Odors from UFOs

Deducing Odorant Chemistry

and Causation from Available Data

PRELIMINARY REPORT

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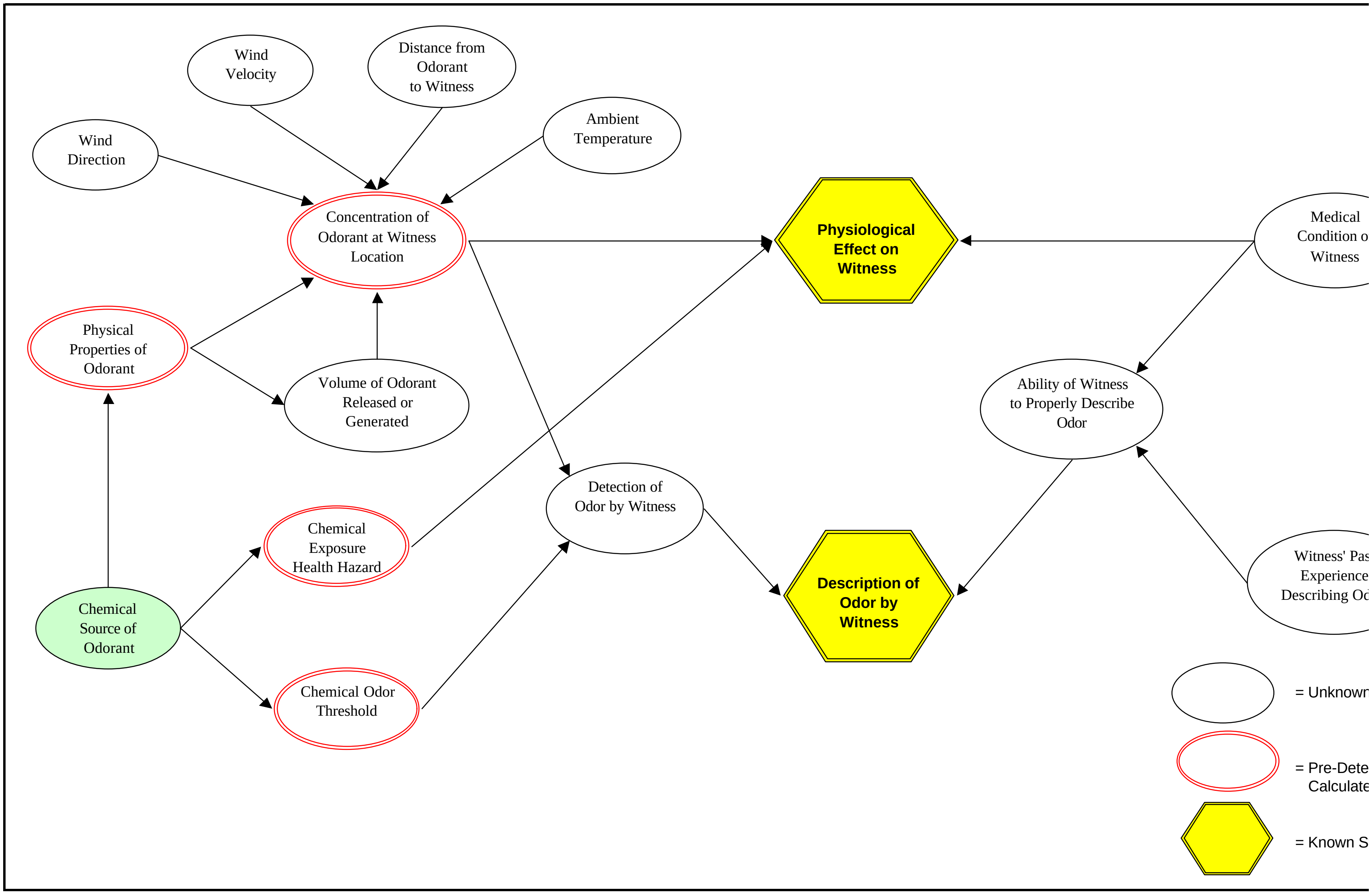
1 Introduction

Some UFO reports document the presence of odors. While the number of UFO odor reports is small, odor detection and recognition provides some information that could help solve the UFO mystery. Odorants, if released or created by the UFO, could provide information about their chemistry and possibly about the energy generated to produce them. Odors have not been considered physical evidence of the UFO presence because odors do not leave a trace. Nevertheless, odor detection implies that a chemical change took place in the environment that was significant enough to be detected.

There are many variables that lead to the detection and description of an odor by a witness. Some of the variables that affect odor detection and recognition and their interrelationships are shown in Figure 1. Unfortunately, in this study the only data we have are the end-results of this complex mechanism: odor description and physiological effects. Thus it is difficult to conduct a proper evaluation of odors associated with UFOs.

This study has two objectives. One objective is to try to determine which chemicals could lead to the odor described and the resulting physiological symptoms (regardless of where the odor came from). The other objective is to propose hypotheses that could explain the presence and/or generation of the odorants. Four hypotheses and the possible ways of discriminating between them are presented. The paper also summarizes some of the standards and techniques used in odor science that could be incorporated into UFO questionnaires in the future.

Figure 1: Influence Diagram showing Variables that Affect Odor Description and Physiological Effects on Witness



2 Literature Survey

Not much has been written in the UFO literature about odors associated with UFO sightings. Ivan Sanderson (1967), John Keel (1977) and James McCampbell (1973) are the few who have contributed their ideas and conclusions about the subject matter.

Sanderson discussed UFO odors in his book *Uninvited Visitors*. Sanderson concluded that UFO odors are rare but when reported they appear to be of three basic kinds: metallic, aromatic and sulphurous. He was very interested in the odors with an overpowering smell of violets because this odor was repeatedly reported in poltergeist cases. Nevertheless, he believed that the metallic odor indicated presence of metal and thus machines. He qualified his statement by saying that the smell of metal is actually one of hot hydrocarbon oils that are so intimately associated with machines. With regard to descriptions of the sulphurous odors, the predominant descriptor was the rotten-egg smell, but he mentioned other nauseating stenches like rotting cabbage, whale oil, and rotting human flesh.[1]

Keel discussed UFO odors in his book *The Eighth Tower*. Keel states that many UFO and monster witnesses smell odors like rotten eggs. Keel writes that this smell is sometimes even more rancid and is compared with the wretched stench of marsh gas. Keel believed that the odors were not produced by the entity itself but by some chemical reaction in the air that was catalyzed by the release of a huge mass of energy. He believed that the odorant had to be of such a huge volume of gas that it could not possibly come from the entity or UFO. He concluded that the smell accompanies the animal and is not necessarily produced by the animal. He concluded that the smell is a byproduct of the chemical process, which produces the transmogrification.[2] Transmogrification (as defined by Keel) is the process by which an intelligent energy field from the "superspectrum" materializes in our world.

James McCampbell looked for explanatory clues for UFO odors in the ball lightning literature. In his book *Ufology*, he summarized his findings and conclusion. He believed that ball lightning and UFOs generate odors via similar mechanisms. The energy released from ball lighting causes chemical reactions in the environment and forms odorant molecules. McCampbell believed that a plasma is present in both ball lightning and the surface of UFOs (especially when they are extremely bright). He believed that a plasma could be sustained on the surface of a UFO only by a continuing absorption of microwave energy emitted by the UFO.

McCampbell states that in a high-voltage spark, nitrogen is elevated to a metastable state and will readily combine with many other elements whereas ordinary nitrogen will not. Nitrogen will combine with hydrogen to form ammonia (NH_3) and with oxygen to form nitrous oxide (NO). This oxide is quite stable at high temperature but below 1,500 °C it reacts with oxygen to form nitrogen dioxide (NO_2). Also produced by electrical discharges is a highly reactive form of oxygen know as ozone (O_3) whose odor one associates with sparking, electrical apparatus. He states that the odor of ball lighting is usually described as sharp and repugnant, resembling ozone burning sulfur or nitric oxide.[3]

McCampbell looked into the Jacques Vallee's catalogue in *Passport to Magonia* and found 19 UFO odor cases amongst its 923 worldwide UFO cases.[4] He concluded that odor descriptions implying sulfur dioxide (SO_2) were the most numerous, but that benzene and its derivative were also mentioned. Moreover, the term pungent and the reference to an electrical circuit almost assuredly implied ozone. He concluded that the case evidence pointed to an electrical disturbance on the surface of UFOs that is undoubtedly associated with the luminosity.

While Sanderson and Keel had many years of experience with UFO reports to draw their conclusions, they did not provide the database of UFO odor cases to draw their conclusions. Some of the cases mentioned in their books were included in this study but we don't know how many were missed. McCampbell does provide his data sources (Vallee's Magonia catalogue) and we included those that took place in the U.S.

All three authors approach odor causation from different angles. McCampbell and Keel both agree that the odorants were created in the air via interactions with energy sources. While McCampbell believes the energy source came from a plasma on the surface of a solid three-dimensional craft, Keel believes the energy was generated when the object materialized. In McCampbell's hypothesis, odorants are created as long as the object is present with intense luminosity, while Keel's odorants are created just at the materialization stage. It appears that if the odor was created just at the materialization stage, then UFO odors should diminish with time. Unfortunately we don't have enough data in this study to test this hypothesis. Sanderson's position on causation is not clear. On the one hand he mentions that metallic odors imply a machine, but then he invokes the similarity between the violets odor and poltergeist smells. All three authors agree with the sulfidic component to UFO odors.

3 Background on Odor Reports

The reporting of odors depends much on the investigator skills and the questionnaire used. The U.S. Air Force Project Blue Book had a Technical Information Sheet that was filled by the UFO witness. The Technical Information Sheet, however, did not ask for odors detected during the sighting.[5] In 1966, the Air Force issued a new questionnaire under Air Force Regulation No. 80-17 to facilitate the University of Colorado two-year study of UFOs (funded by the USAF). The questionnaire was titled "Sighting of Unidentified Phenomena Questionnaire" and it did ask for odors in question number 21.[6] The question asked: "Did you noticed any odor, noise, or heat emanating from the phenomenon or any effect on yourself, animals or machinery in the vicinity? If yes, describe". While the original Blue Book questionnaire did not ask for odors, apparently a 1950's Atomic Energy Commission (AEC) 3-page UFO questionnaire did.[7] The form was prepared by the AEC for reports of UFOs at Los Alamos.

UFO sighting questionnaires have also been developed by private UFO research organizations. A prominent organization, Center for UFO Studies (CUFOS) has a 2-page questionnaire that does ask for the presence of odor[8]. Another large organization that investigates UFO reports is Mutual UFO Network (MUFON) and it currently has numerous questionnaires. The general case questionnaire (two pages) also asks for smells.[9]

While these questionnaires ask for detection of odors, they do not provide a standardized list of odor descriptors for the witness to choose from. As a result, witnesses are free to associate the odor with any smell they can recollect or are able to describe. As a result, the available data set on odor descriptions is unstructured and somewhat random.

4 Data Sources

Most of the UFO cases reporting odors were obtained from Larry Hatch's *U* UFO Database. Hatch's database encompasses most of the existing UFO report compilations and contains references to about 17,660 UFO case reports worldwide.[10] Hatch's database contained only 53 cases worldwide where odors were reported.[11]

The author focused only on U.S. reports because most of the original documents and reports for the US cases were available while those of foreign cases were not. Of the 53 worldwide UFO reports with odors in Hatch's Database, 28 were reported in the U.S. Of the 28 US cases from Hatch's database, 9 were removed for this study due to several reasons:

- Original sources were not available to author (3 cases with odor descriptions like ozone, chemical smell, and extreme skunk odor).
- No UFO was seen when odor was detected (2 cases with odor descriptions like cloying smell and stinky odor).
- No smell was reported in the original text (1 case).
- Smell was reported the day after the sighting and it was emanating from scorched ground (1 case describing a perfume smell).
- A hoofed creature was seen but no UFO was seen (1 case describing a foul odor like leaking gas).
- Odor memory was obtained through hypnosis (1 case describing a strong odor electrical in nature).

A key criteria used to reject some of these cases was that a UFO had to be seen in conjunction with detection of the odor. Moreover, the smell had to be consciously recalled and not through hypnosis.

The second source of case references for this study was obtained from Mark Cashman's UFO Database for Electromagnetic Interference Effects[12]. Cashman's database provided two additional cases where odors were detected in the presence of a UFO. Two additional sources for cases were Vallee's *Passport to Magonia* Catalogue[13] (2 additional cases) and Richard Hall's database from *Uninvited Guests* (2 additional cases)[14]. Finally, one case (not available yet in UFO databases) was brought to my attention by UFO investigator Beverly Trout. Thus, the total number of US UFO-Odor cases evaluated in this study was 26.

5 Summary of U.S. Data on UFO Odor Reports

There was no common pattern amongst the 26 cases evaluated. Amongst those reports that gave approximate distance between witness and object (20 cases), 15 of them reported distances of less than 500 ft. Nine of the 26 cases reported some kind of physiological effect (nausea, dizziness, burning nose and eyes, tiredness). Nine cases reported sound. The most common sound was a whirring sound (4 cases). Other sounds were hissing, beeping, humming, and loud crackling. Seven cases reported electromagnetic effects on their cars (6 cases) and TV (1 case). Numerous shapes were used to describe the object seen. A list of all the shapes described is shown below:

Ovoid, discoid, or saucer shaped	9 cases
Ball, globe, or spherical	4 cases
Cigar or dirigible shaped	3 cases

Not described	3 cases
Round or circular shaped	2 cases
Top shaped	1 case
Rectangular	1 case
Cup shaped	1 case
Cone shaped	1 case
Triangular shaped	1 case

The odors reported in conjunction with UFO sightings were diverse. Descriptions of odor, reported physiological effects, dates, and locations are shown in Table 1.

