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Aerial Detection Of Spill Sources

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AERIAL DETECTION OF SPILL SOURCES

By

C. L. Rudder
A. G. Wallace
C. J. Reinheimer

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Project Officer

John Riley
Office of Air and Water Programs
Environmental Protection Agency
Washington, D.C. 20460

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ABSTRACT

A unique interpretation key emphasizing the environmental aspects of the petroleum industry was developed for use with an aerial surveillance spill prevention system. Aerial baseline and stereogram photographs as well as aerial multiband, aerial oblique, and ground photographs of oil refineries were obtained for inclusion in the key. Processing systems to convert crude oil to fuel and LPG, gasoline, heavy fuel oils, lubricating oils and asphalt were identified with the help of military oil refinery interpretation keys. Three petrochemical facilities within the refinery were also located and identified. The identification of potential spill sources as related to processing systems, product storage and disposition of by-products and waste was performed. The results were confirmed by refinery personnel and included in the oil refinery key. Concurrent with the flight program, fifteen samples of spilled material were obtained along with the appropriate ground truth data. Chemical and spectral analyses of the samples were performed and correlated with the multiband image analysis. Finally, the use of aerial photography for temporal change detection was evaluated and included in the appropriate sections of the key.

This report was submitted in fulfillment of Project #15080, Contract #68-01-0178, under the sponsorship of the Officer of Research and Monitoring, Environmental Protection Agency.

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SECTION 1
CONCLUSIONS

A unique imagery interpretation key emphasizing the environmental aspects of petroleum refineries was developed as an integral part of an aerial surveillance spill prevention system. The petroleum refinery key is a unique collection of aerial photographs, ground photographs, and textual information. The key is organized to expedite the location and identification of spill threats through the use of conventional and multiband aerial photographs. The addition of aerial multiband photographs, spill threat analyses and spectral and chemical analyses of spilled materials distinguish this key from standard military interpretation keys. Results of the chemical and spectral analyses have been correlated with various multiband photographs to increase the capability of the interpreter to detect spill threats identified with specific processing facilities and refining equipment. Throughout the aerial spill detection key, the material descriptively relates oil refinery features to potential contamination of natural water resources. In addition to serving as a reference manual for imagery interpreters, the petroleum refinery key can aid in training imagery interpreters to recognize refinery facilities, equipment, processes and associated spill threat areas. The key, although prepared for petroleum refinery, can serve as a model for other industries for which imagery interpretation keys are desired.

SECTION II
RECOMMENDATIONS

The format and material in the petroleum refinery key was carefully chosen to fulfill a specific need - to expedite the location and identification of spill threats from aerial photographs. Therefore, the petroleum refinery key should serve as a model for generating other industrial keys that are to be used for the same purpose.

In the future, additional remote sensors will undoubtedly become a standard part of an aerial surveillance spill prevention system. Consequently, imagery from such sensors should be added to existing keys or included in future industrial keys.

For future industrial keys new film/filter combinations must be determined for the identification of associated industrial spills, if a multiband camera system is to be an integral part of an aerial surveillance system.

It is recommended that the key be used as a reference in the training of those responsible for monitoring spill threats.

SECTION III
INTRODUCTION

The purpose of the project was to develop an imagery interpretation key for use in the detection and identification of spill threats to inland or coastal waterways from aerial photographs. The U. S. Military services have employed imagery interpretation keys for rapid and accurate identification of pertinent features of a variety of industries. The identification of real and potential spill threats to adjacent waterways, however, differentiates this key from standard military keys. This report discusses the collection, analysis and organization of data responsible for the successful formulation of an oil refinery aerial spill detection key.

In the St. Louis area, a number of oil refineries are located adjacent to or near the Mississippi River. These refineries were selected to serve as "model" oil refineries for the formulation of the imagery interpretation key. The cooperation of personnel in the oil refineries industry was essential to the completion of this project. The appropriate refinery personnel were informed by phone of the objectives of the project, and meetings were arranged to explain the program in detail. Cooperation was agreed upon to identify processing facilities, equipment, and procedures used in the refinery operation and to point out potential spill threat areas. In addition, ground truth teams were permitted to collect samples of spilled material and to take ground photographs of all areas unless company or government regulations prohibited photography. Each relevant refinery representative was given permission to review that draft key for their cooperation.

From photographs gathered during the evaluation of "An Aerial Spill Prevention System",[1] a mosaic of the "model" oil refinery was made. Based on information in the military oil refinery key[2] and from other supplementary information,[3] processing facilities and equipment were identified in the mosaic. Flow diagrams of the various processing facilities were also constructed from the reference material. The identification and processing procedures were confirmed or clarified at periodic meetings with refinery personnel.

The experimental program consisted of gathering aerial baseline, oblique and multiband photographs in addition to ground photographs, ground samples, and ground truth data. Baseline and multiband photographs were shown previously[1] to be an essential to detecting real and potential spill threats. Aerial oblique photographs and ground photographs were also determined to be a necessary part of the key. Such photographs aid the interpreter in making the transition from a normal ground view to a vertical view. Aerial photographs taken at different time periods were compared to determine the effectiveness of change detection as a method for monitoring refinery spills and activity. Finally, samples of spilled material were spectrally and chemically analyzed to aid in multiband imagery analysis.

All of the data gathered during the experimental program was evaluated for inclusion in the oil refinery key. The baseline photographs, oblique photographs, and ground photographs of the processing facilities and equipment were correlated with the ground sample and ground truth analysis. These results were then mutually correlated and related to the spill threat analysis. The selected photographs, and results of spill threat and ground sample analyses were organized into the refinery key to expedite the identification and location of spill threats from conventional and multiband aerial photographs. The final results are contained in the Aerial Spill Detection Key (Petroleum Refineries).

SECTION IV
EXPERIMENTAL PROGRAM

The purpose of the experimental program was to gather aerial oblique, baseline and multiband photographs of oil refineries. In addition, ground photographs of refineries facilities' and equipment were obtained along with samples of spilled materials for spectral and chemical analyses. The equipment, techniques and results of the experimental program are discussed in this section.

Camera Systems

Aerial baseline and multiband photographs were previously determined to be an integral part of a spill prevention system.[1] The baseline camera must produce photographs maintaining high image fidelity for stereoscopic and mensuration analyses. To acquire baseline photographs, a Zeiss RMK 1523 mapping camera, utilizing a 6 in. focal length lens was used. These photographs were recorded on Kodak Double X Aerographic Type 2405 film having a 9 in. image format. The multiband photographs were obtained with an array of three Hasselblad 500 EL/M cameras, each equipped with a 50-mm focal length lens. The multiband photographs were recorded on 70-mm Kodak Tri-X Aerographic Type 2403 film and on Kodak Infrared Aerographic Type 2424 film. Each of these films was used with Kodak filters 99 and 32, separately, to produce the multiband photographs. These film/filter combinations were previosuly concluded to be optimum for the detection of petroleum products.[1] A discussion of the mounting arrangements and associated accessories used for both the Zeiss and Hasselblad cameras can be found in a previous report.[1]

Aerial oblique color and black-and-white photographs along with color ground photographs were obtained for use in the oil refinery imagery interpretation key. The aerial oblique photographs were taken with a hand-held camera directed through an open window of the aircraft. The two cameras employed for this task were a Minolta SRT 101 using a 135-mm focal length lens, and a Pentocan 6 using a 180-mm focal length lens. The Minolta photographs were recorded on 35-mm Plus-X film and the Pentocan photographs were recorded on 2 1/4 in. CPS-220 Ektachrome film. Ground photographs were recorded with the Minolta SRT 101 camera using a 28-mm, 33-mm and 135-mm focal length lenses. Kodacolor-X 35-mm film was used for the ground photography.

