NASA TECHNICAL
MEMORANDUM

NASA TM X-58057
May 1971

PRELIMINARY EVALUATION OF THE CORING POTENTIAL OF THE APOLLO LUNAR SURFACE DRILL TITANIUM CORE STEM

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

NASA TM X-58057

PRELIMINARY EVALUATION OF THE CORING POTENTIAL OF THE APOLLO LUNAR SURFACE DRILL TITANIUM CORE STEM

John F. Lindsay
Manned Spacecraft Center
Houston, Texas 77058

Richard Perry
Lamont-Doherty Geological Observatcry
Palisades, New York

ABSTRACT

Drilling tests to evaluate the coring potential of the Apollo lunar surface drill titanium core stems were conducted at the NASA Manned Spacecraft Center, Houston, Texas, and at the Martin Marietta Corporation, Denver, Colorado. It was found that core recovery is dependent on drilling rates. Core sample compaction and losses during extraction and capping of the stems are discussed. From the viewpoint that cohesion is an important property of lunar soil when coring with the drill, the soil model from the Manned Spacecraft Center was concluded to be more representative of lunar soil than the one from Denver and should be used until more information about lunar soil is available.

PRELIMINARY EVALUATION OF THE CORING POTENTIAL OF THE APOLLO LUNAR SURFACE DRILL TITANIUM CORE STEM

By John F. Lindsay and Richard Perry*
Manned Spacecraft Center

SUMMARY

Drilling tests to evaluate the coring potential of the Apollo lunar surface drill titanium core stems were conducted in two lunar soil simulants: one at the NASA Manned Spacecraft Center in Houston, Texas, and the other at the Martin Marietta Corporation plant in Denver, Colorado. Six complete cores were taken in each model. The tests show that core recovery is dependent on drilling rates. In the Manned Spacecraft Center model, recovery was maximized at approximately 1 in/sec. Coring efficiency also declines as more stem sections are added, but the total decrease in efficiency for up to eight stems is not great. Core is not accepted continuously into the stem at any drilling rate. A more continuous and representative sample of the soil can be obtained, however, if the drilling rate is carefully controlled. The core sample is compacted during drilling. Most of the compaction occurs between the bit and the second stem section. Core loss during extraction and capping of the stem sections averages 4.2 percent in the Manned Spacecraft Center model and 16.6 percent in the Denver model.

INTRODUCTION

A test program was conducted on the Apollo lunar surface drill to evaluate the coring potential of the titanium core stems. Construction of a single model which simulates all of the major physical properties of the lunar soil is difficult. Consequently, the tests were conducted in two models: one at the NASA Manned Spacecraft Center (MSC), Houston, Texas, and the other at the Martin Marietta Corporation, Denver, Colorado, plant. The Denver model is based on Surveyor spacecraft data and consists primarily of crushed basalt. The model closely approximates lunar soil in degree of sorting (standard deviation of the grain-size distribution), but is slightly finer grained; the median grain size is 58μ, as compared to 102μ and 88μ for the lunar soil at the Apollo 11 and 12 sites, respectively. Samples returned on the Apollo 11 and 12 missions showed that the lunar soil is quite cohesive, which is a property not simulated by crushed basalt. Consequently, early in 1970, the MSC model was rebuilt by using crushed basalt, sand, and a proportion of kaolinite to provide cohesion. The grain size

*Lamont-Doherty Geological Observatory, Palisades, New York.

of the MSC model adequately simulates lunar soil in the coarser particle sizes, but it has an overabundance of very fine kaolinite particles. The median grain size of the simulant is 105μ.

METHOD

Drill stem sections were emplaced individually by an unsuited operator, and the power-on period was timed with a stop watch. After emplacement of each stem section, the length of stem projecting above the surface was measured, and a measuring stick was dropped down the inside of the stem to measure the distance to the top of the core sample. Upon completion of drilling, the power head was removed, then the core was extracted from the ground by hand. The joints were broken and the sections were capped and weighed. Measurements were also made of the amount of core lost during extraction and capping.

CORE RECOVERY COMPARED WITH DEPTH DRILLED

The overall reduction in coring efficiency for up to eight stem sections is not great, and the total core recovered is almost a linear function of the depth drilled (figs. 1 and 2). There is little evidence of an exponential decline in core recovery, as may have been expected intuitively. There is, however, a gradual decline in the amount of core accepted into the stem as successive stem sections are added (figs. 3 and 4).