6 Odor Science

Odorants are volatile or gaseous chemical compounds that are carried by inhaled air to the olfactory system. The odorant must possess certain molecular properties in order to provide sensory properties. It must have some water solubility, a sufficiently high vapor pressure, low polarity, some ability to dissolve in fat, and surface activity. To date, no known odorant possesses a molecular weight greater than 294.[15]

According to the committee on Odors from Stationary and Mobile Sources from the National Research Council, "the human olfactory system can discriminate among many thousands of different odorous substances and can detect many of them in extremely low concentrations. Odors convey information about their sources and elicit a wide variety of emotional and physical effects. The human memory for odors is retained over long periods-often over much of a lifetime."[16]

Odors are usually described using four sensory properties: odor intensity, detectability, character, and hedonic tone (pleasantness and unpleasantness). The combined effect of these properties is related to the annoyance that may be caused by an odor. Odor intensity is the strength of the perceived odor sensation and depends in a complex way on the odorant concentration. Odor intensity weakens as odorant concentration decreases but not in direct proportion. The most common devise for measuring the perceived intensity of odors is category scales. One of the most widely used is that by Katz and Talbert:[17]

0	No odor
1	Very faint odor
2	Faint odor
3	Easily noticeable odor
4	Strong odor
5	Very Strong odor

Table 1: U.S. Cases of Odors connected with UFO Sightings

No.	Date	Location	Odor Character	Odor Intensity	Odor Hedonic Tone	Made Witness Ill	Ref.
1	29-Jan-50	South Table Mountain, Colorado	Pungent	-	-	-	18
2	12-Sep-52	Flatwoods, West Virginia	Sickly warm smell like hot, grease metal	Very Strong	Foul smelling mist; nauseating odor; atrocious	Caused eyes to water; burn nostrils and throat	19
3	21-Sep-52	Centerville, Virginia	Strange burning smell	Easily Noticeable	Awful odor, odor made mother ill	Yes	20
4	13-Sep-53	Frametown, West Virginia	Ether mixed with sulphurous smoke	Strong	unpleasant; nauseous	Witness felt pricklings throughout his body, had to stop, lost his balance several times	21
5	22-Jun-54	Cincinnati, Ohio	Burning sulfur	-	-	-	22
6	02-Oct-56	Trenton, New Jersey	Smell like sulfur or brimstone	Very Strong	Noxious; foul; nauseating	Odor made witness sick; lost sense of taste and smell; throat would not swallow properly	23
7	14-Jun-64	Dale, Indiana	Sulfur or burnt rubber	-	-	No	24
8	29-Jun-64	Lavonia, Georgia	Embalming fluid	Strong	-	-	25
9	07-Jul-64	Tallulah Falls, Georgia	Brake liquid or embalming fluid	-	-	-	26
10	20-Aug-65	20 miles from Cherry Creek, New York	Burned Gasoline/ pungent strange	-	-	-	27
11	14-Dec-65	Salt Springs, Florida	Strange odor & metallic taste in their mouth	-	-	-	28
12	07-Jan-66	Wilmer (Alabama).	Sulfur or Rotten Egg	-	-	-	29
13	23-Apr-66	Yorktown, Iowa	Ozone	-	-	-	30
14	02-Oct-66	Cincinnati, Ohio	(1) Bad garbage (2) Chemical odor	Strong	Foul; ill smelling	Dizziness and Nausea	31
15	05-Oct-66	E. Connersville, Indiana	Sulfur and tannic acid	Faint	-	-	32
16	12-Mar-67	Las Cruces, New Mexico	odor similar to that of electrical machinery or burning electrical insulation	Easily Noticeable	-	-	33
17	05-Apr-67	Jonestown, Pennsylvania	Sulfur and camphorated oil	-	-	-	34
18	Spring-67	Haverhill, Massachusetts	Burning match, sulfur, pungent	Easily Noticeable	-	No	35
19	01-Oct-68	Lakeland, Florida	Ammonia Smell	Very Strong	Witnesses complained about odor	Smell burned their noses and eyes	36
20	10-Mar-69	Near Westhope, North Dakota	Burning Rubber	Easily Noticeable	-	Feeling of lightness	37
21	02-Apr-73	E. Greenwich, Rhode Island	Smell like burned powder or gun-smoke	Easily Noticeable	-	Made them feel giddy and tired	38
22	Summer Mid 1970's	Grinnell, Iowa	Sulfur	Heavy	Offensive	No	39
23	10-Nov-75	Ross, Ohio	Sulfur	Strong	Offensive	-	40
24	14-Dec-75	Salt Springs, Florida	Metallic	Faint	-	-	41
25	05-Jan-79	Auburn, Massachusetts	Pungent; sweet skunk smell	Strong	-	-	42
26	20-Sep-80	Scandia, Minnesota	Pungent odor	Easily Noticeable	-	-	43

As an odorant is diluted in air, the odorant intensity becomes so low that detection or recognition of the odor is very difficult. The dilution points upon which detection and recognition are reached are called detection threshold and recognition threshold.

Odor character is the array of the odor notes of the odor sensation that permit one to distinguish odors of different substance on the basis of experience. There are many tens of thousands of different characteristic odors, even disregarding the odors that result from mixtures of odorants. Odor character is evaluated by a comparison with other odors, either directly or through use of descriptor words. In the late 1970's, the ASTM E-18 Sensory Evaluation Committee canvassed 31 lists of odor descriptors and resulted with a list of 830 descriptors. Later, about 100 people in various laboratories cooperatively screened this list and concluded that approximately 160 descriptors are considered useful and important.

Nevertheless, no odor classification system has yet been universally accepted. Since each odor may have a combination of character notes of different applicability, odor character is best described by methods known as multidimensional scaling or profiling. The Odor Profiling Method developed by ASTM in 1985 is described in the next section.

7 Odor Profiling

The American Society for Testing and Materials (ASTM) published an Atlas of Odor Character Profiles in 1985. This atlas provides access to the odor character of 160 chemicals and mixtures and a database for further research in the science of smell. The Atlas was compiled by the Institute of Olfactory Sciences in Park Forest, IL and was sponsored by the Section of Odor Profiling from the ASTM Subcommittee on Instrumental-Sensory Relationships.

According to ASTM, the "Odor Profiling project was designed to develop odor character information on odors of various types, ranging from the very pleasant to the very unpleasant. The Atlas is a compilation of the collected information and should serve the various tasks of characterization of unknown odors (by similarities or dissimilarities to the odors characterized by the Atlas)."[44]

The method selected by ASTM to characterize odors was based on semantic profiling of odors. A list of odor descriptors was provided to the panelists, who smelled the odorous sample and described its odor by rating the applicability of each of the descriptors on a scale of 0 to 5. A score of 0 means that the descriptor is not applicable to the odor evaluated; a score of 5 means that the descriptor is highly appropriate.

In the ASTM evaluation of the different chemicals, 146 odor descriptors were used. Given that there are thousands of odor descriptors, the history behind this selection is important. ASTM summarizes the history and rationale for choosing these 146 odor descriptors as standards below:

> In an early approach to the odor characterization, ASTM Sensory Evaluation Committee E18 collected over 800 terms used in odor character evaluations. Later, the Committee used about 100 individuals from several organizations to classify these descriptors in to three groups – useful, useless, and in-between- when applied to odor descriptions of odors in general. About 160 from the over 800 descriptors were voted useful. Meanwhile, experience with the air pollution samples at IIT Research Institute, Chicago, Illinois, indicated that odors quite different in character sometimes yield very similar profiles when rated on the 44 descriptor Harper's scale. Consultations with Harper and a number of industrial organization, and a review of ASTM's "useful descriptors," led to the 146 descriptor list."[45]

A list of the 146 odor descriptors used by the ASTM panelist is shown in the Appendix. Of the 146 descriptors used in the ASTM Profiling Study, 11 of them are present in the 26 UFO odor cases evaluated in this report. ASTM odor descriptors present in UFO cases are:

1. Burnt, smoky
2. Etherish
3. Like ammonia
4. Sickening
5. Sharp, Pungent, Acid
6. Camphor like
7. Metallic
8. Sulphidic
9. Putrid, Foul, Decayed
10. Burnt Rubber-like
11. Chemical

In order to gain insights into the applicability of odor profiling to UFO smells, we picked one chemical from the ASTM study and reviewed the results. We chose camphor as the chemical because it was reported in one of the 26 UFO cases studied and because of its complex odor profile. The resulting smell characterization for camphor by ASTM Panelists is shown in Table 2. The odor profile table shows two values for each descriptor. One value is the % Applicability. Percent Applicability is defined as the geometric mean of the Percent Usage and the Percentage of the Maximum Possible Score. Percent Usage is the percentage of people who used the particular descriptor for the particular sample. The Maximum Total Score Sum is equal to the number of panelists multiplied by 5. Percentage of the Maximum Possible Score is the ratio of the sum of the scores given by all panelists to the particular descriptor divided by the Maximum Score Sum. A 4% increment in % applicability is equivalent to one standard deviation.

Table 2 shows descriptors for Camphor that had a % Applicability with standard deviations equal or greater than one (shown in descending order of % Applicability). Out of 146 potential descriptors, the panelists selected 36 descriptors within one standard deviation. While the camphor descriptor had the highest % Applicability, there were 17 other descriptors with standard deviations greater than 3. While 99% of the panelists detected the odor, only 60.5% of the panelists used the term Camphor to describe the Camphor odor.

Amongst descriptors within 3 standard deviations, there were three other descriptors also found in UFO odor cases: Etherish, Chemical, and Pungent. Below 3 standard deviations the descriptors used for Camphor become somewhat surprising. At one standard deviation, we find three other descriptors used in UFO odor cases: Sickening, Metallic, and Ammonia. These observations are made just to illustrate the complexity of using witness testimony on odor description to determine odorant source.

Profile results for camphor provide several insights from odor science that we must take into account in evaluating UFO odors:

1. A single chemical will generate multiple descriptions from a diverse population.
2. When interviewing a UFO witness who reports an odor, we should ask for all descriptors of the odorant and then the witness should try to add relative weights to these descriptors (maybe using the same form as the ASTM Odor Profile study).
3. In trying to determine the odorant related to UFO sightings, we should generate a profile of odor descriptors and not just assume that a single odor will be commonly reported.

Table 2: Odor Profile for Camphor[46]

Odorant = Camphor		
Descriptor	**% Applicability**	**# of Standard Deviations on Applicability**
Camphor	52.37	13
Medicinal	39.08	9
Aromatic	26.70	6
Woody, Resinous	25.98	6
Cool, Cooling	24.31	6
Eucalyptus	23.25	5
Fragrant	21.39	5
Etherish, Anaesthetic	18.48	4
Heavy	18.09	4
Cedarwood	17.45	4
Chemical	17.39	4
Disinfectant, Carbolic	15.48	3
Light	14.27	3
Turpentine (Pine Oil)	13.12	3
Sharp, Pungent, Acid	12.47	3
Warm	12.38	3
Mothballs	12.07	3
Minty, Peppermint	11.62	2
Musty, Earthy, Moldy	11.58	2
Sweet	9.25	2
Herbal, Green, Cut Grass	8.32	2
Spicy	8.06	2
Paint	7.62	1
Nail Polish Remover	7.17	1
Cleaning Fluid	7.10	1
Gasoline, Solvent	6.45	1
Oily, Fatty	5.69	1
Bark, Birch Bark	5.48	1
Varnish	4.91	1
Sickening	4.51	1
Sweaty	4.30	1
Metallic	4.28	1
Incense	4.08	1
Ammonia	4.08	1

Given the preponderance of sulfur odors reported in UFO odor cases, we tabulated the odor profile results of 4 chemical substances that contain sulfur. Table 3 shows the Odor Profiles for Diethyl Sulfide, Dipropyl sulfide, Thiopene, and Garlic oil. The table only shows descriptors with % Applicability standard deviations greater than 3.

The profile results for these four sulfur-containing molecules gave us a few insights that might help in this study.

1. Not all sulfur-containing molecules are described as sulfidic (Di-propyl sulfide did not get a high % Applicability rating on the Sulfidic descriptor by the panelists).
2. All four compounds got high % Applicability ratings on the Sickening, Pungent, and Heavy descriptors. These 3 descriptors had a higher standard deviation than the sulfidic descriptor. Perhaps these are more common odor descriptors for sulfur containing molecules than the sulfidic descriptor.
3. Odors from sulfur containing molecules are sometimes described as Garlic like.
4. While many sulfur containing molecules have a Putrid/Foul smell, not all of them do (like dipropyl sulfide).

Another valuable report included in the ASTM Profile study was a table listing the most representative odorants for specific descriptors. Wherever there were five or more odorants representative of a descriptor with Applicabilities of 5% or higher, only the five with the highest % Applicabilities were listed. Table 4 is an extract from the ASTM report showing the most representative odorants for the 11 descriptors that have been reported in UFO odor cases. For each odor descriptor, the table shows the most representative odorant and their % Applicability. This table will be used later in this report when we try to analyze the documented UFO odor descriptions.

