to whether individual tree heights as obtained from differential parallax measurements on aerial photographs can be depended upon to furnish a desired accuracy in timber volume estimates. Of course, the average of repeated measurements on the same trees, or from a practical standpoint on say 25 different trees in the stand for the purpose of obtaining the *stand* height, would yield a figure that would be within the range of accuracy and probability mentioned above. The findings are based on the measurements of one man, using one set of instruments on photographs taken on infra red film with a red filter by a camera with a 12 inch focal length and at a flying height of about 9,600 feet over an area of mixed hardwoods and softwoods in Massachusetts. Any factors other than these could cause a variation in the findings.

As can be realized need exists for a great quantity of basic information. Any suggestions regarding the reasons for the increase in the standard deviation with the height of the tree, or other means of approach, will be greatly appreciated.

THE HOTSPOT IN WIDE-ANGLE PHOTOGRAPHS

Bert Mason Jr., Box 292, Oak Grove, Oregon

ABSTRACT

The phenomenon known as "hotspot," "no-shadow-area," or "hazy spot" in wide-angle vertical aerial photographs contributes greatly to increased mapping costs and lower map accuracy. The spot is caused by absence of shadows and by halation near the prolongation of a line from the sun through the exposure station. Its major effect is the destruction of fine image detail over a considerable portion of the wide-angle photograph. It is not a serious problem in normal or narrow angle photographs in the temperate zones. The most practical method of overcoming the hotspot is to avoid it. The position of the hotspot on the photograph at any given time may be accurately predicted and flights may be planned to avoid it.

I. INTRODUCTION

THE "hotspot" in wide-angle photographs is a phenomenon which, in the author's opinion, may increase the cost of some mapping projects 30 per cent or even more. Little, if anything, has ever been published with regard to the hotspot, and the author has found that many leading photogrammetrists were unaware of its existence or of its economic effect. Ryker is known to have referred to its hindrance to forest interpretations in the 1930's, but no subsequent reference has come to the author's attention until December, 1952, when Beltman[1] and Spurr[2] mentioned it briefly during discussion of shadows on aerial photographs.

The phenomenon has been referred to as the "point-of-no-shadows," "no-shadow-area," and "hazy spot," among other things; but among the author's associates the term "hotspot" has been adopted as a handy expression and is sufficiently explicit for practical purposes.

It is believed that some of today's leaders in photogrammetry may be unfamiliar with the hotspot because they transferred from direct everyday contact with photographs to administrative positions at about the time normal-angle photography was supplanted by wide-angle for topographic mapping. The effect of the hotspot is rarely noticed in 8¼ inch and 12 inch focal length photographs in the latitudes of the United States. Stereoplotter operators of today are aware of the spot, but apparently few know the cause or what can be done about it.

II. CAUSE OF THE PHENOMENON

The hotspot is caused by that portion of the sun's rays which is directed back toward its source by diffuse reflection from objects on or near the prolongation of a line from the sun through the exposure station of the photograph (Figure 1A and 1B). The shadow of the aircraft always

[1] Beltman, B. J., "Shadows on Aerial Photographs," PHOTOGRAMMETRIC ENGINEERING, Dec., 1952, Vol. XVIII, No. 5, p. 831.

[2] Spurr, S. H., "A Further Note Concerning Shadows on Aerial Photographs," *loc. cit.*, p. 833.

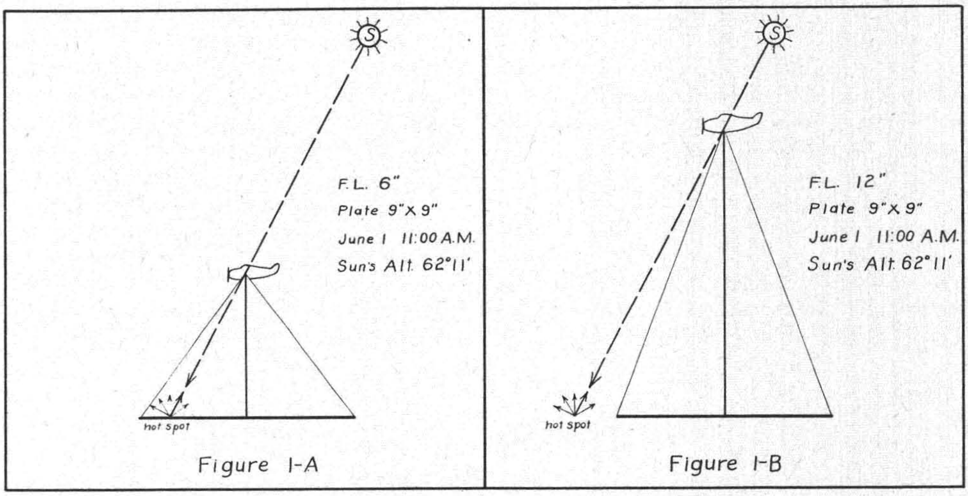


FIG. 1A and 1B. Location of hotspot.

