency and the Ozone Cell of the Ministry of Environment and Forests, Government of India.

GTZ-Proklima offers technical assistance to industries using up to 10 metric tons or 6,250 litres of CTC per year. In close interaction with affected industries, GTZ-Proklima aims to provide competent guidance in identifying CTC substitutes by addressing environmental, health and safety concerns without compromising on quality and cost effectiveness.

GTZ-Proklima maintains strict independence from any branded or proprietary product.

2. CTC in electrical applications

One of the most common uses of CTC that has been identified across the country is in cleaning of electrical applications. Some of these like generators, motors and insulators of high voltage transmission have to be cleaned while they are energized. The major applications are mentioned below:

Switch/Contactors: Electrical contacts develop carbon deposits over time due to the high voltage sparking at the point of contact and disconnection. These deposits reduce conductivity and result in loss of power and therefore contact cleaning is an integral part of preventive maintenance in every industry.

Insulators: The presence of contaminants on high voltage insulators made of ceramics, epoxy and Teflon can cause dielectric breakdown and arcing between otherwise non-conductive surfaces (commonly known as tracking). The result is expensive equipment damage and power outages. Thus periodical cleaning is a requirement in all high voltage applications in power generation units, distribution substations and transmission lines.

Generators/Motors: Oil, grease, dirt, dust, metallic, and chemical contaminants build up over time and reduce or block the required ventilation. If this is allowed to happen, eventually the operating temperature of the motor will rise beyond its maximum rating and damage will occur.

Metallic and chemical contaminants along with abrasive dust and dirt will attack the electrical insulation qualities of the motor/

generator resulting in early failures. Most insulation failures can be blamed on these types of debris collecting in the motor.

For the reasons cited above, motors are cleaned periodically either as regular maintenance or when they are serviced. This application is also specific to large motors in industries and generators in power generation plants.

Transformers: The oil used in the transformers get heated up and burnt during excessive loading and short-circuit conditions. This burnt oil leaves residues on the transformer windings which needs to be cleaned during maintenance.

3. Selecting alternatives to CTC

3.1 Selection criteria

No alternative is ideal in all regards and each one has certain advantages and disadvantages. In order to address environmental, health and safety concerns without compromising on quality and cost effectiveness, any substitute for CTC should meet the following criteria:

- Non-ozone-depleting substance (non-ODS)
- Good cleaning efficacy
- Low toxicity
- High Dielectric strength
- Compatible with insulation material (should not damage)
- Not leaving any residue
- Equal or lower cost compared to CTC
- Locally available
- Non carcinogenic

3.2 Viable alternatives

Based on the selection criteria presented above, GTZ-Proklima identified a range of alternatives for varied applications within the electrical sector. Their suitability has been confirmed through industrial trials. Though Trichloroethylene (TCE) has good cleaning properties and is used by many enterprises, its usage is strongly discouraged because of its inherent cancer risk.

In electrical contact cleaning, one of the main contaminants is carbon deposit. Carbon deposits can be of many kinds – hard coke type, powdery, or sticky bituminous deposits. The suitable alternative has to be selected based on the type of carbon deposit that needs to be removed.

The most relevant properties of available generic solvents for selecting appropriate alternatives to CTC are:

- Flash Point
- Dipole Moment
- Boiling Point
- Hansen Solubility Parameter
- Vapour Pressure
- Dielectric Constant

Flash point

The flash point (in ^{0}C) is the lowest temperature at which a flammable solvent can form an ignitable mixture with air. As a rule of thumb, the higher the flash point temperature the lower is the fire hazard risk. Non-flammable solvents do not have a flash point.

Boiling point

The boiling point (in ^{0}C) is the temperature at which the liquid will start boiling. A lower boiling point means higher losses of solvent into the atmosphere but higher cleaning efficiency.

Dielectric Constant

The dielectric constant of a solvent is a relative measure of its polarity. The lower the dielectric constant of a solvent the better it is for use as electrical contact cleaner.

Vapour pressure

Vapour pressure (in mm Hg) is an indicator for the rate of evaporation under atmospheric conditions. The higher the value the faster the solvent evaporates. If the substance is stored in an open container it can also be considered as a measure of evaporation losses.

