A SEISMIC TECHNIQUE FOR FINDING SMALL OIL FIELDS

By

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ABSTRACT

A seismic method designed specifically for locating small oil fields is described. It utilizes correlation shot points in the initial stages, and common depth point continuous lines later. An alternate way to obtain the correlation control is described in an appendix.

PROBLEM

The search for oil is currently leading to smaller features than ever before, and creating a need for special techniques to find them.

In a number of areas, highly productive anomalies are quite small in area, often occupying less than a quarter section. Pinnacle reefs and the Hummingbird salt collapse situation are examples.

The usual way of seismically exploring for oil was developed in seeking large structures. It involves shooting along section lines or roads, locating a high area, and drilling anywhere in that high area.

This method is well adapted to the large structures, but does not fit the special requirements of small features. Consider the currently-normal manner of exploring for them.

The common depth point technique requires that long straight lines be shot. Economics, at least in the reconnaissance stage of shooting, dictate that the lines be fairly far apart. Thus, there may be, say, two lines several miles apart, each having several anomalies. Fig. 1.

This situation brings up questions. Are there more anomalies between the two lines? There must be. Are the more prominent-appearing features actually larger, or did the lines happen to cross them nearer their highest parts?

If efforts are concentrated on the prominent-appearing features, better ones, even though already detected, may be ignored. If more lines are shot through centres of quarter sections, the needed answers will be found, but at greater expense. Fig. 2.

The economics can be improved by shooting the original lines through centres of quarter sections, rather than along section lines. Then adequate coverage can be obtained with lines a half mile apart. Fig. 3.

REQUIREMENTS

Small features have three special requirements, dictated by their size:

1. Reconnaissance shooting should comprise a fine enough mesh to not overlook the features.

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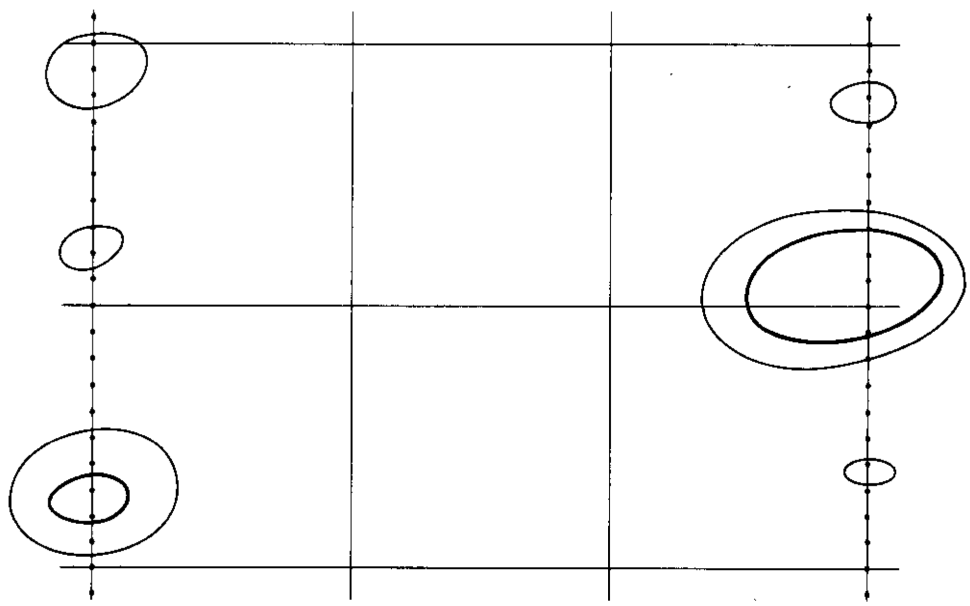

FIG. 1.