Table 3: Summary of Odor Profiles for Four Sulfur Containing Molecules[47]

# of Standard Deviations on Applicability Odorant	Diethyl Sulfide	Dipropyl Sulfide	Thiopene	Garlic Oil
Odorant	C4 H10 S	C6 H14 S	C4 H4 S	Allicin Organic Sulfides
1. Garlic, Onion	10		8	17
2. Sickening	9	5	8	5
3. Heavy	8	3	8	6
4. Household Gas	6		6	
5. Sharp, Pungent Acid	6	3	5	6
6. Sulfidic	5		5	3
7. Gasoline Solvent	4			
8. Putrid, Foul, Decayed	4		3	
9. Woody, Resinous		4		
10. Sewer	3		3	
11. Burnt, Smoky	3		6	
12. Rancid	3			
13. Oily, Fatty	3	3	3	
14. Chemical		3		
15. Sour, Vinegar		3	3	
16. Sweaty		3	3	
17. Musty, Earthy, Moldy		3	3	
18. Aromatic		3		4
19. Spicy				6
20. Seasoning for Meat				4

Table 4: Odorants Representative of Specific Descriptors[48]

Odor Descriptor	Odorants with Highest PA	PA	Odor Descriptor	Odorants with Highest PA	PA
Ammonia	Trimethyl Amine Pyridine 3-Hexanol Cyclo-Hexanol 2,5-Dimethyl Pyrazine	13 11 9 6 6	Household Gas	Thiophene Diethyl sulfide Cyclodithalfarol Thioglycolic Acid Tetrahydro Thiophene	27 25 17 13 12
Burnt Rubber-Like	Cyclodithalfarol Thioglycolic Acid Thiophene 1,2—Cychlohexadione Diethyl Sulfide	16 14 11 9 8	Putrid, Foul, Decayed	Methyl Thiobutyrate Butyric Acid Pentanoic Acid Thioglycolic Acid Pyridine	53 39 37 32 32
Burnt, Smoky	Guaiacol 1,2-Cyclohexadione Cyclotene 2,5-Dimethyl Pyrrole Thiophene	44 39 36 27 26	Sharp, Pungent, Acid	Tetrahydro Thiophene Pyridine Phenyl Acetylene Thioglycolic Acid Butyric Acid	43 40 32 30 30
Camphor-Like	DL-Camphor Eucalyptol L-Menthol Iso-Bornyl Acetate Patchouli Oil	52 41 34 27 26	Sickening	Methyl Thiobutyrate Pyridine Cyclodithalfarol Butyric Acid Thioglycolic Acid	69 63 56 55 54
Chemical	Phenyl Acetylene Anisole Pyridine Cyclohexanol 1-Butanol	38 34 33 32 27	Sulfidic	Cyclodithalfarol Thioglycolic Acid Thiophene Diethyl Sulfide Onion Oil	30 26 24 22 19
Etherish	2,5-Dimethyl Pyrazine Cyclohexanol 3-Hexanol Eucaliptol Phenyl Acetylene	41 40 33 24 23	Metallic	Nonyl Acetate Hexyl Amine 20 ML/L Diphenyl Oxide Maritima Garlic Oil	11 11 9 8 7

8 Potential Chemical Sources of Odors Reported with UFO Sightings

Scientist still lack an understanding of why chemicals smell the way they do. Olfaction research has been impeded by a lack of knowledge concerning the physicochemical properties of molecules that lead to specific olfactory qualities. A diverse range of theories exists that relate the physicochemical properties of the odorant to its olfactory quality. Factors such as molecular size and shape, low energy molecular vibrations, molecular cross-section, desorption from a lipid-water interface into water, proton, electron and apolar factors, profile functional groups, gas chromatographic factors and interactions of the weak chemical type, have all been implicated as variables related to odor quality.[49] In the absence of a clear chemical model for predicting odorant quality, we will rely on deduction and heuristics to obtain a list of potential chemicals that meet the odor descriptors given by UFO odor witnesses.

In order to deduce information from the list of odors associated with UFO sightings on Table 1, we extracted descriptors of odor character and hedonic tone and generated a profile.

Table 5 shows all of the odor descriptors used on the 26 UFO cases being reviewed and the frequency of their use. A total of 38 descriptors were extracted from Table 1. This number exceeded the number of cases because more than one descriptor was used per case. The additional information is useful since odors have many different qualities as we observed in the Odor Profiling summary. The 38 reported descriptors were condensed into 16 distinct categories. The three most common descriptors were sulfidic, pungent and foul.

8.1 Extracting information from the ASTM Odor Profile Study

The ASTM Odor Profile study tabulated for each odor descriptor the top 5 chemicals (out of the 160 evaluated) with the highest % Applicability. An extract of this summary is shown in Table 4. Given that the top 3 descriptors for UFO odors are sulfidic, foul and pungent, we looked at the top 5 chemicals for each of these descriptors to look for patterns. In the sulfidic category all the compounds contained sulfur. In the pungent category there is a diverse group of compounds with no commonality. Two of the top 5 pungent compounds contain sulfur. In the foul category, organic acids dominate the list. Moreover, three of the 5 compounds contain sulfur. All these compounds are liquids at room temperature.

We extracted the top chemicals within these 3 ASTM descriptors that shared at least two UFO odor descriptors. Of the top 15 chemicals, only 4 shared more than one of the top 3 UFO odor descriptors: Thioglycolic Acid, Thiopene, Pyridine and Butyric Acid. Table 6 lists these 4 chemicals and shows which other UFO odor descriptors they also had a high % of Applicability.

Table 5: Type of Odor Descriptors used in 26 Odor UFO Cases

No.	Odor Descriptor Used	No. of Cases
1	Sulfidic	10
2	Foul, Noxious (Includes skunk smell and offensive bad garbage smell descriptors)	6
3	Pungent	5
4	Metallic	3
5	Burnt rubber	2
6	Embalming fluid	2
7	Burned Gasoline/ Burning Smell	2
8	Burned match/ Burned powder or gun-smoke	2
9	Rotten Egg	1
10	Electrical machinery or burning electrical insulation	1
11	Chemical	1
12	Ether	1
13	Camphorated oil	1
14	Tannic acid	1
15	Ozone	1
16	Ammonia	1

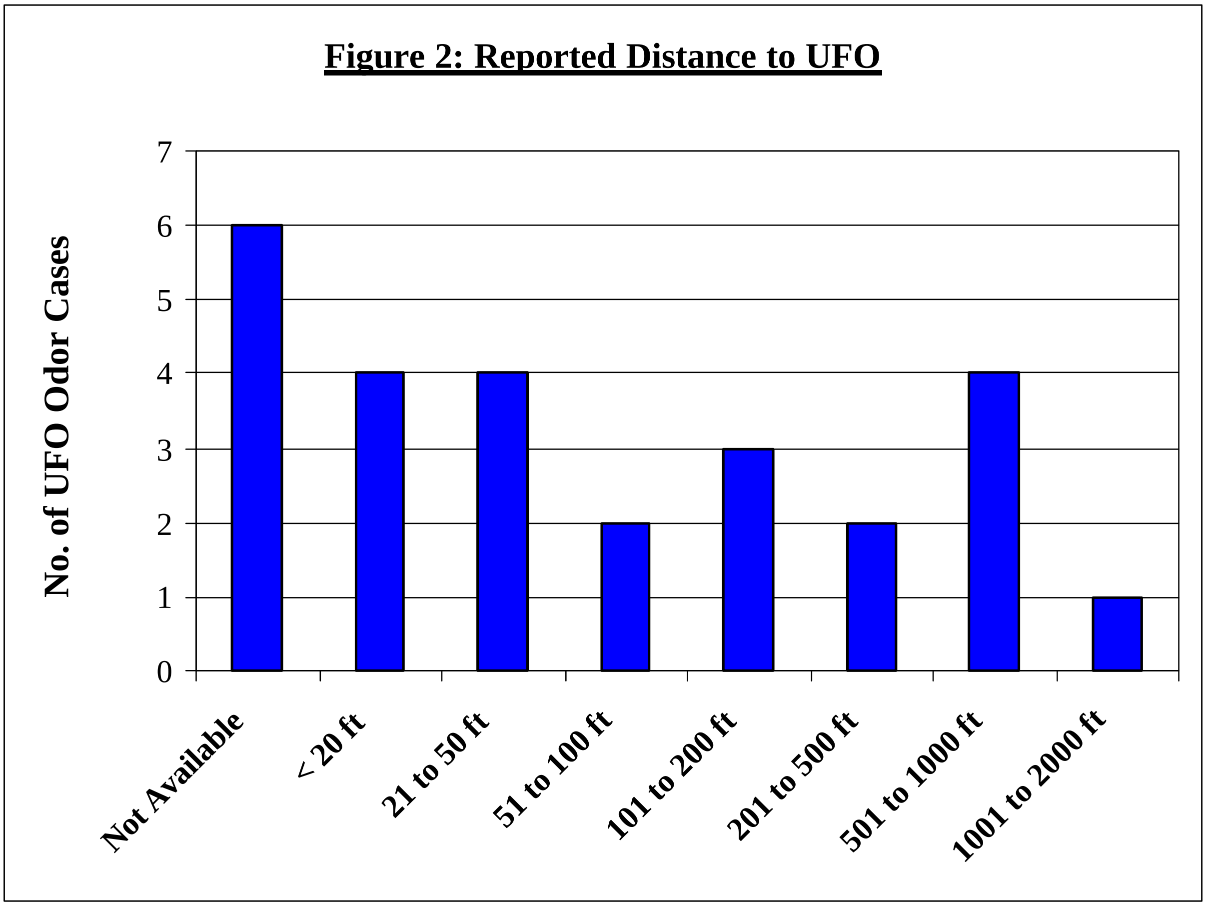
All these molecules are liquids at room temperature and their boiling points exceed 183ºF. Moreover, while some of them are generated in natural organic decomposition, they are fairly complex relative to simpler gas compounds with similar odors. All that we can conclude from this exercise is that there are some sulfur containing molecules whose odor profile will cover many of the descriptors found in UFO odors. If we had no other information about the UFO odor cases but their odor profile then some of these molecules or closely related compounds might be good candidates.

Many of the odors were detected more than 100 ft from the object. Of those reports that gave distance (20), 50% of the witnesses were 100 ft or more away from the object. Figure 2 shows a frequency distribution of the reported distance to the UFO in the 26 UFO odor cases. The distance from the object implies that the odorant was easily transported in the air and was most likely a gas and not a liquid vapor (liquid vapors might condense as they cool down away from their heat source). Distance, however, is not conclusive because wind direction and velocity could easily shorten or extend distance to odorant. Unfortunately, none of the case summaries reported wind direction and velocity. Moreover, none of the cases mentioned the presence of a liquid deposit found at the site after the object left.

While we don't have enough evidence to reject liquid compounds as the odorant source, the next section will focus on simple compounds that are in a gas phase at room temperature.

Table 6: UFO Odor Descriptors Associated with Top 4 ASTM Chemicals

Top 4 Chemicals from ASTM Odor Profile Study that have a % Applicability to the top 3 UFO Odor Descriptors	Sulfidic	Pungent	Noxious; Foul	Metallic	Burnt Rubber	Burned Gasoline	Chemical	Ammonia	Etherish/ Camphor	Sickening
Thioglycolic Acid $HSCH_2COOH$ MW=92	X	X	X		X					X
Thiophene C_4H_4S MW=84	X	X			X					
Pyridine C_5N MW=79		X	X				X	X		X
Butyric Acid $CH_3CH_2CH_2COOH$ MW=88		X	X							X



8.2 Extracting information from Air Pollution Studies

One classification scheme developed by ASTM for pollution odors from water tries to identify the chemical source of the odor via four odor descriptors: sweetness, pungency, smokiness, and rottenness. These descriptors are used on three levels to characterize eight typical odor classes and each class is subdivided into two to four types of chemicals.[50] The degree of odor characteristic perceived was designated as follows: 100 indicate a high level of perception, 50 indicate a medium level of perception and 0 indicates a low level of perception. An extract of this system showing four of the eight odor classes is shown in Table 7 below. This extract focuses on the chemicals that led to high level of perception on 3 odor descriptors mentioned in UFO sightings (pungency, smokiness and rottenness).

Table 7: Odors (in Water) Classified by Chemical Type

Sweetness	Pungency	Smokiness	Rottenness	Odor Class	Chemical Type	Examples
50	**100**	0 to 50	50	Acidic	Acid anhydrides Organic Acids Sulfur Dioxide	Vinegar, perspiration, rancid oils, resins, body odor, garbage
50	50	**100**	**100**	Sulfury	Selenium compounds Arsenicals Mercaptans Sulfides	Skunks, bears, foxes, rotting fish and meat, cabbage, onion, sewage
100	50	50	**100**	Unsaturated	Acetylene derivatives Butadiene Isoprene	Paint thinners, varnish, kerosene, turpentine, essential oils, cucumber
100	50	0 to 50	**100**	Basic	Vinyl monomers Amines Alkaloids Ammonia	Fecal odors, manure, fish and shellfish, stale flowers such as lilac, lily jasmine, and honeysuckle

Insights from this table that might help us decipher the chemical source of the UFO odorants are:

- Witnesses reporting pungency at a high level of perception, might have detected sulfur dioxide, organic acids, and/or acid anhydrides.
- Witnesses reporting Rottenness and Smokiness at a high level of perception might have detected Mercaptans, Sulfides, Selenium compounds, or Arsernicals.
- Detection of Sweetness in conjunction with Rottenness at a high level of perception might indicate that the odorant sources are not the sulfury chemicals listed above but instead amines, alkaloids, acetylene derivatives, and others.

In *Odors from Stationary and Mobile Sources*, the NRC published a table describing the typical odors from major odorous air pollutants[51]. An extract from this table listing air pollutants made from sulfur compounds, nitrogen compounds, selenium compounds, and organic acids is shown below in Table 8.

