

# SPICE



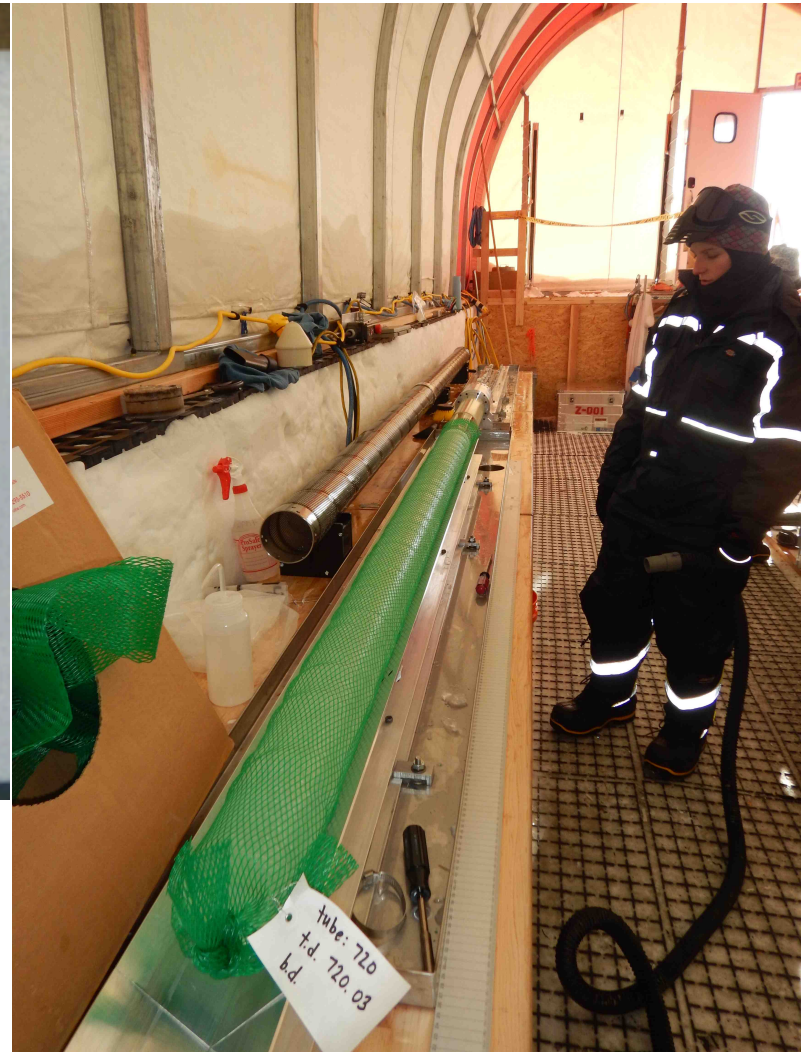
## Huge congratulations to SPICE Team

- great progress, despite many issues requiring attention;
- 736 m of good quality core;
- just starting to drill brittle ice;
- 150 m stored at S. Pole.





- **Image of first visible ash layer at ~306.5 m; ~3.7 ka BP on the timescale of Casey *et al.* 2014.**
- 600 m of core now at NICL; core processing on schedule for this summer.





## SPICE Logistics

### Air support:

- 27,000lbs of Estisol 140, including pallets, and tie downs; another 27,000lbs for next season is wintering in McMurdo.
- 30,000lbs of drilling equipment
- 3,000lbs 10 PAX (with clothing and equipment) to and from Pole
- generators, snow machines, and other support supplies
- two cold-deck flights from Pole with ice core

**Estimated five LC-130 flights needed to move cargo to and from Pole** (from Tony Bartole - SP logistics supervisor. JP8, mogas and premix are not included).

### Other:

- **fuel:** 1,873gal (~13,600lbs) of JP8 used for 50kw generator and MEC furnace; power usage will be monitored next season to evaluate generator size (and fuel) requirements for future projects. Premix and mogas used for 2km commute to drill site not included.
- **impacts at Pole:** SPICE team of 10 stayed and ate at Pole for 12 weeks. Operated 20 hrs/day (two 10-hour shifts).

## SPICE Logistics

### Some perspectives:

- ~six LC-130s required to support SPICE this past season (if JP8 usage is included)
- expect similar number of flights next season (flying E-140 to Pole and returning ice core and drilling equipment to McMurdo).
- assuming available cargo load (ACL) for LC-130s going to Pole is 20,000lbs, total cargo load for drilling is ~120,000lbs.
- ACL for a Twin Otter flying to a remote site is ~2,500lbs but often limited by cube; about 48 Twin Otter missions would be needed to move 120,000lbs to and from a remote site (more if fuel caches are needed for the Otter to get to the remote site).
- Twin Otter missions could be reduced significantly if fuel and drilling fluid could be dropped by air, but airdrops raise other potential issues.
- more flights needed to establish a camp with staff to support drilling at a remote site (camp setup and staff and lower ACLs).
- fewer flights needed to support shallower cores (less drilling fluid) and if smaller generators can be used (less JP8).

### Discussions needed for going forward

- continue to work on reducing weights and cube of drilling and fuel requirements
- continue to minimize size and infrastructure of drill camps at remote sites
- evaluate the costs and practicality of traversing drilling equipment and fuel/fluids

# Estisol-140 and experiences from SPICE project

Over past 4 years, Mark Twickler and the international ice-core community have done a lot of careful work to recommend E-140 as a new drilling fluid for ice coring. Recommendations were endorsed by:

- the SAB and IDPO
- an in-depth comparison of potential fluids (*Talalay et al, 2014*)

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## Environmental considerations of low-temperature drilling fluids

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**ABSTRACT.** The introduction of low-temperature fluid into boreholes drilled in ice sheets helps to remove drilling cuttings and to prevent borehole closure through visco-plastic deformation. Only special fluids, or mixtures of fluids, can satisfy the very strict criteria for deep drilling in cold ice. The effects of drilling fluid on the natural environment are analyzed from the following points of view: (1) occupational safety and health; (2) ozone depletion and global warming; (3) chemical pollution; and (4) biological pollution. Traditional low-temperature drilling fluids (kerosene-based fluids with density additives, ethanol and *n*-butyl acetate) cannot be qualified as intelligent choices from the safety, environmental and technological standpoints. This paper introduces a new type of low-temperature drilling fluid composed of synthetic ESTISOL™ esters, which are non-hazardous substances. ESTISOL™ 140 mixtures with ESTISOL™ 165 or ESTISOL™ F2887 have an acceptable density and viscosity at low temperature. To avoid the potential for biological contamination of the subglacial environment, the borehole drilling fluid should be treated carefully on the surface.

## **Estisol-140 and experiences from SPICE project**

E-140 is a relatively new synthetic fluid being used in a new application (ice-core drilling)

- used by the Danes and by DOSECC in tests of RAID
- IDDO worked with the fluid manufacturer to obtain the latest Safety Data Sheets (SDS) that include recommended exposure limits
  - levels experienced during SPICE are well below the recommended limits
- Main ingredient in E-140 is 2-ethylhexyl acetate, and evidence based on the SDS indicates that it has low toxicity. It also has a very low vapor pressure and high relative vapor density.
- The “Derived No Effect Level” for 2-ethylhexyl acetate is ~20 ppm for short-term exposures.
- E-140 has a low odor threshold (0.2 ppm), which means that it has a strong odor. This is not necessarily an indication of toxicity.

# **Estisol-140 and experiences from SPICE Project**

## **SPICE experiences**

- drillers experienced headaches, burning eyes, and irritated throats from working in the drill trench and control room for extended periods, despite the low readings recorded by the PID
  - PID is a Photo-ionization detection device that measures volatile organic compounds (VOC)
  - PID measurements taken in all locations where E140 vapors were potentially present (e.g. heated control room, drill tent)
- Exposure limits were monitored and confirmed to be well below those recommended by the manufacturer.
  - Highest 15-min “Time-Weighted Average” reading during SPICE Core was 6.9 ppm
  - repeated exposure to E-140 caused skin irritation. Minimizing repeat skin contact has proven to be difficult, despite using the best personal protection equipment available.
  - odor was tolerable, and often not noticeable at cold temperatures.

# **Estisol-140 and experiences from SPICE Project**

## **IDDO Efforts**

- IDDO is continuing to work with SSEC Quality Assurance and Safety, a UW Safety Chemical Hygiene Officer, and a UW Health Services Industrial Hygienist to ensure personnel safety
- following the drill tests in Greenland, IDDO made significant changes in ventilation, operations, and personal protection equipment.

Improvements for SPICE include:

- Increasing/ensuring good ventilation
- 53 air exchanges per hour in the control room
- 22 air exchanges per hour in the drill tent
- minimizing the risk of getting E-140 onto drill suits (this is key)
- providing long-sleeved aprons to cover drill suits



## **Estisol-140 and experiences from SPICE Project**

### **Ongoing IDDO strategies for next season**

- personnel safety is always the number 1 priority
- for the upcoming season, IDDO will implement the following:
  - provide the best personal protective equipment
  - longer Dailove drilling gloves
  - velcro for drill suit cuffs (to keep clothing in place when changing into/out of outer layers)
  - shortening drill shifts to 8hrs/day to reduce exposure time for the drillers
  - cooling the control room to 40-50 F (from the 70 F in 2014-2015), as the fluid properties become more problematic at warmer temperatures.

**IDDO does not plan to use this fluid on future drilling projects**

## **Summary:**

- **E-140 is problematic**
  - Despite precautions, drill operators still experienced significant physiological symptoms, consistent with exposure to solvent vapors (burning eyes, headache, diminished mental acuity) and skin irritation.
  - Effects are exacerbated in heated spaces (control room)
- **E-140 has a number of desirable properties with regard to ice drilling, but IDDO does not plan to use it again after the SPICE project**
- **IDDO is continuing to make every effort toward mitigating the issues from E-140 that were experienced last season**
- **5 of the 7 drillers are returning for second season of SPICE**

### *n*-Butyl acetate - from Pavel Talalay et al, (2014)

*n*-Butyl acetate has a low initial purchase cost, but is an ongoing liability from a safety (fire and explosion) and acute/chronic health hazard standpoint. The main problem of using *n*-butyl acetate as a drilling fluid is the hazard it presents to the physical and mental health of the people working at the drilling site. *n*-Butyl acetate is a very aggressive solvent: there are no elastomers that can operate for a long time in *n*-butyl acetate

*n*-Butyl acetate is a confirmed teratogenic material and is mildly toxic by inhalation and ingestion. *n*-Butyl acetate odors are detectable at 10 ppm. Human systematic effects occur by inhalation, causing conjunctiva irritation and unspecified nasal and respiratory system effects. *n*-Butyl acetate is a skin and severe eye irritant and a mild allergen, and high vapor concentrations will cause narcosis. Recommendations of *n*-butyl acetate exposure limits adopted in different countries vary from 40 to 200 ppm (Talalay and Gundestrup, 2002). Personal communications from PICO, Japanese and Chinese drillers indicated that after a workday in a drilling shelter, workers felt symptoms of the central nervous system (dizziness, headaches). It is impossible to use *n*-butyl acetate without sufficient ventilation and some means of removing the *n*-butyl acetate vapors from inhaled air.