Aircraft

A Cessna 336 or Aerocommander Model 680 aircraft, each with a crew of three, were used for the recording of the aerial photography. The crew consisted of the pilot, aerial photographer, and camera monitor. The aircraft and camera systems met all the requirements to obtain the baseline and multiband photographs.[1]

Flight Program

Aircraft flight altitudes were selected to record baseline photographs at a scale of approximately 1:5000 and multiband photographs at a scale of 1:9000.

The selection of these scales were made during the investigation of "An Aerial Spill Prevention System" and provide adequate area coverage as well as sufficient detail for spill detection.

From 15 June 1972 to 29 August 1972, seven flights were made over the oil refineries. One flight was used to obtain baseline photography and another flight was used strictly to obtain oblique photographs. The remaining flights were utilized to record multiband photographs or a combination of multiband and oblique photographs. A multiband flight consisted of flying two missions over the oil refineries. On the first mission, the multiband camera system was loaded with film type 2448 and film/filter combinations 2403/32 and 2403/99. On the next mission, the multiband camera system was loaded with film type 2448 and film/filter combinations 2424/32 and 2424/99. All the multiband combinations for one flight were taken within a time span of one to two hours on the same day.

The flight lines, filter factors, and pertinent flight parameters were determined in accordance with the specifications made during the previous project.[1] Table 1 lists the flights made over the oil refinery, and includes the flight date, altitude, film/filter combination employed on each camera, the filter corrected f/number, and exposure time.

TABLE 1 FLIGHT PROGRAM OVER OIL REFINERIES

Date	Altitude (ft above ground)	Camera 1				Camera 2				Camera 3			
		Film Type	Filter	f/No.	Shutter Speed	Film Type	Filter	f/No.	Shutter Speed	Film Type	Filter	f/No.	Shutter Speed
15 June 72 ①	2500	2405	12	8	1/600								
19 July 72 ②	1500	2403	99	16	1/500	2403	32	22	1/500	2448	HF3	5.6	1/500
19 July 72 ②	1500–2000	Plus X	K-2	5.6	1/500								
21 July 72	2000	Plus X	K-2	5.6	1/500								
24 July 72	1500	2403	99	13	1/500	2403	32	22	1/500	2448	HF3	5.6	1/500
		2424	99	13	1/500	2424	32	16	1/500	2448	HF3	5.6	1/500
4 Aug 72	1500	2403	99	11	1/500	2403	32	22	1/500	2448	HF3	5.6	1/500
11 Aug 72	1500	2403	99	6.3	1/500	2403	32	32	1/500	2448	HF3+5	5.6	1/500
		2424	99	13	1/500	2424	32	13	1/500	2448	HF3+5	5.6	1/500
29 Aug 72	1400-1500	CPS	HF3+4	5.6	1/500								
		CPS	HF3+4	4	1/1000								

① Baseline flight ② Oblique photographic flight

GP72-0856-203

Photographic Processing

Precision photographic processing of the 70-mm multiband film and color film is necessary for the extraction of scientific data from the photographs. Precision processing insures the tonal variations in the multiband photographs is a result of the target reflective properties and not the results of fluctations in the processing techniques. A discussion of the relevant parameters and required sensitometric data for precision processing can be found in an earlier report.[1]

Spilled Material Collection

Concurrent with the multiband flight program, ten samples were collected at the oil refinery on 19 July 1972 and five more samples were collected on 4 August 1972. Of the first ten samples, two were taken from the lime sludge disposal area, two were taken where oil was purposely placed on the ground to keep down dust, five samples were taken from the water processing ponds. The second group of spill samples was taken from petroleum waste areas: three from an area adjacent to the river and two from a similar area within the refinery. In addition to sample collection, the appropriate ground truth data at each sample site was recorded. Such data included weather conditions, the type of processing taking place in the sample area, a description of the background area, and ground photography. Both chemical and spectral analyses of the relevant samples were performed.

Chemical Analysis

Because of the chemical complexity of the samples, the personnel performing chemical analysis consulted with oil refinery representatives to determine the best tests to chemically identify the samples.

The approved tests included determining 1) the concentration of metallic ions associated with organic compounds, 2) the weight percentage of oil content, 3) the aromatic and aliphatic content, and 4) the amount of suspended solids in the samples. These analyses, where applicable, were performed on thirteen of the samples. Two of the samples were discarded since they were not pertinent to the areas included in the key. A general description of each sample, a correlation of each sample with a photograph in the refinery key, and the results of the chemical analyses are shown in Table 2. A brief description of each of the chemical analyses performed is discussed below.

In some complex petroleum hydrocarbon molecules, metallic ions such as magnesium, calcium, barium,and boron are found as part of the molecular chain. Motor oil additives exemplify petroleum products that contain these metallic ions. Consequently, chemical analysis is simplified by looking for concentrations of these ions rather than identifying the specific hydrocarbon molecule. The metallic ion concentration associated with these molecular chains was determined by leaching a known weight of each sample with methyl isobutyl ketone and performing an atomic absorption spectroscopic analysis of each leached sample against an organo-metallic standard. This test procedure assures that the metallic

TABLE 2 CHEMICAL SAMPLE ANALYSIS

Sample No.	Oil Refinery Key Figure	Sample Description	Metal Ion Concentration† Leached from Hydrocarbon				Oil Content†	Result of Infrared Spectroscopy	Suspended† Solids
			Mg	Ca	Ba	B			
1	Area C Figure 4-93	Oil Placed on Soil to Keep Down Dust	–	–	–	–	75.6	Aliphatic Hydrocarbons	–
2	Area A Figure 4-101	Oil-Water from Entrance to Water Processing Pond	–	–	–	–	68.1	Aliphatic Hydrocarbons	–
3	Area C Figure 4-101	Water Sample from First Oxidation Pond	–	–	–	–	<0.0005	Slight Trace of Aliphatic Hydrocarbons, Water and Methyl Groups	0.004
4	Area D Figure 4-101	Water Sample from Southeast Area of Aerator Pond	–	–	–	–	<0.0005	None	0.004
5	Area D Figure 4-101	Water Sample from Southwest Area of Aerator Pond	–	–	–	–	<0.0005	None	0.004
6	Area E Figure 4-101	Water Sample from Effluent to Final Processing Pond	–	–	–	–	<0.0005	None	0.004
7	Area B Figure 4-101	Soil Sample Adjacent to Processing Ponds	–	–	–	–	10.9	Aliphatic Hydrocarbons	–
8	Area C Figure 4-114	Petroleum Waste	<0.00002	<0.0001	<0.002	<0.01	26.1	Aliphatic Hydrocarbons, Water and Methyl Groups	–
9	Area D Figure 4-114	Petroleum Waste	0.0020	0.0001	0.005	<0.01	42.3	Aliphatic Hydrocarbons Plus Water	–
10	Area E Figure 4-115	Petroleum Waste	0.00140	0.020	0.250	<0.01	31.6	Aliphatic Hydrocarbons Plus Water	–
11	Area A Figure 4-116	Petroleum Waste	<0.00002	0.0002	<0.002	<0.01	25.2	Some Aliphatic Hydrocarbons Plus Water	–
12	Area B Figure 4-116	Petroleum Waste	<0.00002	0.0012	<0.002	<0.01	46.8	Aliphatic Hydrocarbons and Methyl Groups	–
13	Not Shown in Key	Lime Sluge from Water Softening Process	<0.00002	<0.0002	–	–	Negligible	None	–

† All values expressed in weight percentages.

ions detected are part of the organic chain and not free metal ions usually found in most materials. The weight percent of each ion in each sample, where applicable, is shown in column 4 of Table 2.