Odorants could also react during transport in the atmosphere. Reactions could occur with other compounds in the atmosphere or via disassociation due to sunlight or moisture in the air. In a study conducted by Polgar (1975) to study odors associated with mixtures of sulfur compounds, variations in odor qualities with distance from the source were observed.[52] Table 9 summarizes the results from Polgar's study[53]. The study is important because it shows the different odor qualities given to different concentration of sulfur containing compounds (H_2S, CS_2, and COS). Polgar concluded that Carbon disulfide (CS_2) can photo-oxidize into Carbonyl sulfide (COS) during transport in the atmosphere. While CS_2 has a sweet, mild, rotten egg smell or a medicine-iodine odor quality, COS smells like burnt rubber. Another interesting note is that even in small concentrations the rotten egg smell of H_2S tends to overwhelm any distinctive odor quality from CS_2 or COS.

Table 8: Major Odorous Air Pollutants, Olfactory Thresholds, and Related Data

Category	Chemical Name	Formula	Odor	Molecular Weight	Odor Threshold (ppm)
Sulfur Compounds					
Sulfur oxides	Sulfur dioxide	SO_2	Pungent	64	0.47
Sulfides	Hydrogen sulfide	H_2S	Rotten eggs	34	.0047-0.18
	Carbon disulfide	CS_2	Rotten	76	0.21-0.84
Mercaptans	Methyl mercaptan	CH_3SH	Decayed cabbage	48	$2x10^{-5}$-0.041
	Ethyl mercaptan	C_2H_5SH	Decayed cabbage	62	$3x10^{-5}$-0.001
	Propyl mercaptan	C_3H_7SH	Unpleasant	76	0.0016-0.024
	Allyl mercaptan	CH_2=$CHCH_2SH$	Garlic	74	0.003-0.017
Thioethers	Dimethyl sulfide	$(CH_3)_2S$	Decayed cabbage	62	0.003
	Diethyl sulfide	$(C_2H_5)_2S$	Foul, garlic	90	0.0048
Nitrogen Compounds					
Inorganic	Ammonia	NH_3	Pungent	17	0.47-54
Aliphatic amines	Dimethylamine	$(CH_3)_2NH$	Fishy	45	0.047
	Trimethylamine	$(CH_3)_3N$	Fishy-ammoniacal	59	0.00021
Cyanides	Hydrogen cyanide	HCN	Bitter almonds	27	0.9
	Allylsocyanide	CH_2=$CHCH_2NC$	Sweet repulsive (nauseating)	67	0.18-1.6
	Allylsothiocyanate	CH_2=$CHCH_2SNC$	Mustard oil (nose and eye irritant)	99	0.008-0.42
Selenium Compounds					
Selenides	Hydrogen selenide	H_2Se	Putrid	81	$4x10^{-4}$-0.0012
	Ethylselenomercaptan	C_2H_5SeH	Foul, fetid	109	$4x10^{-4}$-0.0012
	Diethyl selenide	$(C_2H_5)_2Se$	Putrid (nauseating)	137	0.011
Hydrocarbons & Oxygenates					
Aldehydes	Formaldehyde	H_2CO	Pungent	30	1.0
	Acetaldehyde	CH_3CHO	Pungent	44	0.066-2.2
Organic Acids	Butyric acid	$CH_3CH_2CH_2COOH$	Rancid perspiration	88	0.001-2.2
	Isovaleric acid	$(CH_3)_2CHCH_2COOH$	Body odor	102	0.015
Oxygen	Ozone	O_3	Irritating	48	0.51

Table 9: Odor Quality and Threshold of Sulfur Compound Mixtures

Sample	Odorants at Threshold (ppm)	Quality
1. H_2S	0.02	Rotten eggs
2. CS_2	0.67	Medicine, iodine, burnt
3. CS_2	0.45	Sweet, mild, rotten eggs
4. CS_2, aged 4 days	0.78	Sweet, mild, rotten eggs
5. CS_2, aged 3 days	0.77	Sweet, mild, rotten eggs
6. COS	0.05	Burnt rubber, carbamate
7. COS	0.12	Burnt rubber, carbamate
8. COS, aged 3 days	0.12	Rotten eggs, burnt rubber
9. 71% H_2S, 29% CS_2	0.01	Rotten eggs
10. 28% H_2S, 72% CS_2	0.05	Rotten eggs
11. 9% H_2S, 91% CS_2	0.13	Rotten eggs,
12. 20 H_2S, 80% CS_2	-	6 out of 6: burnt rubber or carbamate, 2 could detect rotten eggs
13. COS/ CS_2 (1/1,000)	0.23	Medicine, iodine
14. H_2S /COS (1/70)	-	6 out of 6: rotten eggs
15. H_2S /COS/ CS_2 (1/3.4/1,250)	0.15	Burnt Rubber, shoe wax, sulfur

8.3 Summary of Potential Chemical Sources for Odorants

The sulfidic descriptor for odorants could refer to general chemicals groups like arsenicals, mercaptans, sulfides, and selenium compounds. From Tables 8 and 9 we learned that only Sulfur dioxide is described as pungent and that mercaptans and thioethers tend to have a decayed cabbage, foul and unpleasant smell.

Other UFO odor descriptors that could be pooled with the sulfidic descriptor are the rotten egg smell, the burned rubber smell, the burned match smell, and the burned gasoline smell. The rotten egg smell is usually associated with Hydrogen sulfide but it is also described with Carbon disulfide. While Polgar describes odors emitted from COS as burned rubber, according to a consultant from Odor Science and Engineering Inc., Carbonyl sulfite (COS) smells like a burned match or burned gun power[54]. The burned gasoline odor is more complex. When gasoline is burned, there are many different compounds exhausted from the gas pipe. Depending of the year of the case, the gas-pipe emissions could contain different amounts of SO_2, lead compounds, volatile organic compounds, and NO_X besides the expected CO and CO_2.

The pungent descriptor for odorants could refer to general chemical groups like acid anhydrides, organic acids, and sulfur dioxide. In the previous analysis of ASTM Odor Profiles, we found two organic acids that met the pungent descriptor plus other UFO odor descriptors. Table 8 lists some typical air polluting compounds that are considered pungent: sulfur dioxide, ammonia, formaldehyde and acetaldehyde.

The noxious and foul descriptors for odorants could refer to many chemicals typically associated with air pollutants. Amongst these are hydrogen sulfide, carbon disulfide, methyl mercaptan, ethyl mercaptan, propyl mercaptan, dimethyl sulfide, ethyl sulfide, and allylsocyanide. Some selenide compounds that also meet this descriptor are hydrogen selenide, ethylselono mercaptan, and diethyl selenide. Only allylsocyanide and diethyl selenide have a putrid and nauseating smell.

There are some UFO odorant descriptors (metallic, chemical, camphor, etherish, embalming fluid, and tannic acid) whose chemistry is hard to deduce. Of the ASTM chemicals used to describe a metallic odor, garlic was in the top 5. Given that garlic oil is a sulfur-containing compound, perhaps the metallic descriptor is correlated with the sulfidic descriptor. According to the ASTM Profile study, the Chemical descriptor was slightly correlated with medicinal and Etherish-Anaesthetic odors. The Camphor and Ether descriptors shared a chemical with high % Applicability called Eucalyptol. The Embalming fluid odor most likely refers to Formaldehyde (H_2CO) which has a pungent odor.

The source of a tannic acid odorant is also complex. Tannin can be extracted from the wood, bark or leaves of certain trees and other plants. Tannins are complex dark-colored polyhydroxy phenolic compounds, related to catechol or pyrogallol, and vary in composition from species to species. They are commercially used in the leather industry.[55] Also, the witness could have mentioned Tannic acid in reference to the wine industry. Tannin is one of the aspects of wine that a taster must determine. A strong cup of tea at room temperature describes the tannin flavor readily.[56] One ASTM descriptor that might reflect this quality is Bark-like.

From all these potential chemical sources for the UFO odorants, we screened out all of those that were liquids at room temperature and had a low vapor pressure or high boiling point. Our focus in this section is mainly on gases. Under these criteria, all organic acids were eliminated. Because all chemicals in the cyanide group were liquids, we eliminated allylsocyanide. Nevertheless, we added acetonitrile (the lowest molecular weight cyanide) to the list of potential chemicals as an example. Acetonitrile, however, is a liquid and boils at 183 F.

All of the organo-selenium compounds are liquids or solids except for Hydrogen selenide. Selenium Dioxide is a solid crystal. Selenium is readily oxidized by ozone into its most stable form Selenium dioxide.[57] Selenium is included in this list because it is strikingly similar to sulfur in most of its chemistry. “Selenium is a relatively rare element and is frequently found in base metal sulfide minerals. Recovery of selenium is dependent upon their concentration during the processing of nonferrous ores, principally copper-bearing ores.”[58]

“Various studies have indicated that between 5 and 90% of the selenium contained in coal deposits is released to the atmosphere in either vapor form or as fine particles that may escape pollution control devices. Coal consumption is the major anthropogenic source of atmospheric selenium.”[59] “It has been estimated that combustion of fossil fuels, especially hard coal, accounts for about 35% of total anthropogenic atmospheric selenium emissions of 6,300 ton per year. However, anthropogenic sources account for only 40% of estimated annual global emissions, the balance coming from natural sources, such as dust, volcanoes and hot springs, sea salt spray, and vegetative emissions.”[60]

There were two reports of an odor like embalming fluid. Embalming fluid contains about 37% formaldehyde, 10-15% methanol and the balance is water. Of the two aldehydes listed above as pungent we selected formaldehyde and not acetaldehyde. Formaldehyde (H_2CO) is a simple molecule that could be chemically produced in the environment. Acetaldehyde (CH_3CHO) is a colorless liquid that rapidly volatilizes at 69°F.

Of all the mercaptans listed above only methyl mercaptan is a gas at ambient temperature. Thus we selected methyl mercaptan as a potential source of odor. Dimethyl sulfide ($(CH_3)_2S$) is a liquid with a boiling point of 100 °F, thus we removed it from the list. Carbon disulfide (CS_2) is a liquid with a boiling point of 115 °F. While we would usually exclude liquids, we decided to keep CS_2 in the list because Carbon disulfide (CS_2) can photo-oxidize into Carbonyl sulfide (COS) during transport in the atmosphere.

Nitrous dioxide and sulfur dioxide were included because they are common pollutants from auto and industrial emissions. Moreover, as suggested by McCampbell, we included products from lightning strikes (Ozone and NOx). The final list of potential gases and vapors that could be described as foul, pungent, or sulfidic are shown in Table 12. This list is neither exhaustive nor mutually exclusive. It only contains 11 chemicals that are either common pollutants or are easily formed in nature.

In order to further discriminate against all these chemicals, we used the physiological effects that resulted from exposure to the UFO odorants. Of the 26 cases, only 8 reported physiological effects. In this study we assumed a cause and effect between exposure to the chemical and physiological reaction. Table 10 shows the 8 cases with physiological effects. Amongst the 8 cases, the following physiological effects were reported:

- Nausea 2
- Watering eyes 2
- Burns nostrils and throat 2
- Dizziness/Loss of Balance 3
- Made witness ill, sick, tired 3
- Felt Prickliness 1
- Lost sense of taste and smell 1
- Cannot swallow properly 1

Information on the symptoms resulting from exposure to the chemicals listed in Table 11 was obtained from Material Safety Data Sheets published by either the chemical manufacturer or the US government. Table 11 lists the acute symptoms from inhalation, skin, and eye contact. Since all witnesses detected the odor, then they inhaled the odorant. Thus acute symptoms resulting from inhalation provide the most useful clues. Of all the symptoms described in the UFO odor cases, the ones that stand out are nausea, watering eyes, burning nostrils/throat, and dizziness. All the chemicals listed in Table 11 will cause irritation to the nose and throat. Most of these chemicals will cause nausea except for sulfur dioxide, carbonyl sulfide, formaldehyde and ozone. Only sulfur dioxide was reported to directly cause watery eyes.

The feeling of dizziness, lightness, and giddiness (reported in 3 cases) could be attributed to hydrogen sulfide, carbon disulfide, carbonyl sulfide, nitrous dioxide, nitric oxide, and/or nitrous oxide. Inhalation of hydrogen sulfide is reported to cause staggering, dizziness, and weakness. Inhalation of nitrous dioxide, nitric oxide and carbon disulfide is reported to cause dizziness. Moreover, inhalation of nitrous oxide is reported to cause drowsiness and euphoria while inhalation of high concentrations of carbonyl sulfide may cause narcotic effects.

Table 10: Extract of Cases with Physical Effects on Witnesses

Case No.	Odor Descriptor Used	Odor Intensity	Odor Hedonic Tone	Made Witness Ill
2	Sickly warm smell like hot, grease metal	Very Strong	Foul smelling mist; nauseating odor; atrocious	Caused eyes to water; burn nostrils and throat
3	Strange burning smell	Easily Noticeable	Awful odor, odor made mother ill	Yes
4	Ether mixed with sulphurous smoke	Strong	Unpleasant; nauseous	Witness felt pricklings throughout his body, had to stop, lost his balance several times
6	Smell like sulfur or brimstone	Very Strong	Noxious; foul; nauseating	Odor made witness sick; lost sense of taste and smell; throat would not swallow properly
14	(1) Bad garbage (2) Chemical odor	Strong	Foul; ill smelling	Dizziness and Nausea
19	Ammonia Smell	Very Strong	Witnesses complained about odor	Smell burned their noses and eyes
20	Burning Rubber	Easily Noticeable	-	Feeling of lightness
21	Smell like burned powder or gun-smoke	Easily Noticeable	-	Made them feel giddy and tired

A summary of how well these 11 chemicals met the predominant UFO odor descriptors and the predominant physiological symptoms is shown in Table 12. No chemical was able to meet all selected parameters. Hydrogen sulfide and carbon disulfide were the two chemicals that matched the most (5) parameters. Sulfur dioxide, methyl mercaptan, hydrogen selenide, carbonyl sulfide, and nitrous dioxide met 4 of the 7 parameters.