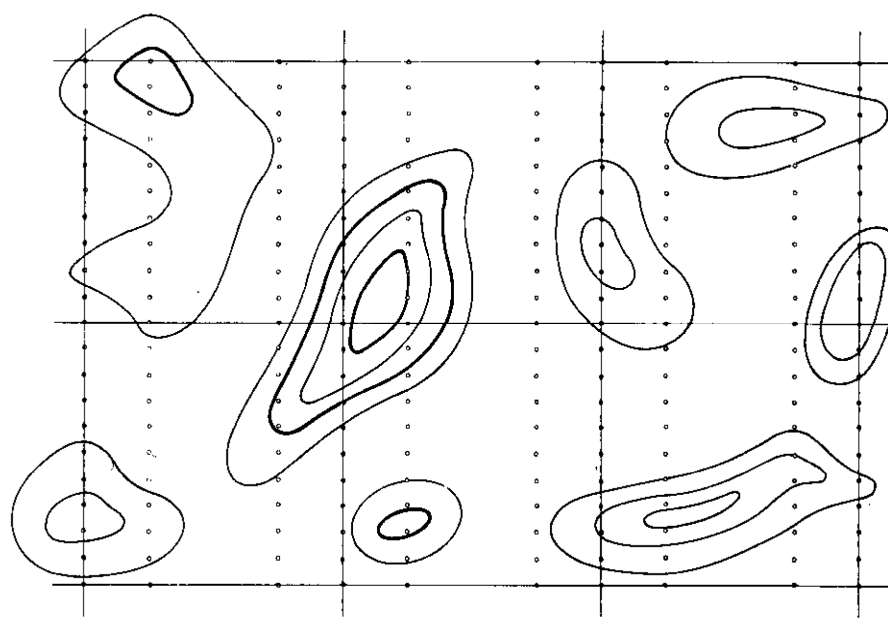

FIG. 2.

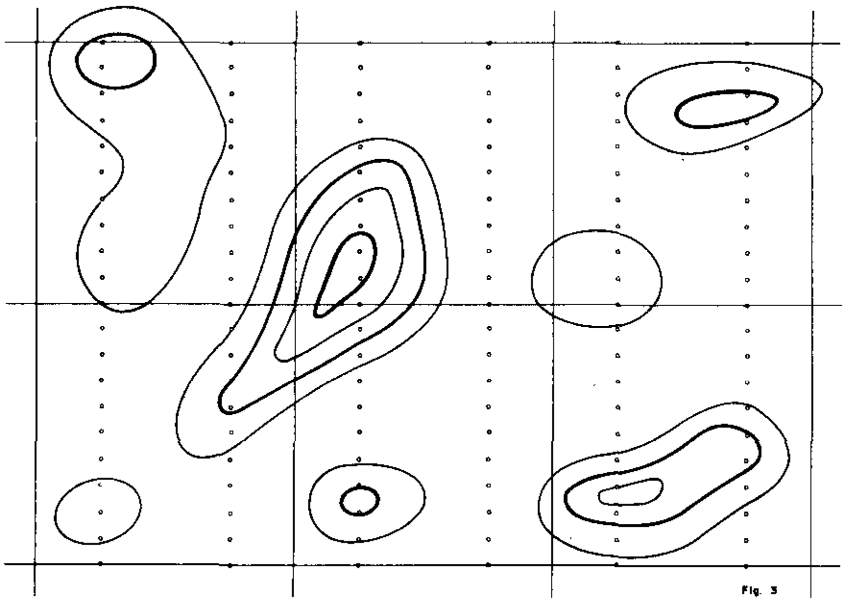

FIG. 3.

2. Anomalies found need adquate detail to outline them thoroughly.
3. Every well drilled as a result of the shooting should be drilled on a shot point.

TECHNIQUE

The method proposed is to shoot isolated correlation shot points, one in each quarter section, on legally-drillable locations, followed by lines of CDP (common depth point) shooting across the anomalies located.

The correlation points are to be shot at or near the centres of the quarter sections. Thus they will be about one-half mile apart. They will form the fine grid needed, and be close enough together to be highly correlatable. They should be in the drilling tolerance areas, but for efficiency and record quality, can be shifted around within those areas to fit topography, etc. The instrument spreads can be quite short, say 400 feet long, and can be laid out in any convenient directions, preferably those with minimal topographic relief, for better record quality.

