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METEOROLOGICAL DATA FOR SRI STUDY OF
MESOSCALE WEATHER EFFECTS BY PILOT PLANT

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FOREWORD

This report presents the results of a brief effort to examine the frequency of occurrence of a given set of weather conditions at Daggett, Ca., the site of the 10 MW solar thermal pilot plant. This study was undertaken in response to an action item entitled: "Frequency of Occurrence of Atmospheric Conditions in the Barstow Area", accepted by Aerospace at the SRI Mesoscale Weather Study Review Meeting at SLL on 21 February 1980.

The study was conducted by The Aerospace Corporation under Contract No. DE AC-03-80SF-10800 under the cognizance of Mr. R. Hughey, Director of the Division of Solar Energy, and the general direction of Dr. S. D. Elliott, Program Manager, DOE/SAN.

The author of this study was Dr. Charles M. Randall of the Chemistry and Physics Laboratory at The Aerospace Corporation. This report was prepared by the Energy and Resources Division of The Aerospace Corporation. Mr. S. D. Huffman is the General Manager, and Mr. H. Bernstein is the Group Director. Dr. P. Mathur is the Principal Investigator on this contract.

ATTACHMENT

METEOROLOGICAL DATA FOR SRI STUDY OF
MESOSCALE WEATHER EFFECTS BY PILOT PLANT

by

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ABSTRACT

The data required to estimate the probability of occurrence of initial meteorological conditions leading to an effect on the weather by the pilot solar thermal electric plant are discussed. No completely appropriate data summaries are available. Vertical atmospheric profiles are the most appropriate source of raw data for a statistical analysis, but these are not available from the pilot plant location either. The available stability data for the pilot plant site are presented. A procedure is outlined to obtain the required estimates of occurrence frequency if desired. However, it is recommended that more substantial effects be demonstrated with a physically realistic model before great effort is expended on data analysis.

Chandrakant Bhumralkar of SRI International in Menlo Park has been studying the possible effects of the Daggett solar thermal electric pilot plant on the weather. These studies are being conducted with a 2 dimensional (vertical plus one transverse dimension) computer model. Power plant effects are investigated by selecting a set of initial conditions to describe the atmosphere at 9:00 A. M. The model is then used to compute the atmospheric conditions during the day proceeding from the selected initial conditions. Parallel runs are made with, and without the power plant present. Differences between the results of these parallel runs are then attributed to the power plant.

On 21 February 1980 Bhumralkar presented a progress review of this study at Sandia Livermore. Most cases considered with the model to date have shown the power plant to have little or no effect on the mesoscale weather. However, in one case the presence of the power plant was shown to trigger the formation of clouds and rain. The initial conditions for this case were intentionally chosen to try and stimulate an effect, and not because they necessarily represented actually occurring conditions. During the discussion at the review the need to determine the frequency of such conditions was addressed. The Aerospace representative at that review, Phil DeRienzo, agreed to find out what information Aerospace might be able to supply relating to the frequency of occurrence of the initial conditions leading to cloud formation when the power plant was present. This question was referred to me, and my response is contained in this report.

By reviewing copies of Bhumralkar's viewgraphs for the 21 February meeting and talking with him personally by phone on 21 March 1980, I believe that three essential initial conditions were present simultaneously for the model to predict pilot plant induced effects.

1. Almost unstable atmospheric conditions.
2. A layer of high humidity (80% RH) air overlaying the entire region at an altitude of 800 m above the surface.
3. Direct insolation so the pilot plant is operating.

To assess quantitatively the probability of the simultaneous occurrence of these initial conditions would require first a quantitative description of the range of conditions deemed critical. Then the simultaneous occurrence of all three required conditions could in principal be determined from meteorological records, if the required records were available. No statistical review of the available meteorological data has been performed which provides the required simultaneous probability. In fact the meteorological records which are available would require significant processing to determine this simultaneous probability, as we now discuss.