Dipole Moment

Dipole moment (in Debye) is a measure of the polarity of a solvent. It determines what type of compounds it can dissolve and with what liquids it is miscible. Typically, polar solvents dissolve polar compounds best and non-polar solvents dissolve non-polar compounds best. Similarly, polar contaminants dissolve best in

polar solvents, while non-polar compounds, like oils or waxes, dissolve best in non-polar solvents.

Hansen Solubility Parameter

The Hansen solubility parameter is a numerical value that indicates the relative solvency behaviour of a specific solvent. It is available for every solvent and any liquid or polymer. This number is calculated from the dispersion, polarity and hydrogen bonding properties of the solvent. It is indicative of the forces that hold together the molecules. It should be noted that solvents with Hansen numbers below 17.5 are more effective in cleaning mineral oils, lubricants and greases.

Table 1
Properties of selected solvents

Parameters	Flash point ^{0}C	Boiling point ^{0}C	Vapour pressure mmHg	Dielectric Constant @ 20 ^{0}C	Hansen solubility parameter
Acetone	–20	56	180	20.56	20.0
Isopropyl alcohol	12	82	33	19.92	23.5
Methylene dichloride*	None	40	350	8.93	20.3
Mineral turpentine oil	36-38	146-197	25	–	15.8
Perchloro ethylene	None	121	14	2.28	20.3
White Petrol	–18	50-120	180	–	7.3

*Only MDC is suggested for online cleaning due to its non-flammability and higher rate of evaporation.

4. Process alternative

4.1 Solvent cleaning

The solvent cleaning is executed mostly by wiping method – a swab or cloth is soaked in solvent and the component to be cleaned is wiped with this swab. This not only results in a very inefficient cleaning and wastage of solvent, but it causes harm to the personnel's health. If solvent use is unavoidable, it is highly recommended to use a hand-operated spray-gun. The advantage is that solvent can be applied directly onto the contaminants, saving on solvent quantity, avoidance of direct skin contact and that of cleaning even inaccessible interior surfaces.

This is most suitable method for cleaning of smaller/low voltage electrical equipment which can be switched off for cleaning. When this is not possible, and the equipment has to be cleaned while it is energised, only MDC can be used as it has very low flammability, high rate of evaporation and low dielectric constant.

There is another very efficient way of cleaning the big generator and motor windings. This is explained in the following section.

4.2 Air pressure and vacuum

Compressed air can also be used to remove dust and light dirt from the exterior and interior of a motor. The air should be dried to remove the moisture content. Compressed air should never be used when metallic dusts such as copper, iron or carbon are present.

During this process wearing of goggles and masks are mandatory as flying particles during cleaning can cause serious injuries.

4.3 Dry blasting

Carbon dioxide (CO_2; dry ice) particle media blasting is a technique that can be used to clean energized power distribution equipment. Contaminants are removed by the impact of the CO_2 particle. The dry ice shears and lifts the contaminant off the surface with no/very

minimal damage and leaves no residual waste. This shearing or lifting force is caused by the sublimation (direct transition from solid phase to gaseous phase) of the dry-ice particles resulting in a sudden 400-fold increase in volume of the gas directed along the plane of the substrate. The contaminant is swept up, or in the case of outdoor switches, blown out of the enclosure. The released CO_2 gas is a naturally occurring atmospheric compound and presents no significant environmental concern.

Operationally, CO_2 pellets have a dielectric constant of 3.1 kV/mm at ambient pressure (about equal to dry air), enabling users to clean energized equipment with no safety hazard. The theory of operation is to generate a large volume of compressed very dry air, transport it to the hot stick/nozzle assembly, mix it with CO_2 pellets in the hot stick, and then direct the mixed stream in a safe manner to the object to be cleaned. The air must be extremely dry because of the tendency for a high voltage arc, often called flashover or tracking or arc blast, to develop along contaminated or wet surfaces. However this process requires special training for the personnel and additional equipment.

5. Health and safety

5.1 Hazard potential of alternatives

Any solvent is a potential hazard for health and safety. Most solvents are toxic but the degree of hazard varies from one substance to another. The hazard of electric shock, when coupled with the effects of solvents could be fatal to the personnel.

At the workplace the intake of chemicals occurs mainly through inhalation and skin contact. Another major risk in the electrical systems is flammability. While these hazards affect directly and immediately the workplace the environmental hazards like contamination of air and ground water are rather indirect effects not only at the workplace but also on a global scale. Thus this guide rates the hazard of each solvent on these four factors.