19.09.2012

## **ESTISOL ester fluids**

ESTISOL esters have developed to be the formulators preferred alternative to aliphatic and aromatic hydrocarbons in formulated chemicals products. ESTISOL esters may reduce or eliminate the VOC content, they improve the products health & safety profile and ensure an environmentally sound product profile.

ESTISOL esters can act as straight replacements, solvency boosters, or carrier fluids in formulated products, e.g. industrial cleaners, degreasers, blanket & roller washes, printing inks, hand cleaners, paint strippers, and oil field chemicals.

ESTISOL grade	Raw material base	Boiling range (°C)	Flash point (°C)	Pour point (°C)	Viscosity (cP/25°C)	Density (at 20°C) Kg/m <sup>3</sup>	Iodine value (g I <sub>2</sub> /100g)	VOC (*)
140	Synthetic	195-205	75	-90	1,3	870	<0,1	YES
150	Synthetic	220-225	102	-25	2.5	1.085	<0,1	NO
165	Synthetic	180-190	81	<-30	3	1.100	<0,1	YES
170	Vegetable	180-300	78	<-20	4	873	<1	YES
180	Vegetable	175-195	95	<-10	4	872	<1	YES
240	Vegetable	255-320	130	<-30	5	855	<1	NO
242	Vegetable	270-280	138	-8	3	854	<1	NO
260	Vegetable	260-320	160	-5	4	868	37	NO
295	Vegetable	300-360	180	9	7	874	60	NO
300	Vegetable	320-355	180	-9	6	878	106	NO
305	Vegetable	300-360	180	-8	7	864	25	NO
312	Vegetable	320-340	172	-30	6	863	<1	NO
390	Vegetable	>350	190	-12	14	864	45	NO

(\*): Based on vapor pressure criteria: non-VOC classification requires a vapor pressure < 0.1 kPa/20°C

# Safety data sheet

## according to 1907/2006/EC, Article 31

Printing date 26.06.2014

Revision: 26.06.2014

### 1 Identification of the substance/mixture and of the company/undertaking

- **1.1 Product identifier**
- **Trade name:** *ESTISOL 140*
- **1.2 Relevant identified uses of the substance or mixture and uses advised against**  
No further relevant information available.
- **Application of the substance / the mixture** Solvents
- **1.3 Details of the supplier of the safety data sheet**
- **Manufacturer/Supplier:**  
Esti Chem A/S  
Erhvervsparken 16  
DK - 4621 Gadstrup  
Tel.: +45-56-65 33 72  
Fax.: +45-56-65 33 75
- **Further information obtainable from:**  
product safety department  
birgit.pape@additiv-chemie.de
- **1.4 Emergency telephone number:**  
+45-56653372 - Office hours (Mo.-Fr. 8:00 - 16.00)  
+45-40113372 - Outside office hours

### 2 Hazards identification

- **2.1 Classification of the substance or mixture**
- **Classification according to Regulation (EC) No 1272/2008**



GHS07

Skin Irrit. 2 H315 Causes skin irritation.

- **Classification according to Directive 67/548/EEC or Directive 1999/45/EC**



Xi; Irritant

R38: Irritating to skin.

- **Information concerning particular hazards for human and environment:**  
The product does not have to be labelled due to the calculation procedure of the "General Classification guideline for preparations of the EU" in the latest valid version.
- **Classification system:**  
The classification is according to the latest editions of the EU-lists, and extended by company and literature data.

- **2.2 Label elements**

- **Labelling according to Regulation (EC) No 1272/2008**  
The product is classified and labelled according to the CLP regulation.
- **Hazard pictograms** GHS07
- **Signal word** Warning
- **Hazard statements**  
H315 Causes skin irritation.
- **Precautionary statements**
  - P280 Wear protective gloves/protective clothing/eye protection/face protection.
  - P264 Wash thoroughly after handling.
  - P321 Specific treatment (see on this label).
  - P362 Take off contaminated clothing and wash before reuse.
  - P332+P313 If skin irritation occurs: Get medical advice/attention.
  - P302+P352 IF ON SKIN: Wash with plenty of soap and water.
- **2.3 Other hazards**
- **Results of PBT and vPvB assessment**
- **PBT:** Not applicable.

(Contd. on page 2)

GB



# Safety data sheet

## according to 1907/2006/EC, Article 31

Printing date 26.06.2014

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**Trade name: ESTISOL 140**

(Contd. of page 1)

· **vPvB:** Not applicable.

### 3 Composition/information on ingredients

· **3.2 Chemical characterization: Mixtures**· **Description:** Mixture of substances listed below with non hazardous additions.· **Dangerous components:**

CAS: 103-09-3	2-ethylhexyl acetate	 Xi R38	> 50%
EINECS: 203-079-1		 Skin Irrit. 2, H315	
Reg.nr.: 01-2119483620-40-XXXX			

· **Additional information:** For the wording of the listed risk phrases refer to section 16.

### 4 First aid measures

· **4.1 Description of first aid measures**· **General information:** No special measures required.· **After inhalation:** Supply fresh air; consult doctor in case of complaints.· **After skin contact:** Immediately wash with water and soap and rinse thoroughly.· **After eye contact:** Rinse opened eye for several minutes under running water.· **After swallowing:** If symptoms persist consult doctor.· **4.2 Most important symptoms and effects, both acute and delayed** No further relevant information available.· **4.3 Indication of any immediate medical attention and special treatment needed**

No further relevant information available.

### 5 Firefighting measures

· **5.1 Extinguishing media**· **Suitable extinguishing agents:**

CO2, powder or water spray. Fight larger fires with water spray or alcohol resistant foam.

· **5.2 Special hazards arising from the substance or mixture** No further relevant information available.· **5.3 Advice for firefighters**· **Protective equipment:** Wear self-contained respiratory protective device.

### 6 Accidental release measures

· **6.1 Personal precautions, protective equipment and emergency procedures** Wear protective clothing.· **6.2 Environmental precautions:** Do not allow to enter sewers/ surface or ground water.· **6.3 Methods and material for containment and cleaning up:**

Absorb with liquid-binding material (sand, diatomite, acid binders, universal binders, sawdust).

· **6.4 Reference to other sections** No dangerous substances are released.

### 7 Handling and storage

· **7.1 Precautions for safe handling** No special measures required.· **Information about fire - and explosion protection:** No special measures required.· **7.2 Conditions for safe storage, including any incompatibilities**· **Storage:**· **Requirements to be met by storerooms and receptacles:** Provide solvent resistant, sealed floor.· **Information about storage in one common storage facility:** Store away from foodstuffs.· **Further information about storage conditions:** None.

(Contd. on page 3)

# Environmental considerations of low-temperature drilling fluids

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**KEYWORDS:** glaciological instruments and methods, ice coring, subglacial lakes

## INTRODUCTION

It is commonly understood that drilling is a process of creating a borehole, and one of the main technological elements of drilling, including access holes in subglacial environments, is the removal of borehole products when cutting or melting the ice. The removal of material is critically important to all drilling systems, as the presence of excessive material at the bottom of the borehole leads to decreasing penetration rates and even loss of the drill. For intermediate and deep drilling, it is also necessary to prevent borehole closure through visco-plastic deformation by filling the borehole with a fluid (Talalay and Hooke, 2007).

Review of the properties of fluids used for drilling in permafrost confirms that they are not suitable for drilling in cold ice (Chistyakov and others, 1999; Talalay, 2011), which is why various one- or two-compound low-temperature drilling fluids were utilized under these circumstances (Talalay and Gundestrup, 2002; Gerasimoff, 2003). Three types of borehole fluid have been used in ice-core drilling: (1) two-component kerosene-based fluids with density additives, (2) alcohol compounds and (3) ester compounds.

Water is also used as a circulation medium in hot-water drilling systems. In this case, water has two main functions: (1) to convey heat to the bottom of the hole to melt the ice and (2) to remove melted water by mixing with pumped hot water. The main advantages of exploration of the subglacial environment with hot-water drilling systems are that the equipment can provide cleaner samples of subglacial water and sediments and that access to the ice-sheet base is rapid. On the other hand, hot water, even when heated to 90°C, filtered to 0.2 µm and ultraviolet (UV)-treated at the surface, could pick up microorganisms from near-surface snow and circulate them in large numbers through the borehole. In addition, in cold ice the long-term radial freeze rate is ~0.4 cm h<sup>-1</sup>, with an initial freeze rate up to four times higher (personal communication from K. Makinson, 2013), which makes subglacial exploration extremely difficult.

Another negative impact of the hot-water circulation medium is thermal pollution of glacial ice and subglacial water, which changes the ambient temperature around the borehole. Although penetration into the subglacial environment by hot-water drilling technologies is technically possible, we do not consider water as a 'low-temperature' drilling fluid.

Hereinafter we review the main constituents of the special low-temperature drilling fluids with freezing (pour) points lower than the minimal temperature in the borehole. The average annual temperature in central Antarctica (and thus the minimal borehole temperature) at 10 m depth is in the range -50°C to -58°C (King and Turner, 1997), and this can be taken as the anti-freezing requirement of low-temperature drilling fluids. The effects of drilling fluids on the natural environment are analyzed from the following points of view: (1) occupational safety and health; (2) ozone depletion and global warming; (3) chemical pollution; and (4) biological pollution.

## DRILLING FLUID COMPOSITIONS

### Two-component kerosene-based fluids

Two-component kerosene-based fluids are based on kerosene-like products, such as the low-temperature jet fuels Jet A1 and TS-1, or solvents of the EXXSOL™ D-series and Isopar™ K (Table 1). These fluids are all very similar in function but differ in the content of aromatics, waxes, sulfur and other impurities. Kerosenes have a density of ~800–850 kg m<sup>-3</sup> at -30°C compared with 917–924 kg m<sup>-3</sup> for ice. Therefore, they are made denser by mixing with fluorocarbons or other compounds with a density that significantly exceeds the density of ice (Table 2).

