PHOTOGRAMMETRY AS APPLIED TO PIPELINE LOCATION*

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CONSTRUCTION of pipelines to carry oil from field to refinery may seem commonplace. However it is a modern day revolution in transportation. With more than 175,000 miles of oil and petroleum products pipelines in operation today, at least one-third of these has been constructed within the past ten years. Even with the heavy defense demand for steel, some 16,000 miles of line have been constructed within the past two years.

The use of aerial photography in the search for new sources has introduced the geologist and petroleum engineer to aerial photography. Geological field parties are consistently traversing and mapping remote corners of the world defining structural anomalies and contacts. Gravity meter-magnetometer surveys have been making use of the aerial photograph for several years with the aerial photograph playing an important part in reducing the mapping effort formerly conducted by geologists. The discovery of new fields in Arabia and Alberta has created major location problems in establishing modern turnpikes to the refineries.

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During the past eleven years the Company's engineers have been responsible for the location and mapping of pipeline routes in terrain varying from the Canadian Rockies to the deserts of Saudi Arabia. Pipelining was responsible for making evident the advantages obtainable from photogrammetry.

In 1942 the Company was retained to establish the route of the Big Inch pipeline beginning at the Arkansas-Missouri border and extending through Pennsylvania. During this work the Little Rock District Corps of Engineer office was of great assistance in furnishing information on river soundings and control data. It was here that a stereo model and the application of photogrammetry was first seen. Although time did not permit making use of the Multiplex type of compilation, it was evident that this procedure had endless possibilities.

The selection of a pipeline route is controlled by several factors. It is assumed that the through-put requirements of the line and the terminal sites, as well as the physical characteristics of the crude oil or product to be transported, have been furnished by the owner.

Climatic conditions are a real factor in design. It is interesting to note that in a surface pipeline now operating in Venezuela, the viscosity of the oil transported is such that after tropical rains the surface of the pipe cools to such a degree that the oil jells and pump stations must shut down until the sun sufficiently heats up the crude oil.

Although soil conditions, gradients, safety, climate and many other factors

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have a direct bearing on the design and location of a route, the discussion in this paper will be limited to those conditions which may be controlled by modern mapping techniques and photogrammetry.

Probably the most important requisites to the location of an economical pipeline are as follows:

1. Following the shortest practicable route from field to refinery.
2. Avoiding extreme differences in elevation.
3. Accessibility for both construction and maintenance of the line.

To demonstrate the use of stereo plotting equipment, a hypothetical pipeline operation will be explained.

The initial phase in route selection is to acquire all available source material including topographic, highway, railroad, geologic, tidal and weather maps of the projected line together with existing aerial photographic coverage. The new strategic maps being prepared by the Army Map Service will be of inestimable value in collating the source material and reconnaissance data.

Evaluation will readily make evident the major control points including river crossings, by-passing of large cities and passes through mountainous terrain. Several alternate routes are then selected and a preliminary field reconnaissance is made, preferably in a light, slow plane or helicopter. This aerial investigation will eliminate all but possibly two or three routes.

The next phase is a detailed reconnaissance by a team of petroleum, location and construction engineers. Their experience in evaluating construction costs and methods over varying types of terrain will reduce the alternates to a narrow area normally two miles in width. When this decision has been made, flight lines can be defined and aerial photography obtained for the entire route, the prime purpose being to prepare maps at a scale of 1 inch to 1,000 feet in open areas and 1 inch to 200 feet in built-up areas.

It has been found that the use of an enlarged photo index at an approximate scale of 1 inch to 1,000 feet will effect material savings in time and cost over the uncontrolled mosaic and the index is generally of equal value in selecting long tangents of line.

The location engineers and geologists are then in a position to make an over-all stereoscopic study of the area and to define a tentative route on contact prints. On a recent line running through Eastern Canada, it was possible to effect material savings in the cost of the trenching process by having the geologist define soil conditions on the contact prints. Since the trenching operation can account for 30 per cent of construction costs, several hundred thousand dollars were saved on this 360 mile line.

The forester also can contribute especially where clearing can be a vital factor. On the Trans Mountain Pipeline between Edmonton and Vancouver, Canada, several areas were encountered where the cedars averaged 5 feet in diameter and created serious clearing problem because there were relatively no access roads and governmental statutes required the removal of this timber from the area. The forester's inventory has eliminated a great deal of field study by the construction engineer, and has afforded him an accurate estimate on which to base his construction methods and costs. Definition of swamp areas can also be discerned from the contact prints.

With the line established, the next and final step is the preparation of accurate planimetric maps supplemented by a profile of the route. These maps serve two purposes.

The first purpose is to delineate in detail the most practicable route in such a manner that angles and distances can be accurately measured. This makes possible sending this map into the field for use as an instruction sheet by the survey party. These maps show roads and drainage patterns for a two mile width; however, complete planimetric detail is afforded for a one mile width along with a profile of the projected route.