The ideal data base to make an assessment of probability does not exist. This ideal data base would consist of a long history of daily vertical atmospheric soundings from Daggett at 9:00 A. M. (the model start time) to determine the vertical temperature and humidity profiles, together with insolation data for the same days. Humidity data is required directly as an initial condition for the model. The stability of the atmosphere refers principally to rate of temperature change with increasing altitude in the atmosphere, (the lapse rate). If the decrease in temperature with altitude is sufficiently rapid, then if a parcel of air initially at equilibrium with its surroundings begins to move upward adiabatically it will be less dense than the surrounding and therefore continue to move up. The atmosphere is said to be unstable. Unfortunately, vertical soundings are not available for Daggett at all and the insolation data only go back four years, hardly adequate for a search for extreme conditions.

One approach to this lack of vertical atmospheric profiles for Daggett would be to use data from the nearest climatologically similar site.

Routine atmospheric soundings are currently made once per week day at about 2:00 A. M. local standard time from Edwards AFB about 65 miles west of Daggett. If these soundings were to be used either the SRI model would have to be initialized at 2:00 A. M. rather than 9 or some means developed to extrapolate the soundings forward in time to the 9:00 A. M. starting time of the SRI model. The spatial distance between Daggett and Edwards could be

considered either by using the Edwards sounding to estimate what a Daggett sounding might have been, or by assuming, for the purposes of this model, that the pilot plant was at Edwards, in which case insolation data for Edwards would be needed. Insolation data exist at least for the last few years from Edwards.

Another approach is to use the hourly surface observation by the FAA at the Daggett airport. These go back to 1948 in computer compatible format. Because of the general paucity of routine vertical atmospheric soundings, procedures have been developed to provide a qualitative estimate of stability based only on surface observations (Ref. 1, 2). These procedures have been used with a 10 year sample of the Daggett data for air pollution analyses to evaluate the simultaneous occurrence frequency of stability classes with wind direction. (Ref. 3) The stability classes are defined in Table 1. The frequency of occurrence of each stability class during the ten year period was extracted from Ref. 3 and is provided in Table 2. If conditions included in C and D ("slightly unstable" and "neutral") all correspond to "unstable" initial conditions in the SRI model, then one of the three required initial conditions may be fairly common. Such a tentative possibility should be accepted with caution until the meaning of "unstable" in the SRI model and "neutral" and "slightly unstable" in the Pasquill classification scheme are defined in the same quantitative terms. The different time base also may be significant. The SRI model requires values at 9:00 A.M. only. The NOAA (Ref. 3) computations include 24 hourly values each day.

The frequency of occurrence of initial condition 1 and 3 could in principle be estimated from the Daggett meteorological data once the required translation between the Pasquill stability classes and the SRI stability requirement is quantitatively defined. This could be reduced to a computer code and used to process the FAA data base.

An estimate of second initial condition would be more difficult, and it is probably the most unusual of the required conditions. High humidity over the normally dry desert can occur only if moist air can get to Daggett. One source of such air is the Pacific Ocean but the air must get through the normal inversion layer in the LA basin and get over at least Cajon Pass (elev. 4200 ft) or the San Bernardino mountains. Another, and less likely source of moist air, but one which does happen, is moist air moving into the Daggett area from the East or the Gulf of Mexico. The probable presence of moist air aloft either from the Pacific or Gulf could probably be identified by a meteorologist from synoptic weather data. The results of this estimation could then be combined with analysis of the Daggett surface observations for the same time period.

In considering the humidity the local environment of the plant might be important. The prevailing surface winds are from the west. Immediately upwind under these conditions are more than 100 acres of open water surface in the existing evaporation pond adjacent to the pilot plant site. Further upwind are the alfalfa ranches in the Daggett area. To the west of Barstow there are additional irrigated agricultural areas along the Mojave river. If the flow were right, air from the irrigated agricultural areas in the Antelope Valley around Lancaster could also reach the Daggett area without going over any high mountain ridges.