During the past 20 years many of the boreholes drilled in Antarctica and Greenland have been successfully completed using a mixture of a kerosene-like fluid and dichlorofluoroethane HCFC-141b as densifier (North Greenland Icecore

**Table 1.** Reference data for low-temperature drilling fluid components

	Density kg m <sup>-3</sup>	Dynamic viscosity mPa s	Kinematic viscosity mm <sup>2</sup> s <sup>-1</sup>	Boiling point °C	Flash point °C	Autoignition temperature °C	Freezing (pour) point °C	Evaporation rate	Workplace air level ppm by vol.	ODP	GWP
EXXSOL™ D-30	762 at 15°C	0.75 at 25°C	NA	130–166	29	>200	<–55	35 (nBuAc = 100)	RCP: 197	NA	NA
EXXSOL™ D-40	771 at 15°C	0.96 at 25°C	NA	161–198	42	260	<–75 (–57)	18 (nBuAc = 100)	RCP: 197	NA	NA
EXXSOL™ D-60	792 at 15°C	1.29 at 25°C	NA	190–221	63	250	<–55	6 (nBuAc = 100)	RCP: 197	NA	NA
Isopar™ K	763 at 15°C	NA	1.84 at 25°C	177–197	49	349	–78 (–60)	7 (nBuAc = 100)	Exxon Mobil: 175	NA	NA
HCFC-141b	1240 at 20°C	0.416 at 25°C	NA	32.1	None	None	–103.5	>1 (Ether = 1)	NIOSH: 1000	0.12	725
DuPont™ FEA-1100	1200 at 20°C	NA	NA	33	None	None	NA	NA	NA	0	5
Ethanol	789.3 at 20°C	1.2 at 20°C	NA	78.3	12	363	–114.1	8.3 (Ether = 1)	ACGIH: 1000	NA	NA
n-Butyl acetate	882 at 20°C	0.732 at 20°C	NA	126.5	22	425	–78	12 (Ether = 1)	ACGIH: 150	NA	NA
ESTISOL™ 140	870 at 20°C	1.3 at 25°C	NA	199	75	270	–93	NA	NA	NA	NA
ESTISOL™ 165	1100 at 20°C	3.0 at 25°C	NA	180–190	81	NA		NA	NA	NA	NA
ESTISOL™ 240	855 at 20°C	4.0 at 25°C	NA	250–290	130	NA		NA	NA	NA	NA
ESTISOL™ F2887	1083 at 20°C	7.0 at 25°C	NA	>280	167	NA		NA	NA	NA	NA
COASOL™	958–960 at 20°C	NA	5.3 at 20°C	274–289	131	400	–60		NA	NA	NA
KF96-1,5cs	850–855 at 25°C	NA	1.53 at 25°C		min 50	~450	–76	NA	NA	NA	NA
KF96-2,0cs	870–875 at 25°C	NA	2.07 at 25°C		min 75	~450	–84	NA	NA	NA	NA

Sources: Flick (1998); Haynes (2013); Exxon Mobil Corp.; DuPont Company; Esti Chem A/S; Dow Chemical Company Ltd; Shin-Etsu Chemical Co. Ltd.

Notes: NA: data are not available or not applicable.

RCP: reciprocal calculation procedure developed by the American Conference of Governmental Industrial Hygienists (ACGIH).

NIOSH: National Institute for Occupational Safety and Health, USA.

ODP: ozone depletion potential based on United Nations Environment Programme/World Meteorological Organization scientific assessment for effect on stratospheric ozone.

GWP: global warming potential calculated from the UNEP scientific report for greenhouse effect.

**Table 2.** Estimation of the main technological properties of low-temperature drilling fluids

	Density				Kinematic viscosity				Approximate price	
	–30°C kg m <sup>-3</sup>	–40°C kg m <sup>-3</sup>	–50°C kg m <sup>-3</sup>	–60°C kg m <sup>-3</sup>	–30°C mm <sup>2</sup> s <sup>-1</sup>	–40°C mm <sup>2</sup> s <sup>-1</sup>	–50°C mm <sup>2</sup> s <sup>-1</sup>	–60°C mm <sup>2</sup> s <sup>-1</sup>	US\$ L <sup>-1</sup>	
EXXSOL™ D-30 + HCFC 141b ( $F_m = 34.2\%$ )	916.8	925.5	934.3	943.0	1.7	2.1	2.6	3.3	3.5	
EXXSOL™ D-60 + HCFC 141b ( $F_m = 31.7\%$ )	932.7	941.6	950.6	959.6	3.0	3.8	5.2	7.6	3.2	
Ethanol–water solution ( $F_m = 50\%$ )	966.1	973.2	980.4	987.5	47.4	97.8	214.0	NA	0.3	
Ethanol–water solution ( $F_m = 70\%$ )	926.0	934.1	942.1	950.2	19.7	35.1	65.2	127.7	0.4	
Ethanol	831.6	840.1	848.5	856.9	4.5	5.9	7.9	10.9	0.6	
n-Butyl acetate	930.4	940.1	949.8	959.5	1.6	2.1	2.8	3.8	1.2	
Lusolvan® FBH + EXXSOL™ D40 ( $F_v = 14\%$ )	930	NA	NA	NA	18.9	32.4	NA	NA	3.9	
ESTISOL™ 240	897.1	903.8	910.5	917.2	24.4	44.8	97.5	NA	3.5	
ESTISOL™ 240 + COASOL ( $F_v = 22\%$ )	939.1	945.7	952.4	959.1	25.4	48.4	111.6	NA	3.6	
ESTISOL™ 140	913.7	922.0	930.4	938.8	7.6	12.2	25.6	58.5	2.7	
ESTISOL™ 140 + ESTISOL™ 165 ( $F_m = 4.5\%$ )	925.8	934.3	942.9	951.4	7.2	12.4	24.7	61.7	2.7	
ESTISOL™ 140 + ESTISOL™ F2887 ( $F_m = 5.1\%$ )	924.4	932.5	940.6	948.6	8.1	14.1	28.1	67.5	2.8	
KF96-1,5cs	904.2	914.2	924.2	934.2	5.3	7.2	10.3	15.0	6.5 (1998)	
KF96-2,0cs	923.2	932.9	942.6	952.3	5.6	7.0	9.1	12.1	6.5 (1998)	

**Table 3.** Experience of accessing subglacial water with kerosene-based drilling fluids

Location	Year	Depth of access m	Subglacial water rise height m	Drilling fluid type	Interval of recovered refrozen water m
NGRIP-2, Greenland	2003	3085	43	EXXSOL™ D60 + HCFC 141b	3042–3052
Kohnen station, Antarctica	2006/07	2774	173	EXXSOL™ D40 + HCFC 141b	NA
Vostok, Antarctica	2011/12	3769	386	Jet fuel TS-1 + HCFC 141b	3383–3460

Project (NGRIP)-2, 3095 m depth; European Project for Ice Coring in Antarctica (EPICA) Dome C2, 3270 m depth; EPICA Dronning Maud Land (DML), 2774 m depth; Berkner Island, 998 m depth; Talos Dome, 1620 m depth; West Antarctic ice sheet (WAIS) Divide, 3405 m depth; Vostok station, 3769 m depth). Recently three boreholes in which drilling fluid of this type was used reached subglacial water, and in all cases subglacial water flushed the drill fluid back into the under-pressurized boreholes (Table 3). As fluorocarbons are known to play a role in ozone depletion, at the present time the production and use of HCFC-141b is banned in some countries and in others has been stopped or is gradually being reduced. Unfortunately, attempts to find another appropriate densifier for two-component kerosene-based fluids have been unsuccessful.

The Ice Drilling Design and Operations group (IDDO; University of Wisconsin–Madison, USA) tested a two-compound fluid consisting of Isopar™ K and segregated hydrofluoroether HFE-7100 produced by the 3M Corporation (personal communication from M. Gerasimoff, 2004). Experimental tests showed that this mixture separated into two phases over a very narrow temperature range at  $\sim -45^{\circ}\text{C}$ ; this makes it unusable in boreholes in cold ice.

The Centre for Ice and Climate at the University of Copenhagen, Denmark, investigated as densifier the diisobutyl-ester of succinyl-, glutar- and adipic acid (2:4:3) produced by the BASF chemical company under the Lusolvan® FBH trademark (personal communication from S. Sheldon, 2011). Lusolvan® FBH is readily miscible with EXXSOL™ D40 solvent. The viscosity of this mixture is very high, which would have an undesirable influence by slowing the tripping operation in the borehole. To achieve a higher free lowering rate the borehole could be drilled with a larger clearance (10–12 mm) between the drill and borehole walls. However, this would lead to a significant increase in the volume of cuttings (or melted water), shorter run duration, decreased ice production rate, increased power consumption and so on.

The Polar Research Center at Jilin University studied two types of densifier: decafluoropentane HFC-4310mee and ESTISOL™ F2887, a synthetic ester made from a polyvalent alcohol produced by Esti Chem A/S. It was found that HFC-4310mee is not miscible with EXXSOL™ D40 solvent at any observed temperatures, and ESTISOL™ F2887 is miscible with EXXSOL™ D40 at room temperature but the mixture separates out into immiscible liquids at subzero temperatures.

In principle, it would be interesting to test as a densifier for kerosene-based drilling fluids a fourth-generation foam-expansion agent DuPont™ FEA-1100, which is a hydrofluoroolefin of the HFO-1336mzz type (Loh and others, 2009). It has high solubility in organic compounds, but the

miscibility with kerosene is questionable. DuPont™ FEA-1100 is characterized by good environmental properties and compatibility with the common metals, plastics and elastomers. Commercial sale of DuPont™ FEA-1100 is planned for 2013, but at the time of writing it is not available on the market.

Thus, at present a new suitable densifier for two-component petroleum-based fluids has not been found. It seems logical to focus future research on the identification of new non-toxic, non-flammable, density-appropriate and environmentally friendly non-petroleum fluids because use of kerosene as the main component in these fluids is hampered by its toxicity.

### Alcohol compounds

During the past few decades, many holes in ice were drilled with ethanol–water solution (Zagorodnov and others, 1994). This is a hydrophilic liquid, which dissolves water and ice up to the equilibrium concentration at a given temperature. Drilling technology involving this kind of fluid is reliant on the removal of ice cuttings or melted water by dissolution. Therefore, the amount of drilling fluid required is less than when drilling with a hydrophobic drilling fluid as the total volume of liquid is 5–75% of borehole volume depending on the temperature profile of fluid in the borehole. The use of ethanol for accessing Vostok Subglacial Lake was discussed at the first stage of project development (Chistyakov and Talalay, 1998), but the idea was subsequently dismissed because of the strong aseptic properties of ethanol.

Hydrophilic liquids dissolve ice not only at the borehole bottom, but also from the borehole walls. In the case of borehole temperature changes (e.g. due to convection processes in the borehole), the water freezes out from aqueous solution and forms slush in the borehole. The other property that has limited the use of ethanol in aqueous solution is its very high viscosity.