In Alberta, the new regulations permit drilling a well for oil anywhere within a 1320-foot square in the centre of a quarter section. A well drilled for gas may be anywhere in a 2640-foot square in the centre of the section. These two allowances overlap to the extent of a 660-foot square in each quarter section. Fig. 4. If oil alone is considered, then shot points should be placed in the 1320-foot squares. If both oil and gas are prospective, shot points should be in the 660-foot squares. The latter also fits the gas-only situation fairly well, as shot points in the 2640-foot squares need to be near the corners, to be a half mile apart.

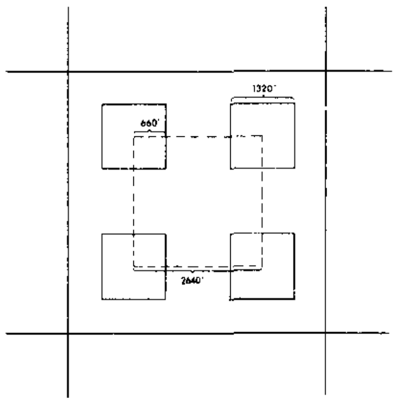

FIG. 4.

As oil is the usual objective in these small anomalies, the oil-only, 1320-foot square will normally be the one in which the shot point is located. Fig. 5.

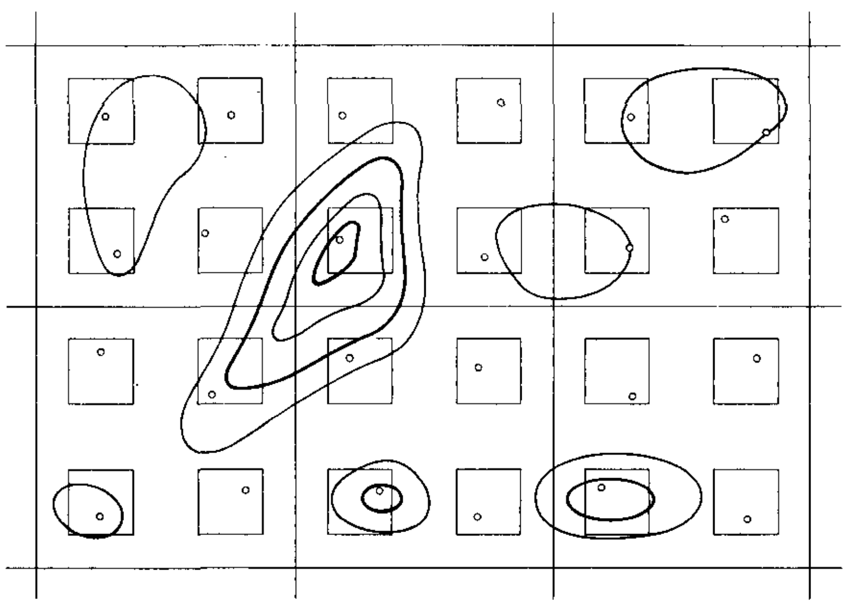

FIG. 5

In areas outside Alberta, with different drilling regulations, the pattern of shooting should be fitted to the drilling rules as well as possible, while maintaining the one shot point per quarter section frequency.

This shot point frequency is about a minimum for detecting the small features. Decreasing it would tend to bypass some of the features, and increasing it would make the economics of the plan less advantageous.

Although these correlation points are necessarily 100%, as CDP uses a multiplicity of both seismometers and shot holes, many of the modern techniques of data enhancement are applicable to them. For example, de-ghosting and deconvolution will make records more correlatable, in that picks can be made with more confidence, and are more precise. Occasionally, even stratigraphic changes can be defined with them, particularly if digital recording and binary gain are used.

In the correlation work, the field operations cannot proceed with the same smooth continuity as is customary in CDP shooting. The points will probably be shot most efficiently with a "bob-tailed" or smaller than normal, crew.