falls exactly at the point of greatest intensity of the hotspot and may be readily identified in 6 inch focal length photographs of open ground made from altitudes up to 1,500 feet above the terrain. It is truly a "point-of-no-shadow," for every object near the line through the sun and the exposure station conceals its own shadow from the camera.

The hotspot always occurs in vertical photographs made when the sun is shining brightly and the tangent of the sun's altitude is equal to or greater than the camera focal length divided by one-half the shortest dimension of the plate. For example: using a 6 inch focal length lens on a 9×9 inches plate the hotspot will always appear when the sun is higher than approximately 53° 05′ above the horizon, and it will occur in the corners when the sun is as low as approximately 43° 17′.

$$\text{sun's alt.} = \tan^{-1} 6''/4.5'' = \tan^{-1} 1.33 = 53° \, 5'$$
$$\text{sun's alt.} = \tan^{-1} 6''/6.38'' = \tan^{-1} 0.942 = 43° \, 17'$$

Using a 12 inch focal length lens on a 9×9 inches plate, the computation becomes

$$\text{sun's alt.} = \tan^{-1} 12''/4.5'' = \tan^{-1} 2.67 = 69° \, 28'$$
$$\text{sun's alt.} = \tan^{-1} 12''/6.38'' = \tan^{-1} 1.88 = 62° \, 00'$$

Since at latitude 45°, the sun never reaches an altitude of more than $68\frac{1}{2}°$, it is apparent that in the latitudes of the United States the hotspot is seldom a problem in 12 inch focal length photography.

Although the hotspot is always present under the conditions above specified, it may not always be readily apparent. Appearance is dependent upon atmospheric conditions and the cover of the area photographed. Obviously, the hotspot does not occur under an overcast, for there is no point-source of illumination. Light or moderate haze has little apparent effect other than to make the exact center of the spot less definite. Relative humidity has no noticeable effect. The author has noted the hotspot at full intensity on the semi-arid plateaus of eastern Oregon and Washington, Arizona and New Mexico, in the rainforests of the Cascades and Coast Ranges of the Pacific Coast, on the islands of the Pacific, in Central America, Florida, Central Europe, and elsewhere.

III. Effect of the Phenomenon

By far the most important effect of the hotspot is the destruction of photographic detail through halation. A clever laboratory technician may burn in the affected area (Figure 2A and 2B) on prints or diapositive plates to make it less apparent; but he can never restore the lost photographic detail which is so essential to topographic plotting. Highly competent Multiplex operators have repeatedly found themselves unable to locate the ground surface in the affected area within three or four contour intervals when working at a "*C*" factor of 1:700. In some cases it is very difficult to use wide-angle photographs in mosaics because of the hotspot.

The ultimate effect of these difficulties is to increase greatly the cost of mapping. If