### Ester compounds

At the end of the 1980s, specialists from the Polar Ice Coring Office (PICO, University of Alaska Fairbanks, USA) suggested using as a low-temperature drilling fluid *n*-butyl acetate, an ester used mainly as a solvent in the nitrocellulose and cellulose industries (Gosink and others, 1991, 1994). In the following years, two deep-drilling projects were completed with this fluid, within the Greenland Ice Sheet Project 2 (GISP2), Summit, Greenland (3053 m), and at Dome F, Antarctica (3035 m). At the preliminary stage, *n*-butyl acetate has been chosen as the drilling fluid for the forthcoming deep ice-core drilling project at Dome A, Antarctica (Talalay and others, 2014).

*n*-Butyl acetate has a low initial purchase cost, but is an ongoing liability from a safety (fire and explosion) and

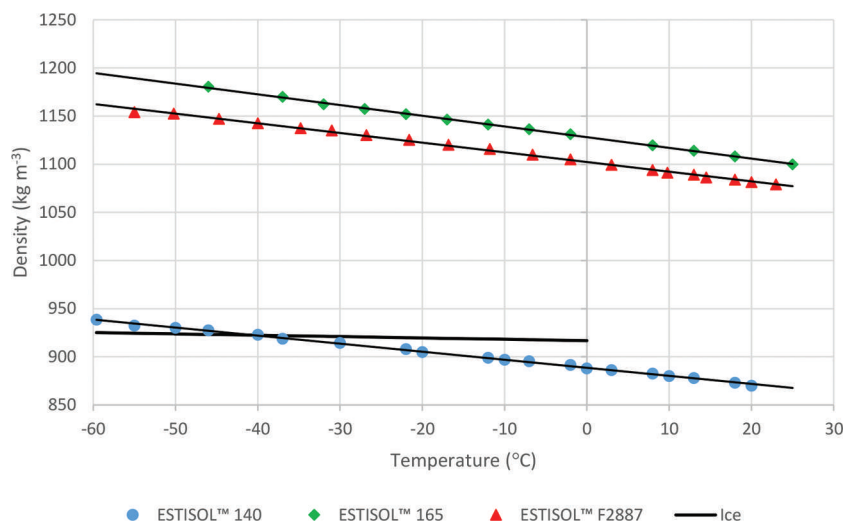


Fig. 1. Density of single- and two-component ESTISOL™ esters vs temperature.

acute/chronic health hazard standpoint. The main problem of using *n*-butyl acetate as a drilling fluid is the hazard it presents to the physical and mental health of the people working at the drilling site. *n*-Butyl acetate is a very aggressive solvent: there are no elastomers that can operate for a long time in *n*-butyl acetate.

The new type of ester mixtures produced initially by Dow Chemical Company and since 2006 by Esti Chem A/S under the trademark ESTISOL™ have become the preferred alternatives to aliphatic and aromatic hydrocarbons in formulated chemical products. In industry, ESTISOL™ esters can act as straight replacements, solvency boosters or carrier fluids in formulated products (e.g. industrial cleaners, degreasers, blanket and roller washers, printing inks, hand cleaners, paint strippers and oilfield chemicals).

Danish specialists from the Centre for Ice and Climate chose for laboratory and field-testing a mixture of ESTISOL™ 240 and COASOL™ (Larsen and others, 2011). COASOL™ is the same mixture of refined di-isobutyl esters as the above-mentioned Lusolvan® FBH. ESTISOL™ 240 and COASOL™ are characterized by low vapor pressure, almost no odor, low toxicity and good biodegradable properties.

Another promising product of Esti Chem A/S is the aliphatic synthetic ester ESTISOL™ 140, a clear fluid with a fruit-like odor, which is immiscible with water. ESTISOL™ 140 is almost sufficiently dense by itself (Fig. 1; Table 4) to compensate for ice overburden pressure, but in some cases, to provide long-term stability of the borehole walls, two other ESTISOL™ products, ESTISOL™ 165 and ESTISOL™ F2887, added in small quantities (2–6 wt%) could be used as

densifiers for ESTISOL™ 140-based drilling fluids. Tests showed that ESTISOL™ 140 is miscible with ESTISOL™ 165 and ESTISOL™ F2887, and the density–temperature relationship is linear.

From a simple geometric model in the case when the components do not react either chemically or physically (i.e. each molecule component occupies on average a fixed volume), the density of ESTISOL™ 140-based drilling fluids can be obtained at any desirable concentration according to

$$\rho = \frac{888.6 - 0.836t}{1 - \frac{F_m(242 - 0.276t)}{1128.1 - 1.112t}} \quad (1)$$

for a mixture of ESTISOL™ 140 and ESTISOL™ 165, and

$$\rho = \frac{888.6 - 0.836t}{1 - \frac{F_m(216.2 - 0.169t)}{1102.3 - 1.005t}} \quad (2)$$

for a mixture of ESTISOL™ 140 and ESTISOL™ F2887, where  $F_m$  (kg kg<sup>-1</sup>) is the mass fraction of densifier (ratio of densifier mass to the mass of the total mixture).

The viscosity of single- and two-compound ESTISOL™ esters was measured using a DC-6506 type rotational viscometer (Fangrui Instrument Co. Ltd) with an embedded thermostat that can maintain the temperature in the range –65°C to 100°C. In contrast to density, viscosity does not remain in direct proportion to temperature: at low temperatures viscosity increased in an exponential relationship (Fig. 2; Table 5). The viscosity of single ESTISOL™ 165 and F2887 esters is much higher than that of ESTISOL™ 140 ester, but adding small amounts of these esters to the base

Table 4. Experimental density–temperature equations of the single- and two-component ESTISOL™ esters under atmospheric pressure

Fluid type	Temperature interval	Density (kg m <sup>-3</sup> ) vs temperature (°C)	R <sup>2</sup>
ESTISOL™ 140	–59.6°C to +20°C	$\rho = -0.836t + 888.6$	0.998
ESTISOL™ 165	–46.0°C to +25°C	$\rho = -1.112t + 1128.1$	0.999
ESTISOL™ F2887	–55.0°C to +23°C	$\rho = -1.005t + 1102.3$	0.998
ESTISOL™ 140 + ESTISOL™ 165 ( $F_m = 4.5\%$ )	–60.0°C to +22°C	$\rho = -0.851t + 900.3$	0.998
ESTISOL™ 140 + ESTISOL™ F2887 ( $F_m = 5.1\%$ )	–60.0°C to +22°C	$\rho = -0.809t + 900.1$	0.998



fluid has almost no influence on the viscosity of the two-component mixture. The viscosity of ESTISOL™ 140-based fluids can be considered reasonable at borehole temperatures down to  $-50^{\circ}\text{C}$ ; at temperatures below  $-50^{\circ}\text{C}$  the relatively high viscosity may influence the travel time of the drill and therefore the total drilling time.

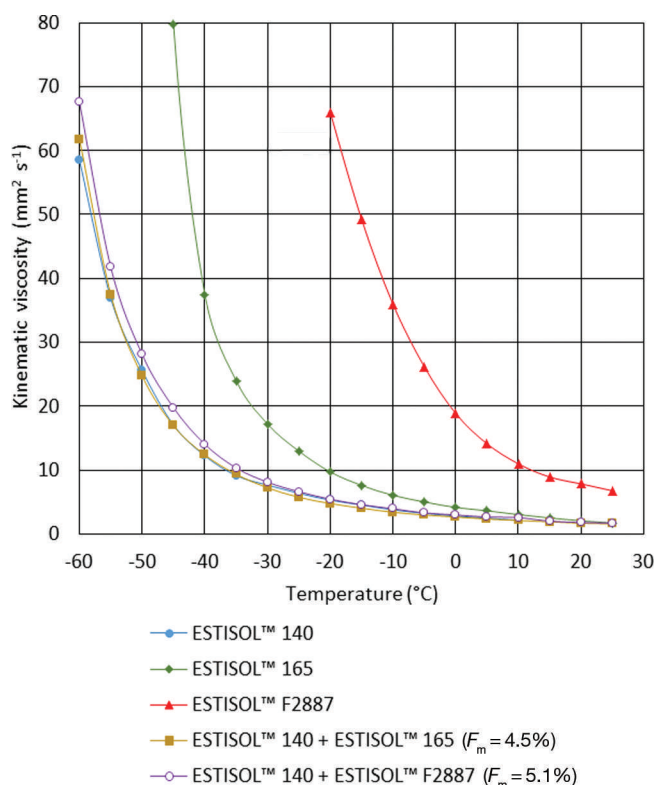
It should also be stated that the viscosity of ESTISOL™ 140 obtained in our experiments is higher than the experimental data from the Centre for Ice and Climate, University of Copenhagen (S. Sheldon and others, unpublished information), especially at low temperatures. They reported that the kinematic viscosity of this synthetic ester is  $4.3\text{ mm}^2\text{ s}^{-1}$  at  $-45^{\circ}\text{C}$ , which is nearly three times lower than our results. This variation might be explained by the different experimental set-up used to obtain the data.

In May–June 2012, Danish specialists drilled a test borehole at an interval of 103–131 m at the North Greenland Eemian Ice Drilling (NEEM) camp, northwest Greenland, using a Hans Tausen electromechanical drill with single ESTISOL™ 140 fluid (S. Sheldon and others, unpublished information). A drill descent speed of  $1.1\text{ m s}^{-1}$  was easily achieved in liquid at a temperature of  $\sim -29^{\circ}\text{C}$  within the nominal clearance of 5.8 mm between the borehole walls and the outer barrel of the drill. Ice core of excellent quality was recovered, and no problems were encountered with cleaning and processing of the core as excess liquid evaporated quickly from the core surface. In general, the field tests proved the applicability of ESTISOL™ 140 for deep drilling in ice sheets.

### Dimethylsiloxane oils

Low-molecular dimethylsiloxane oils (DSOs) can also be considered as a good alternative for borehole fluids, and are discussed at length elsewhere (Talalay, 2007). Low-molecular DSOs are clear, colorless, tasteless, odorless and chemically neutral liquids. They are hydrophobic and essentially inert substances that are stable in contact with water, air, oxygen, metals, wood, paper and plastics. From the wide range of DSOs, two grades of silicones (KF96-1,5cs and KF96-2,0cs) most closely fit the requirements for drilling fluids.

With respect to accessing Vostok Subglacial Lake, DSO was planned to be delivered by special tanker to the bottom of the drilled deep borehole 5G-1 (Verkulich and others, 2002). It was anticipated that, being heavier than the kerosene-based drilling fluid and lighter than water, this hydrophobic liquid would create a 100 m thick ecologically friendly ‘buffer layer’ at the bottom of the hole. Unfortunately, due to logistical issues, the plan was not fulfilled and in February 2012 subglacial water was reached with jet fuel TS-1 mixed with HCFC 141b (Vasiliev and others, 2012). As low-molecular DSOs have never been used in ice-drilling



**Fig. 2.** Viscosity of single- and two-component ESTISOL™ esters vs temperature.

projects, it is not possible to determine their suitability for deep drilling of ice. This can only be determined after field experiments have been conducted in a test borehole.