The oil content was determined by either petroleum ether extraction or by hexane extraction, depending on the nature of the sample. From ten grams of the extracted sample, the soluble residue remaining after evaporation was subjected to gravimetric analysis. The oil content of each sample in weight percentage determined from these analyses is given in column five of Table 2.

All of the samples were examined by infrared spectroscopy to estimate the aromatic and aliphatic contents of the samples. Absorption in the 3.4, 6.8, and 7.2 micron bands indicates the presence of aliphatic hydrocarbons; absorption at 6.6 microns is characteristic of aromatic hydrocarbons. The presence of the 7.2 micron absorption band in the infrared spectroscopy is also indicative of the presence of methyl groups. Water in the sample is characterized by the absorption in the 2.9, 6.1, and 12.15 micron bands. An analysis of the infrared spectroscopic tests revealed no aromatic content in any of the oil samples. Therefore, all of the samples are 95 - 98% aliphatic in content. The results of infrared spectroscopic analysis of each sample is given in column 6 of Table 2.

The amount of suspended solids in the water samples was determined by filtration and gravimetric analysis. The results, expressed in weight percent, are shown in column 7 of Table 2.

Spectral Analysis

Spectral reflectance scans were performed on the samples that were subjected to chemical analysis. The reflectance spectra were obtained from a modified Beckman DK-2 Spectrophotometer. The Beckman Spectrophotometer is designed to measure the diffuse reflectivity of a sample by use of an integrating sphere. As shown in Figure 1a, the light source is directed, alternately, at the sample and then the reference material. The reflected radiation is scattered within the integrating sphere and measured by an appropriate detector. Both the sample and reference material are mounted against the side of the integrating sphere. Because the samples collected during this project were liquid, the Beckman had to be modified to obtain reflectance spectra. The modifications are shown in Figure 1b. The radiation incident normal to the sample was directed to a mirror which reflected the radiation onto the liquid sample contained in a glass beaker. The diffuse and specular radiation reflected from the sample was then reflected back into the integrating sphere for measurement. With this modification, absolute reflectance measurements can not be made since the mirror does not collect all of the diffusely scattered radiation. As a result, the reflectance spectra of the samples is expressed in relative reflectance units. It should be emphasized, however, that since all the samples were analyzed the same way, each reflectance spectrum can be compared relative to the others. The reference material used in generating these curves was magnesium oxide. This reference material has a uniform spectral response in the 300 to 1,000 nanometer region.

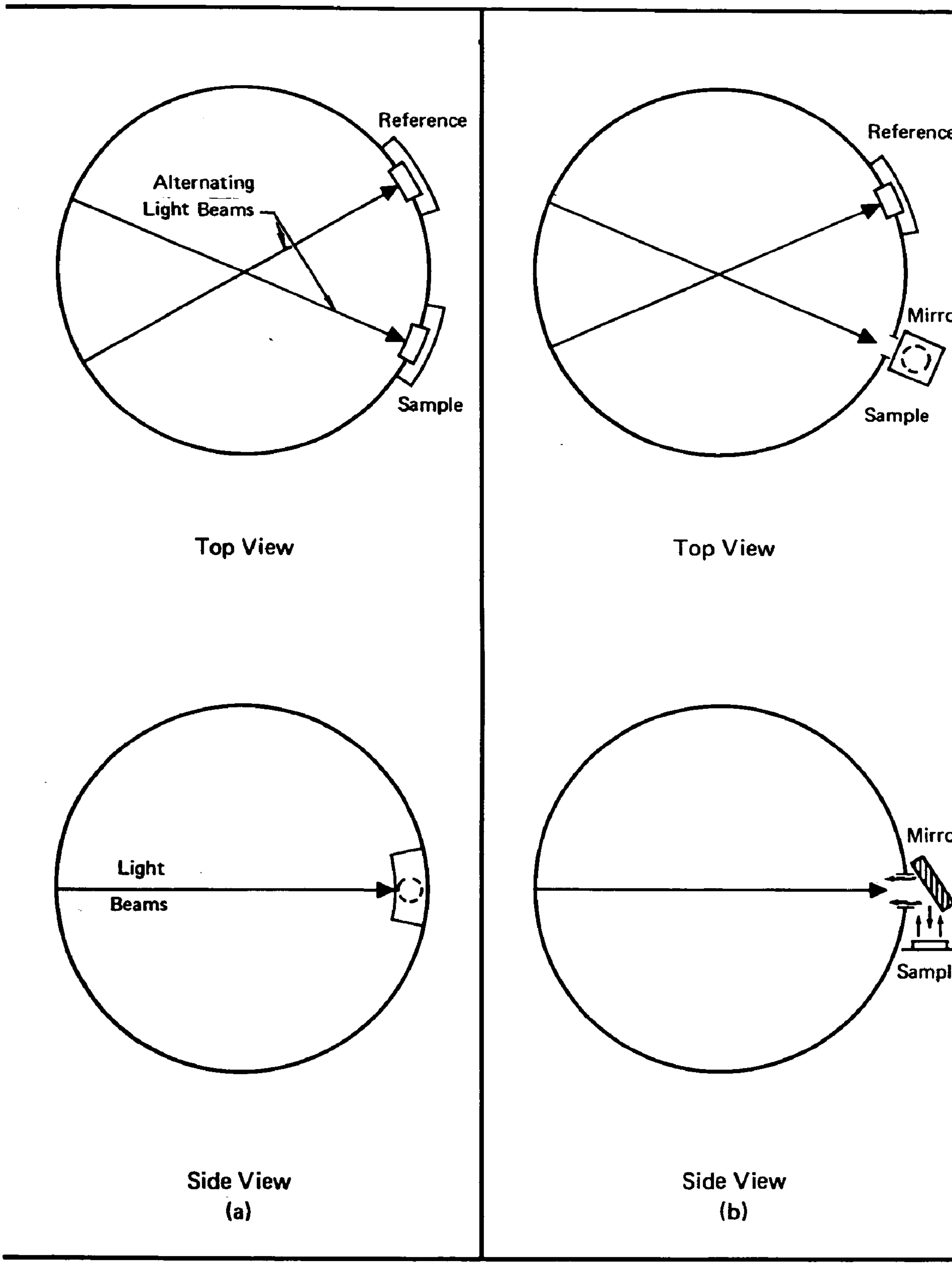

FIGURE 1 BECKMAN DK-2 INTEGRATING SPHERE a) IN NORMAL USE AND b) MODIFIED FOR LIQUID SAMPLES

The reflectance spectrum of each of the various samples is shown in Figures 2 through 12. As samples 4, 5 and 6 taken for the water processing showed the samples' spectral characteristics, only one reflectance spectrum is shown. Since the spectral curves are independent of the illuminating source, the solar spectrum must be considered for determining the relative reflected energy from any sample in any spectral band. Figure 13 shows the solar spectrum[4] for direct and global radiation incident on a horizontal surface of the earth for an air mass of approximately 1.0. The air mass depends on the optical path the sun's radiation must transverse before reaching the earth's surface and is related to the sun's zenith angle.

The sun's zenith angle at local apparent noon varied from 15 to 20 degrees during the period of the multiband flights. For these angles the air mass value of 1.0 is found to be a good approximation for the atmospheric optical thickness. In Figure 13 the solar spectrum is seen to peak in the blue-green spectral region. In addition, the red to near-infrared region contains 2 to 3 times the energy than the ultraviolet-blue spectral region. These spectral characteristics must be considered when examining Figures 2 through 12.