Of 5 the sulfur containing compounds selected, only sulfur dioxide met the pungency and watery eyes parameter. While sulfur-containing compounds alone cannot explain the other complex odors detected by the witnesses (formaldehyde, camphor, etherish, and tannic acid), it is very likely that a sulfur-containing molecule was indeed detected by the witness. The odorants detected could very well be a combination of H_2S and SO_2 and other gases. It would help corroborate the presence of sulfur or selenium if the UFO left traces on the ground that contained either of these chemicals. Unfortunately, none of the cases evaluated in this study left physical traces that were investigated.

Table 11: Potential Chemical Sources of UFO Odors and their Physiological Effect on Witnesses

Potential Chemical Smell	Physiological Effects
Hydrogen sulfide (H_2S)	Inhalation could *cause irritation of the eyes, nose, throat*, and respiratory system. May cause *nausea*, vomiting, cramps, *dizziness*, headache, diarrhea, sneezing, staggering, excitability, dry cough, pale complexion, muscular weakness, drowsiness, rhinitis, bronchitis, pharyngitis, and other lung effects such as pneumonia and pulmonary edema. Other effects include asphyxia, tremors, fatigue, weakness and numbing in the extremities, convulsions, coma, and death.[61]
Sulfur Dioxide (SO_2)	Inhalation causes*: Severe irritation to the eyes, nose, throat* and lungs. Causes *watery eyes and nose*, cough, choking, sneezing, and bronchoconstriction with increased pulmonary resistance. It can also cause systemic acidosis, respiratory paralysis, and pulmonary edema.[62]
Carbonyl Sulfide (COS)	Acute inhalation of high concentrations may cause narcotic effects in humans. Carbonyl sulfide may also *irritate the eyes and skin*.[63]
Carbon disulfide (CS_2)	**Inhalation:**[64] Vapors *cause irritation to the respiratory tract*, followed by symptoms of headache, *dizziness*, fatigue, garlic breath, *nausea*, vomiting, and abdominal pains. Affects the central nervous system and peripheral nervous system. Overexposure may produce hallucinations, narcosis, unconsciousness, convulsions, and even death. **Skin Contact:** May produce reddening and burning, cracking and peeling. Skin absorption can occur even in the presence of vapors, with toxic effects paralleling inhalation. **Eye Contact:** Vapors cause *eye irritation*.
Methyl mercaptan (CH_3SH)	**Inhalation:** [65] Acute symptoms: Cough. Headache. *Nausea*. Shortness of breath. Sore throat. Unconsciousness. **Effects of Short Term Exposure:** The substance *irritates the eyes, the skin and the respiratory tract*. Inhalation of this gas may cause lung edema. The substance may cause effects on the central nervous system, resulting in respiratory failure. Exposure at high levels may result in death. Medical observation is indicated.
Hydrogen Selenide (H_2Se)	**Inhalation Risk:**[66] Acute symptoms from inhalation: Burning sensation. Cough. Labored breathing. *Nausea*. Sore throat. Weakness. **Effects of Short Term Exposure:** The substance *irritates the eyes and the respiratory tract*. Inhalation of the gas may cause pneumonitis. Exposure at high levels may result in death.

Table 11 (con't)

Potential Chemical Smell	Physiological Effects
Acetonitrile Methyl Cyanide (CH_3 CN)	**Inhalation:**[67] Early symptoms may include *nose and throat irritation*, flushing of the face, and chest tightness. Higher concentrations may produce headache, *nausea*, vomiting, respiratory depression, weakness, blood changes, thyroid changes, irregular heart beat, abdominal pain, convulsions, shock, unconsciousness and death, depending on concentration and time of exposure. **Skin Contact:** May cause irritation. May be absorbed through skin with health effects to parallel those of inhalation. **Eye Contact:** Splashes may cause eye irritation with redness and pain.
Ammonia (NH_3)	**Inhalation:**[68] Corrosive. Extremely *destructive to tissues of the mucous membranes and upper respiratory tract*. Symptoms may include *burning sensation*, coughing, wheezing, laryngitis, shortness of breath, headache, *nausea* and vomiting. Inhalation may be fatal as a result of spasm inflammation and edema of the larynx and bronchi, chemical pneumonitis and pulmonary edema **Skin Contact:** Dermal contact with alkaline corrosives may produce pain, redness, severe irritation or full thickness burns. May be absorbed through the skin with possible systemic effects. **Eye Contact:** Corrosive. Can cause blurred vision, redness, pain, severe tissue burns and eye damage. Eye exposure may result in temporary or permanent blindness.
Formaldehyde (H_2CO)	**Inhalation:** [69] May cause sore throat, coughing, and shortness of breath. *Causes irritation and sensitization of the respiratory tract*. Concentrations of 25 to 30 ppm cause severe respiratory tract injury leading to pulmonary edema and pneumonitis. May be fatal in high concentrations. **Skin Contact:** Toxic. May cause irritation to skin with redness, pain, and possibly burns. Skin absorption may occur with symptoms paralleling those from ingestion. Formaldehyde is a severe skin irritant and sensitizer. Contact causes white discoloration, smarting, cracking and scaling. **Eye Contact:** *Vapors cause irritation to the eyes* with redness, pain, and blurred vision. Higher concentrations or splashes may cause irreversible eye damage.
Nitrous Dioxide (NO_2)	**Inhalation Risk:**[70] Acute Symptoms from Inhalation: Cough. *Dizziness*. Headache. Sweating. Labored breathing. *Nausea*. Shortness of breath. Sore throat. Vomiting. Weakness. Wheezing. Symptoms may be delayed. **Effects of Short Term Exposure:** The substance and the *vapor irritate the eyes, the skin and the respiratory tract*. Inhalation of the gas or the vapor may cause lung edema. Exposure at high level may result in death. The effects may be delayed. Medical observation is indicated.
Nitric Oxide (NO)	**Inhalation Acute Health Hazard:**[71] May produce no immediate reaction or slight *respiratory irritation*, with headache, *dizziness, nausea* and vomiting. Within 5-8 hours: Methemoglibinemia with cyanosis may develop, followed by dyspnea, choking, dizziness, headache, tightness and burning sensation in chest, sleeplessness, restlessness, nausea, vomiting, lassitude, palpitation.
Nitrous Oxide (N_2O)	**Inhalation Risk:** [72] Acute Symptoms from Inhalation: *Drowsiness*. Unconsciousness. Euphoria.
Ozone (O_3)	**Inhalation Risk:** [73] Acute Symptoms from Inhalation: Cough. Headache. Shortness of breath. Sore throat. **Effects of Short Term Exposure:** The substance *irritates the eyes and the respiratory tract*. Inhalation of the gas may cause lung edema. Inhalation of the gas may cause asthmatic reactions. The substance may cause effects on the central nervous system, resulting in headache and impaired vigilance and performance.

Table 12: Potential Chemical Sources of UFO Odors and their Physiological Effect on Witnesses

Potential Chemical Smell	Typical Descriptor	Sulfidic Criteria	Pungent Criteria	Foul Criteria	Nausea	Watery Eyes	Irritating Nose and Throat	Dizziness/Lightness
Hydrogen sulfide (H_2S)	Rotten eggs	X		X	X		X	X
Sulfur Dioxide (SO_2)	Pungent/ Burned Matches[74]	X	X			X	X	
Carbonyl Sulfide (COS)	Burnt Rubber; Rotten	X		X			X	X
Carbon disulfide (CS_2)	Medicine, iodine, burnt, rotten eggs	X		X	X		X	X
Methyl mercaptan (CH_3SH)	Decayed cabbage	X		X	X		X	
Hydrogen selenide (H_2Se)	Putrid	X		X	X		X	
Acetonitrile Methyl Cyanide (CH_3 CN)	Ether				X		X	
Ammonia (NH_3)	Pungent		X		X		X	
Formaldehyde (H_2CO)	Pungent		X				X	
Nitrous Dioxide (NO_2)	Pungent Acrid		X		X		X	X
Ozone (O_3)	Irritating		X				X	

9 Evaluating the Sulfur Odor

Since sulfur appears to be a predominant component of the odor chemistry in UFO cases, we want to evaluate its possible sources. Even if we know that the witness detected a sulfur containing odorant, we don't know (a) whether the source of the sulfur was the environment or the object and (b) whether the odorant was created by the environment or by the object. Figure 3 describes the four possible alternatives for sources of sulfur and odorant. The feasibility and likelihood of these four hypotheses are further described in the next sections.

Figure 3: Matrix of Potential Hypotheses for Sulfur Odorants

Source of Sulfur \ Causation of Smell	Environment	Object
Environment	**EE:** Sulfur smell was in the environment and got to the witness via environmental conditions (wind or diffusion). The source of the sulfur could have been industrial waste, industrial emissions, marsh gases, or plant/animal decay.	**EO:** The sulfur was already in the environment (as air pollution) but the odorant was created by energy emissions from the object. Some form of energy interacted with the sulfur and other air pollutants to produce the odorants.
Object	**OE:** The object emitted the sulfur-containing molecule but the odorant was created when it interacted with the air environment.	**OO:** The sulfur odorant was generated by the object as either a fuel exhaust or as a release of its internal atmosphere.

9.1 Hypothesis EE (Environment as source of Sulfur and Odor Causation)

A case investigator should always try to eliminate Hypothesis EE first. All potential industrial and natural sources for the odorant should be pursued in the local area. The radius for the search depends on the wind velocity and direction at the time of the sighting. The radius could exceed several tens of miles depending of wind dispersion. If the source is industrial pollution, Hypothesis EE could be tested by returning to the site at the same time with the same wind velocity/direction conditions. If the source was plant/animal decay, it is very likely that the smell would have stayed and would have been detected by the investigators. In most of these cases, however, the odor left the scene when the object left the scene.

Large quantities of hydrogen sulfide are naturally released into the atmosphere. Half of these natural releases come from volcanoes, flooded ground, or hydro-geological sources and the other half comes from oceans. Flooded ground (swamps, rice fields) contain hydrogen sulfide which is generally formed in the soil by bacterial reduction of sulfates. Water is another natural medium that contains hydrogen sulfide. The dissolved or gaseous hydrogen sulfide found in lakes, saltwater ponds, and marine sediments originates from sulfate-reducing bacteria. Finally, Hydrogen sulfide is found in natural gas and oil reserves.[75] All these natural occurring sources of hydrogen sulfide have to be investigated and eliminated by the case investigator.

Another potential natural source of pungent/sulfidic odorants is ball lightning. Ball lightning could explain both the odor and the UFO. While the purpose of this study is not to explain the UFOs as ball lightning, ball lightning could be a natural explanation for some of the cases.

James Barry writes in *Ball Lightning and Bead Lightning* that “many observers report a distinctive odor accompanying the presence of ball lightning. The odor is described as sharp and repugnant, resembling ozone, burning sulfur, or nitric oxide. An odor is reported most often when the distance between the ball lightning and the observer is small. Odors like ozone, burning sulfur, and nitric oxide are common ionization products of a lightning discharge”.[76]

Stanley Singer writes in *The Nature of Ball Lightning*, that “the appearance of ball lightning has been associated with distinctive odors by observers. Smells described as being of sulfur and ozone are common. In a few cases the odor was compared with that of nitrogen dioxide; one observer concluded that the smell was identical to that of a concentrated nitrogen dioxide-air mixture (and not a dilute mixture) made up for his comparison later. General odors of burning have also been reported. Approximately one-quarter of the globes reported in Rayle’s survey were associated with a smell. Ordinary lightning flashes also produce these odors, as do electrical discharges in air. The analysis of air samples taken from the vicinity of the path taken by one ball lightning in the vent given in detail previously showed the presence of both nitrogen dioxide and ozone.”[77]

9.2 Hypothesis EO (Pollution as Sulfur Source, Object as Odor Causation)

Hypothesis EO is the one proposed by McCampbell and Keel. Both authors believe that energy emissions directly related to the object interacted with air pollutants and created the odorants. To understand the likelihood of this hypothesis we need to know the composition of air and its pollutants. The composition of an unpolluted dry air is shown in Table 13.

Table 13: Composition of Dry Unpolluted Air[78]

Component	Concentration (ppm)
Nitrogen	780,800
Oxygen	209,500
Argon	9,300
Carbon dioxide	315
Neon	18
Helium	5.2
Methane	1.0+
Krypton	1.0
Nitrous oxide	0.5
Hydrogen	0.5
Xenon	0.08
Nitrogen dioxide	0.02
Ozone	0.01+

In the U.S., the EPA tracks the amount of air pollutants yearly at numerous monitoring stations. The annual composite averages for 5 key pollutants are shown in Table 14 for 1980 through 1995. There are also hydrocarbon pollutants in the ambient air but at a much lower concentration. Table 15 shows the top 5 most abundant ambient air hydrocarbon pollutants in 39 U.S. Cities.

Table 14: U.S. Ambient Air Pollutant Concentrations[79]

Pollutant	Units	1980	1985	1990	1995
Carbon monoxide	ppm	9.3	7.3	5.9	4.5
Ozone	ppm	0.143	0.127	0.113	0.113
Sulfur dioxide	ppm	0.0112	0.0092	0.0081	0.0056
Nitrogen dioxide	ppm	0.024	0.023	0.020	0.019
Lead	$\mu g/m^3$	0.73	0.25	0.09	0.04

Table 15: Median Concentration of the Five Most Abundant Ambient Air Hydrocarbons in 39 U.S. Cities[80]

Pollutant	Units	Median Concentration
Isopentane	ppb	45.3
n-butane	ppb	40.3
Toluene	ppb	33.8
Propane	ppb	23.5
Ethane	ppb	23.3

The data shows that polluted air contains sulfur and other hydrocarbons at the parts per billion level. Moreover, unpolluted air contains methane (about 1 ppm) and nitrous oxide (about 0.5 ppm) that could react with ozone to produce odorants. Air pollutants like sulfur dioxide, nitrogen dioxide and ozone are all pungent odorants but their concentrations are usually below their odor threshold level. Odor thresholds are the minimum physical concentrations of a chemical that causes a stimulus and elicits a response. Table 16 shows the odor thresholds for a few selected chemicals. The table shows that the average concentrations of sulfur dioxide and ozone in air do not exceed their odor thresholds.