The correlation records can be played back as record sections, but with gaps between records. To simplify filing, and make an individual record easier to find, the sections should all be made from parallel lines of shot points, for example, all east-west lines. Prints of the sections can then be cut apart to form lines in any desired directions, or used as separate records.

In most areas, it is preferable to use only time interval data in interpreting the correlation points. Interval times, in not being affected by near-surface problems, are more reliable than total times, or depths. The short spreads and single coverage of the correlation points do not permit as good evaluation of the near-surface as is obtained with stacked shooting. Anomalies show up quite well on interval maps. In some areas, interval mapping alone is preferable for the CDP detail lines also.

The correlation points are subject to all the ills of any 100% shooting — multiples and other noise are worse problems than they are on stacked sections. But, these points cover the ground thoroughly, and locate features to be investigated further. They condemn areas of only regional dip.

After the correlation network has been shot, CDP lines can be positioned quite well to cross the features in as many directions as may be necessary. Fig. 6. Techniques for data enhancement that might have been considered too expensive for a reconnaissance CDP program can be used on these more select lines.

The method should be used only with the firm resolve that no wells will be drilled on the correlation shooting alone. After some detail has been shot, the reliability of the reconnaissance can be better determined. However, in no case should a well be drilled before its location is checked by some sort of continuous line through it. If record quality is so good, and problems are so few, that CDP is not necessary, then 100% lines should be used.

Choice of the best drilling location in a tolerance block also needs consideration. The Alberta drillable areas are in each case, one quarter

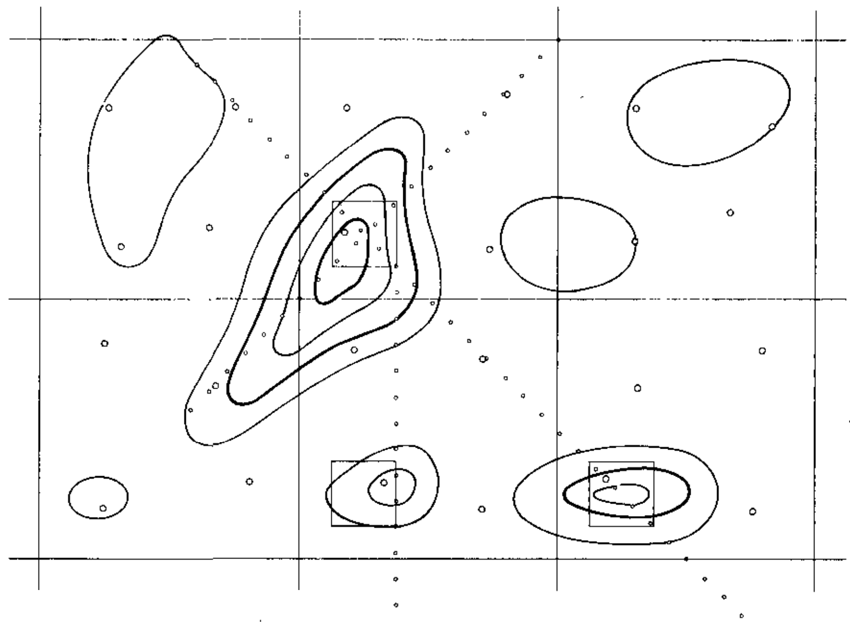

FIG. 6.

of the total area involved — 1320-foot square in a quarter section, 2640-foot square in a section. Therefore, the odds are about three to one that the best location on an anomaly will be outside the drillable area. So, within a block, the best place is probably on one of its corners. The detail, then, should be designed to check the corners. Two diagonal lines will check the four corners, as will two parallel lines along opposite sides. For better verification, the detail should cross one or more of the correlation points. This repetition of control is essential if different instruments are used for the detail, or if some time has elapsed since the reconnaissance shooting.