Since the spill sample reflectance spectra are self explanatory, only some general observations are made here. All of the petroleum or oil-ground samples show either a fairly flat spectral response or increase sharply in the red and near-infrared spectral regions. These results multiplied by the solar spectrum indicates that the red and near-infrared reflected energy is much greater than the ultraviolet-blue reflected energy.

In the prior multiband analysis[1], it was concluded that film/filter combination 2403/32 showed more detail in the multiband photographs because of the recorded ultraviolet, blue, and red radiation. From these curves, however, only the red and blue reflected radiation can be responsible for these results. The samples containing mixtures of oil with earth (Figures 2 and 6) have fairly flat spectral responses with some increase in the near-infrared spectral regions. In contrast, samples containing water and oil (Figures 4 and 5) show absorption in the near-infrared spectral regions. These results verify the absorptive and reflective properties in the near-infrared of water and ground respectively. Also both water samples show little reflected ultraviolet radiation which accounts for water penetration observed on the multiband photograph 2403/18A. The correlation of the spectral responses of the petroleum waste with the multiband photography is generally quite good. Figures 7, 10, and 11 show strong near-infrared reflectance properties which has been observed in the black-and-white near-infrared multiband photographs (2424/99 and 2424/32). It is interesting to note that the chemical analysis of two of the samples shown in Figures 7 and 11 show a strong presence of methyl groups. These methyl groups, however, are difficult to correlate with any specific petroleum product.