## ENVIRONMENTAL ISSUES OF LOW-TEMPERATURE DRILLING FLUIDS

### Occupational safety and health

Occupational safety and health considerations should address the physical, chemical and biological factors external to all types of workers employed as drillers, scientists, technicians and support personnel, and all the related factors affecting their health. Occupational safety and health encompasses the assessment and control of environmental factors that can potentially affect health. It is targeted towards preventing disease and creating healthy supportive environments.

During drilling, a large volume of drilling fluid is circulated in an open or semi-enclosed system with agitation, providing significant potential for chemical exposure and subsequent health effects. Severe health

**Table 5.** Experimental viscosity–temperature equations of the single- and two-component ESTISOL™ esters under atmospheric pressure

Fluid type	Temperature interval	Kinematic viscosity ( $\text{mm}^2\text{ s}^{-1}$ ) vs temperature ( $^{\circ}\text{C}$ )	$R^2$
ESTISOL™ 140	$-60^{\circ}\text{C}$ to $+10^{\circ}\text{C}$	$\lg \lg (\nu + 1) = \frac{467.2}{t+273.1} - 1.947$	0.999
ESTISOL™ 165	$-50^{\circ}\text{C}$ to $+25^{\circ}\text{C}$	$\lg \lg (\nu + 1) = \frac{593.1}{t+273.1} - 2.327$	0.996
ESTISOL™ F2887	$-20^{\circ}\text{C}$ to $+25^{\circ}\text{C}$	$\lg \lg (\nu + 1) = \frac{548.0}{t+273.1} - 1.895$	0.996
ESTISOL™ 140 + ESTISOL™ 165 ( $F_m = 4.5\%$ )	$-60^{\circ}\text{C}$ to $+25^{\circ}\text{C}$	$\lg \lg (\nu + 1) = \frac{478.9}{t+273.1} - 2.002$	0.999
ESTISOL™ 140 + ESTISOL™ F2887 ( $F_m = 5.1\%$ )	$-60^{\circ}\text{C}$ to $+25^{\circ}\text{C}$	$\lg \lg (\nu + 1) = \frac{467.9}{t+273.1} - 1.935$	0.998

problems can occur if an employee inhales or absorbs harmful chemicals from drilling fluids through his or her mouth or nose, or via skin contact. The most dangerous chemical hazard from drilling fluids is usually from inhalation and skin contact.

The workplace air contaminant levels of vapour or gas in indoor air listed in Table 1 should be avoided in working rooms at a temperature of 25°C and pressure of 101 325 Pa, or protective equipment should be provided and used. The permissible exposure is specified as a time-weighted average (TWA) for a normal 8 hour working day/40 hour working week, to which nearly all workers may be exposed repeatedly without adverse effect.

*Kerosenes* are suspected carcinogens. Human systematic effects occur by ingestion and intravenous routes, causing hallucinations and distorted perceptions, coughing, nausea or vomiting, and fever. Excessive exposure to jet fuels, which are used as base components of kerosene-based drilling fluids, may cause irritation to the nose, throat, lungs and respiratory tract. Central nervous system effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and even death ([www.hovensa.com/pdf/jet a.pdf](http://www.hovensa.com/pdf/jet_a.pdf)). Jet fuels are severe skin irritants: contacts with skin may lead to irritation, infection and dermatitis.

Aromatic hydrocarbons with low boiling point (e.g. benzene, toluene and xylene) are more dangerous. The content of aromatics in EXXSOL™ D-series and Isopar™ K solvents is <0.1–0.6%, compared with the concentration of aromatics in jet fuels of 20–25%, which is why these solvents are considered less harmful than other kerosenes. Nevertheless, vapor concentrations above the exposure limit can cause eye and lung irritation and may result in headaches, dizziness or drowsiness ([www.exxonmobilchemical.com/Chem-English/Files/Resources/exxsol-d40-fluid-product-safety-summary-en.pdf](http://www.exxonmobilchemical.com/Chem-English/Files/Resources/exxsol-d40-fluid-product-safety-summary-en.pdf)). Prolonged or repeated skin contact in an occupational setting may result in irritation.

*Fluorocarbons* were introduced in the 1940s as inert harmless agents, but later toxicological data showed that they are not inert and are slightly or moderately toxic if ingested or inhaled. Most fluorocarbons have similar patterns of toxicity. At high concentrations, fluorocarbons cause adrenaline to sensitize the heart so that arrhythmia may develop. Long-term exposure to high concentrations of this class of chemicals may cause adverse effects on the liver, nervous system and reproductive development.

*Ethanol* is a confirmed carcinogenic, tumorigenic and teratogenic material and is mildly toxic by inhalation. Ethanol has shown experimental reproductive effects, and human mutation data have been reported. Exposure to concentrations over the recommended threshold limit may cause headache and irritation of the eyes, nose and throat, and, if continued for an hour, drowsiness and lassitude and loss of appetite and concentration. Ethanol is also an eye and skin irritant.

*n-Butyl acetate* is a confirmed teratogenic material and is mildly toxic by inhalation and ingestion. *n*-Butyl acetate odors are detectable at 10 ppm. Human systematic effects occur by inhalation, causing conjunctiva irritation and unspecified nasal and respiratory system effects. *n*-Butyl acetate is a skin and severe eye irritant and a mild allergen, and high vapor concentrations will cause narcosis. Recommendations of *n*-butyl acetate exposure limits adopted in different countries vary from 40 to 200 ppm (Talalay and Gundestrup,

2002). Personal communications from PICO, Japanese and Chinese drillers indicated that after a workday in a drilling shelter, workers felt symptoms of the central nervous system (dizziness, headaches). It is impossible to use *n*-butyl acetate without sufficient ventilation and some means of removing the *n*-butyl acetate vapors from inhaled air.

ESTISOL™ esters are not considered hazardous according to the calculation procedure of the 'General classification guideline for preparations of the EU [European Union]' (safety data sheets for ESTISOL™ 140, ESTISOL™ 165 and ESTISOL™ F2887 provided by Esti Chem A/S, Gadstrup, Denmark). They are not classified (i.e. hazardous) substances for transport by road or air cargo, and do not present an explosion hazard. ESTISOL™ esters do not contain any relevant quantities of materials that have to be monitored in the workplace. The permissible exposure to ESTISOL™ esters in indoor air of the work area is not specified. So far, during the use of ESTISOL™ 140 in limited field experiments in Greenland a fruit-like odor was noted. However, even at subzero temperatures in the range –10°C to –25°C inside the drilling trench, appropriate ventilation would be desirable.

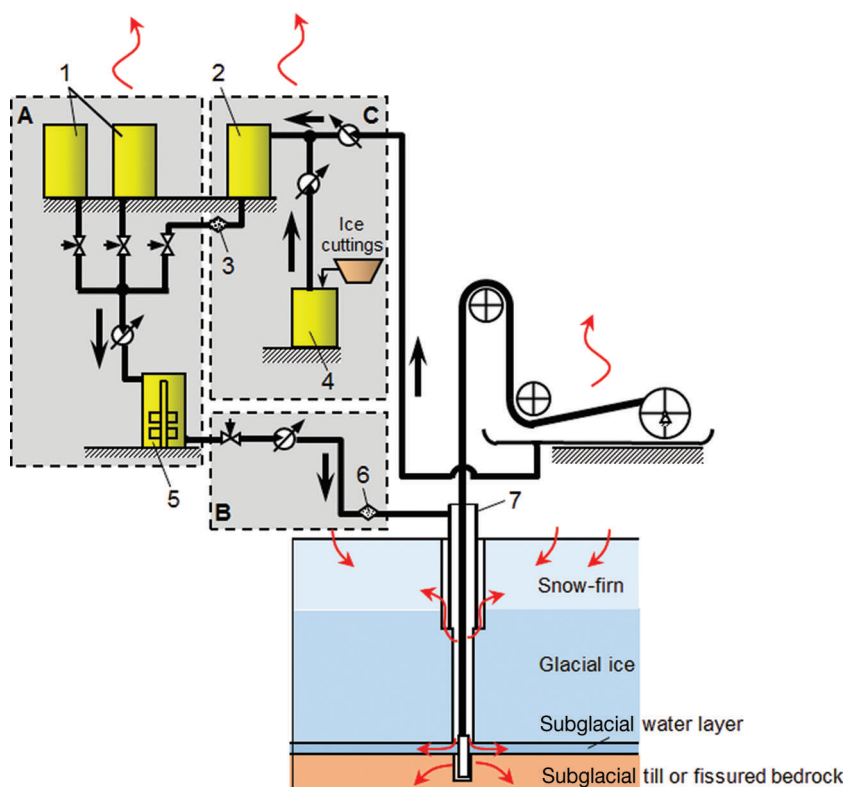
COASOL™ is also not classified as dangerous according to European Communities criteria. Based on test results, contact with the eye may cause mild irritation if the material is not washed from the eye, and prolonged exposure may cause skin dryness (<http://www.dow.com/productsafety/pdfs/233-00694.pdf>). COASOL™ tends to cause swelling and degradation of certain elastomeric polymers including natural rubbers, and field tests revealed that rubber-soled shoes were quickly destroyed following spillage of a mixture of ESTISOL™ 240 and COASOL™ on the floor of a drilling shelter.

DSOs are inert liquids that are acceptable for use as ingredients in cosmetics, for preventing human skin from chafing and as defoamers for food and beverages (Talalay, 2007). There are no adopted workplace air DSO contaminant levels and, as a result, there are no recommendations for the control of workplace contaminant concentrations. Shin-Etsu Chemical Co., a DSOs manufacturer, notes only one potential hazard to human health: in contact with the eye, low-molecular DSOs cause temporary irritation but not permanent harm.

## Ozone depletion and global warming

Molina and Rowland (1974) drew attention to the potential biological hazard resulting from depletion of the ozone layer due to release of fluorocarbons into the atmosphere. No matter how paradoxical it appears, discovery of the annual depletion of ozone above the Antarctic was first announced in May 1985 (Farman and others, 1985), 5 years after the first use of CFC-11 at Vostok station (Ueda and Talalay, 2007).