LIMITATIONS

This approach will not be economically good if, because of heavy timber, or rocky ground, trails must be cleared to most of the shot points. However, some areas that require trail-clearing have an existing network of trails created by numerous overlapping seismic programs. When this is the case, then by use of an air photo or other map of the trails, careful planning, full use of the latitude within tolerance blocks, and the clearing of a limited number of short spur trails, the correlation phase of this plan can be shot quite economically. In open country, pasture or cultivated land, especially after the harvest, the method works without any necessity for clearing trails.

On farm land, the points, being inside the fields, will require the payment of permit fees, but these fees are rarely prohibitive. At any rate, some inside shooting is necessary in any seismic program that is to check well locations.

The method will not work in an area in which multiples are so severe a problem that they can be handled only by stacking. Also, occasionally, other types of noise may require stacking. Many multiple situations, though, can be handled adequately for reconnaissance by being aware of their presence, observing the relationship of picks to topography, etc. Then the detail stage can use the best multiple-attenuation methods available.

OLD RECORDS

Much old shooting is correlation type, and, when shot, did not do very well at defining prospects or predicting well relationships. However, those shot points were normally at mile intervals, making them difficult to correlate. They were usually on section lines, with predictions for well locations extrapolated by guess. Depth calculations were made on them, sometimes with poor velocity and near-surface assumptions. And, of course, the instruments and techniques of that period were used.

In contrast, the correlation shooting proposed is at half-mile intervals, and therefore much more correlatable. It is on well locations, so no extrapolation is necessary. Time intervals, which do not use near-surface or velocity assumptions, are mapped from it. It has the advantage of modern equipment and techniques. And, follow-up detail is an integral part of the plan.

If old shooting is available in the area, it can be used to advantage to supplement the new work. It will probably be on section lines, so the two will not duplicate each other, but will make mapping more complete, giving a better over-all picture, and perhaps saving some detail shooting. Also, some of the new processing techniques can be applied to the old records, making them better and more compatible with the new.

COMPUTER PROCESSING

The correlation shot points, especially if they cover a fairly large area, are well suited to handling by electronic computer. Once picks are made, various time intervals can readily be computed, plotted on maps, and contoured; using existing computer programs. Also cross sections can easily be plotted, using north-south, east-west, or diagonal lines of points — or, if desired, stepping from point to point along irregular lines between wells, etc.

COSTS

Correlation points cost on the order of $150 to $200 per shot point. Multiplying by 4 and by 36 gives $21,600 to $28,800 for a township. Rounding off, $20,000 to $30,000. A combination of difficult drilling, permits, and need for special playback procedures could raise the upper estimate to $35,000. The detail is more variable, depending on amount of stack required, number of anomalies detailed, etc. Assuming costs of $500 to $1500 a mile, and three lines, each three miles long, an average anomaly could be detailed for about $4500 to $13,500.

Reducing these estimates to a simple rule of thumb, consider the costs to be about $30,000 a township for reconnaissance, and $10,000 per anomaly for detail.

EMPHASIS

Shooting on section lines puts primary stress on those features that happen to fall on section lines. Follow-up investigation then determines whether they also extend to drillable locations. But when the shooting starts with the legally-drillable locations, it constitutes a search for features that are well situated for drilling.

LARGE FEATURES

The system described, while designed for detecting small oil fields, contains no characteristics that discriminate against larger features. If a large structure occurs in the area being explored, the regular grid of shot points will be an excellent means of detecting it. The CDP detail, just as for the small features, can be positioned quite well for exporing the anomaly being investigated. These lines will probably be longer, and more widely spaced.

TYPICAL PROCEDURE

The method is, of course, only general, and will be varied to fit each situation — existing regional control, land availability, etc. Typical steps might be:

Determine area of interest.

Shoot correlation points, completely filling the area at a spacing of four per section.

Interpret, using intervals only, or primaries.

Examine anomalies found. Determine which are to be pursued further.

Shoot CDP lines over the selected anomalies, using whatever special field and playback procedures best fit the area.

Bid on leases, drill wells, etc., with the confidence that the best features are being exploited, and that they have been adequately investigated.

APPENDIX

ALTERNATE CORRELATION CONTROL METHOD

A variation of the four shot point per section correlation reconnaissance for small oil fields is described. It uses an "H" spread to obtain four control points per shot point.