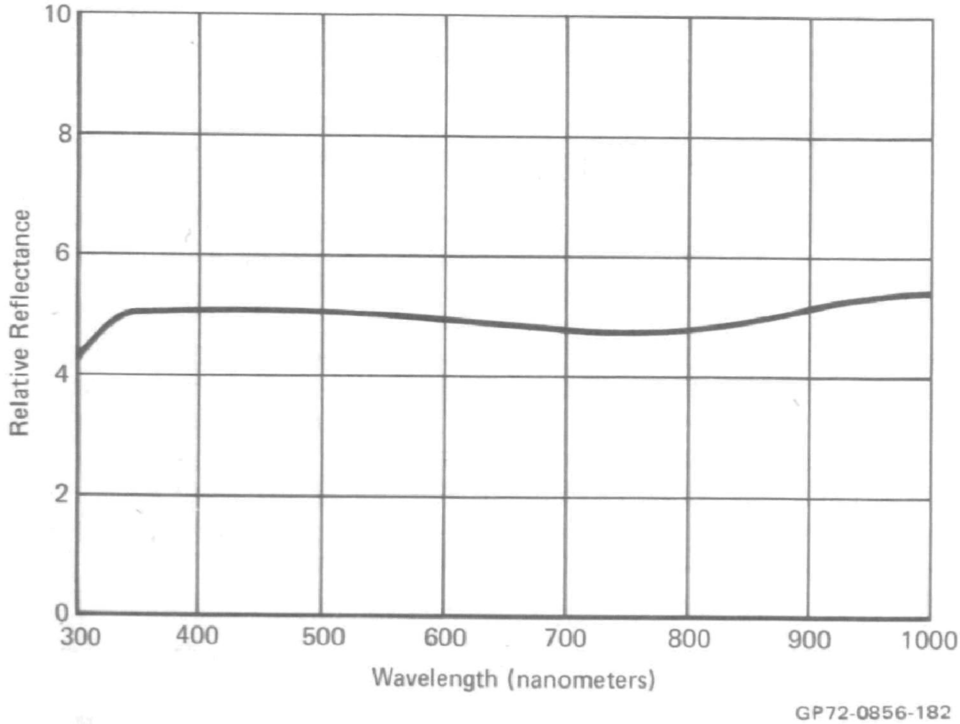

FIGURE 2 REFLECTANCE SPECTRUM OF OIL-GROUND COMBINATION - SAMPLE 1

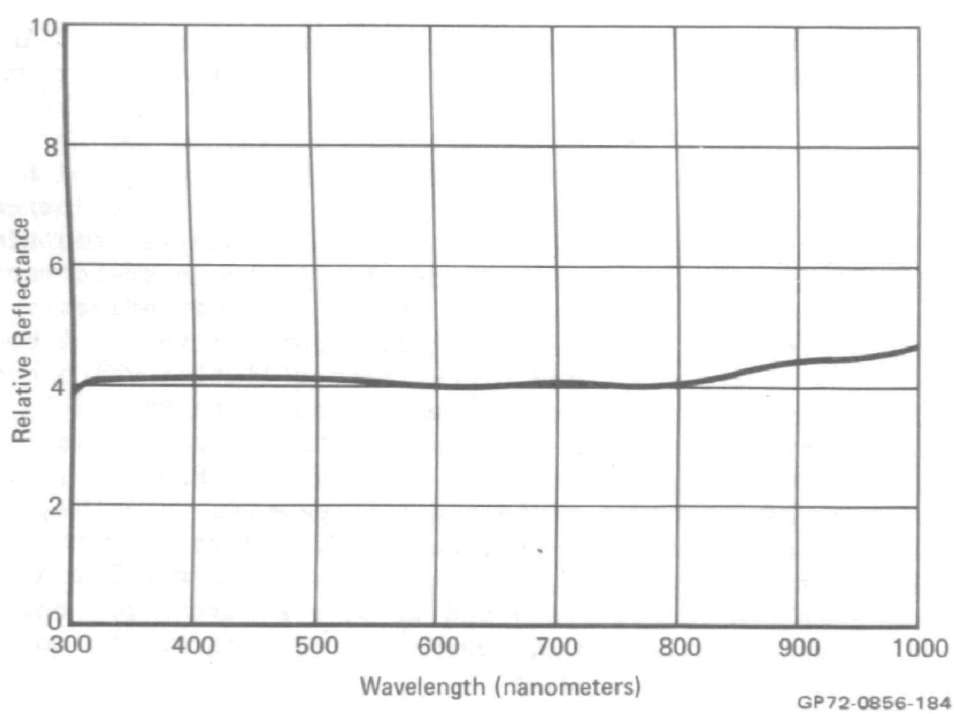

FIGURE 3 REFLECTANCE SPECTRUM OF OIL-WATER MIXTURE FROM ENTRANCE TO PROCESSING PONDS - SAI - SAMPLE 4

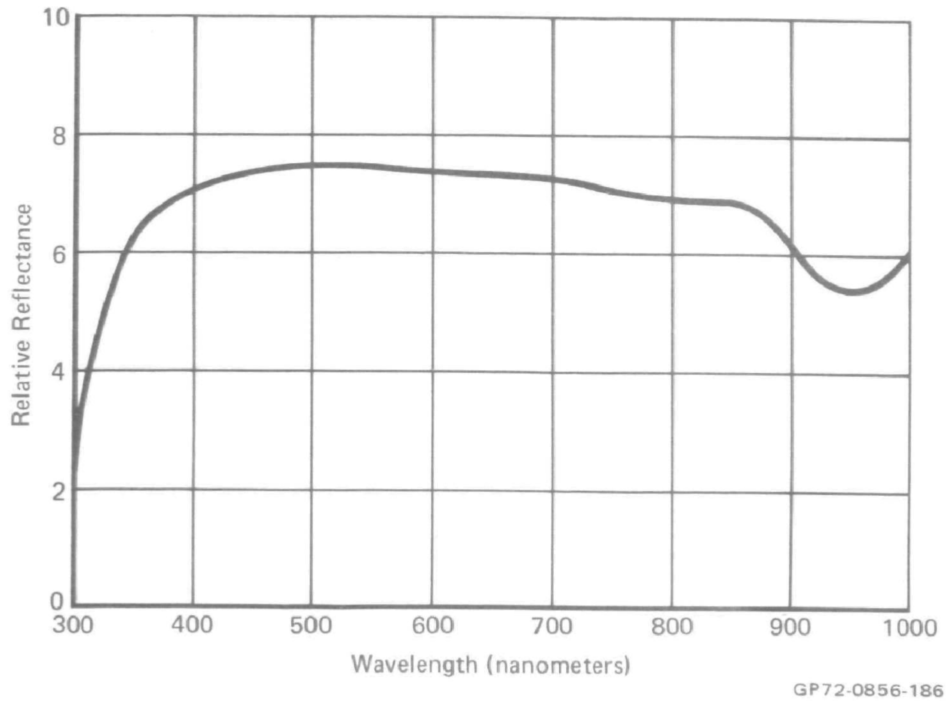

FIGURE 4 REFLECTANCE SPECTRUM OF WATER FROM FIRST PROCESSING POND - SAMPLE 3

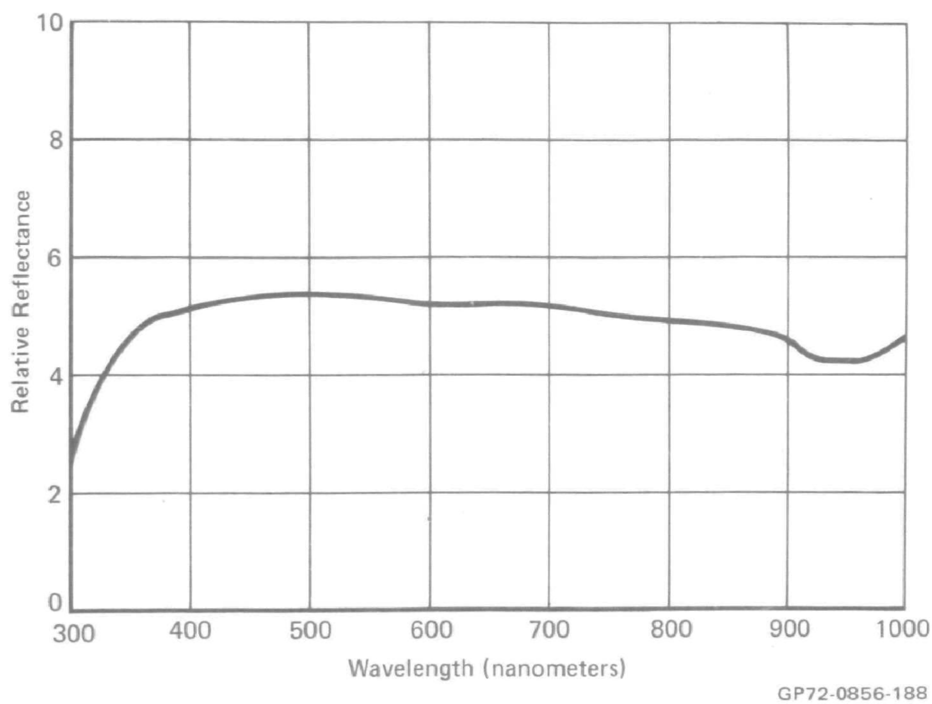

FIGURE 5 REFLECTANCE SPECTRUM OF WATER FROM AERATOR POND

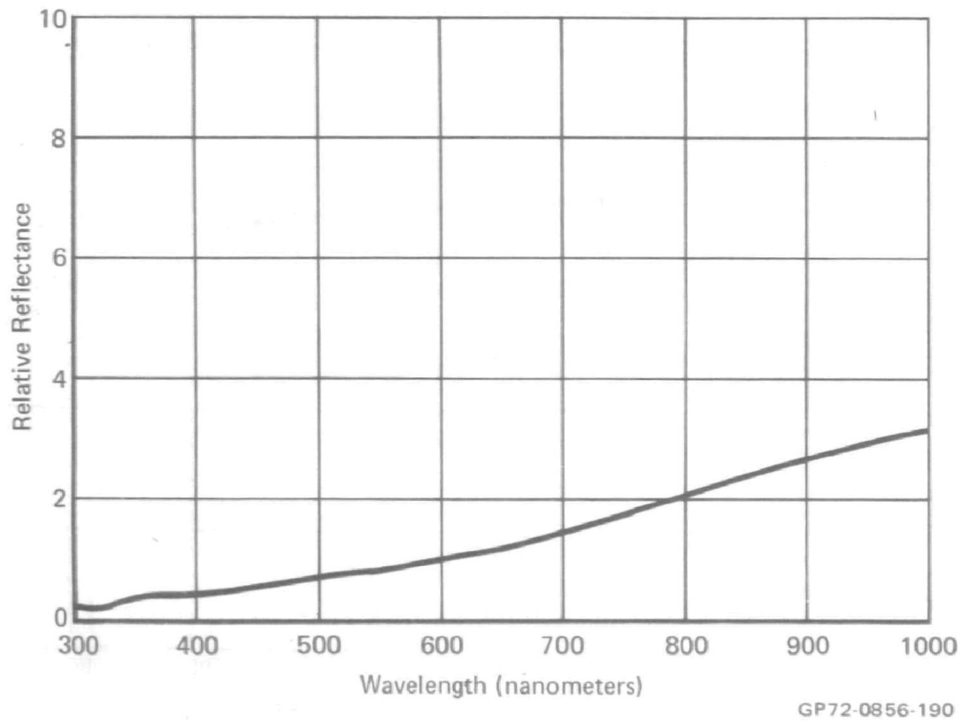

FIGURE 6 REFLECTANCE SPECTRUM OF OIL-SOIL ADJACENT TO PROCESSING PONDS - SAMPLE 7

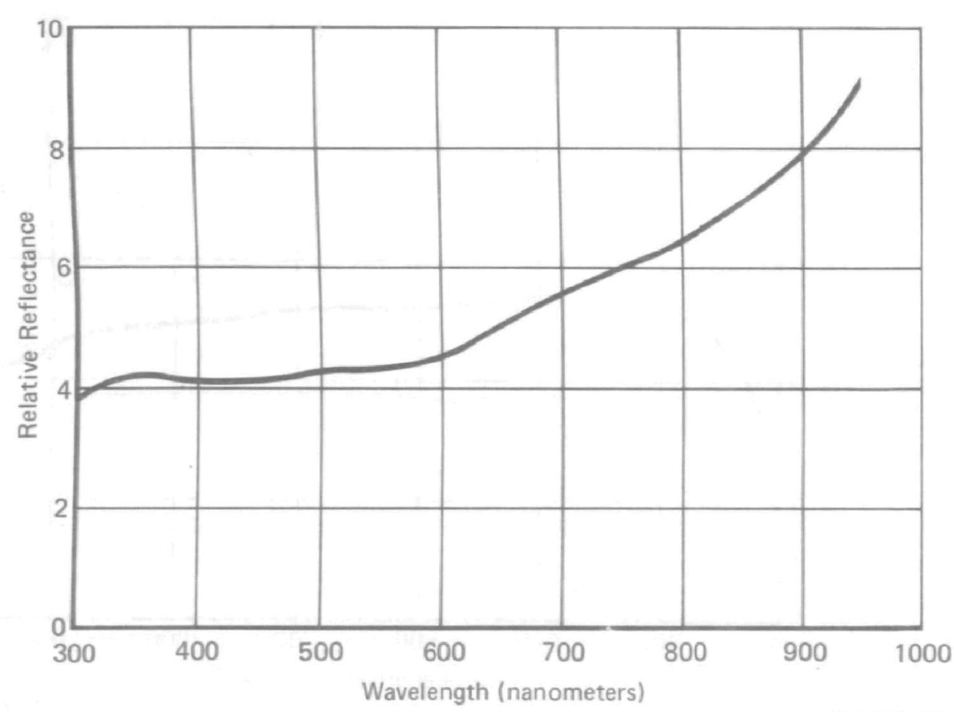