The importance of the answer should be established before embarking on such an expensive data analysis procedure. SRI's present results are interesting, but hardly predict earth shaking meteorological consequences of power plant operation. Initial conditions as severe as seemed physically plausible produced a localized rain shower in the area of the power plant under conditions when thunderstorms might well be occurring in the general area anyway. Furthermore, as Bhumralkar is quick to point out, the present results are due to a two dimensional model which precludes air motion around mountains or channeling of air through canyons and valleys. This is hardly a satisfying model to use in a valley on the lee side of mountains with peaks extending to 11,500 ft. A 3 dimensional model predicting the

occurrence of significant precipitation (or other phenomena) over a wide area which would be a much more compelling reason to pursue further the determination of the frequency of occurrence of the required initial conditions.

The components of the pilot plant including the perturbation should be identified. Is it the solar peculiar components of the plant, (i. e., heliostats and hot receiver on a tower) or the conventional components (i. e., wet cooling towers) which lead to the effects? If it is the cooling towers, then the 10 MW pilot plant can make only a negligible impact when compared to the existing 600 MW, fossil fueled plant at the site which also uses wet cooling towers and has an enormous evaporation pond. Considering the pilot plant as a whole its thermal effect on the environment would be expected to be less than a fossil plant since almost all of the solar energy incident on the plant area is in fact dissipated within the plant area, in contrast to a fossil plant which represents a huge source of thermal energy. For example near noon on a summer day the 600 ft. radius pilot plant receives about 364 MW of solar radiation. Of this a maximum of 10 MW ($\sim 3\%$) actually leaves the plant site. Consider by contrast the nearby fossil fuel plant generating 500 MW_e at an efficiency of 33% will be adding 1000 MW of thermal energy to the environment at that point.

SUMMARY AND RECOMMENDATIONS

SUMMARY:

There are no available data summaries which provide the frequency of occurrence of the initial conditions identified which lead the SRI 2 D model to predict the occurrence of showers due to pilot plant operation.

The best type of data for the determination of occurrence frequency, namely vertical atmospheric profiles at 9:00 A. M. plus simultaneous daily insolation values, are not available for Daggett.

A procedure to use available Daggett data to estimate the frequency of occurrence of the required initial conditions has been outlined in this report.

An alternative to the use of Daggett surface data is the analysis of vertical atmospheric soundings from Edwards AFB and made at 2:00 A. M.

RECOMMENDATIONS:

1. Demonstrate with a realistic physical model that there is a meteorological effect due to pilot plant operation associated with the plants solar energy source and further that the effect has sufficiently significant economic or safety considerations to justify estimates based on the available raw data.
2. Analyse the available raw data, if a significant effect of pilot plant operation is demonstrated. This analysis could be carried out with the following steps.
 - a. Establish a quantitative correlation between the atmospheric stability criteria used by the SRI model and the procedures to estimate stability from surface observations, such as Ref. 1.
 - b. Establish the quantitative range of initial conditions in the SRI model leading to significant meteorological effects.

- c. Determine the synoptic conditions leading to moist air over Daggett.
- d. Obtain the required synoptic data to determine the dates of every occurrence of these conditions at Daggett at the required time of day for a period of 10 years or more.
- e. Count the number of occurrences when all three conditions were satisfied simultaneously.

Table 1.

Stability Classes Used in Analysis of
Stability for Daggett California Data

Stability Class	Pasquill Category	Description
A	1	Extremely Unstable
B	2	Unstable
C	3	Slightly Unstable
D	4	Neutral
E	5	Slightly Stable
F	6-7	Stable to Extremely Stable

Table 2.

Frequency of Occurrence of Atmospheric Stability Classes
For January 1955 Through December 1964
At Daggett California
(Ref. 3)

Stability Class	Winter December January February	Spring March April May	Summer June July August	Fall September October November	Annual
A	0.7	2.6	4.8	2.5	2.7
B	5.7	6.0	8.7	7.6	7.0
C	11.7	12.9	16.8	12.6	13.5
D	36.5	57.0	48.1	35.8	44.4
E	19.0	14.1	17.4	22.5	18.2
F	26.4	7.4	4.2	19.0	14.2

REFERENCES

1. F. Pasquill, "The Estimation of the Dispersion of Windborne Material", Meteorology Magazine 90, 33-49 (1961).
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3. National Climatic Center, "Seasonal and Annual Wind Distribution by Pasquill Stability Classes (6) Star Program, for Station 23161, Daggett California", 9 February 1972.