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**THE FLAMMABILITY OF LIP,
FACE AND HAIR
PREPARATIONS IN THE
PRESENCE OF 100% OXYGEN**

63-27

FEDERAL AVIATION AGENCY
AVIATION MEDICAL SERVICE
AEROMEDICAL RESEARCH DIVISION
CIVIL AEROMEDICAL RESEARCH INSTITUTE
OKLAHOMA CITY, OKLAHOMA

Civil Aeromedical Research Institute, Federal Aviation Agency, Oklahoma City, Oklahoma. CARI Report 63-27. **THE FLAMMABILITY OF LIP, FACE AND HAIR PREPARATIONS IN THE PRESENCE OF 100% OXYGEN** by J. Robert Dille, Charles R. Crane, and George E. Pendergrass, November 1963.

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NOVEMBER 1963**

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ABSTRACT

The effects of high concentrations and pressures of oxygen and of static sparks upon lip, face, and hair preparations were determined because of questions that frequently arise and apprehension that exists. A wide margin of safety was found for their use at or below one atmosphere of pressure. However, their use in experimental or therapeutic compressions is not deemed safe due to a marked increase in the effects of a static spark upon these compounds at two atmospheres oxygen pressure.

Oxygen itself does not burn but it is both necessary for and greatly accelerates the burning of combustible materials. Even iron and steel are combustible at elevated temperatures in the presence of high concentrations of oxygen. The most common cause of oxygen explosions probably is contact between oxygen under high pressure and valves, gauges, and fittings that are contaminated with oil.

Because of the widespread use in aviation of high concentrations of oxygen and the common practice of using hydrocarbon preparations on the lips, face, and hair, it is little wonder that pilots have long been concerned that this combination might be hazardous. Two previous studies were undertaken to answer questions that have been raised.^{1,2} One of these² was performed after a reported case of spontaneous combustion which burned the lips of a pilot who had previously applied "chap stick" and who was on 100% oxygen. There are widespread rumors within the aviation community of other similar episodes, but no documentation of these could be found. There is serious doubt that many of these reported incidents actually occurred. It has been pointed out, however, that the investigation of all types of oxygen fire and explosion problems has been notoriously under-reported.³

The two previous studies cited above concluded that there was no increased hazard involved in the use of lip preparations in the

presence of 100% oxygen. Apprehension still exists, however, among both military and civilian pilots, fostered by the rumored incidents and by local policies against the use of such preparations. Unanswered are questions pertaining to the use of face and hair preparations (many of which contain alcohol), the hazard introduced by a static spark, the effects of oxygen at elevated pressures as seen with experimental or therapeutic compressions, and the significance of an intolerable "burning" sensation noted by some individuals when these preparations are used in the presence of 100% oxygen.

Since antichap preparations and oxygen-by-mask are frequently used together without ill effects, any hazard which exists under conditions of normal use is extremely small. Therefore no statistically valid determination of the chances of combustion of various products under conditions of normal use was feasible. Instead, the combustibility of these products under conditions of increased temperature, increased oxygen pressure, and in the presence of a static spark was investigated.

METHODS AND MATERIALS:

An oxygen-exposure chamber was constructed from a small, cylindrical, steam autoclave by replacing the metal door with a plexiglass plate machined from 1½ inch thick stock. Oxygen was introduced through the original steam-inlet port in the bottom of the chamber and was

allowed to flow out through a port in the top of the chamber where the pressure-indicating gauge was originally attached. An electrical resistance heating bar, 2 inches by 14 inches by $\frac{1}{4}$ inch, with a fully enclosed element, was supported on insulated legs in the bottom of the chamber, with the attached electrical cord passing through a gas inlet port and sealed against leakage with a plastic material. A surface temperature sensor, Yellow Springs Instrument Company #408, was attached to the surface of the heater with the lead wires passing through a sealed gas port and connected to a Yellow Springs Instrument Company "Tele-Thermometer".

For those experiments in which a spark was discharged through the test material, a length of plastic-insulated, high-voltage wire was passed through the chamber wall and positioned approximately $\frac{3}{4}$ inch above the test material surface. The high voltage was supplied by a Model T Ford ignition coil operated with a 12-volt D.C. power supply.