Each hazard has been further classified into six grades and each grade is characterized through a corresponding colour shade. The least risk is marked in light blue, followed by shades of yellow and orange. Dark red represents the most severe risk.

Table 2
Hazard rating

	Risk	Inhalation	Skin	Environment	Flammability
E	High	Severely toxic	Severely toxic	Very hazardous	Extremely flammable
D		Very toxic	Very toxic		Highly flammable
C		Toxic	Toxic	Hazardous	Flammable
B		Harmful	Harmful		Combustible
A		Irritant	Irritant		Possibly combustible
-	Low	None	None	Not classified	Non-flammable

For details on the hazard classification methodology please visit www.ctc-phaseout.org

Table 3 shows the hazard ratings of the alternatives discussed in the previous section:

Table 3
Hazard rating of specific alternatives

Substance	CAS #	Hazard rating			
		Inhalation	Skin	Environment	Flammability
Acetone	67-64-1	A	A		D
Isopropyl alcohol	67-63-0	A			D
Methylene dichloride	75-09-2	D	C		
Mineral turpentine					D
Perchloro ethylene	127-18-4	D	C	E	
White petrol	Blend	D	C*	E*	D*

*Based on limited current information. To be re-evaluated

The selection of a solvent should be made so as to minimize the hazard. As is apparent from the ratings above, most of the substances are classified as 'Very toxic' for 'Inhalation' and 'Toxic' under 'Skin'. Safe use can therefore not be ensured by a prudent selection alone. The following section introduces measures to safeguard health and safety while using hazardous solvents.

5.2 Risk control measures

This guide recommends the following general principles of prevention:

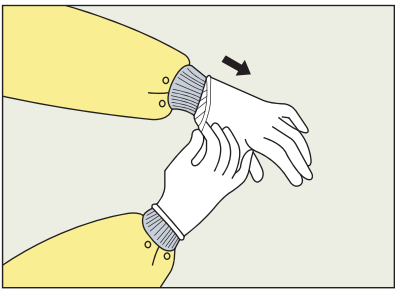
i. Avoid the need for solvent use;
ii. Substitute with less hazardous or non hazardous substances;
iii. Reduce the risks at source using technically up to date methods;
iv. Use measures that give collective protection before considering individual protection;
v. Ensure appropriate instruction and training of all staff concerned;
vi. Provide adequate personal protective equipment (PPE) if a significant risk still remains;

5.3 Good servicing practices

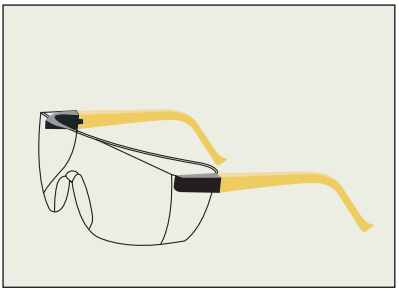
- **Prudent substance selection:** Select the safest possible substance (see table 3 'Hazard ratings of specific alternatives').
- **Consult an MSDS:** Demand a material safety data sheet (MSDS) of the solvent from the retailer. Study specifically the sections on health risks, fire risks and first aid.
- **Limit the quantity:** Often the required quantity for cleaning is overestimated. Therefore assess the required quantity carefully and restrict the use accordingly. It is believed that solvent exposure can be reduced significantly by this measure alone.
- **Purge with inert gases:** Purging with air should be completely avoided as a mix of the solvent with contaminants could prove to be explosive in some cases. Therefore always use only inert gases like CO_2.
- All electrical equipment should be properly grounded & de-energised before carrying out cleaning operation. If online operation is inevitable due to equipment design or operational limitations use only insulated hand tools and solvent with low dielectric constant.
- **Ensure good ventilation:** Many solvents are toxic. While performing the cleaning operation the solvent evaporates into the surroundings. If the cleaning personnel experiences drowsiness or nausea, it is an indication that concentration of solvent vapours is above tolerable limits in the surroundings and there is a need for better ventilation of the cleaning area. The possible options include:
  - Shift cleaning operations to an area with high ceilings and cross-ventilation.
  - If there is a perceivable flow of air, clean downwind so that the air first reaches the cleaning personnel and then the part being cleaned.
  - If none of these prove sufficient, consider the installation of local exhaust ventilation (LEV). LEVs capture contaminants before they disperse into the air of the workplace. Such systems consist of a hood, a duct and an air cleaner.