FIGURE 7 REFLECTANCE SPECTRUM OF PETROLEUM WASTE - SAMPLE 8

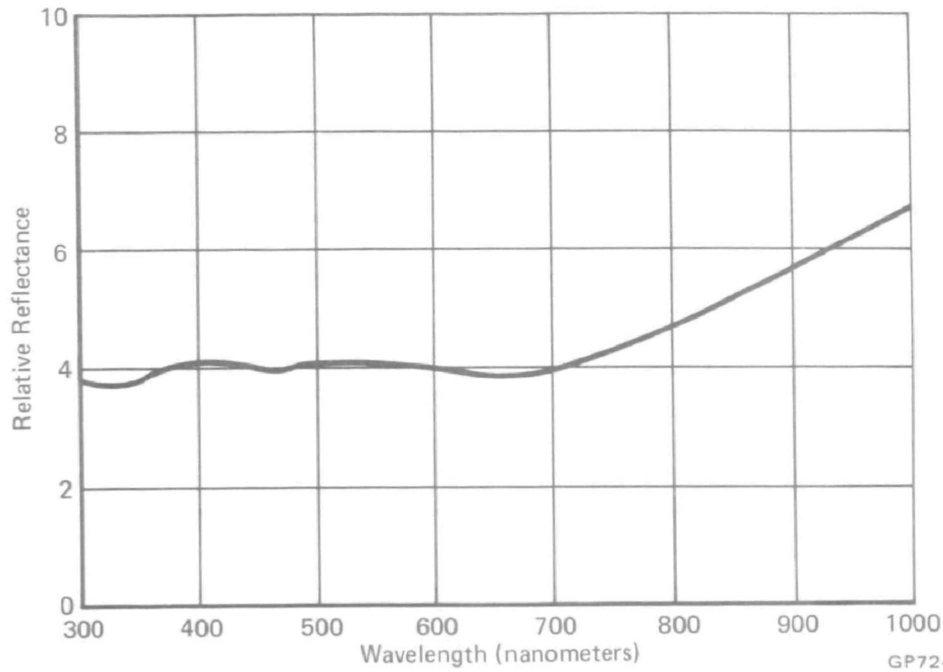

FIGURE 8 REFLECTANCE SPECTRUM OF PETROLEUM WASTE - SAMPLE 9

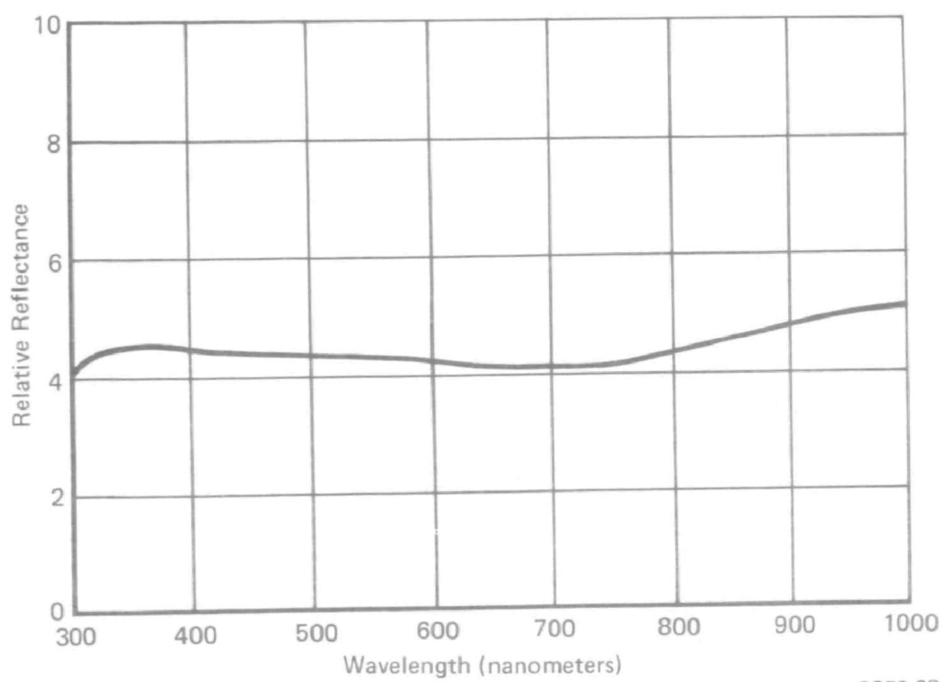

FIGURE 9 REFLECTANCE SPECTRUM OF PETROLEUM WASTE - SAMPLE 10

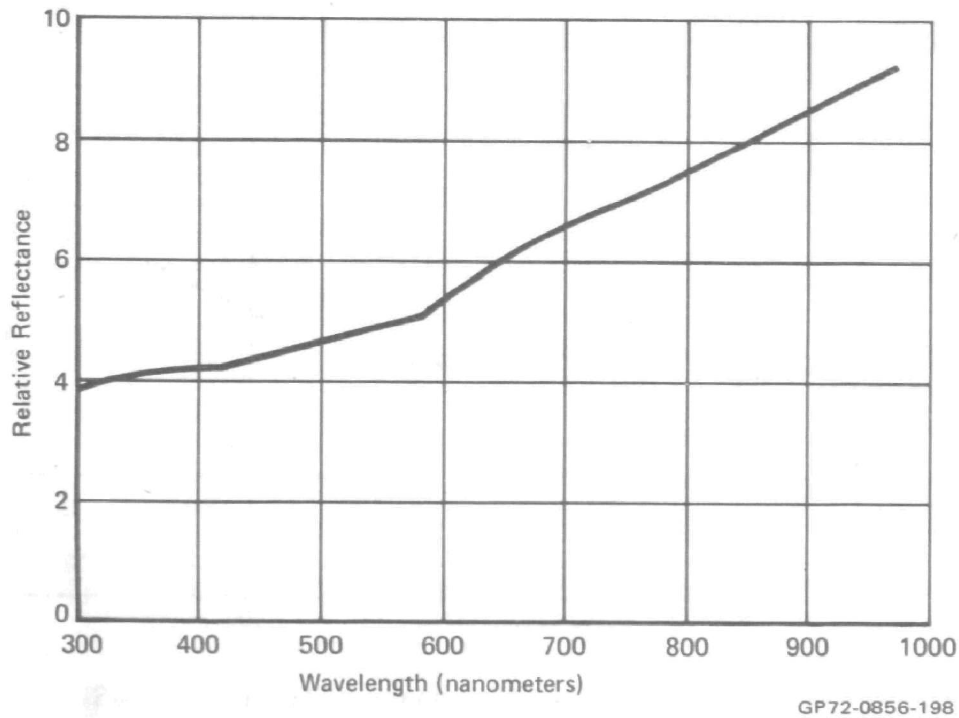

FIGURE 10 REFLECTANCE SPECTRUM OF PETROLEUM WASTE - SAMPLE 11

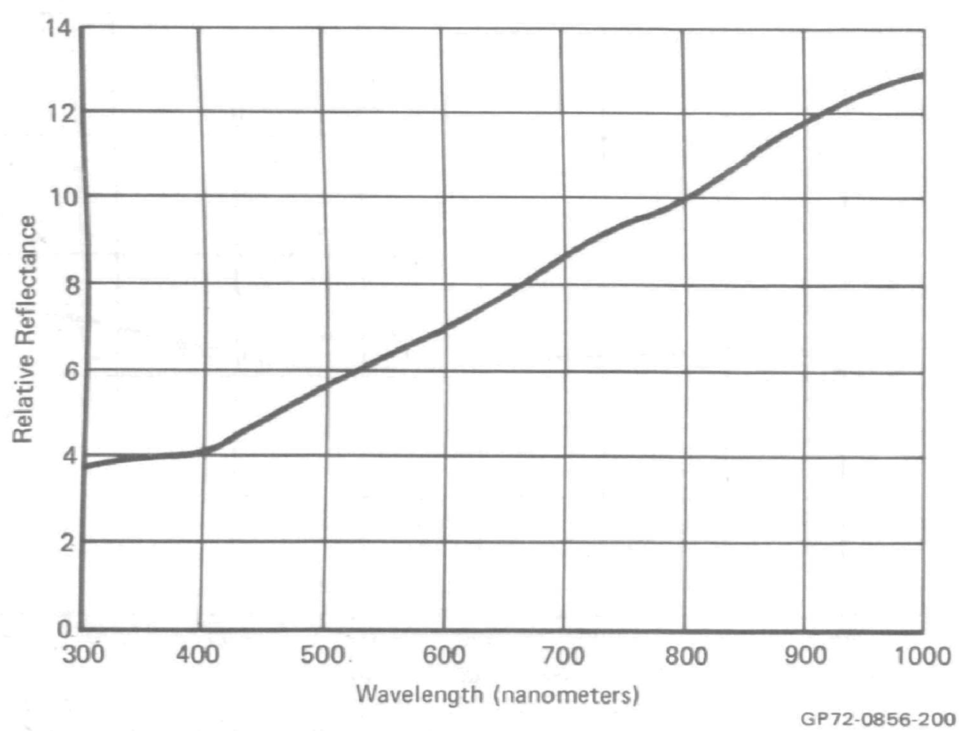

FIGURE 11 REFLECTANCE SPECTRUM OF PETROLEUM WASTE - SAMPLE 12

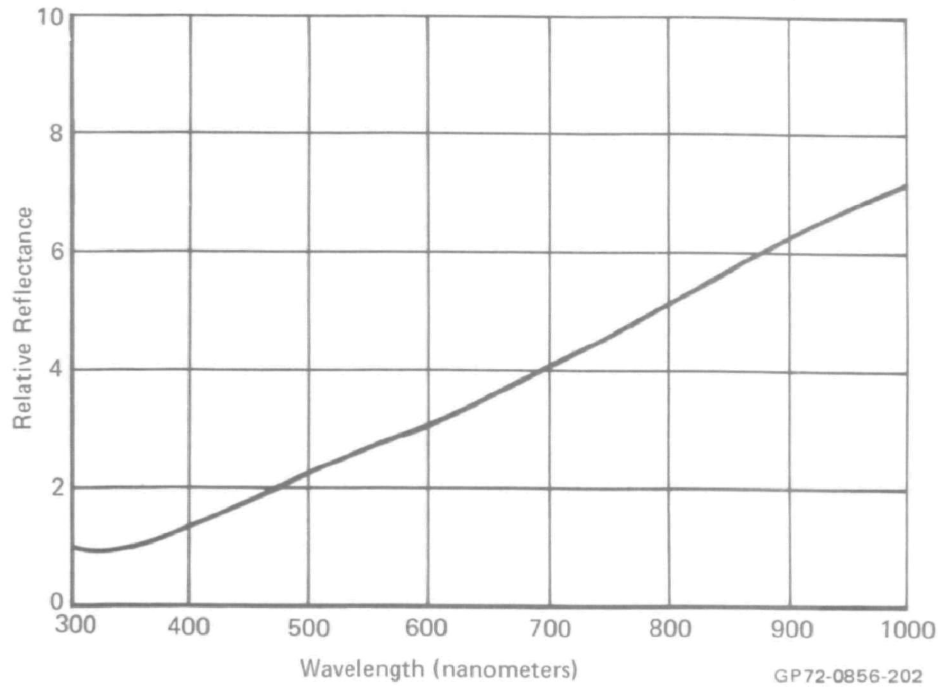

FIGURE 12 REFLECTANCE SPECTRUM OF LIME SLUDGE - SAMPLE 13

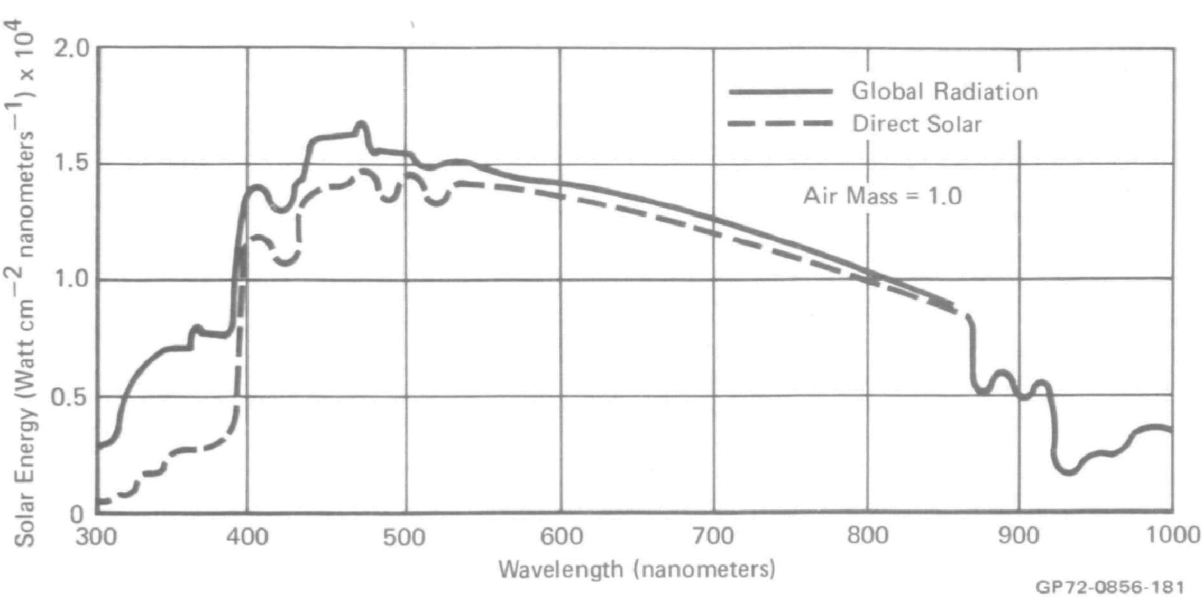

FIGURE 13 SPECTRAL DISTRIBUTION OF THE GLOBAL AND DIRECT SOLAR RADIATION INCIDENT AT SEA LEVEL ON A HORIZONTAL SURFACE

SECTION V
DATA ANALYSIS

All of the data obtained during the experimental program was evaluated for inclusion in the Aerial Spill Detection Key. Those photographs which best depicted specific areas had to be chosen from the hundreds of photographic frames recorded during this project. These photographs were correlated with textual information, flow diagrams, ground truth data, and the sample analyses. This section briefly describes the logical selection and reduction of accumulated data.