According to the Montreal Protocol, chlorofluorocarbons listed in Group I (CFC-11, CFC-113) were totally phased-out by 1996. The Montreal Protocol placed HCFC-141b, recently used as a densifier of kerosene-based fluids, on its Class II substance list. Originally, Class II compounds were designated for restrictions starting in 2015 and outright prohibition by 2030. Some countries have accelerated that process: in North America the US Environmental Protection Agency (EPA) forced a phase-out of HCFC-141b in 2003, and in Europe HCFCs have been banned since 2004. At this time HCFC-141b is produced mostly in developed countries, where consumption and production of HCFC should



**Fig. 3.** Schematic diagram of drilling fluid circulation system (red arrows show drilling fluid losses): A: preparation section; B: pumping section; C: recycling section; 1: containers for components of drilling fluids; 2: container for recycled drilling fluid; 3: coarse-mesh filter; 4: hydro extractor; 5: mixing tank; 6: fine filter; 7: casing.

halt in 2013. These countries will cap and reduce the production and consumption of HCFC-141b gradually, starting in 2015, but it is still currently available on the market in China, South Africa and a few other countries.

Fourth-generation foam-expansion agents are characterized not only by zero ozone depletion potential (ODP) but also by lower global warming potential (GWP) compared with HFCs. Recent estimates indicate that DuPont™ FEA-1100 has a very short atmospheric lifetime of ~16 days.

### Chemical pollution

Drilling fluids can contaminate large quantities of air, the surface and near-surface snow-firn layer, ice cuttings and, potentially, subglacial water resources. Chemical pollution is closely connected with drilling fluid processing (Fig. 3) as, at every step of processing, fluid is lost due to evaporation and spills (Yu and others, 2013). In contrast to regions with temperate climates, the biodegradation of drilling fluids is not likely to occur in regions with polar climates, as chemical dissolution of materials by bacteria or other biological means is almost impossible. The effects of drilling fluids are particularly important if fluid remains in the borehole; because of the movement of the ice, fluid in the hole will eventually reach the sea after a period of many thousands of years.

*Air chemical pollution* results from the release of drilling fluid compounds into the atmosphere. Contamination of air comes from evaporation of drilling fluid while it is prepared and spilled. At the particular location of the drilling site, the emissions would be temporary, and the total air quality impacts from drilling activities are likely to be small. The main problem of air contamination concerns toxicological and hazard control of the workplace. The high volatility of

drilling fluids raises human health questions. For liquids with a high rate of vaporization it is necessary to carefully control air contamination and ensure that the threshold limits in air and the minimal inflammable concentrations are not exceeded. From this perspective, use of fluids with a low rate of vaporization is preferable.

*Contamination of surface and near-surface snow-firn layers* can result from two independent processes: (1) spillage of drilling fluid during processing and (2) drilling fluid losses in the borehole. It is well known that the upper part of the ice sheets comprises a permeable snow-firn layer, the thickness of which depends on the accumulation rate and temperature. In different regions of inland Antarctica, the depth of the firn-ice transition varies in the range 64–115 m (Paterson, 1994). In order to reduce loss of the drilling fluid, the permeable snow-firn zone is isolated with casing in drilling operations. To prevent leaks at the bottom of the casing, a special shoe is installed (Johnsen and others, 1994); however, the safety of the standard construction of the casing joint and casing shoe is not always sufficient to prevent fluid leakage. Problems with leakage of drilling fluid in different parts of the casing almost always become apparent while drilling (Talalay and Gundestrup, 2000; Vasiliev and others, 2007).

*Ice-cutting contamination* is particularly important when considering the burial of cuttings. According to Article 2 of the Protocol on Environmental Protection to the Antarctic Treaty, waste like contaminated ice cuttings ‘shall be cleaned out or removed from the Antarctic Treaty area’. In spite of the fact that ice cuttings were polluted by drilling fluid, in recent drilling projects they have been buried near the drilling site and this will have local physical or chemical effects on the ice-sheet status. The greatest

concern associated with such impacts is the possible adverse effects on future science efforts in the same location.

*Contamination of subglacial water resources* occurs when a body of water is adversely affected by the addition of drilling fluid, which is not a naturally occurring substance in aquatic ecosystems and causes degradation of ecosystem functions. The contamination effect depends on the solubility in water of components of the drilling fluid. Oil hydrocarbons, fluorocarbons, *n*-butyl acetate, ESTISOL™ esters, silicon oil and some drilling fluids are hydrophobic liquids in which water wets a liquid boundary surface to some extent, and after physical mixing promoted by flow turbulence the water and the liquid form an emulsion. Emulsions may separate into oil and water again under calm conditions. Chemicals that are lighter than water will accumulate on the base of the ice sheet, while heavy compounds will settle on or in the subglacial till or sediments and harm the ecosystem there. Aromatic compounds are more soluble in water than saturated hydrocarbons; therefore, creatures may be poisoned without direct contact with the oil by the polluted water. Water-soluble pollutants (i.e. ethanol) are miscible (or dissolve) in water due to their chemical composition, and the harmful effect depends on the pollutant concentration.

There are currently no references on environmental monitoring of several of the deep-drilling projects that have been completed at various sites on the Antarctic and Greenland ice sheets, and follow-up studies have not been conducted on the impacts of earlier drilling operations. According to measurements made by one of the authors (P. Talalay) during deep drilling in NGRIP-2, the volume of drilling fluid pumped into the hole from the surface was  $21.3 \text{ L m}^{-1}$ , of which the volume of drilling fluid required to fill the drilled-in interval of the hole was  $13.2 \text{ L m}^{-1}$ . Recycling of the drilling fluid at the surface reduced drilling fluid consumption to  $16.5 \text{ L m}^{-1}$ . Wastage of completely lost drilling fluid therefore amounted to  $3.3 \text{ L m}^{-1}$ , and the volume rate of recycled drilling fluid was  $4.8 \text{ L m}^{-1}$ .

Summing up, it is apparent that during drilling of the NGRIP-2 borehole  $\sim 10 \text{ m}^3$  drilling fluid was lost at this site. Unfortunately, it is not possible to estimate how much of the drilling fluid wastage contaminated the air or snow–firn layer. The contamination of ice cuttings can be determined. The average weight of cuttings after the hydro extractor was  $5.74\text{--}5.79 \text{ kg m}^{-1}$  (Talalay and Gundestrup, 2000) and the weight of the dry cuttings should be equal to  $5.18 \text{ kg m}^{-1}$ . Subtracting the latter value from the former gives us the amount ( $\sim 0.6 \text{ kg m}^{-1}$ ) of drilling fluid still contained in the cuttings, and it was not possible to extract more fluid from the cuttings by centrifugal force. Consequently, during drilling of the NGRIP-2 borehole  $\sim 15$  tons ( $16.3 \text{ m}^3$ ) of cuttings were buried at the drill site, which contain  $\sim 1.8 \text{ m}^3$  drilling fluid.

## Biological pollution

The interaction of drilling activity on the Antarctic ice sheet with surface or air biota is unlikely, but the impact of drilling fluid on subglacial water biota can occur at almost any inland drilling site. Biological pollution can be considered from two points of view: (1) the poison effect from components of the drilling fluid; and (2) ingress into the subglacial water of modern microflora from the surface.

Kerosenes are very harmful to microbiota. Even at very small concentrations in the aquatic environment ( $\sim 1 \text{ mg m}^{-3}$ ) the aromatic hydrocarbon component can be poisonous to

microorganisms. On the other hand, a microbiological study of kerosene-based drilling fluid sampled at different depths from 110 to 3600 m in the 5G borehole at Vostok station showed that the drilling fluid itself contained bacteria of different origins, such as the ‘ubiquitous and omnivores’ genus *Sphingomonas*, a well-known degrader of aromatic hydrocarbons, and human and animal pathogens (Bulat and others, 2003). The number of microbial cells in the lower, relatively warm ( $-6^\circ\text{C}$  to  $-10^\circ\text{C}$ ) part of the borehole was found to be  $\sim 100 \text{ cells mL}^{-1}$  (Alekhina and others, 2012).

Molecular microbiology studies of the frozen subglacial water samples recovered from the NGRIP-2 borehole filled with kerosene-based drilling fluid showed the presence of microbial DNA and a few phylotypes of bacteria, but the origin of these microorganisms is questionable as the samples were heavily contaminated by drilling fluid (Bulat and others, 2005). When the subglacial water first entered the borehole, it contacted and mixed with the toxic drilling fluid, and it is almost impossible to get uncontaminated samples out of a borehole that is stabilized with kerosene-based drilling fluid (Wilhelms, 2007).

Unfortunately, most of the other low-temperature drilling fluids have the same toxic properties. For example, ethanol is a well-known antiseptic used as a bactericide and fungicide. It kills microorganisms by denaturing their proteins and dissolving their lipids, and is effective against most bacteria and fungi and many viruses (McDonnell and Russell, 1999). However, ethanol is ineffective against bacterial spores, which can remain in ethanol–water solution in great numbers.

The effects and associated toxicological mechanisms of esters on microorganisms have been confirmed by experiments (e.g. Zhou and others, 2011), but the specific effects on microbiota of *n*-butyl acetate and ESTISOL™ esters should be investigated in case these liquids are to be considered for future use in accessing subglacial lakes. Silicone oils are not toxic to microorganisms; however, tested microorganisms showed an apparent decrease in colony-forming units in silicone oils (Özdamar and others, 1999; Mackiewicz and others, 2004).

In order to avoid the potential for biological contamination of the subglacial environment and subsequent impact on microbial function, before dumping drilling fluid into the hole the fluid should be carefully treated on the surface and microbial contamination control methods should be introduced. Sterilization of drilling fluid is necessary for the complete destruction or removal of all microorganisms (including spore-forming and non-spore-forming bacteria, viruses, fungi and protozoa) that could contaminate subglacial water. In principle, drilling fluid should be cleaner than subglacial water. The microbial populations of Vostok Subglacial Lake are currently unknown, but can be predicted from research on accretion ice at Vostok station, where the concentration of microorganisms was found to be  $24\text{--}100 \text{ cells mL}^{-1}$  (Alekhina and others, 2012).

Standard sterilization methods include heating, filtration and UV treatment. Some aspects of sterilization methodology have already been developed for hot-water ice-drilling technology and the proposed exploration of Ellsworth Subglacial Lake (Mowlem and others, 2011) and Subglacial Lake Whillans (Fricker and others, 2011). It should be noted that many of these methods are not suitable for sterilization of organic drilling fluids; for example, the filtration of kerosene-based drilling fluids through fine microbiological

membranes is not possible as components from the drilling fluid form films, which completely block the membrane pores (Bulat and others, 2003). Heat treatment of water and chemicals also differs in procedure, temperature and duration (Reichert and Young, 1993). Therefore, development of new protocols will be required for sterilization of low-temperature drilling fluids.