Table 16: Odor Thresholds of Selected Air Pollutants

Chemical Name	Formula	Concentration in Air (ppm)	Odor Threshold (ppm)[81]
Sulfur dioxide	SO_2	< 0.02	0.47
Ozone	O_3	< 0.2	0.51
Hydrogen sulfide	H_2S	Not Available	0.0047
Methane Thiol	CH_3SH	Not Available	0.0021
Carbon Disulfide	CS_2	Not Available	0.2
Ammonia	NH_3	Not Available	0.47
Formaldehyde	H_2CO	Not Available	1.0
Nitrous Oxide	NO	0.5	Not Available

Odor threshold data shows that the average person will detect and recognize H_2S at a volumetric concentration that is 100 times more diluted than that of sulfur dioxide, ozone, or ammonia. While it does not take much volume to detect an odor like H_2S (~5 ppb), it does take at least 0.5 ppm to detect odors from ozone, sulfur dioxide and ammonia. Moreover, for odors from formaldehyde, at least 1 ppm is needed for detection.

In the odor UFO cases, Hypotheses EO assumes that there is a distinct change in the composition of the air associated with the presence of the object. The witnesses were breathing regular polluted air before the sighting took place and did not detect odors. Therefore, we cannot assume that the sulfidic, pungent, and foul odorants were present beforehand at odor threshold concentrations. Chemicals that cause sulfidic, pungent, and foul smells must have been below the odor threshold level until chemical reactions produced enough of these molecules to be detected by the witnesses.

One potential mechanism to initiate the production of odorants is the one used by ball lightning (which some scientists believe is surrounded by energy plasma). The descriptions of ball lightning odors have a strong resemblance to the odors reported from UFO witnesses: sulfidic, pungent and foul. Thus, it appears that ambient air has the required molecules at hand to generate the odorants given sufficient energy. Moreover, experiments have proven that NO, N_2O, NO_2 and O_3 can be produced in atmospheric coronas in specially designed plasma reactors.[82] Nevertheless, most of the literature on lightning chemistry focuses on NO_x and O_3 generation and does not mention any potential reactions of SO_2 into H_2S or other foul smelling sulfur molecules.

Ozone, however, is a strong oxidant and H_2S is a strong reducing agent. Thus, we would expect that any hydrogen sulfide present with ozone would readily react into sulfur dioxide as shown in the formula below:

$$H_2S + O_3 \rightarrow SO_2 + H_2O$$

While lightning researchers say that a foul sulfury smell is detected after a lightning strike, they don’t explain the chemical mechanism leading to the production of the sulfidic odorants. All we can say is that if the UFO generates a corona discharge around its surface, then it could cause reactions in the air leading to known pungent odors like ozone, NO, and NO_2.

Generation of surplus ozone (due to a corona discharge or ultraviolet ray emissions) could also produce other odorants like formaldehyde. Methane is present in air at high enough levels (1.0 ppm) to potentially react and create formaldehyde at the required odor threshold level of 0.5 ppm. Ozone could act as the catalyst for these reactions.

Smog pollution scientists, who have studied numerous reactions between ozone and other air pollutants, have discovered chemical reactions whereas ozone reacts with methane to form formaldehyde and other odorants. Below is an example of chemical reactions that could lead to formaldehyde production. This section was extracted from the section of Air Pollution from the *Kirk-Othmer Encyclopedia of Chemical Technology*.[83]

"In the presence of sunlight, *hv*, in clean air, ozone can generate hydroxyl radicals via:

(1) $O_3 + hv \rightarrow O_2 + O(^1D)$

(2) $O(^1D) + H_2O \rightarrow 2\ OH$

Where $O(^1D)$ is an excited form of an O atom that is produced from a photon at a wavelength between 280 and 310 nm. This seed OH can then produce the following chain reactions:

(3) $OH + CH_4 \rightarrow H_2O + CH_3$

(4) $CH_3 + O_2 + M \rightarrow CH_3O_2 + M$

(5) $CH_3O_2 + NO \rightarrow CH_3O + NO_2$

The NO_2 can then photolyze producing O_3 and the CH_3O radical continues to react:

(6) $CH_3O + O_2 \rightarrow$ HCHO (Formaldehyde) + HO_2

The HO_2 radical also forms more NO_2:

(7) $HO_2 + NO \rightarrow NO_2 + OH$

Resulting in more O_3. In addition, OH is regenerated to begin the cycle again."

So far we have found mechanisms to convert common air pollutants into odorants (ozone, NO_2, NO, formaldehyde) that are not sulfidic and foul. Sulfidic and foul, however are predominant descriptors in UFO odors, thus we need to find chemical routes to form them. To explain the production of foul odorants, we must search for chemical reactions between readily available sulfur containing air pollutants (like SO_2) that produce chemicals whose odors are foul. These reactions must meet at least three criteria: (1) they must be chemically feasible (2) they must be thermodynamically feasible and (3) there must be an initiating step that catalyzes or initiates the reaction.

Energy emissions (ultraviolet rays, microwaves or others) from the object might catalyze the reaction between sulfur dioxide and other air pollutants to produce the necessary sulfidic odorants. Only a fraction of SO_2 in air must be converted into H_2S or CH_3SH (methyl mercaptan) for it to be detected. For example, the average SO_2 level in the US is about 20 ppb. If all the local SO_2 were converted into H_2S, then the amount of H_2S produced (10.6 ppb) would be double its odor threshold level (5 ppb). Likewise, if the local SO_2 level was converted into methyl mercaptan, then about 15 ppb of methyl mercaptan would be produced which is 7 times its odor threshold level.

We looked at 10 possible reactions where SO_2 or SO_3 (SO_2 photolyzes into SO_3 in the presence of ultraviolet rays) would react with other air pollutants to form malodorous sulfur molecules (H_2S, COS, CS_2, and CH_3SH). Table 17 lists the 10 reactions we examined and the calculated Heat of Reaction. All reactions, except the first two, have positive heat of reactions and

Table 17: Possible Chemical Routes to Malodorant Sulfidic Molecules from Air Pollutants and their Heat of Reactions

#	Chemical Reaction	ΔH_f (Kcal/mol)[84]
1	$SO_3 + CH_4 \rightarrow COS + 2\ H_2O$	-37
2	$SO_2 + CH_4 \rightarrow H_2S + CO + H_2O$	0
3	$SO_2 + CO \rightarrow COS + O_2$	63
4	$2\ SO_2 + CH_4 \rightarrow CS_2 + 2H_2O + O_2$	72
5	$SO_2 + CH_4 \rightarrow CH_3SH + O_2$	83
6	$2\ SO_3 + CH_4 \rightarrow 2H_2S + CO_2 + 2\ O_2$	103
7	$SO_3 + H_2O \rightarrow H_2S + 2O_2$	147
8	$SO_3 + CO_2 \rightarrow COS + 2\ O_2$	155
9	$SO_2 + H_2O \rightarrow H_2S + O_3$	158
10	$SO_2 + CO_2 \rightarrow COS + O_3$	165

thus are endothermic (require heat input). Endothermic reactions, however, are less likely to occur in the open atmosphere conditions under investigation than exothermic reactions.

Moreover, heats of reaction say nothing about reaction kinetics (how fast the reactions go). These reactions might require extremely high temperatures and some sort of catalyst. For example, the reverse of reaction #9 has been studied in a laboratory and the reaction rate constant determined. Cadle (1966) determined that the reaction between H_2S and O_3, at room temperature and without a catalyst, is very fast.[85] Thus, the reverse reaction (that shown under #9), is the thermodynamically less preferred reaction. Reaction #3 through #10, all generate either O_2 or O_3 and are thermodynamically unlikely to happen under the reported conditions (ambient temperatures and pressures). Reaction #1 and #2 are potential candidates from a thermodynamic point of view, but the reaction kinetics were not calculated by the author. Perhaps reactions between these two air pollutants (methane and SO_2) are the mechanisms that produce the mal-odorants (COS and H_2S).

9.3 Hypothesis OE (Object as Sulfur Source, Environment as Odor Causation)

In Hypothesis OE, the object emits the sulfur containing molecule(s) but the odorant is created when the sulfur molecule(s) interacts with the air environment. This hypothesis is similar to EO in that odorants are created via chemical reactions with the environment. In Hypothesis EO, we assumed air pollutants were the source of the sulfur and we assumed that energy emissions from the object were the catalyst for odorant creation. Hypothesis OE, on the other hand, assumes that an unknown sulfur compound is emitted from the object and its interaction with the air and object's energy creates the odorant molecules. The difference is subtle and the hypothesis more speculative since there is no evidence for the "unknown sulfur compound."

Nevertheless, by invoking the addition of sulfur containing molecules by the object, we avoid being limited by the concentration of SO_2 in the atmosphere. The object could be generating more SO_2 or some other more complex sulfur-containing molecule (perhaps a liquid that rapidly evaporates, oxidizes, and/or decomposes). If the sulfur compound is not SO_2, then we also avoid being limited by the simple gas/vapor reactions of SO_2 into H_2S, COS, CS_2 and CH_3SH.

Reasons for a vapor or liquid being ejected from the object are speculative. One reason could be that it is an exhaust gas from the propulsion system. Another reason could be that the released compound escaped the internal atmosphere of the object.

One possible way of testing this hypothesis is to look for complex sulfur containing molecules on the ground close to where the object was hovering. If the chemical reactions that took place were simple gas phase SO_2 reactions, then we would expect to find no residue or maybe small deposits of CS_2. On the other hand, if the reactants were complex sulfur containing liquids, then we would expect traces of sulfur containing liquids. This finding, however, will not distinguish this hypothesis from the next one, where sulfur odorants are entirely released from the object.

9.4 Hypothesis OO (Object as Sulfur Source, Object as Odor Causation)

In this hypothesis, the sulfur odorant came directly from the object as either an exhaust from its propulsion system or as an internal atmosphere release. In this case, no chemical reactions are needed to explain the presence of odorants. Odorants could be gases, liquid-vapors, or liquids. Moreover, the list of potential chemicals causing the odorant becomes extensive.

Odorant releases from the internal atmosphere of the object might be possible if the UFO occupants are indeed alien in nature. The chemical odorant could be either the source of energy or nourishment for the beings. Recent discoveries in our ocean depths show the possibilities. For example, oceanographers have found life at the bottom (more than a mile deep) of the Pacific Ocean, near deep volcanic rifts that do not depend on photosynthesis. Among these rifts are hot vents that emit H_2S. Tiny microbes feed on the hydrogen sulfide, and become nourishment for symbionts and predators.[86] The ability of some microbes to live off chemicals rather than light and for highly complex ecosystem to be powered by this principle shows that alien life could be feeding and/or breathing in a sulfur-phillic environment.

Hypothesis OO, however, does not require an alien component. It could very well be that the witnesses saw a U.S. military craft or missile being tested. The propulsion system for US crafts or missiles would likely use conventional chemical fuels. In this case, odors could have come from the combusted fuel being exhausted from the object's propulsion system. To better understand the likelihood for this source of odorant, we looked at the types of rocket fuels and propellants that are used. Liquid propellants consist of an oxidizer and a fuel. Table 18 shows a list of the most common liquid oxidizers and fuels being used.

While none of the oxidizers in the list contain sulfur, at least one fuel could contain sulfur. Kerosene is a distilled product from crude oil and it usually contains sulfur. The sulfur content specification in commercial grade kerosene has gradually been lowered in the U.S. It has changed from no specification to maximum levels of 5%, 300 ppm, and potentially 50 ppm in 2004.

Kerosene and liquid oxygen were the propellants used in the Soviet ICBM-Vostok rockets.[87] Moreover, kerosene is still being used today as a fuel in Russian Proton rockets. Early rockets like the Aerobee (1949-58) used to burn a mixture of furfural alcohol, aniline and red fuming nitric acid (RFNA). The V2 rockets (1946-51) used liquid oxygen and alcohol.[88] Many modern rockets, however, use liquid oxygen and liquid hydrogen and solid fuel propellants.

Table 18: Liquid Propellants[89]

Fuels	Formula	Oxidizers	Formula
Ammonia	NH_3	Oxygen	O_2
Aniline	$C_6H_5NH_2$	Fluorine	F_2
Ethyl alcohol	C_2H_5OH	Chlorine	Cl_2
Furfuryl alcohol	$C_5H_6O_2$	Ozone	O_3
Hydrazine	N_2H_4	Nitric acid	HNO_3
Hydrazine hydrate	N_2H_4,H_2O	Hydrogen peroxide	H_2O_2
Dimethyl hydrazine	$(CH_3)_2N_2H_2$	Nitrogen tetroxide	N_2O_4
Xylidine	$C_8H_{11}N$	Tetranitro methane	$C(NO_2)_4$
Triethyl amine	$(C_2H_5)_3N$	Oxygen bifluoride	F_2O
Triethyl aluminium	$(C_2H_5)_3Al$	Chlorine trifluorine	ClF_3
Kerosene	$C_{10}H_{20}$	Nitrogen trifluorine	NF_3
Hydrogen	H2	Perchloryl fluoride	$FClO_3$

The earliest solid fuel propellants (black powder) do contain sulfur and this propellant is still being used in fireworks, signaling rockets, igniter booster charges, and life-saving rockets. Black powder is composed of KNO_3 (57 to 80%) C (13 to 29% charcoal) and sulfur (8 to 22%). Another type of pressed powder used for fueling small rockets is ammonium nitrate in combination with guanadine nitrate. These nitrate solid fuels, however, do not contain sulfur. One common solid propellant called extruded ballistite (JPN) consists mainly of nitrocellulose and nitroglycerin but contains about 1.25% potassium sulfate. Another solid propellant that contains sulfur uses 70% NH_4CHO_4 in a polysulphide base.[90]

While sulfur-containing liquid fuels are not very common, sulfur is present in several solid propellants. Black powder is currently being used in small rockets by researchers and hobbyists and other more complex solid propellants like JPN are being used in larger rockets. Whether the UFO witnesses saw a rocket, missile, or other craft propelled by any of these sulfur-containing fuels is impossible to determine today, but the possibility remains.