For the determination of ignition temperatures in an oxygen atmosphere, a ceramic crucible, 6 inches high by 3 inches diameter at the top and $1\frac{1}{2}$ inches diameter at the bottom, was filled $\frac{1}{4}$ full with sand and the sample planchets were partially embedded in this sand. Oxygen from a cylinder was passed through a pressure regulator, a flow-meter and a glass delivery tube which was positioned approximately $\frac{1}{2}$ inch above the surface of the sand. A calibrated copper-constantan thermocouple was embedded in the test material and the leads connected to a recording potentiometer (Texas Instrument, Servo-Riter). The crucible was placed on an electric hot plate and, in addition, the lower $\frac{1}{4}$ of the crucible was wrapped with electrical heating tape. Both the hot plate and the heating tape were controlled through variable transformers.

The materials to be tested, which were obtained through local retail outlets consisted of the following:

Chap-Stick (Chap Stick Company), Chap-Aid (L. Perrigo), Lip-Eze (Chap Stick Company), Camphor Ice (McKesson & Robbins), Lipstick (Revlon), Lanolin U.S.P., Vaseline (Cheesebrough-Pond's), Bfylcream (Beecham), Vitalis (Bristol-

Myers), Skin Bracer (Mennen), 'Lectric Shave (William's), Afta (Mennen), Hand Lotion (Jergen's), Chap-Ans (Chap Stick Company), Electric Motor Oil (Gulf).

PROCEDURE:

Spontaneous Ignition in Oxygen Atmosphere

The material to be tested was placed in stainless steel planchets, one inch in diameter by $\frac{1}{4}$ inch high. These were placed on the heating strip in the chamber and oxygen was allowed to flush through the chamber until its concentration exceeded 95%, as determined by a Chemtronics, Inc., Oxygen Analyzer.

The chamber was then sealed off, at ambient pressure, and the material allowed to stand in the oxygen atmosphere at various temperatures for a given period of time. The samples were observed constantly for any indication of spontaneous combustion.

Ignition by a Static Discharge in Air and in Oxygen

Planchets containing the samples were placed on the heating strip and the high-voltage electrode was positioned over them. In both air and oxygen atmospheres, the samples were immediately exposed to a series of momentary as well as sustained (approximately three-second) electrical discharges. The samples were then allowed to stand in the oxygen atmosphere for varying periods of time before exposure to additional electrical discharges.

Ignition Temperatures in an Oxygen Atmosphere

The sample planchets were placed in the sand bath with the thermocouple embedded in the sample material and the oxygen flow-rate adjusted so that the O_2 concentration inside the crucible remained above 95%. The two heaters were turned on and the variable transformers adjusted so that the temperature of the sample increased about $5^\circ C$ /minute. A continuous record of time vs. temperature was obtained from the recorder.

Exposures to Oxygen Pressures in Excess of One Atmosphere

Samples were placed on the heating strip in the modified autoclave and sufficient oxygen

was flushed through to raise the concentration above 95%. The exit port was closed and the oxygen pressure inside the chamber increased to 15, 30, and 45 psi gauge, which was equivalent to an absolute O₂ pressure of approximately two, three, and four atmospheres respectively. The samples were then allowed to stand at 94° F for one hour at 45 psi gauge. Selected samples were placed in the chamber at either 15 or 30 psi gauge and then tested with the spark discharge.

RESULTS:

Spontaneous ignition in Oxygen Atmosphere

None of the compounds tested ignited spontaneously on exposure to a 100% oxygen environment at a pressure of one atmosphere for periods up to 3 hours and at temperatures of 94° F and 112° F.

Ignition by a Static Discharge in Air and in Oxygen

Table I lists the compounds that were exposed to a spark discharge in both air and 100% oxygen at a pressure of one atmosphere; they were tested at both 94° F and 112° F; ((-) = no ignition; (+) = ignition). Each material was tested at least three times under each set of conditions.