TECHNIQUE

The correlation control described can be obtained in an alternate method that gives four, instead of one, of the centre-of-quarter-section points from each shot point. It consists of shooting what can be called an "H" spread. For it, a shot point is located at the midpoint of a section line, with four short spreads at midpoints of adjacent section lines perpendicular to the one containing the shot point. Fig. 1a.

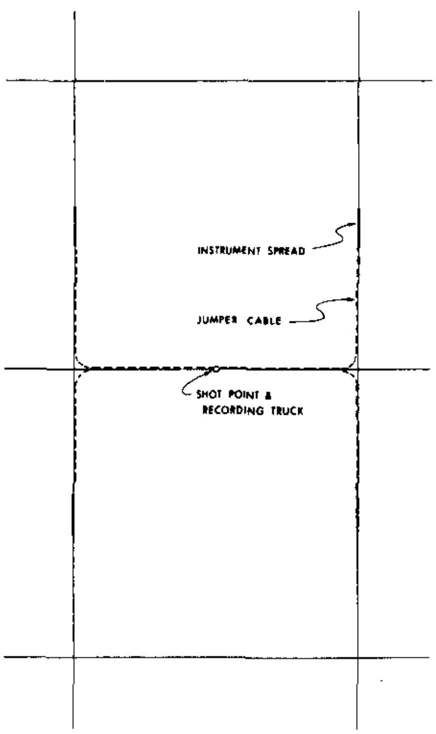

FIG. 1a.

To think of this pattern in terms of the letter, picture an "H" with crossbar the same length as the uprights, and exactly half way up the uprights. The shot point is then at the centre of the crossbar, and the spreads are at the ends of the uprights. Jumper cables connecting the recording truck to the spreads form the "H."

In this arrangement, shot point, jumper cables, and spreads are all on section lines, so there is no need to go inside fields, or incur permit charges. The depth points, though, at which seismic information is obtained, being midway between shot and instrument spreads, are at the centres of quarter sections. That is, they are on legally drillable locations. Fig. 2a.

As all four depth points are equidistant from the shot point, interval times will be comparable, with no moveout correction needed. The same is true of their relationship with other H spreads, so the reconnaissance mapping can be made using uncorrected interval times. Moveout adjustment will be necessary though, to combine these data with those from the detail work.

COSTS

This method, requiring no permits, allowing trucks to operate on section line roads, and using only one shot point for four depth points, is much more economical than the correlation point network. Costs, though, are very difficult to estimate. Three miles of cable are required, and in a special arrangement. If the seismic contractor doing the work happens to already have cable that can be jury-rigged into this configuration, there is little problem. If cable has to be purchased for the shooting, then the program must be large enough to pay for the extra cable.

VARIATIONS

If desired, the spreads can be lengthened to cause subsurface coverage to completely cross the legally-drillable block. Fig. 3a. As there are a limited number of traces available though, it will probably usually be preferable to keep the spreads short. Relationships between the ends of a short spread — taking normal moveout into account — will indicate the direction of dip fairly well for guiding further exploration.

If for any reason, 100% continuous-line coverage through drillable locations is desired, various arrangements of such coverage can be ob-

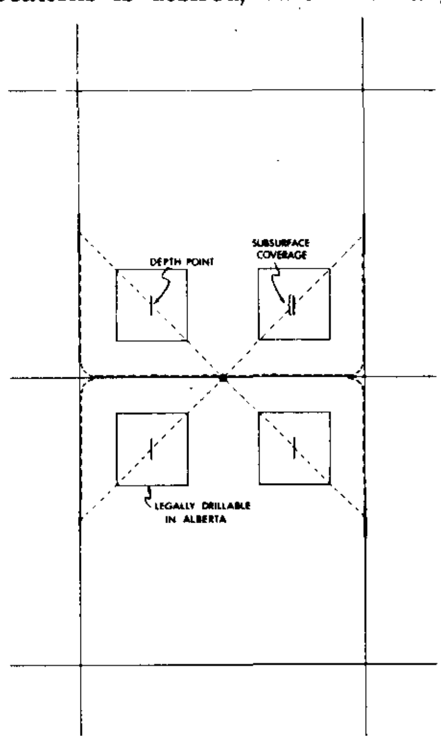

FIG. 2a.