9.5 Testing the Hypotheses

Lacking the capability of tacking air samples before, during, and after a UFO sighting, we must rely on simpler means of rejecting any of these hypotheses. Ways of discriminating between the four hypotheses are shown in Table 19 below. Unfortunately, the 26 odor-UFO cases we evaluated did not have enough information and in-depth investigation to be able to discriminate between the four hypotheses being postulated.

10 Conclusion

Some UFO witnesses have detected and described odors that are believed to be associated with the sighting. Amongst these witnesses, some have reported health effects resulting from exposure to the odorant. While witnesses' descriptions of UFO odors are diverse, the predominant odor descriptors are sulfidic, pungent and foul. Reported physiological effects include nausea, watering eyes, burned nostrils and throat, dizziness/loss of balance, and tiredness.

Deducing chemistry from odor descriptions is very difficult because of witness unreliability in properly describing odors. Description of odors is complex and individuals will describe the same odor using many different terms. Odor profiling is the preferred way of classifying an odor rather than using a single descriptor. Based on odor descriptions given by witnesses, we generated a UFO odor profile. While the predominant descriptors were sulfidic, pungent and foul, other descriptors included metallic, chemical, embalming fluid, camphor, tannic acid, ether, ozone and ammonia like.

The chemistry of odors is still not well known. In the absence of a clear chemical model for predicting odorant quality, we relied on deduction and heuristics to obtain a list of potential chemicals that met the odor descriptors given by UFO odor witnesses. Based on our review of the literature on Odor Profiling Tests and Air Pollution, we deduced several potential chemical sources for the odorants. If the chemical source of the UFO odor is a liquid, then the ASTM Odor profile data indicates that the chemicals that best meet the UFO odor profile are Thioglycolic Acid, Thiopene, Pyridine and Butyric Acid. If the chemical sources of the UFO odorant are gases, then the most likely candidates are: Hydrogen sulfide, Sulfur dioxide, Carbonyl sulfide, Methyl mercaptan, Nitrous oxide, and Nitrous dioxide. Ozone, formaldehyde, and ammonia could also be present. Exposure to these gases also lead to acute symptoms similar to those reported by the UFO witnesses who inhaled and detected the odors.

Table 19: Ways to Discriminate amongst the Hypotheses

Condition Required to Reject Hypotheses	Hypotheses			
	EE	EO	OE	OO
1. No industrial or natural source of odorants is found near sighting location (given proper air dispersion modeling)	X			
2. Odor left immediately after the UFO disappeared	X			
3. Odor remained hours after the object left scene		X	Not rejected if sulfur-containing liquid was deposited and odorant was created via reaction with air	Not rejected if liquid odorant was deposited
4. Odor strength did not increase with the intensity of light/energy emissions from the UFO		X		
5. Odor was detected where there was no measurable SO_2 pollution level		X		
6. Odor is not detected when object's lights are turned off while object remains at close distance	X			
7. Chemical traces were found of simple sulfur containing compounds	X			
8. Chemical traces were found of complex sulfur containing compounds	X	X		
9. Composition of chemical traces are those of liquid/solid fuel or combustion products thereof	X	X	X	
10. Witness enters object and does not detect any foul sulfidic odor				X

There is a strong likelihood that sulfur is present in the odorant detected by the UFO witnesses. The source of the sulfur molecule and the creation of the odorant are not known. Four hypotheses were postulated to explain sulfur source and odor causation. Lack of good data and in-depth case reports prevent us from testing these hypotheses. Nevertheless, discriminating factors are listed so that future investigators of UFO odor cases can obtain the evidence and data needed to reject hypotheses and select the most likely one. Once we select the most likely hypothesis, we might gain knowledge that will help us add another piece of information to the UFO puzzle.

11 Unanswered Questions: Potential Future Research Projects

1. Do UFO odor cases from outside the U.S. have the same odor profile as U.S. cases?
2. Are odor reports associated with abductions similar to those associated with UFO sightings?
3. Why are there so few odor cases? Why are UFO odor cases the exception rather than the rule?
4. How can we explain cases where entities/humanoids are present with a foul odor but no UFO object is present? How prevalent is this feature? Does it require a new hypothesis?
5. How long does the odor last?
6. Is there any correlation between odor chemistry and chemistry of physical traces left in the soil?
7. If odors are generated by energy emission from UFOs, then why don't all UFOs (which presumably fly in the same polluted air and with similar propulsion systems) generate odors? Maybe the UFOs represent a multitude of phenomena that are not the same. Maybe there is more than one type of propulsion system. Maybe odors are all related to ball lightning and true UFOs don't smell?
8. Do witnesses get sick with physiological symptoms of nausea, dizziness, irritating throat/nose when in the presence of entities or is this only UFO sighting related?
9. Is it possible to estimate the energy emitted from the UFO if we assume that the key chemical reaction producing H_2S is the oxidation of methane with SO_2?

12 Appendix

13 References

American Society for Testing and Materials, *Atlas of Odor Character Profiles*, ASTM Data Series DS61, ASTM Publication Code Number 05-06 100036, Compiled by Andre Dravnieks, 1985

American Society for Testing and Materials, *ASTM D 1292-65*, "Standard Method of Test for Odor in Water", Philadelphia: ASTM, 1973

American Society for Testing and Materials, *Compilation of Odor and Taste Threshold Values Data*, Fazzalari, F.A. Ed., ASTM Data Series DS48A, Philadelphia, PA

Barrere, Marcel, Jaumette Andre, Baudouin Fraeijs De Veubeke, & Jean Vandenkerchove, *Rocket Propulsion*, Elsevier Publishing Co., Amsterdam, 1960

Barry, James Dale, *Ball Lightning and Bead Lightning*, Plenum Press, New York, 1980

Broad, William J., *The Universe Below*, Simon & Schuster, New York, NY, 1997

Cadle, Richard D., Ledford, Margaret, "The Reaction of Ozone with Hydrogen Sulfide," *Air and Water Pollution Int. J.*, Pergamon Press, 1966, Vol. 10

Cashman, Mark, Temporal Doorway Website, “Project 1947 EM Effects Catalog”, http://www.temporaldoorway.com/ufo/catalog/database/displayquerypage.asp

Castellan, Gilbert W., *Physical Chemistry*, Second Edition, Addison-Wesley Publishing Co., 1971

Clark, Jerome, *The UFO Encyclopedia, Vol. 2, The Emergence of a Phenomenon: UFOs from the Beginning through 1959*, Omnigraphics Inc., Detroit, MI, 1st Edition, 1992

Corbitt, Robert, *Handbook of Environmental Engineering*, McGraw-Hill Publishing Co., 1989

Council on Environmental Quality, *Environmental Quality: Along the American River*, Office of the President, 1996

Fowler, Raymond, *UFO’s: Interplanetary Visitors*, Bantam Books, Hicksville, NY, 1979

Gross, Loren, *UFOs a History-1952*, 6 books, book # 5

Gross, Loren, *UFOs a History-1954*, 5 books, book # 2

Gross, Loren, *UFOs a History-1956*, 5 books, book # 4

Hall, Richard, *Uninvited Guests*, Aurora Press, Santa Fe, NM, 1988

Hatch, Larry, *U* UFO Database, http://www.jps.net/larryhat/index.html

Hendry, Allan, *The UFO Handbook*, Doubleday & Co., 1979

Hill, Robert D., Rhamin Iraj, Robert G. Rinker, *Industrial Engineering Chemistry Res*., “Experimental Study of the Production of NO, N_2O, and O_3 in a Simulated Atmospheric Corona”, 1988, Vol. 27, No. 7

International Chemical Safety Cards, Website for Material Safety Datasheets on Methyl Mercaptan, Hydrogen Selenide, Nitrogen Dioxide, Nitrous Oxide, and Ozone, http://hazard.com/msds/mf/cards/file

Keel, John A., *The Eighth Tower*, Signet Books, 1977

Kennedy, G.P., *Vengeance Weapon 2*

Kirk-Othmer Encyclopedia of Chemical Technology, Fourth Edition, Vol. 1, 21, John Wiley and Sons

Lorenzen, Jim and Coral, *UFO's over the Americas*, Signet Books, 1968

Lorenzen, Jim and Coral, *The APRO Bulletin*, November 1966; March 1967; March-April 1973; January-1976; March 1981

Mallinckrodt Baker Inc., Material Safety Data Sheets for Carbon Disulfide, Acetonitrile, Aqueous Ammonia, and Formaldehyde, http://www.jtbaker.com/msds

Matheson Gas Products Inc., Material Safety Data Sheet for Nitric Oxide, http://hazard.com/msds/h/q126/q119.html

Mattson, W.O., Tagg, M.D, *We Develop Missiles, Not Air*!, Cultural Resources Publication No. 2, Holloman Air Force Base, NM, June 1995

McCampbell, James M., *UFOlogy*, Jaymac-Hollman, 1973

McKetta, John J, ed., *Encyclopedia of Chemical Processing and Design*, Volume 49, Marcel Dekker Inc.

MUFON, *MUFON Field Investigator’s Manual*, Fourth Edition, MUFON, 1995

MUFON, *MUFON UFO Journal*, Issues No. 254 and 272

National Research Council – Committee on Odors from Stationary and Mobile Sources, *Odors from Stationary and Mobile Sources*, National Academy of Sciences Publication #2877, Washington DC, 1979

NICAP, *The UFO Investigator*, Vol. 2 No. 11; Vol. 3 No. 4; Vol. 4 No. 11; Vol. 4 No. 1; May-1967

Nriagu, J.O., “Global Cycling of Selenium,” *Occurrence and Distribution of Selenium*, (M. Ihnat, ed.), CRC Press, Boca Raton, Fl, 1989

Olsen, Thomas, *Reference for Outstanding UFO Sighting Reports*, 1966

Quimme, Peter, *American Wine*, Signet Books, 3rd Edition, 1980

Polgar, L.G., R.A. Duffee, and L.J. Updyke, “Odor Characteristics of Mixtures of Sulfur Compounds Emitted from the Viscose Process”, Presented at the 68th Annual Meeting, Air Pollution Control Association, Boston, June 1975

Riegel’s *Handbook of Industrial Chemistry*, Edited by James A. Kent, Van Nostrand Reinhold Co., Eight Edition

Rodeghier, Mark, *UFO Reports Involving Vehicle Interference*, Center for UFO Studies, Evanston, IL, 981

Sanderson, Ivan T., *Uninvited Visitors*, Cowles Education Corporation, 1967

Schiffman, Susan S., *Odor Quality and Chemical Structure*, American Chemical Society Series 148, “Characterization of Odor Quality Utilizing Multidimensional Scaling Techniques”, Washington D.C., 1981

Singer, Stanley, *The Nature of Ball Lightning*, Plenum Press, New York, 1971

Steiger, Brad, *Project Bluebook*, Ballantine Books, Ninth Printing-1990

Steiger, Brad, and Joan Whritenour, *Flying Saucer Invasion: Target Earth*, Award Books, NY, 1969

Stoiko, Michael, *Soviet Rocketry: Past, Present and Future*, Holt, Rinehart & Winston, 1970

Stringfield, Leonard, *Situation Red: The UFO Siege*, Fawcett Crest Books, New York, 1977

Sullivan, Walter, *Scientific Study of Unidentified Flying Objects*, Bantam Books, 1969

Sutton, George P., *Rocket Propulsion Elements*, Third Edition, John Wiley & Sons, NY, 1963

Ullmann’s Encyclopedia of Industrial Chemistry, Fifth Edition

U.S. Department of Commerce, *Statistical Abstract of the United States 1998*, The National Data Book, 118th Edition, October 1998

U.S. Environmental Protection Agency Website, Material Data Sheet for Carbonyl Sulfide, http://www.epa.gov/ttn/uatw/hlthef/carbonyl.html

Vallee, Jacques, *Passport to Magonia*, Contemporary Books, Chicago, 1969, 1993

Vallee, Jacques and Janine, *Challenge to Science: The UFO Enigma*, Ballantine Books, New York, 1966

Vincoli, Jeffrey W., *Risk Management for Hazardous Chemicals*, Volume II, Material Safety Data Sheet for Hydrogen Sulfide, CRC Press, 1997

14 Sources and Notes

[1] Sanderson, Ivan T., *Uninvited Visitors*, Cowles Education Corporation, 1967, p. 85-86
[2] Keel, John A., *The Eighth Tower*, Signet Books, 1977, p. 97-103
[3] McCampbell, James M., *UFOlogy*, Jaymac-Hollman, 1973, p. 34
[4] Vallee, Jacques, *Passport to Magonia*, Appendix A, A Century of UFO Landings, Regnery, 1969 (UFO odor cases from the Magonia catalogue evaluated by McCampbell were #51, 72, 73, 94, 101, 102, 199, 584, 615, 616, 684, 721, 768, 832, 844, 875, 879, and 909)
[5] Steiger, Brad, *Project Bluebook*, Appendix B: USAF Technical Information Sheet, p. 372-380, Ballantine Books, Ninth Printing-1990
[6] Sullivan, Walter, *Scientific Study of Unidentified Flying Objects*, Bantam Books, 1969, p. 829-837
[7] *Denver Post*, November 14, 1950, Article about a UFO sighting over Los Alamos, NM, newspaper article photocopy was sent to author by Loren Gross
[8] Hendry, Allan, *The UFO Handbook*, Doubleday & Co., 1979, p. 21-21
[9] *MUFON Field Investigator’s Manual*, Fourth Edition, MUFON, 1995, p. 59
[10] http://www.jps.net/larryhat/index.html

U is a UFO DATABASE, MAPPING and RESEARCH TOOL package developed specially for DOS / Windows computers by Larry Hatch. As of April 2000 *U* holds over 17,660 carefully filtered UFO events distilled from hundreds of books, major journals, catalogs, downloads and other sources.