LEVs cannot be bought off the shelf and they have to be sized by experts to meet the specific requirements.

- **Wear goggles:** Certain cleaning operations may result in splashing of solvents therefore goggles are required for eye protection.
- **Wear gloves:** Skin contact with the solvent during cleaning occurs regularly. All solvents remove the fat content of the skin. Gloves can protect the skin adequately.



Gloves



Goggles

Care should be taken in selecting gloves and other protective clothing as different solvents affect the materials from which they are made in different ways. Some solvents may, for example, pass through some glove materials in a very short time. Table 4 guides the selection of appropriate gloves:

Table 4
Selection of gloves

Chemical handled	Glove Material
Acetone	Butyl, Nitrile, Neoprene, Laminate film
Hexane or White petrol	Nitrile, Neoprene, Viton
Isopropyl alcohol	Nitrile, Neoprene, Butyl, Viton
Methylene dichloride*	Nitrile, for light exposures (splashes), Viton, PVA

*will damage all natural and synthetic glove materials

Face shield

Mask

- **Use respirators:** In any enclosed or confined space such as the inside of a large motor/generator, even a non-toxic solvent may have anaesthetic or asphyxiating effects if it is used in sufficient quantities. Breathing apparatus or respirator may be required to prevent serious injury or even death.
- Always use insulated tools while servicing electrical equipment.
- If the contacts are severely pitted better replace them.
- Ensure moving parts are free from any obstruction to reduce possibility of sparking.
- Deposits like globules on contacts should be removed with blunt knife and use of rough emery cloth should be avoided.
- To avoid sparks apply silicon grease after every cleaning process in high transmission line maintenance.
- Use anti track spray on insulators before rainy season to avoid spark & flash.
- Worker should be trained on hazard and safety precautions.
- While using solvents eliminate open flames and use of lighted matches and cigarettes.
- Make sure fire fighting equipment is always available.
- Use insulated foot and leg protection.
- Use nonconductive flame-resistant head, face, and chin protection (hard hats, full face shields, etc.)

6. Glossary

This glossary defines terms you are likely to encounter in material safety data sheets (MSDS)

Acute effect: The effect caused by a single short term exposure to a high amount of concentration of a substance.

Aerosols: Liquid droplets or solid particles dispersed in air that are of fine enough particle size (0.01 to 100 microns) to remain dispersed for a period of time.

Alkali: Any of a class of substances that liberates hydroxide ions in and have a pH of more than 7. Strong alkalis in solution are corrosive to the skin and mucous membranes. They are also called bases and may cause severe burns.

Anhydrous: Does not contain water (e.g. anhydrous lime)

Asphyxiation: A condition whereby oxygen in the air is replaced by an inert gas such as nitrogen, carbon dioxide, ethane, hydrogen or helium to a level where it cannot sustain life. Normal air contains 21 percent of oxygen. If this concentration falls below about 17 percent, the human body tissue will be deprived of supply of oxygen, causing dizziness, nausea and loss of coordination. This type of situation may occur in confined work places.

Auto-ignition temperature: The minimum temperature at which a material ignites without application or a flame.

Boiling point: The temperature at which liquid changes to a vapour state at a given pressure (usually 760 mm of Hg or one atmosphere).

Caustic: The ability of an alkali to cause burns.

Chronic health effect: An adverse effect on a human body with symptoms developing slowly over a long period of time.

Chronic toxicity: A chronic effect resulting from repeated doses of or exposure to a substance over a relatively prolonged period of time.

Confined space: Any area that has limited openings for entry or exit that would make escape difficult in an emergency, has a lack of ventilation, contains known and potential hazard, and is not normally intended or designed for continuous human occupancy (e.g. a storage tank, manhole of collection conveyances systems in effluent treatment plants).

Dielectric constant: The dielectric constant of a solvent is a relative measure of its polarity.

Explosion proof-equipment: Apparatus or device enclosed in a case capable of withstanding an explosion of specified gas or vapour and preventing the ignition of specified gas or vapour surrounding the enclosure by sparks, flash or explosion and operating at an external temperature so that surrounding flammable atmosphere will not be ignited.

Flammable: A flammable liquid is defined as a liquid with a flash point between 21 and 55 degrees Celsius. It may catch fire on contact with a source of ignition.

