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RESEARCH MEMORANDUM

CONCEALMENT OF UNDERGROUND EXPLOSIONS

Albert L. Latter

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Assigned to ______________________

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The RAND Corporation
1700 MAIN ST. • SANTA MONICA • CALIFORNIA

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PREFACE

With minor changes the following report was submitted by the author to the conference on ''Inspection of Sites of Unidentified Seismic Events'', which was held 16-18 March, 1960, at the U. S. Naval Postgraduate School, Monterey, California. The report is being made into a Research Memorandum because of the limited distribution of the conference proceedings.

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SUMMARY

The Cowboy experiments on decoupling of underground nuclear explosions have been completed. They show that the principle of decoupling by means of a large hole is correct. The decoupling factor of 300 estimated in RAND Report R-348 is still the best estimate for a hole in salt relative to a tamped shot in Nevada tuff. The most surprising result of Cowboy is that decoupling is not an all or none effect. If the elastic limit of the medium is exceeded, the decoupling factor is reduced, but only gradually. As a result it appears possible to explode a 20 KT device in a cavity no bigger than some which already exist, without producing a signal that could be detected by the Geneva system.

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CONCEALMENT OF UNDERGROUND EXPLOSIONS

It has been predicted that the seismic signal from an explosion in a large underground cavity would be much smaller than that from the same yield explosion carried out under ordinary (Rainier) conditions.* Specifically, the expected decoupling factor for a nuclear explosion in a salt or hard rock cavity relative to a fully tamped explosion in Nevada tuff is about 300. This estimate is based on measurements of earth displacement and seismic energy from the Rainier explosion, and on the assumption that the cavity is sufficiently large that the surrounding medium behaves elastically. To ensure elastic behavior of the medium a cavity volume of 7×10^4 cubic meters per kiloton has been stipulated for cavities at a depth of about one kilometer in salt. Such a volume will keep the medium from going into tension and also prevent shear stresses which exceed the elastic limit even under the action of the reflected shock wave. With this volume criterion, expert construction engineers have stated that it is feasible to construct cavities to accommodate 100 KT explosions. A 100 KT explosion in such a cavity would make a seismic signal so weak that it would not even be detected by the Geneva system.

To obtain experimental proof of the decoupling principle, the Cowboy series of tests were conducted with conventional explosives in two salt cavities at a depth of about 800 feet. The cavities were spherical with diameters of 12 feet and 30 feet, and the charges ranged from 20 pounds

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* Details are contained in RAND Report R-348, A Method of Concealing Underground Nuclear Explosions, by A. L. Latter, R. E. LeLevier, E. A. Martinelli, and W. G. McMillan (March 30, 1959); also the verbatim records of the Conference on the Discontinuance of Nuclear Tests, Technical Working Group II, seventh session.

to 2000 pounds. A further objective of Cowboy was to determine how the decoupling factor would be degraded if the hole size were less than the stipulated value and the medium were allowed to be inelastic. This question is difficult to treat theoretically, but it had been conjectured that decoupling is an all or none effect and would not occur if the stresses exceeded the elastic limit.

Cowboy was quite successful and demonstrated the decoupling principle beyond doubt. To be specific, it was found that the seismic signal from a fully tamped explosion in salt was about 120 times bigger than that from the same yield in a salt cavity provided the elastic condition was satisfied. It should be noted that this result does not contradict the predicted decoupling factor of 300. The latter refers to the ratio of tamped tuff to a hole in salt, whereas the value 120 is for the ratio of tamped salt to a hole in salt. The disparity, a factor 2 or 3, is to be ascribed to a medium dependence for tamped explosions. In other words, as an incidental result of Cowboy, it appears that a decoupling factor of 2 or 3 can be achieved relative to Rainier simply by exploding the device in a medium like salt instead of tuff.

The important question concerning the degradation of the decoupling factor when the medium is allowed to behave inelastically, has also been largely answered by the Cowboy experiments. The results are rather surprising. Decoupling is definitely not an all or none effect. The thousand pound charge in the 12 foot sphere produces pressures too large to satisfy the elastic condition by a factor of about 15. Nevertheless, in this case the observed decoupling was degraded only by a factor of 4, giving a decoupling factor salt-to-salt of about 30. Translated for the Geneva system, this means a decoupling factor, tuff to salt, of about 75. Furthermore the damage to the cavity was slight and it was possible to use the cavity again. Accordingly a 2000 pound charge was exploded, this time resulting in a decoupling factor about one half that obtained with the 1000 pound charge. This means, relative to the Geneva system, that the hole size may be reduced by a factor of about 30 from the value stipulated to ensure elasticity, and still there will be a decoupling factor of the order of 35 (tuff to salt).

These results apply of course to conventional rather than nuclear explosives. There is the question, how to interpret these results for the nuclear case. In this connection theoretical analysis shows that the stress conditions imposed by the transient pressures on the cavity wall are more severe than those associated with the sustained pressure in the cavity. The transient pressures for nuclear explosions have been calculated to last for a time which is short compared to the characteristic period of the cavity. For conventional explosives the opposite is true. It seems plausible therefore that the Cowboy experiments provide, if anything, a lower limit on the decoupling factor when inelastic behavior is permitted.

The important consequences of the Cowboy tests are:

1. The decoupling principle is correct.
2. The decoupling factor for a hole in salt relative to a tamped shot in salt is about 120.
3. The decoupling factor which is relevant for the Geneva system

is for a hole in salt relative to a tamped shot in Nevada tuff. The best estimate of this quantity is still 300 (based upon the arguments given in RAND Report R-348).

4. The disparity between the factor 300 and the factor 120 is best explained as due to a medium effect for tamped explosions. It follows that a decoupling factor of 2 or 3 results simply by using salt rather than Nevada tuff.

5. A violator does not have to build the cavity with a large margin of safety. The decoupling factor is reduced by exceeding the elastic limit but only in a gradual way.

6. It would be possible to explode a 20 KT device in a cavity which, according to the elastic requirements, could accommodate only 1 or 2 KT--it should be noted that these small cavities already exist--and the seismic signal from such a 20 KT explosion would not even be detected by the Geneva system.