Preliminary Analysis

From baseline photographs of the oil refinery areas obtained earlier[1], mosaics of two oil refineries were constructed. A preliminary analysis of the various facilities and equipment was made with the help of the military oil refinery key[2]. One refinery area was also chosen as the representative refinery for the Aerial Spill Detection Key. These mosaics were instrumental in deciding 1) what additional aerial photographs were needed, 2) where samples should be taken, and 3) where ground photographs should be obtained. After the various processing facilities and equipment had been tentatively identified, the appropriate textual information and flow diagrams were assembled with the use of the military keys[2] and other reference sources[3]. In addition, a spill threat evaluation of each of the processing facilities was made based on previous experience[1]. The identifications and spill threat analysis was ascertained during periodic meetings with oil refinery personnel.

Baseline, Oblique and Ground Photography

Baseline photographic frames were selected from the flight program which best exemplified the various processing facilities and pieces of associated refinery equipment. Where appropriate, stereograms were constructed to help the interpreter identify important features that were not discernible from strict vertical photographs. Both the aerial oblique photographs and ground photographs were examined and correlated with selected baseline photographs. The oblique and ground photographs which best depicted the specific features of each processing facility and piece of equipment were chosen for the Aerial Spill Detection Key. The textual information was reevaluated to point out the similarities and differences of the representative oil refinery with other typical refineries.

Multiband Photography

Multiband and color photographic frames containing the processing facilities and disposal areas identified on the baseline photographs were assembled for evaluation. Each area was closely examined for the presence of petroleum spills. Many times, only normal accumulation of petroleum on the ground could be observed. These areas, however, are valuable as examples of the utilization of multiband photography for the detection of petroleum products. In some areas, no petroleum spills or accumulation of oil on the ground was observed. These areas were also included in the key as representations of the use of multiband photography. The results of the sample and chemical analysis, were correlated with the appropriate multiband photographs.

The results of the multiband, chemical, and spectral analyses and ground truth data were compiled into textual information for the oil refinery key. In order to keep these sections relatively simple for interpretation, the detailed analysis of the various film/filter combination were excluded. Instead, generalizations with regard to contrast fluctuations of petroleum spills to a specific background were specified for the various multiband photographs. Sometimes, the overall scenery contrast of one multiband photograph will appear better than that of another, although the text seems to indicate otherwise. This is a result of referring petroleum spills to a specific background and should be emphasized to imagery interpreters. The reflective properties of petroleum and the background were included in each area as they may vary from area to area. The spectral response of the film/filter combinations, however, were referred to an appendix, since they are applicable to all the multiband photographs.

SECTION VI
DISCUSSION

The primary purpose for developing the Aerial Spill Detection Key (Petroleum Refineries) is to provide a reference manual for the imagery interpreter. While an interpreter may be skilled in interpretation techniques, he cannot be expected to identify, from memory, the various processing facilities and equipment of a large variety of industries observed on aerial photographs. Consequently, the appropriate key serves as a reference to refresh or acquaint him with the important industrial facilities and equipment by the use of sample vertical, oblique,and ground photographs accompanied by flow diagrams and brief textual information. The development of the Aerial Spill Detection Key is unique in that it contains not only the information normally found in industrial keys, but is oriented to spill detection. Such orientation is achieved by textual information regarding spill threat analysis, multiband photography, and sample analyses (both chemical and spectral).

Having collected the data for the refinery key, the final step was to organize the key to facilitate the identification and location of oil refinery facilities, equipment, and associated spill threats on aerial photographs. The format of the key was primarily based on that of the military keys. The Aerial Spill Detection Key has been logically organized into the following sections: Introduction, Petroleum Refining, Equipment and Features, Refinery Processes and Support Facilities, References, Glossary, and Appendices. The introduction defines the purpose, contents, and use of the refinery key. A general discussion of the petroleum refinery industry with an accompanying flow diagram of the refining processing system serves to acquaint the interpreter with the basic background of refinery operations. The next section is composed of a collection of ground, vertical, oblique,and stereographic photographs of the equipment and facilities employed in the refinery. The photographs are accompanied by brief statements identifying the structure with respect to an appropriate processing facility. Therefore, if an interpreter cannot identify a particular structure on an aerial photograph, he can refer to this section for help. Upon identification, he is then referred to the processing and support section where additional information is available. This information includes the purpose, process, identifying features, and petroleum products of the processing facility. Examples of oblique, vertical,and ground photographs accompany the textual information. Finally, the application of multiband and color photography, where appropriate, completes each processing and support section. The spill threat analysis of each processing facility is included in the multiband photographic section and points out the need for identifying petroleum spills in order to locate both real and potential spill sources. Examples of color and multiband photographs show the interpreter how petroleum spills can be positively identified and distinguished from other nonhazardous spills.

In addition, the chemical analysis is correlated with the appropriate multiband photographs. The sample spectral reflectance curves are located in an appendix to keep each section as brief as possible. These curves, however, serve a useful purpose since they verify the multiband interpretation and demonstrate the spectral characteristics of various petroleum products and backgrounds. The list of references provides the interpreter with additional sources of information. The glossary contains terminology used in the key that may be unique to refinery operations with which the interpreter is not familiar. The appendices include instructions for determining the heights of objects from stereograms, a nomograph for calclulating storage tank capacities, the multiband film and filter spectral characteristics common to each multiband analysis section and the sample reflectance spectra referenced above. The results can be found in the Aerial Spill Detection Key (Petroleum Refineries).

The development of a key of this type is the first of its kind. A considerable amount of work has been expended in generating and organizing the key for a specific purpose, namely, the detection of spill sources associated with oil refineries. Consequently, the accompanying key should serve as a model for the construction of similar keys for other industries.

SECTION VII
ACKNOWLEDGEMENTS

The work reported herein was performed by personnel of the Reconnaissance Laboratory at the McDonnell Aircraft Company. Mr. Charles L. Rudder was the Principal Investigator on the program. Mr. Albert G. Wallace researched petroleum refinery processing facilities and coordinated the assembly of the Aerial Spill Detection Key. Mr. Charles J. Reinheimer supervised the flight test program and the sample analyses, and was responsible for the multiband photographic analysis. Mr. Erich D. Kassler assembled the equipment key, collected aerial oblique and ground photographs and coordinated photographic reproduction. Mr. Robert E. Thompson, and Mr. Raymond M. Bradley, Jr., are gratefully acknowledged for producing the numerous baseline and color photographs required for the petroleum key. Messrs. William A. Dalton and Joseph L. Berrey are recognized for their participation in collecting the aerial baseline and multiband photographs.

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SECTION VIII

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SELECTED WATER RESOURCES ABSTRACTS

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16. Abstract

An imagery interpretation key of the petroleum industry was developed for use with an aerial surveillance spill prevention system. Aerial baseline and stereogram photographs as well as aerial multiband, aerial oblique, and ground photographs of oil refineries were obtained for inclusion in the key. Processing systems to convert crude oil to fuel and LPG, gasoline, heavy fuel oils, lubricating oils and asphalt were identified with the help of military oil refinery interpretation keys. Three petrochemical facilities within the refinery were also located and identified. The identification of potential spill sources as related to processing systems, product storage and disposition of by-products and waste was performed. The results were confirmed by refinery personnel and included in the oil refinery key. Concurrent with the flight program, fifteen samples of spilled material were obtained along with the appropriate ground truth data. Chemical and spectral analyses of the samples were performed and correlated with the multiband image analysis. Finally the use of aerial photography for temporal change detection was evaluated and included in the appropriate sections of the key.

17a. Descriptors

Petroleum Refineries, Water Pollution Sources, Remote Sensing, Aerial Photography

17b. Identifiers

Photo interpretation, Color Photography, Multiband Photography, Petroleum Products, Spectral Analysis, Chemical Analysis

17c. COWRR Field & Group

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