DRILLING RATE

The efficiency of the coring system is dependent on the drilling rate (fig. 5). In general, coring efficiency increases in both models as the drilling rate decreases to a point at which the efficiency decreases again.

In the Denver model, the maximum efficiency is relatively well defined at approximately 38 percent for a drilling rate of 2 to 2.5 in/sec. Maximum efficiency in the MSC model is 69 percent at a drilling rate of 1 in/sec. Unfortunately, because of difficulties in controlling drilling rates by hand, the curves are not as well outlined by experimental data as they could be with additional work.

The decline in coring efficiency at very low drilling rates probably reflects the internal wall friction of the titanium stems. Because of the internal wall friction, an upward force is required to keep the core moving. By holding back on the drill, this force is reduced until it is no longer adequate to overcome the internal friction. The soil is then forced to flow up the drill flutes to the surface.

The great difference in coring efficiency shown for the two soil models probably reflects their cohesive properties. With virtually no cohesive forces in the Denver model, the soil particles act independently and tend to flow around the drill bit and up the flutes of the stem. Conversely, the MSC soil is quite cohesive and tends to act more as a semisolid plug and thus is forced into the stem rather than up the flutes. The increase in efficiency in the MSC model may also be partially caused by the kaolinite acting as a lubricant and reducing the internal wall friction.

It can be concluded from the foregoing that drilling rate is very important in terms of coring efficiency. Since coring efficiency also appears to depend on the cohesion of the soil, it is probably best to rely on the results from the MSC model and to suggest that a drilling rate of 1 in/sec be adopted for coring on the lunar surface.

COMPACTION OF THE CORE

Without an elaborate layered soil model, the effects of compaction on the core are difficult to study. Crude density measurements were made on several cores by weighing the stem sections and determining the number of grams per inch of stem (fig. 6). In all cores measured, the density increased from the lowermost stem section (no. 1) to the second stem section, indicating that not all of the compaction takes place as the core enters section 1 through the bit. From stem section 2 upwards, compaction decreased slightly in all three of the MSC cores measured. Thus, it is concluded that most of the distortion of the core by compaction occurs between the bit and stem section 2 and that little further distortion occurs for up to eight stem sections.

CORE LOSS DURING EXTRACTION

At MSC, a small amount of core was lost during extraction and capping of the stem section in three of the six cores. At Denver, small losses were recorded in five of the six cores. Of 361.4 inches of core retrieved from the MSC soil model, only 4.2 percent was lost during extraction and capping. In contrast, of 173.0 inches of core retrieved from the Denver soil model, 16.6 percent was lost during extraction and capping of the stem sections.

Since soil cohesion is a prominent factor when considering core loss during extraction and capping of the stem sections, it is reasonable to suggest that the MSC model is nearer reality. However, all of the tests were made in shirtsleeves; thus, a somewhat greater loss could be expected on the lunar surface.

INTEGRITY OF THE CORE

From the scientific viewpoint, it is desirable to return a core that is a continuous and representative sample of the lunar debris layer. Vibration during drilling will clearly modify the sample to some extent, but more important is the question of the continuity of the core sample; that is, does the stem accept core in an unbroken chain or is the coring an intermittent process. Tests suggest that the latter is the case (figs. 3 and 4). Variation in drilling rate changes the recovery potential of the titanium core stem, but it also changes the amount of core entering the stem as each stem section is added. Core is lost as each stem section is implanted. Because density is independent of drilling rate and core length recovered, the shortening of the core cannot be attributed to compaction.

CONCLUSIONS

Cohesion appears to be an important property of the lunar soil when coring with the Apollo lunar surface drill. From this viewpoint, the NASA Manned Spacecraft Center soil model should be used in future tests until information about the lunar soil is available to allow further refinements.

Core recovery by the Apollo lunar surface drill titanium core stems is maximized if drilling rates are carefully controlled. Data from the Manned Spacecraft Center soil model suggest that 1 in/sec is the most appropriate drilling rate.

Core is not accepted continuously into the stem at any drilling rate. However, the discontinuities in the core increase if drilling rates greater or less than the optimum rate are used. A more continuous and representative sample of the lunar debris layer can be obtained if the drilling rate is carefully controlled.

The efficiency of the coring system declines gradually as more stem sections are added. However, the total decrease in efficiency for up to eight stem sections is not great. Core loss during extraction and capping of the stem section averaged 4.2 percent in the Manned Spacecraft Center model and 16.6 percent in the Denver model.