TABLE I

COMPOUND	AIR	O ₂
Chap-Aid	-	-
Chap-Stick	-	-
Camphor Ice	-	-
Lip-Eze	-	-
Lipstick	-	-
Vaseline	-	-
Lanolin	-	-
Brylcream	-	-
Afta	-	-
Skin Bracer	-	+ (a)
Vitalis	+ (a)	+ (a)
'Lectric Shave	+ (a)	+ (a)
Motor Oil	-	- (b)

(a) These 5 samples were all (-) if the alcohol was allowed to evaporate before sparking.

(b) A momentary flame appeared in one of six trials.

Ignition Temperatures in an Oxygen Atmosphere

Sample materials were slowly heated in an O₂ atmosphere, using the arrangement described previously, until they reached the temperature at which they would ignite spontaneously, i.e., in the absence of an externally-applied flame. The upper limit of the calibration for the thermocouple used was 350° C; however, no samples were heated above 300° C. The results are described in Table II.

TABLE II

COMPOUND	IGNITION	REMARKS
Vaseline	+	Ignited @ 290-300° C.
Lanolin	-	No ignition below 300° C.
Brylcream (1)	+	Ignited @ 147° C, still boiling at ignition.
Brylcream (2)	-	Heated slowly to b.p. in air, continued heating at this temp. until boiling stopped. Renewed heating in O ₂ , the non-volatile residue darkened, then charred, but no ignition below 300° C.
Afta	-	Same procedure as Brylcream (2), No ignition below 300° C.
Camphor Ice	+	@ 252° C.
Vitalis	+	Boiled 85-100° C; residue ignited @ 240° C.
Chap-Aid	+	No boiling; smoked @ 200° C; ignited @ 265° C.
Lipstick	+	Slight boiling 170-190° C; ignited @ 290-300° C.
Lip-Eze	+	Boiling @ 100° C; smoke @ 175-250° C; ignited @ 275° C.
Chap-Stick	+	Smoke @ 250° C; ignited @ 255-260° C.
Skin Bracer	-	Boiling began @ 93° C; all evaporated by 120° C; no residue.

COMPOUND IGNITION REMARKS

'Lectric Shave	+	Boil @ 94° C; ceased boiling by 145° C; smoked @ 186° C; ignited @ 230° C.
Chap-Ans	+	Boil @ 100° C; smoke @ 140° C; ignited @ 290° C.
Jergens Lotion	-	Boil @ 100° C; splattered @ 140-170° C; evaporated by 250° C; no residue.
Electric Motor Oil	+	Smoke @ 230° C; ignited @ 290° C.

Exposures to Oxygen Pressures in Excess of One Atmosphere

Twelve preparations were exposed for one hour at 94° F in an O₂ environment of approximately four atmospheres absolute pressure (45 psi gauge), without exposure to the spark discharge. There was no spontaneous ignition of any of these twelve samples: Lip-Eze, Lipstick, Chap-Stick, Brylcream, Afta, 'Lectric Shave, Chap-Aid, Camphor Ice, Lanolin, Vaseline, Vitalis, Skin Bracer.

Three compounds were tested with a spark discharge in the presence of an elevated O₂ pressure, but the resulting fires were so intense that no more compounds were tested in this fashion. The three which were tested with a spark and did ignite were:

- Chap-Stick, @ 30 psi gauge.
- Brylcream, @ 15 psi gauge.
- Camphor Ice, @ 15 psi gauge.

DISCUSSION

Oxygen fires require oxygen, heat and a combustible material. Their chances of occurrence depend upon the concentration and partial pressure of the oxygen, the temperature, and the combustibility of the material.

It was not considered essential for our purposes to know the exact composition of the proprietary items tested, and such information is frequently difficult to obtain anyway. However, cosmetic and protective preparations of this nature usually contain one or more of the following types of demulcent or emollient substances: complex carbohydrates (polysaccharides) of plant origin; glycerol; sterols or ste-

rol esters; fatty acids or fatty-acid esters, including neutral fats of plant or animal origin; fatty alcohols; oils, greases or waxes from petroleum; and in recent years the polyethylene glycols (carbowaxes) and the silicones. The three simple substances, i.e., lanolin, vaseline (petrolatum) and a light mineral oil, included in this study were considered to cover the range of combustibility of the principal constituents likely to be encountered in any commercial preparations available for similar uses.