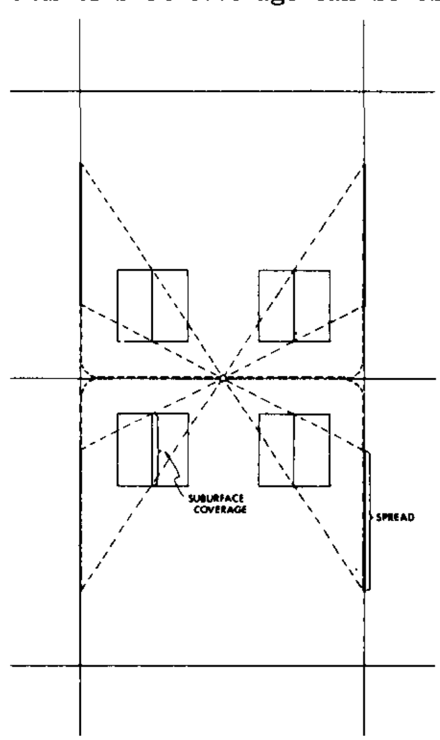

FIG. 3a.

tained by extending the instrument spreads along the uprights, the crossbar, or both.

Similarly, if CDP shooting is being conducted along the crossbar, additional instrument spreads along the uprights will produce interesting patterns of 100% cross-spread information, as the holes along the crossbar are shot.

To reduce the amount of cable needed, or to increase the number of traces available, the one recording truck at the shot point can be replaced by two trucks, one at each end of the crossbar of the H. Fig. 4a. Communications between them and the shot point can be provided by a telephone line, or by radio.

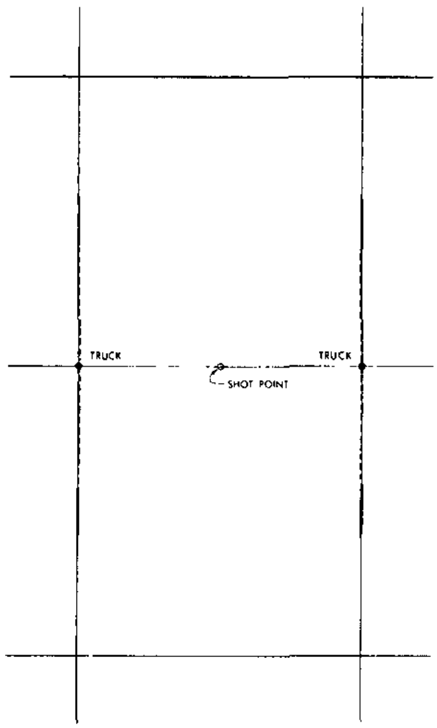

FIG. 4a.

FIELD OPERATIONS

In the field, cable-laying procedures needed are somewhat similar to those in CDP shooting, so crews should rather easily adapt to them. There is some additional responsibility on the surveyor, to ensure that the four spreads are indeed equidistant from the shot point.

In continuous line shooting, economy of effort is obtained by leaving the forward cable on the ground, when moving to the next shot point. It then becomes the back spread. Similarly, with the H method, one of the uprights is left to be used on the next shot point.

Cable-handling is the most time-consuming part of this operation. Extra cable, if available, can advantageously be laid out in advance.

CONCLUSIONS

This method is untried, but looks very promising as a way to get properly-located data rapidly and economically. No special problems other than those of cable acquisition and handling are anticipated.

The H spread yields correlation data, very like that obtained from the separate correlation shot points. Therefore, except for logistics and economics, most of the discussion of the method of using four shot points per section followed by CDP detail, also applies when the H spread is substituted for the four shot points.