## CONCLUSIONS

The search for a new environmentally friendly drilling fluid for coring in central Antarctica remains one of the most pressing problems for future drilling projects, including those projects intending to access subglacial lakes. Hot water is considered by the scientific community as the cleanest drilling fluid medium, but it cannot solve the environmental problems completely because modern microorganisms contained in snow-ice can ingress into the subglacial water. Furthermore, the thermal pollution of hot-water circulation could immensely influence the viability of subglacial microorganisms.

Not all recent low-temperature drilling fluids (kerosene-based fluids, ethanol and *n*-butyl acetate) qualify as intelligent choices from the safety, environmental and technological standpoints. It is likely that the next stage of evolution of ice-drilling fluid technology will develop with the introduction of synthetic ESTISOL™ esters, which are non-hazardous substances. ESTISOL™ 140 mixtures with ESTISOL™ 165 and ESTISOL™ F2887 have an acceptable density and viscosity at low temperatures, and field tests have proved ESTISOL™ 140 applicability for deep drilling in ice sheets. Low-molecular DSOs can also be considered a good alternative for borehole fluids, but the final conclusion about the applicability of DSOs in deep ice drilling can be made only after field experiments in a test borehole.

If ESTISOL™ esters or DSOs are planned for use to access subglacial lakes then the specific harm for all types of microorganism should first be investigated. In addition, a new protocol should be developed to regulate sterilization of the drilling fluid on the surface before dumping into the borehole.

## ACKNOWLEDGEMENTS

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# Safety data sheet

## according to 1907/2006/EC, Article 31

Printing date 26.06.2014

Revision: 26.06.2014

**Trade name: ESTISOL 140**

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· **7.3 Specific end use(s)** No further relevant information available.

### 8 Exposure controls/personal protection

· **Additional information about design of technical facilities:** No further data; see item 7.· **8.1 Control parameters**· **Ingredients with limit values that require monitoring at the workplace:**

The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.

· **DNELs**

Workers - Hazard via inhalation route, local / systemic:

- long term exposure 71,8 mg /m<sup>3</sup>

- acute/short term exposure 143,6 mg/m<sup>3</sup>

Workers - Hazard via dermal route:

- long term exposure 55,11 mg/kg bw / day

· **Additional information:** The lists valid during the making were used as basis.· **8.2 Exposure controls**· **Personal protective equipment:**· **General protective and hygienic measures:**

The usual precautionary measures are to be adhered to when handling chemicals.

· **Respiratory protection:** Not required.· **Protection of hands:**

Only use chemical-protective gloves with CE-labelling of category III.

To minimize the wetness in the glove due to perspiration changing of gloves during a shift is required.

For the protection against chemicals in areas with heightened risk of injury (mechanical hazard) no recommendation for a suitable glove material can be given.

The glove material has to be impermeable and resistant to the product/ the substance/ the preparation.

Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation

· **Material of gloves**

Neoprene gloves

Butyl rubber, BR

Natural rubber, NR

· **Penetration time of glove material**

For the mixture of chemicals mentioned below the penetration time has to be at least > 60 minutes (Permeation according to EN 374 Part 3: Level 1).

The determined penetration times according to EN 374 part III are not performed under practical conditions.

Therefore a maximum wearing time, which corresponds to 50% of the penetration time, is recommended.

Value for the permeation: Level ≤ 1

The exact break through time has to be found out by the manufacturer of the protective gloves and has to be observed.

· **Eye protection:** Goggles recommended during refilling

### 9 Physical and chemical properties

· **9.1 Information on basic physical and chemical properties**· **General Information**· **Appearance:**

**Form:** Fluid

**Colour:** Clear

· **Odour:** Fruit-like

· **Odour threshold:** 0,2 ppm

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- **Change in condition**  
     Melting point/Melting range: -93 °C  
     Boiling point/Boiling range: 199 °C
- **Pour point** Undetermined.
- **Flash point:** 75 °C
- **Ignition temperature:** 270 °C
- **Danger of explosion:** Product does not present an explosion hazard.
- **Explosion limits:**  
     Lower: 1.1 Vol %  
     Upper: 7.5 Vol %
- **Density at 20 °C:** 0.865 g/cm<sup>3</sup>
- **Solubility in / Miscibility with water:** Not miscible
- **9.2 Other information** No further relevant information available.

### 10 Stability and reactivity

- **10.1 Reactivity**
- **10.2 Chemical stability**
- **Thermal decomposition / conditions to be avoided:** No decomposition if used according to specifications.
- **10.3 Possibility of hazardous reactions** No dangerous reactions known.
- **10.4 Conditions to avoid** No further relevant information available.
- **10.5 Incompatible materials:** No further relevant information available.
- **10.6 Hazardous decomposition products:** No dangerous decomposition products known.

### 11 Toxicological information

- **11.1 Information on toxicological effects**
- **Acute toxicity:**

· **LD/LC50 values relevant for classification:**

Oral	LD50	3000 mg/kg (rat)
------	------	------------------

- **Primary irritant effect:**
- **on the skin:** Irritant to skin and mucous membranes.
- **on the eye:** No irritating effect.
- **Sensitization:** No sensitizing effects known.
- **Additional toxicological information:**  
     The product shows the following dangers according to the calculation method of the General EU Classification Guidelines for Preparations as issued in the latest version:  
     Irritant
- **Acute effects (acute toxicity, irritation and corrosivity)**  
     Dermal (rabbit): OECD 404 (Acute Dermal Irritation / Corrosion Category 2 (Irritant))

### 12 Ecological information

- **12.1 Toxicity**
- **Aquatic toxicity:** No further relevant information available.
- **12.2 Persistence and degradability** No further relevant information available.
- **12.3 Bioaccumulative potential** No further relevant information available.
- **12.4 Mobility in soil** No further relevant information available.

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**Trade name: ESTISOL 140**

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- **Additional ecological information:**
- **General notes:**  
*Water hazard class 1 (German Regulation) (Self-assessment): slightly hazardous for water*  
*Do not allow undiluted product or large quantities of it to reach ground water, water course or sewage system.*
- **12.5 Results of PBT and vPvB assessment**
- **PBT:** Not applicable.
- **vPvB:** Not applicable.
- **12.6 Other adverse effects** No further relevant information available.

### 13 Disposal considerations

- **13.1 Waste treatment methods**
- **Recommendation**  
*Must not be disposed together with household garbage. Do not allow product to reach sewage system.*
- **Uncleaned packaging:**
- **Recommendation:** Disposal must be made according to official regulations.

### 14 Transport information

- |   |                 |
|---|-----------------|
| · <b>14.1 UN-Number</b><br>· <b>ADR, ADN, IMDG, IATA</b>                                    | Void            |
| · <b>14.2 UN proper shipping name</b><br>· <b>ADR, ADN, IMDG, IATA</b>                      | Void            |
| · <b>14.3 Transport hazard class(es)</b><br>· <b>ADR, ADN, IMDG, IATA</b><br>· <b>Class</b> | Void            |
| · <b>14.4 Packing group</b><br>· <b>ADR, IMDG, IATA</b>                                     | Void            |
| · <b>14.5 Environmental hazards:</b><br>· <b>Marine pollutant:</b>                          | No              |
| · <b>14.6 Special precautions for user</b>  | Not applicable. |
| · <b>14.7 Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code</b>      | Not applicable. |
| · <b>UN "Model Regulation":</b>   | -               |

### 15 Regulatory information

- **15.2 Chemical safety assessment:** A Chemical Safety Assessment has not been carried out.

### 16 Other information

*This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.*

- **Relevant phrases**  
*H315 Causes skin irritation.*  
*R38 Irritating to skin.*
- **Department issuing MSDS:** product safety department

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**Safety data sheet**  
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Printing date 26.06.2014

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**Trade name: ESTISOL 140**

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**· Contact:** Mrs. Birgit Pape**· Abbreviations and acronyms:**

*ADR: Accord européen sur le transport des marchandises dangereuses par Route (European Agreement concerning the International Carriage of Dangerous Goods by Road)*

*IMDG: International Maritime Code for Dangerous Goods*

*IATA: International Air Transport Association*

*GHS: Globally Harmonized System of Classification and Labelling of Chemicals*

*EINECS: European Inventory of Existing Commercial Chemical Substances*

*ELINCS: European List of Notified Chemical Substances*

*CAS: Chemical Abstracts Service (division of the American Chemical Society)*

*DNEL: Derived No-Effect Level (REACH)*

*LC50: Lethal concentration, 50 percent*

*LD50: Lethal dose, 50 percent*

GB



# SAFETY DATA SHEET

## SECTION 1: Identification of the substance/mixture and of the company/undertaking

**Product identifier****Product name:** Eastman(TM) 2-Ethylhexyl Acetate**Product No.:** EAN 905890. 01212-00, P0121200, P0121201, P0121205, P0121206**Synonyms, Trade Names:** 01212-00**Additional identification****Chemical name:** 2-ethylhexyl acetate  
**CAS-No.:** 103-09-3**Relevant identified uses of the substance or mixture and uses advised against****Identified uses:** Solvent**Uses advised against:** None known.**Details of the supplier of the safety data sheet****Manufacturer / Supplier**Eastman Chemical Company  
200 South Wilcox Drive  
Kingsport, TN 37660-5280 US  
+14232292000Visit our website at [www.EASTMAN.com](http://www.EASTMAN.com) or email [emnmsds@eastman.com](mailto:emnmsds@eastman.com)**Emergency telephone number:**

For emergency health, safety, and environmental information, call 1-423-229-4511 or 1-423-229-2000.

For emergency transportation information, in the United States: call CHEMTREC at 800-424-9300 or call 423-229-2000.

## SECTION 2: Hazards identification

**Hazard classification:****Physical hazards**

Flammable liquids Category 4

**Health hazards**

Skin corrosion/irritation Category 2

**OSHA Specified Hazards:** not applicable**Warning label items including precautionary statement:****Pictogram:**

**Signal words:** WARNING!

**Hazard Statement(s):** H227: Combustible liquid.  
H315: Causes skin irritation.

**Precautionary statement:**

**Prevention:** P210: Keep away from heat/sparks/open flames/hot surfaces. No smoking.  
P264: Wash hands thoroughly after handling.  
P280: Wear protective gloves/protective clothing/eye protection/face protection.

**Response:** P370 + 378: In case of fire: Use water spray, carbon dioxide, dry chemical or foam for extinction.  
P302+P352: IF ON SKIN: Wash with plenty of soap and water.  
P332+P313: If skin irritation occurs: Get medical advice/attention.  
P362: Take off contaminated clothing and wash before reuse.