[11] Extract of 53 cases was obtained via email from Larry Hatch in a file titled SMELLS.TXT. This extract contained date, location, and all the references for each case.

[12] http://www.temporaldoorway.com/ufo/catalog/database/displayquerypage.asp. *Project 1947 EM Effects Catalog*, compiled by Mark Cashman contains 1,100 cases. This is a collection of cases where UFOs were reported to interfere with the operation of vehicles, engines, or electrical / magnetic equipment.

[13] Vallee, Jacques, *Passport to Magonia*, 1969, 1993, Contemporary Books, Chicago

[14] Hall, Richard, *Uninvited Guests*, 1988, Aurora Press, Santa Fe, NM, page 230

[15] http://www.leffingwell.com/olfacton.htm (Original Source: Demole, E.,H. Wuest, Syntheses Stereoselectives de deux trioxydes $C_{18}H_{30}O_3$ stereoisomeres, de'ambreinolide et sclareol-lactone a partir de derives du(+)-manool, Helv. Chem. Acta, 50:1314 (1967)

[16] *Odors from Stationary and Mobile Sources*, National Academy of Sciences, Publication #2877, Washington DC, 1979, by National Research Council – Committee on Odors from Stationary and Mobile Sources, p. 2

[17] *Odors from Stationary and Mobile Sources*, National Academy of Sciences, Publication #2877, Washington DC, 1979, by National Research Council – Committee on Odors from Stationary and Mobile Sources, p. 90-91

[18] Vallee, Jacques, *Passport to Magonia*, Case #72; Flying Saucer July 1959

[19] Sanderson, Ivan T., *Uninvited Visitors*, Cowles Education Corp, 1967, p. 37-52; Clark, Jerome, *The UFO Encyclopedia, Vol. 2, The Emergence of a Phenonemon: UFOs from the Beginning through 1959,* 1st Edition, 1992, p. 144-146; Vallee, *Passport to Magonia*, Case #101; Bowen, Charles, *The Humanoids*, p. 52

[20] Gross, Loren.:*UFOs a History-1952*, 6 books, book # 5, Page 41

[21] Vallee, *Passport to Magonia*, Case #102

[22] Gross, Loren, *UFOs a History-1954*, 5 books, book # 2, Page 27

[23] Gross, Loren, *UFOs a History-1956*, 5 books, book # 4, Page 50; Keel, John A., *The Eighth Tower*, Signet Books, 1977, p. 98; Thomas Olsen, *Reference for Outstanding UFO Sighting Reports*, 1966, p. 349, R-70

[24] Fowler, Raymond, *UFO's Interplanetary Visitors*, page 14; NICAP: UFO Investigator, Volume 2 Issue 11, p. 8; MUFON Journal #254; Vallee, Jacques, *Passport to Magonia*, #613

[25] Hall, Richard, *Uninvited Guests*, Aurora Press 1988, p. 248

[26] Vallee, Jacques, *UFO Enigma: Challenge to Science*, Page No. 48; Saucer News, XI, 4, Dec. 1964; Fate, Nov. '64, p.66, "UFO's that Look Like Tops"; Vallee, *Passport to Magonia*, Case #615

[27] Atic; Vallee, *Passport to Magonia*, Case #684; UFO Investigator, Vol. 3, No. 4, p. 7.

[28] MUFON UFO Journal, Bob Gribble, "Looking Back", Issue No. 272, p. 17

[29] Vallee , *Passport to Magonia*, Case #721

[30] Flying Saucer Review, London, Volume 17 Issue 1, p. 28

[31] Stringfield, Leonard, *Situation Red*, Page No. 52

[32] The APRO Bulletin, Jim & Coral Lorenzen, Year 66 Month 11; Lorenzen, *UFO's over the Americas*, Signet Books, 1966, p. 111, R-109

[33] The APRO Bulletin, Jim & Coral Lorenzen, Year 67 Month 3; Ronald Story, *Encyclopedia of UFO's*, p. 249, R-100

[34] NICAP: UFO Investigator, Volume 4, Issue 1, page 6, May-1967; Mark Rodeghier, *UFO Reports Involving Vehicle Interference*, p. 34, R-79

[35] Fowler, Raymond, *UFOs: Interplanetary Visitors*, Bantam Book, Hicksville, NY, 1979, pp. 208-209; http://www.temporaldoorway.com/ufo/report/67spring.htm

[36]Steiger & Whritenour, *Flying Saucer Invasion*, Page No. 100

[37] The UFO Investigator, Vol. IV, No. 11, P 3

[38] The APRO Bulletin, Jim & Coral Lorenzen, March-April 1973, page 4.

[39] Summary of UFO Report was sent to author on June 13, 2000 via email by UFO investigator Beverly Trout; Case was briefly mentioned in the *Ohio UFO Notebook*, Combined Issues #19 and #20, Summer of 1999, in a letter to the editor by Beverly Trout (MUFON State Director for Iowa)

[40] Stringfield, Leonard, *Situation Red*, Page No. 38

[41] The APRO Bulletin, Jim & Coral Lorenzen, January-1976, p2 and 5

[42] Hall, Richard, *Uninvited Guests*, Aurora Press 1988, p. 302-303

[43] APRO Bulletin V.29 No.3 P.8, March 1981// Newspapers: Scandia, MN 20 Sept. 1980: Forest Lake Times (Weekly) V.77 No.19 Thurs. 25 September 1980, p. 1

[44] *Atlas of Odor Character Profiles*, ASTM Data Series DS61, ASTM Publication Code Number 05-06 100036, Compiled by Andre Dravnieks, 1985, p. 1
[45] Ibid, p. 4
[46] Ibid, p. 58-59
[47] Ibid, p. 108-109, 250-251, 272-273, 310-311
[48] Ibid, p. 330-341
[49] *Odor Quality and Chemical Structure*, American Chemical Society, Series 148, "Characterization of Odor Quality Utilizing Multidimensional Scaling Techniques", Schiffman, Susan S., Washington D.C., 1981
[50] *Odors from Stationary and Mobile Sources*, National Academy of Sciences, Publication #2877, Washington DC, 1979, by National Research Council – Committee on Odors from Stationary and Mobile Sources, p. 123; ASTM D 1292-65, Standard Method of Test for Odor in Water, Philadelphia: ASTM, 1973
[51] *Odors from Stationary and Mobile Sources*, National Academy of Sciences, Publication #2877, Washington DC, 1979, by National Research Council – Committee on Odors from Stationary and Mobile Sources, p. 182-183; ASTM D 1292-65, Standard Method of Test for Odor in Water, Philadelphia: ASTM, 1973
[52] Polgar, L.G., R.A. Duffee, and L.J. Updyke, Odor Characteristics of Mixtures of Sulfur Compounds Emitted from the Viscose Process. Presented at the 68th Annual Meeting, Air Pollution Control Association, Boston, June 1975
[53] *Odors from Stationary and Mobile Sources*, National Academy of Sciences, Publication #2877, Washington DC, 1979, by National Research Council – Committee on Odors from Stationary and Mobile Sources, p. 175
[54] Phone conversation in October 1999 with consultant from Odor Science & Engineering, Inc., 1305 Blue Hills Ave., Broomfield, CT 06002
[55] *Riegel's Handbook of Industrial Chemistry*, Edited by James A. Kent, Van Nostrand Reinhold Co., Eighth Edition, p. 574
[56] Quimme, Peter, *American Wine*, Signet Books, 3rd Edition, 1980, p. 80
[57] *Kirk-Othmer Encyclopedia of Chemical Technology*, Fourth Edition, Vol. 21, John Wiley and Sons, pp. 686-719
[58] *Encyclopedia of Chemical Processing and Design*, (John J. McKetta ed.), Volume 49, Marcel Dekker Inc., pp. 328-340
[59] Ibid
[60] J.O. Nriagu, "Global Cycling of Selenium," *Occurrence and Distribution of Selenium*, (M. Ihnat, ed.), CRC Press, Boca Raton, Fl, 1989, pp. 328-340
[61] *Risk Management for Hazardous Chemicals*, Volume II, Jeffrey W. Vincoli, Material Safety Data Sheet for Hydrogen Sulfide, CRC Press, 1997, p. 1789-1794
[62] *Risk Management for Hazardous Chemicals*, Volume II, Jeffrey W. Vincoli, Material Safety Data Sheet for Sulfur Dioxide CRC Press, 1997, p. 2803-2808
[63] Material Data Sheet for Carbonyl Sulfide, US Environmental Protection Agency Website, http://www.epa.gov/ttn/uatw/hlthef/carbonyl.html
[64] Material Safety Data Sheet for Carbon Disulfide, Mallinckrodt Baker Inc., http://www.jtbaker.com/msds/c0957.htm
[65] International Chemical Safety Cards, Methyl Mercaptan, ICSC: 0299, http://hazard.com/msds/mf/cards/file/0299.html
[66] International Chemical Safety Cards, Hydrogen Selenide, ICSC: 0284, http://hazard.com/msds/mf/cards/file/0284.html
[67] Material Safety Data Sheet for Acetonitrile, Mallinckrodt Baker Inc., http://www.jtbaker.com/msds/a0518.htm
[68] Material Safety Data Sheet for Aqueous Ammonia, Mallinckrodt Baker Inc., http://www.jtbaker.com/msds/a5472.htm
[69] Material Safety Data Sheet for Formaldehyde, Mallinckrodt Baker Inc., http://www.jtbaker.com/msds/f5522.htm
[70] International Chemical Safety Cards, Nitrogen Dioxide, ICSC: 0930, http://hazard.com/msds/mf/cards/file/0930.html
[71] Material Safety Data Sheet for Nitric Oxide, Matheson Gas Products Inc., http://hazard.com/msds/h/q126/q119.html
[72] International Chemical Safety Cards, Nitrous Oxide, ICSC: 0067, http://hazard.com/msds/mf/cards/file/0067.html
[73] International Chemical Safety Cards, Ozone, ICSC: 0068, http://hazard.com/msds/mf/cards/file/0068.html
[74] Phone conversation in October 1999 with consultant from Odor Science & Engineering, Inc., 1305 Blue Hills Ave., Broomfield, CT 06002
[75] *Ullmann's Encyclopedia of Industrial Chemistry*, Fifth Edition, Volume A13, "Hydrogen Sulfide", pp. 467-485
[76] Barry, James Dale, *Ball Lightning and Bead Lightning*, Plenum Press, New York, 1980, p. 37

[77] Singer, Stanley, *The Nature of Ball Lightning*, Plenum Press, New York, 1971, p. 71
[78] Corbitt, Robert, *Handbook of Environmental Engineering*, McGraw-Hill Publishing Co., 1989, p. 4.2
[79] *Statistical Abstract of the United States 1998*, The National Data Book, 118th Edition, October 1998, US Department of Commerce, p. 242; *Environmental Quality: Along the American River*, Council on Environmental Quality, Office of the President, 1996
[80] *Kirk-Othmer Encyclopedia of Chemical Technology*, "Air Pollution", Fourth Edition, Vol. 1, John Wiley and Sons, p. 721
[81] *Compilation of Odor and Taste Threshold Values Data*, Fazzalari, F.A. Ed., ASTM Data Series DS48A, American Society for Testing and Materials
[82] Hill, Robert D., Rhamin Iraj, Robert G. Rinker, *Industrial Engineering Chemistry Res*., "Experimental Study of the Production of NO, N_2O, and O_3 in a Simulated Atmospheric Corona", 1988, Vol. 27, No. 7, pp. 1264-1269
[83] *Kirk-Othmer Encyclopedia of Chemical Technology*, "Air Pollution", Fourth Edition, Vol. 1, John Wiley and Sons, pp. 718721
[84] Castellan, Gilbert W., *Physical Chemistry*, Standard Heats of Formation Table, p. 137, Second Edition, Addison-Wesley Publishing Co., 1971
[85] Cadle, Richard D., Ledford, Margaret, "The Reaction of Ozone with Hydrogen Sulfide", *Air and Water Pollution Int. J*., Pergamon Press, 1966, Vol. 10, pp. 25-30
[86] Broad, William J., *The Universe Below*, Simon & Schuster, NY, NY 1997, pp. 95-112
[87] Stoiko, Michael, *Soviet Rocketry: Past, Present and Future*, Holt, Rinehart & Winston, 1970, pp.93-95
[88] Mattson, W.O., Tagg, M., *We Develop Missiles, Not Air*; Kennedy, G.P., *Vengeance Weapon 2; Journal of Spacecraft and Rockets*, March-April 1995
[89] Barrere, Marcel, *Rocket Propulsion*, Elsevier Publishing Co., Amsterdam, 1960, Table 8, pp. 634-636
[90] Sutton, George P., *Rocket Propulsion Elements*, Third Edition, John Wiley & Sons., NY, 1963, pp. 220-225, 346, 346