The ignition temperatures determined for the compounds tested indicate there is relative safety in the use of lip, face and hair preparations in the presence of 100% oxygen at pressures of less than 760 mm Hg. The presence of these compounds in or on a high pressure oxygen distribution system is contraindicated, however, since temperatures as high as 1700° F can be attained by the impinging of gas into a dead-end cavity or friction from a small volume, high velocity leak. Static discharges are possible from the flow of gas and from solid particles in the stream. The presence of combustible materials on the hands following application to the face or hair can result in their exposure to these high pressure, high velocity conditions. Ignition must also be assumed possible from cigarettes, matches, lighters, and from short-circuits in mask-mounted microphones.

Alcohol vapors from some preparations were ignited with a spark in oxygen at ground level atmospheric pressure. Since evaporation from the thin film of applied material is rapid, this would not be likely to constitute an inflight hazard. With this exception, none of the compounds could be ignited at one atmosphere O₂ pressure and at skin temperature even with sustained, high-energy sparking.

Ignition of two out of three compounds tested did occur when the same spark was applied in the presence of 100% O₂ at a pressure of two atmospheres (1520 mm Hg); another was ignited at three atmospheres. Furious combustion ensued once ignition occurred. Because of this, use of these preparations is felt to be contraindicated in positive pressure chambers where O₂ pressure will exceed one atmosphere despite

the routine precautions taken against static sparking in their operation.

While sparks have been responsible for mask ignition in industry, it is generally believed that static sparking is insufficient to ignite a solid material. However, it is possible, though unlikely, for a static spark of 2.5 millijoules energy (much weaker than the ones we used) to ignite tufts of paper or cloth fibers at room temperature and at an oxygen partial pressure of 480 mm Hg, but these materials are not present about a clean oxygen mask.

The presence on oxygen masks of normal skin oils, which are comparable in combustibility to the materials tested, has been found not to contribute significantly to the ignition and combustion of masks.⁴ The importance of an added amount of an oily preparation was not evaluated, however. Since ignition of fibers can be facilitated by the presence of oily substances, we view the presence of oils upon oxygen masks as an increased hazard, albeit small and unmeasured. The addition to the face of a commercial preparation is undoubtedly of more importance quantitatively than qualitatively. Therefore their presence probably constitutes a problem greater than that of the normal skin oils solely because of the greater amount present.

Rather extensive correspondence with persons engaged in aviation physiology revealed three cases of oxygen fires and explosions. One involved contact between a high velocity stream of oxygen and an oily hair preparation on the hands; one was an oxygen mask fire which burned the face and hands of a U.S. Navy pilot who denied using any lip, face or hair preparation;* and the other was a commercial pilot whose oxygen mask, which was hanging on his chest, burst into flames while he was lighting a cigarette. Adequate explanations exist for the causes of these fires, to allow one to exclude as a cause, the exposure of oils to oxygen at pressures of less than one atmosphere.

A "burning" sensation, occasionally severe enough to lead to mission abort, which has resulted from exposure to 100% oxygen following use of some of these preparations, is unexplained by our study.

* Not the same incident cited from Reference two.

CONCLUSIONS

A large margin of safety exists in using hydrocarbon face, lip, and hair preparations in the presence of 100% oxygen at or below one atmosphere. Their presence upon the hands, which may come into contact with high pressure oxygen sources probably constitutes the chief hazard.

There is some evidence that contamination with oily preparations will slightly increase the chances of ignition of solid material. Once ignition occurs, most materials burn furiously in high concentrations and partial pressures of oxygen.

Once the alcohol evaporates from pre- and post-shave compounds (in about one minute), the chances of ignition of these compounds by a static spark is negligible.

Because of the marked increase in the effects of a static spark upon these compounds at two atmospheres oxygen pressure (1520 mm Hg), their use is not deemed safe under these conditions, despite all precautions taken to prevent static sparking.

The temperatures required to ignite these compounds may occur around high pressure systems and from cigarettes, matches, microphone short circuits, or static spark.

ACKNOWLEDGEMENT

The authors wish to express their appreciation for the valuable technical assistance offered by Donald E. Rowlan, Mackie A. Allgood, and John W. Fitch.

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