**Storage:** P403+P235: Store in a well-ventilated place. Keep cool.

**Disposal:** P501: Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

**Hazard(s) not otherwise classified (HNOC):** None known.

### SECTION 3: Composition/information on ingredients

#### Substances / Mixtures

**General information:**

Chemical name	Concentration	Additional identification	Notes
2-ethylhexyl acetate	100%	CAS-No.: 103-09-3	

\* All concentrations are percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

# This substance has workplace exposure limit(s).

### SECTION 4: First aid measures

**Description of first aid measures**

**Inhalation:** Treat symptomatically. Move to fresh air. Get medical attention if symptoms persist.

**Eye contact:** Any material that contacts the eye should be washed out immediately with water. If easy to do, remove contact lenses. Get medical attention if symptoms persist.

**Skin contact:** Immediately flush with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Get medical attention. Wash contaminated clothing before reuse. Destroy or thoroughly clean contaminated shoes.

**Ingestion:** Seek medical advice.

**Most important symptoms and effects, both acute and delayed:** May irritate and cause redness and pain.

**Indication of any immediate medical attention and special treatment needed**

**Hazards:** None known.

**Treatment:** Treat symptomatically.

## SECTION 5: Firefighting measures

**General fire hazards:** Combustible liquid and vapor. USE WATER WITH CAUTION. Material will float and may ignite on surface of water.

**Extinguishing media**

**Suitable extinguishing media:** Water spray. Dry chemical. Carbon Dioxide. Foam.

**Unsuitable extinguishing media:** None known.

**Special hazards arising from the substance or mixture:** None known.

**Advice for firefighters**

**Special fire fighting procedures:** Use water spray to keep fire-exposed containers cool.

**Special protective equipment for fire-fighters:** Self-contained breathing apparatus and full protective clothing must be worn in case of fire.

## SECTION 6: Accidental release measures

**Personal precautions, protective equipment and emergency procedures:** Wear appropriate personal protective equipment.

**Environmental precautions:** Avoid release to the environment.

**Methods and material for containment and cleaning up:** Eliminate sources of ignition. Absorb spill with vermiculite or other inert material, then place in a container for chemical waste. Large Spillages: Flush spill area with water spray. Prevent runoff from entering drains, sewers, or streams.

**Notification Procedures:** In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations.

## SECTION 7: Handling and storage:

**Precautions for safe handling:** Avoid contact with eyes, skin, and clothing. Wash thoroughly after handling.

**Conditions for safe storage, including any incompatibilities:** Keep container closed.

**Specific end use(s):** Solvent

## SECTION 8: Exposure controls/personal protection

### Control parameters

#### Occupational exposure limits

Country specific exposure limits have not been established or are not applicable unless listed below.

### Exposure controls

**Appropriate engineering controls:** Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

#### Individual protection measures, such as personal protective equipment

**General information:** Eye bath. Washing facilities. Safety shower.

**Eye/face protection:** It is a good industrial hygiene practice to minimize eye contact.

#### Skin protection

**Hand protection:** Wear chemical-resistant gloves, footwear, and protective clothing appropriate for the risk of exposure. Contact health and safety professional or manufacturer for specific information.

**Other:** No data available.

**Respiratory Protection:** If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn. In the United States of America, if respirators are used, a program should be instituted to assure compliance with OSHA Standard 63 FR 1152, January 8, 1998. Respirator type: Air-purifying respirator with an appropriate, government approved (where applicable), air-purifying filter, cartridge or canister. Contact health and safety professional or manufacturer for specific information.

**Hygiene measures:** Observe good industrial hygiene practices.

**Environmental Controls:** No data available.

## SECTION 9: Physical and chemical properties

### Information on basic physical and chemical properties

#### Appearance

<b>Physical State:</b>	Liquid
<b>Form:</b>	Liquid
<b>Color:</b>	Colorless
<b>Odor:</b>	Sweet
<b>Odor Threshold:</b>	0.007 ppm
<b>pH:</b>	No data available.
<b>Freezing Point:</b>	-93 °C
<b>Boiling Point:</b>	199 °C
<b>Flash Point:</b>	71 °C (Tag closed cup)
<b>Evaporation Rate:</b>	No data available.
<b>Flammability (solid, gas):</b>	No data available.
<b>Flammability Limit - Upper (%)—:</b>	No data available.
<b>Flammability Limit - Lower (%)—:</b>	No data available.
<b>Vapor pressure:</b>	0.532 mbar (20 °C)
<b>Vapor density (air=1):</b>	5.9
<b>Specific Gravity:</b>	0.873 (20 °C)
<b>Solubility(ies)</b>	
<b>Solubility in Water:</b>	Slightly Soluble
<b>Solubility (other):</b>	No data available.
<b>Partition coefficient (n-octanol/water):</b>	No data available.
<b>Autoignition Temperature:</b>	No data available.
<b>Decomposition Temperature:</b>	(DTA) No exotherm
<b>Dynamic Viscosity:</b>	No data available.
<b>Kinematic viscosity:</b>	No data available.
<b>Explosive properties:</b>	No data available.
<b>Oxidizing properties:</b>	No data available.

**Other information**

<b>Minimum ignition temperature:</b>	268 °C (ASTM D2155)
--------------------------------------	---------------------

**SECTION 10: Stability and reactivity**

<b>Reactivity:</b>	None known.
<b>Chemical stability:</b>	Stable
<b>Possibility of hazardous reactions:</b>	None known.
<b>Conditions to avoid:</b>	Incompatible materials.
<b>Incompatible materials:</b>	Strong oxidizing agents.
<b>Hazardous decomposition products:</b>	Carbon Dioxide. Carbon Monoxide.

**SECTION 11: Toxicological information****Information on likely routes of exposure**

<b>Inhalation:</b>	None known.
<b>Ingestion:</b>	None known.
<b>Skin contact:</b>	Causes skin irritation.
<b>Eye contact:</b>	None known.

**Information on toxicological effects****Acute Toxicity****Oral**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
Oral LD-50: (Rat): > 3,200 mg/kg  
Oral LD-50: (Rat): 5,890 mg/kg  
Oral LD-50: (Mouse): > 3,200 mg/kg

**Dermal**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
Dermal LD-50: (Guinea Pig): > 17,460 mg/kg  
Dermal LD-50: (Rabbit): > 5,000 mg/kg

**Inhalation**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
No data available.

**Repeated dose toxicity**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
No data available.

**Skin corrosion/irritation:**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
(Guinea Pig, 24 h): moderate

**Serious eye damage/eye irritation:**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
(Rabbit): Slight

**Respiratory or skin sensitization:**

**Product:** No data available.

**Specified substance(s)**

2-ethylhexyl acetate  
(Human) - Not a skin sensitizer.

**Mutagenicity****In vitro**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**In vivo**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Carcinogenicity**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Reproductive toxicity**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Specific target organ toxicity - single exposure**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Specific target organ toxicity - repeated exposure**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Aspiration hazard**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Other adverse effects:** No data available.

**SECTION 12: Ecological information****Toxicity****Acute toxicity****Fish**

**Product:** No data available.

**Specified substance(s)**  
2-ethylhexyl acetate No data available.

**Aquatic invertebrates**

**Product:** No data available.



**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

### Chronic Toxicity

#### Fish

**Product:**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

#### Aquatic invertebrates

**Product:**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

### Toxicity to Aquatic Plants

**Product:**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

### Persistence and degradability

#### Biodegradation

**Product:**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

#### Biological Oxygen Demand:

**Product**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

#### Chemical Oxygen Demand:

**Product**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

#### BOD/COD ratio

**Product**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

### Bioaccumulative potential

**Product:**      No data available.

**Specified substance(s)**  
2-ethylhexyl acetate      No data available.

**Mobility in soil:**      No data available.

### Known or predicted distribution to environmental compartments

2-ethylhexyl acetate      No data available.

**Results of PBT and vPvB assessment:** No data available.

2-ethylhexyl acetate No data available.

**Other adverse effects:** No data available.

## SECTION 13: Disposal considerations

### Waste treatment methods

**General information:** No data available.

**Disposal methods:** Dispose of waste and residues in accordance with local authority requirements. Incinerate. Since emptied containers retain product residue, follow label warnings even after container is emptied.

## SECTION 14: Transport information

*Important Note: Shipping descriptions may vary based on mode of transport, quantities, package size, and/or origin and destination. Consult your company's Hazardous Materials/Dangerous Goods expert for information specific to your situation.*

### DOT

Class combustible liquid, Packing group III for quantities of 450 liters (119 gallons) or more; not regulated for smaller quantities

Possible Shipping Description(s):

NA 1993 Combustible liquid, n.o.s. (2-ethylhexyl acetate) combustible liquid III

### IMDG - International Maritime Dangerous Goods Code

Class not regulated

Possible Shipping Description(s):

not regulated

### IATA

Class not regulated

Possible Shipping Description(s):

not regulated

## SECTION 15: Regulatory information

**Safety, health and environmental regulations/legislation specific for the substance or mixture:**

**This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.**

**WHMIS (Canada) Status:** controlled

**WHMIS (Canada) Hazard Classification:** B/3, D/2/B

**SARA 311-312 Hazard Classification(s):**

immediate (acute) health hazard

fire hazard

**US EPCRA (SARA Title III) Section 313 - Toxic Chemical List**

NONE

**OSHA:** hazardous

**TSCA (US Toxic Substances Control Act):** This product is listed on the TSCA inventory. Any impurities present in this product are exempt from listing.

**DSL (Canadian Domestic Substances List) and CEPA (Canadian Environmental Protection Act):** This product is listed on the DSL. Any impurities present in this product are exempt from listing.

**AICS / NICNAS (Australian Inventory of Chemical Substances and National Industrial Chemicals Notification and Assessment Scheme):** This product is listed on AICS or otherwise complies with NICNAS.

**MITI (Japanese Handbook of Existing and New Chemical Substances):** This product is listed in the Handbook or has been approved in Japan by new substance notification.

**ECL (Korean Toxic Substances Control Act):** This product is listed on the Korean inventory or otherwise complies with the Korean Toxic Substances Control Act. KE-00048

**Philippines Inventory (PICCS) :** This product is listed on the Philippine Inventory or otherwise complies with PICCS.

**Inventory of Existing Chemical Substances in China:** All components of this product are listed on the Inventory of Existing Chemical Substances in China (IECSC).

## SECTION 16: Other information

**HMIS® Hazard Ratings:** Health - 2, Flammability - 2, Chemical Reactivity - 0

*HMIS® rating involves data interpretations that may vary from company to company. They are intended only for rapid, general identification of the magnitude of the specific hazard. To deal adequately with the safe handling of this material, all the information contained in this MSDS must be considered.*

**Revision Information:** Not relevant.

**Key literature references and sources for data:** No data available.

**Training information:** No data available.

**Issue date:** 04/30/2014

**SDS No.:**

**Disclaimer:**

This information is provided without warranty. The information is believed to be correct. This information should be used to make an independent determination of the methods to safeguard workers and the environment.