Flammable/explosion limits: Flammable/explosion limits produce a minimum and a maximum concentration of gases/vapours/fumes in air that will support combustion. The lowest concentration is known as the lower flammable/explosion limit (LEL), the highest concentration is known as upper flammable/explosion limit (UFL).

Flash point: Minimum temperature at which, under specific conditions, a liquid gives off sufficient flammable gas/vapour to produce a flash on contact with a source of ignition.

General exhaust/ventilation: A system for exhausting or replacing air containing contaminants from a general work area.

Hansen Solubility Parameter: A numerical value that indicates the relative solvency behaviour of a specific solvent. This number is calculated (based on volume percentage) from the properties dispersion, polarity and hydrogen bonding of the solvent. Hansen solubility parameter is available for every solvent, any liquid or polymer.

Hazard: A potential to cause danger to life, health, property or the environment.

IDLH (Immediate danger to life and health): The maximum concentration from which one could escape with in 30 minutes without any escape-impairing symptoms or irreversible health effects. Usually used to describe a condition where self contained breathing apparatus (SCBA) must be used

Incompatible: Condition of materials that could cause dangerous reactions from direct contact with one another. Particularly relevant when storing different substances in the same place.

Local exhaust: A system or device for capturing and exhausting contaminants from the air at the point where the contaminants are produced. (e.g. dust in shaving and buffing)

MSDS (Material safety data sheet): Consolidated information on specific identity of hazardous chemical substances, also including information on health effects, first medical aid, chemical and physical properties, emergency measures etc.

OEL (Occupational exposure limit): An exposure level established by a regulatory authority (e.g. OSHA, NIOSH).

Poisoning: Normally the human body is able to cope with a variety of substances within certain limits. Poisoning occurs when these limits are exceeded and the body is unable to deal with a substance (by digestion, absorption or excretion)

Risk: The measured probability of an event to cause danger to life, health, property or the environment.

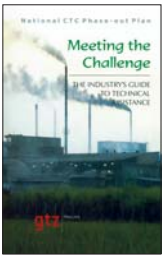
TLV (Threshold limit value): A concentration threshold in the atmosphere which is set specially for each pollutant. It refers to the limit accepted in the atmosphere of working area.

TLV-STEL (TLV short term exposure limit): Concentration threshold in an atmosphere contaminated with a specific type of pollutant for a 15 minute exposure (if not otherwise specified)

TLV-TWA (TLV time weighted average): Concentration threshold in an atmosphere contaminated with a specific type of pollutant, usually for a continuous eight hour exposure

Toxicity: The inherent potential of a chemical substance to cause poisoning.

7. Other publications for you



Meeting the Challenge provides essential information on CTC Phase out and industry sectors most affected by it. The publication also elaborates on 'applications' across sectors affected by CTC phase out as also GTZ-Proklima's mandate, approach and technical assistance provided to affected industries.

Languages: English, Hindi, Gujarati, Kannada and Malayalam

Solvent Alternatives is a compilation of technical information on a variety of CTC alternatives that are in use in industry – across industry sectors and applications. The advisory elaborates on use and potential risks involved therein, with regard to profiled substances

Languages: English

Industry specific guidelines for the substitution of CTC in about 10 sectors are under preparation. Their launch is expected from December 2008. Similar to this guideline for RAC enterprises, other guidelines will inform of alternatives to CTC in other sectors and their safe use.

Languages: English

All publications are also available for free download at our website www.ctc-phaseout.org

Notes

Ozone Cell, Ministry of Environment and Forests, Government of India, is the central agency coordinating the phase-out of CTC. The cell has established the regulatory framework and national phase-out plan. It ensures that domestic CTC production and import progressively decrease in compliance with national targets.

The Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH is an international cooperation enterprise for sustainable development with worldwide operations. GTZ-Proklima is a sectoral program which implements bilateral and multilateral projects in order to assist partner countries in fulfilling their obligations under the Montreal Protocol. With more than 130 projects, GTZ-Proklima is the largest bilateral partner of the Multilateral Fund of the Montreal Protocol. GTZ-Proklima, on behalf of the Government of Germany and under the overall coordination of Ozone Cell, Ministry of Environment and Forests, provides support to Indian industries for smooth transition to a CTC-free world. In the current project GTZ-Proklima holds an additional mandate on behalf of the Government of France which provides financial support through its French Global Environment Facility (FFEM). GTZ-Proklima does not promote any particular product or brand but provides technical assistance to CTC consuming industries.

National CTC Phase-out Plan

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