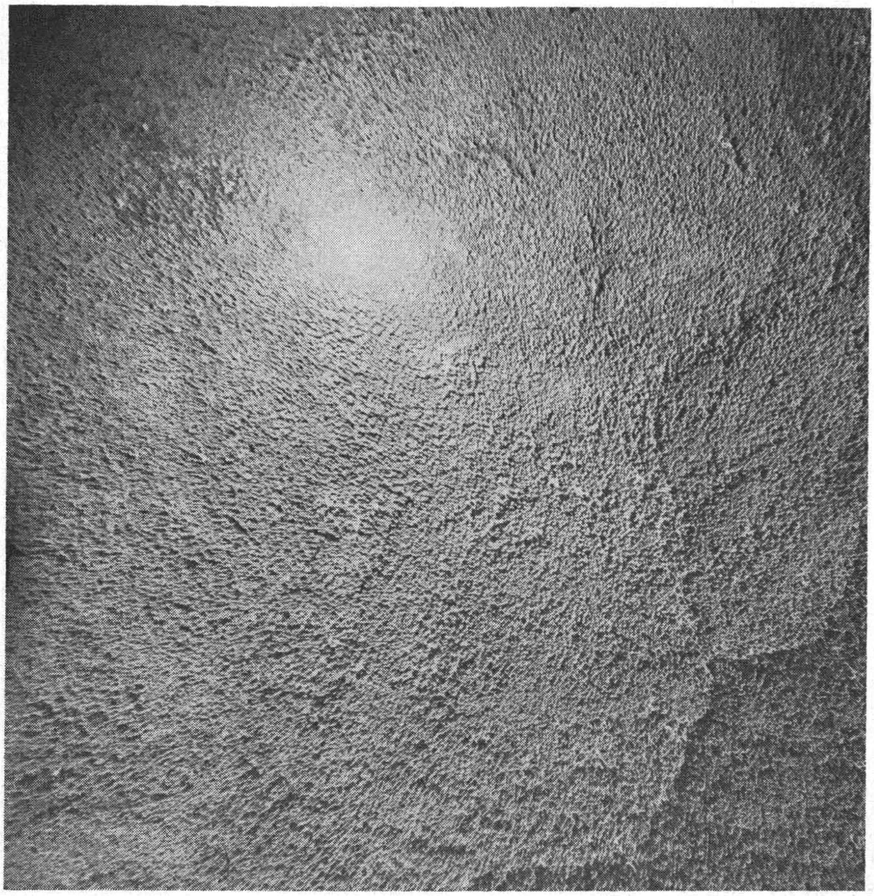


FIG. 2A. A straight contact print from 1/12,000, negative made with 6″ F. L. lens. Time 11:10, July 14. Approximate latitude, 46° 30′ N. Approximate longitude, 122° 30′ W. Hotspot is in the northwest quarter of the photograph.

allowance for the spot is not made in flight planning, much reflying may become necessary. A far greater amount of sidelap than would be otherwise required is often needed. A greater amount of control is required. The number of flying hours per day must be restricted if the spot is to be avoided. The spot cannot be ignored if consistently accurate mapping is the goal.

IV. MEANS OF OVERCOMING THE PHENOMENON

The most obvious and most effective means of overcoming the spot is to photograph under a high overcast. Of course, the difficulties of ordering a high thin overcast at the photographer's convenience relegate the opportunity for this solution to the realm of luck. The superlative photography for the mapping of wooded areas which is secured under overcast indicates that halation, rather than lack of shadows, is responsible for the photogrammetrist's difficulties.

The possibility may exist of eliminating or reducing the spot through physical means such as filters or polarization, etc. This would be a project for the physicist rather than for the practicing photogrammetrist, who has few funds to spend on extensive experimentation.

The practical solution of the problem, which has been developed by the author and his associates, is to predict the position of the hotspot and to avoid it. Certain statements may be made as to the position of the hotspot in the photograph:

1. In photographs made north of latitude $23\frac{1}{2}$°N, the spot will occur only in the northern half of the frame; in the southern