Areas where unavoidable sidehill construction or other construction problems may require alternate studies are contoured at a 10 foot contour interval. Contour information has been used for field orientation through extensive wooded areas lacking planimetric detail. Important river crossings as well as projected pump station sites invariably require complete topography.

The second purpose of these maps is to provide the right-of-way department with sufficient information so that it can immediately begin the necessary title searches and obtain all options, easements or permits. It is desired that this be done in advance of the survey operation. The scope of information afforded by these maps is so complete that the problem of realignment in the field is reduced to a minimum.

It has been found that the long bar Multiplex is helpful in making studies of long tangents of line. Upon completion of triangulation the location engineer using the projected stereo image, along with his first-hand knowledge of the construction problem gained during the reconnaissance phase, delineates the final route. His decision is also based on the requirements of State Highway departments, railroad companies and other utilities insofar as casing requirements at crossings are concerned. These critical points together with important river crossings are selected on the stereo model and are connected with the best possible line through utilizing the visual profile on the Multiplex table.

Through taking advantage of the terrain the petroleum engineer can be assisted in determining the hydraulic gradient. As the thickness of pipe used in a given area is dependent on this hydraulic gradient, a saving of hundreds of thousands of dollars can be made on a major pipeline where the terrain lends itself to a change of elevation by a lateral movement of pipe.

It may be well to point out that the average contruction cost of a 30 inch pipeline today may be in the neighborhood of $75,000 a mile with the cost of the pipe accounting for approximately $50,000 per mile. The effect of a reduction in pipe thickness can be readily seen.

Employing these methods the pipeline division is receiving these maps at a rate of 200 miles per month.

Among the discovered advantages for this procedure the following are outstanding:

1. Decisions of all major and minor route locations are made by experienced engineers working efficiently in an office instead of the more arduous covering of hundreds of miles on the ground. The field investigation is thus limited to small areas in making the few questionable decisions in critical areas which may have been arrived at in the stereo operation.

2. Complete maps are prepared and used by the right-of-way department far in advance of the ground survey party, with a minimum of disturbance to surrounding property owners.

3. Ground survey is conducted more efficiently because the right-of-way is secured in advance of the survey. Nearly all realignment is eliminated and field surveys can be scheduled for favorable weather conditions without delaying office design or mapping.

4. The use of the maps by the designer, right-of-way man, surveyor and contractor eliminates the confusion attendant to the use of a miscellaneous collection of photographs, State and County maps, geological data and other source material.

5. Preparation of railroad, river and utility crossing drawings needed for submission

to authorities are not dependent on the field survey; the issuance of all permits is thereby expedited.

This method is believed to be an improvement in pipeline location procedure offering savings not so much in actual survey costs as in the more important fields of good route location, general co-ordination of the project and avoidance of construction delays affecting scheduled completion.

FOREST SERVICE PROCEDURE OF UTILIZING HIGH AND LOW ALTITUDE PHOTOGRAPHY IN ITS COMPANION-INSTRUMENT PHOTOGRAMMETRIC PROCEDURE*

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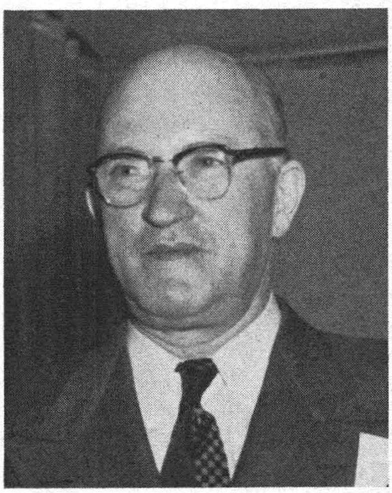
FOR an understanding of the work of the U. S. Forest Service, particularly as it applies to photogrammetry, it is desirable to outline briefly its many responsibilities and interests that are vitally concerned in the application of the science of photogrammetry. It is strongly believed that the Forest Service, with its diverse activities, has probably profited more from photogrammetry than any other civilian agency.



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The U. S. Forest Service is responsible for the management of more than 180,000,000 acres; this amounts to approximately 10 per cent of the area of the continental United States. This involves the administration of 150 national forests located in 40 states, Alaska and Puerto Rico (Figure 1). The agency is faced with many management problems within this vast forest domain. Briefly some of them are: The prevention, detection and suppression of forest fires. Management of national forest timber, which includes inventory surveys, insect and disease control, timber stand improvement, and timber sales. Wide public use of national forests requires recreational planning, special use planning, mining claim adjustments, and the management of game and fish resources. To utilize grazing lands within the national forests, it is necessary to prepare range inventories for revegetation and resource conditions, and to plan and administer range allotments. There are also problems of land acquisition, land exchange and boundary surveys. Sound management of forest water resources requires the study and survey of dam and reservoir sites, irrigation layouts and power development. Travel within the forests requires the survey and construction of many thousands of miles of roads and trails.

Each of these operations, vital, not only to the Forest Service, but to the

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