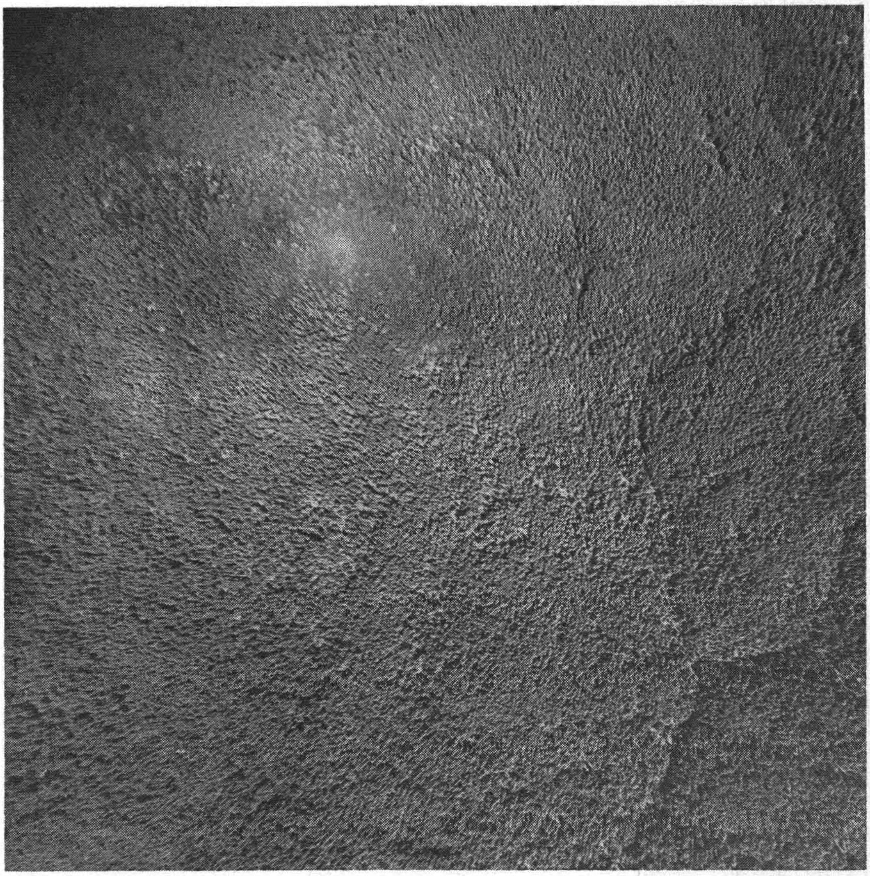


FIG. 2B. A print from the same negative as Figure 2A, but dodged to minimize the hotspot.

hemisphere, it will occur in the southern half of the frame.

2. In photographs made in the morning, the spot will appear in the western part of the photograph; and in the afternoon it will be in the eastern portion.

3. The point of greatest intensity will be distant from the principal point by an amount equal to the cotangent of the sun's altitude times the camera focal length; or Distance = F(cot Altitude).

4. The flying height of the aircraft has absolutely nothing to do with the position of the spot.

In consideration of these facts and utilizing the fundamental equation of spherical trigonometry[3] giving the relation between the altitude, latitude, declination, and hour angle, and with the equation for azimuth,[4] the author has prepared a series of diagrams (Figure 3A and 3B) showing the position of the hotspot in 9×9 inches photographs made with a 6 inch focal length lens throughout the photographic period of the 1st and 15th day of each month during which the spot must be considered. These diagrams were prepared for the latitude and longitude of Portland, Oregon, and for practical purposes are applicable to the entire states of Oregon and Washington. They are to slide-rule accuracy, and this is sufficient. Other diagrams are easily made up for any chosen latitude and longitude. The diagrams are made as though the photograph were oriented with its sides parallel to cardinal directions. In planning flights in directions other than North-South or East-West, it is convenient to place a square frame over the diagram and to orient it in the proper direction to study the placement of the hotspot.

[3] $\sin h = \sin D \sin L + \cos D \cos L \cos t$.

[4] $\tan Z = \sin t / \cos L \tan D - \sin L \cos t$.

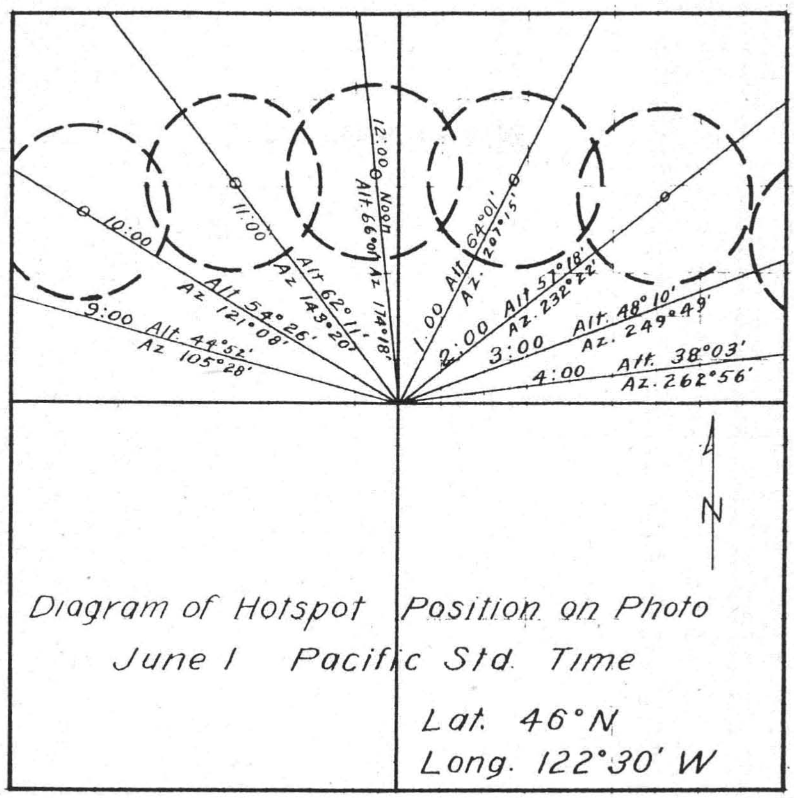


Figure 3-A

A study of the diagram for June 1 (Figure 3A) brings out a few highly important considerations in flight planning:

1. If N-S flights are to be flown, the best hours of the photographic day must be sacrificed; for if flights are made between 11:00 A.M. and 1:00 P.M., the center of every model will be worthless, and greater than 60 per cent sidelap will be necessary to obtain satisfactory coverage.

2. If N-S flights are made, flying must be begun at the west side (if the flying requires more than half a day) and must progress easterly throughout the day. If flying is begun on the east side, the hotspot will cover the same detail in the westernmost morning flight as it covers in the easternmost afternoon flight (Figure 4A) and an expensive reflight will be required. This has actually happened to contractors who were flying for the author's organization.

3. If E-W flights are made, the entire photographic day may be utilized, but sufficient sidelap must be maintained so that the hotspot area of each flight may be covered by the flight to the north (Figure 5). The diagrams permit pre-determination of the required sidelap for any date of photography (Figures 3A and 3B).

4. If random flights are made, as in many highway projects, the correct time of day should be chosen from the diagram for each azimuth of flight (Figure 6). It will be noticed that with narrow mapping areas, shifting the center of the flight line may sometimes be resorted to in avoiding the hotspot if its position has been predetermined. In other cases, it may be necessary to make two flights where one would have sufficed if the hotspot did not exist.

5. If the latitude and longitude and direction of flight of the project are known, the date and time of day of photography

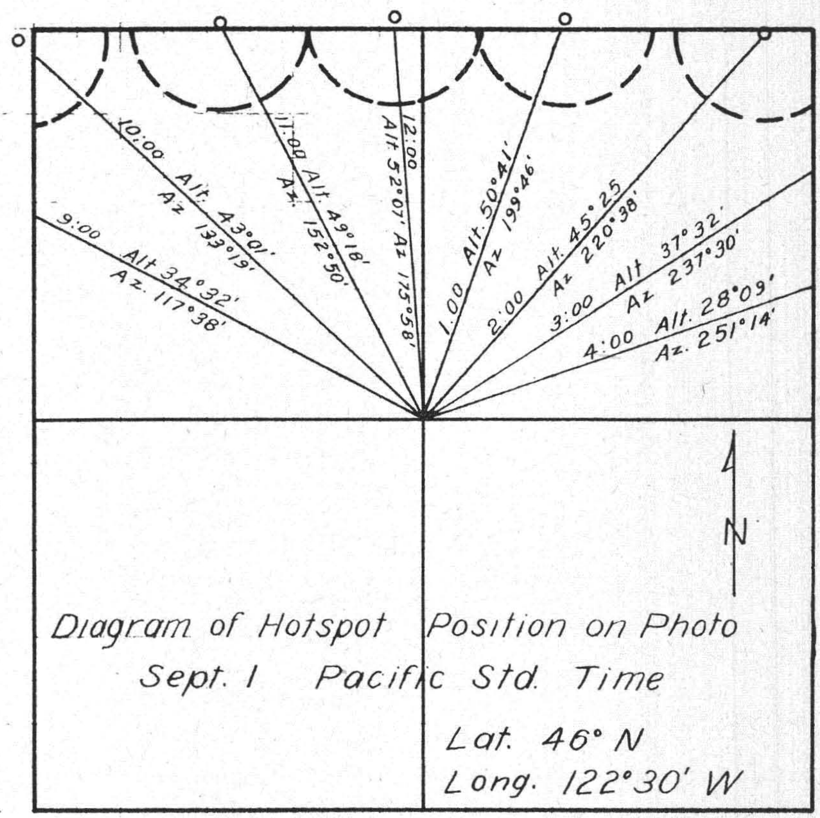


Figure 3-B

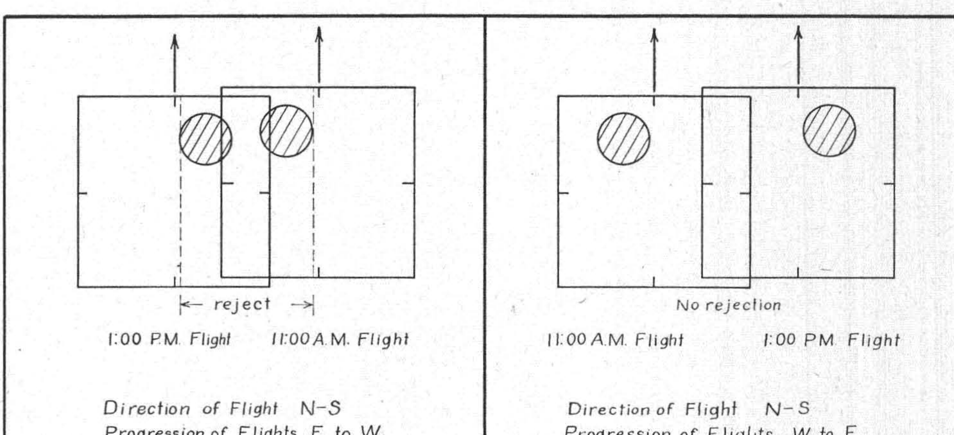


Figure 4-A

Figure 4-B

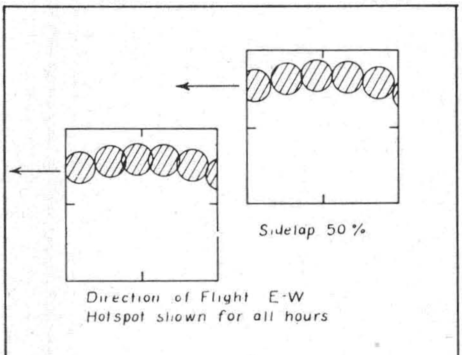


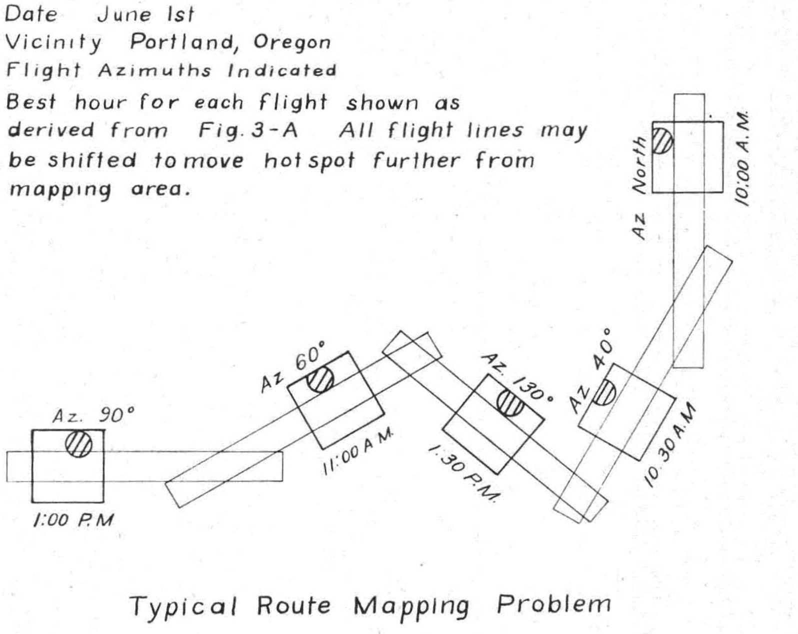
Figure 5

may be determined. Likewise, if the latitude, longitude, date, and hour are known, the azimuth of flight may be determined and large tilts may be roughly analyzed.

An example is included (Figure 6) to show the method of flight planning for a typical highway mapping job. The date is June; the location is near Portland, Oregon. The indicated plan will undoubtedly be frowned upon by the flight contractor, but will be heartily approved by the stereoplotter operator or mosaic artist. Where there is an option for the time of flight, that one has been shown which would best fit the convenience and economy of the flight contractor.

V. Conclusion

It is believed that in the past the hotspot has been largely disregarded in photogrammetric contracts and flight planning because its economic effect has not been appreciated and its cause and solution have not been sufficiently investigated. Once the simplicity of the solution of the problem is appreciated, greater economy and accuracy should result.



Typical Route Mapping Problem

Figure 6