The core is modified by compaction during drilling. The compaction occurs between the bit and the second stem section. Compaction does not occur above the second stem.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, May 31, 1971
914-40-52-01-72

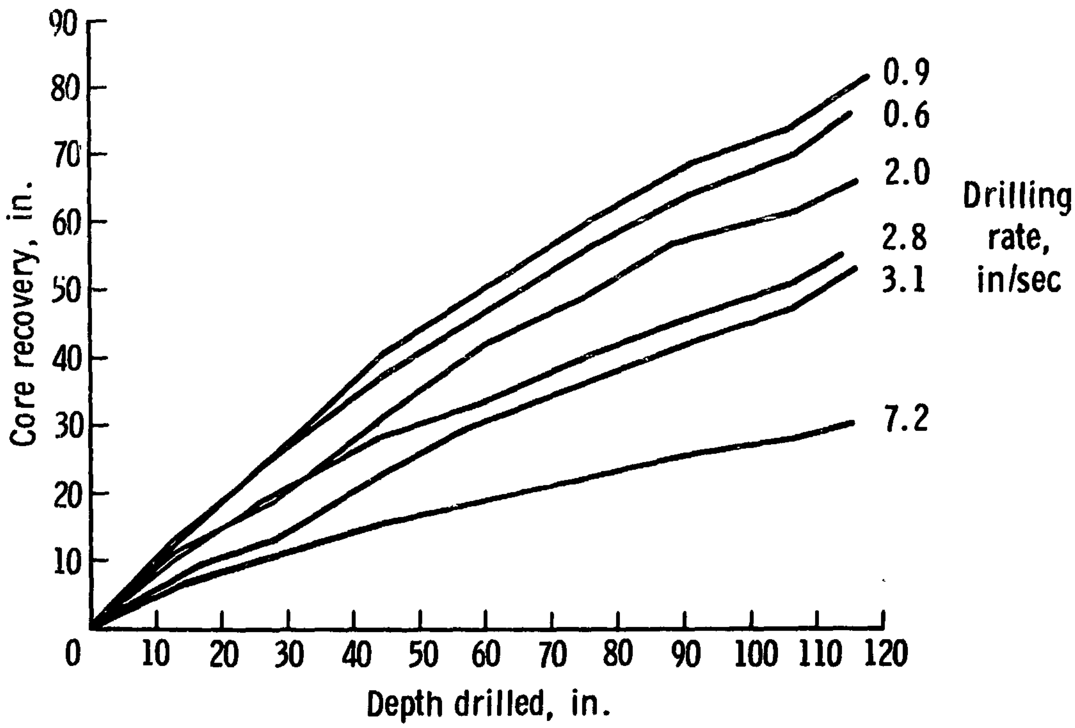

Figure 1. - Core recovered as a function of depth drilled and drilling rate for the MSC lunar soil model.

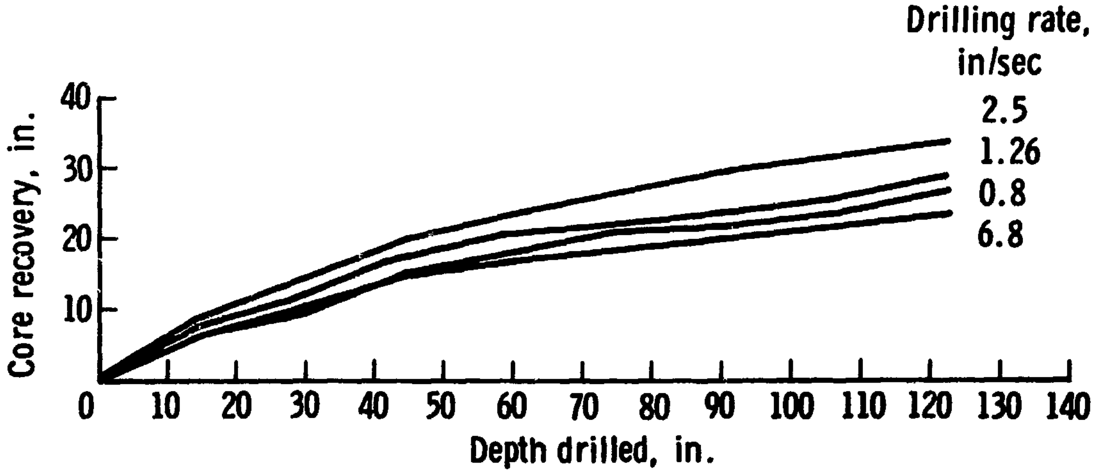

Figure 2. - Core recovered as a function of depth drilled and drilling rate for the Denver lunar soil model.

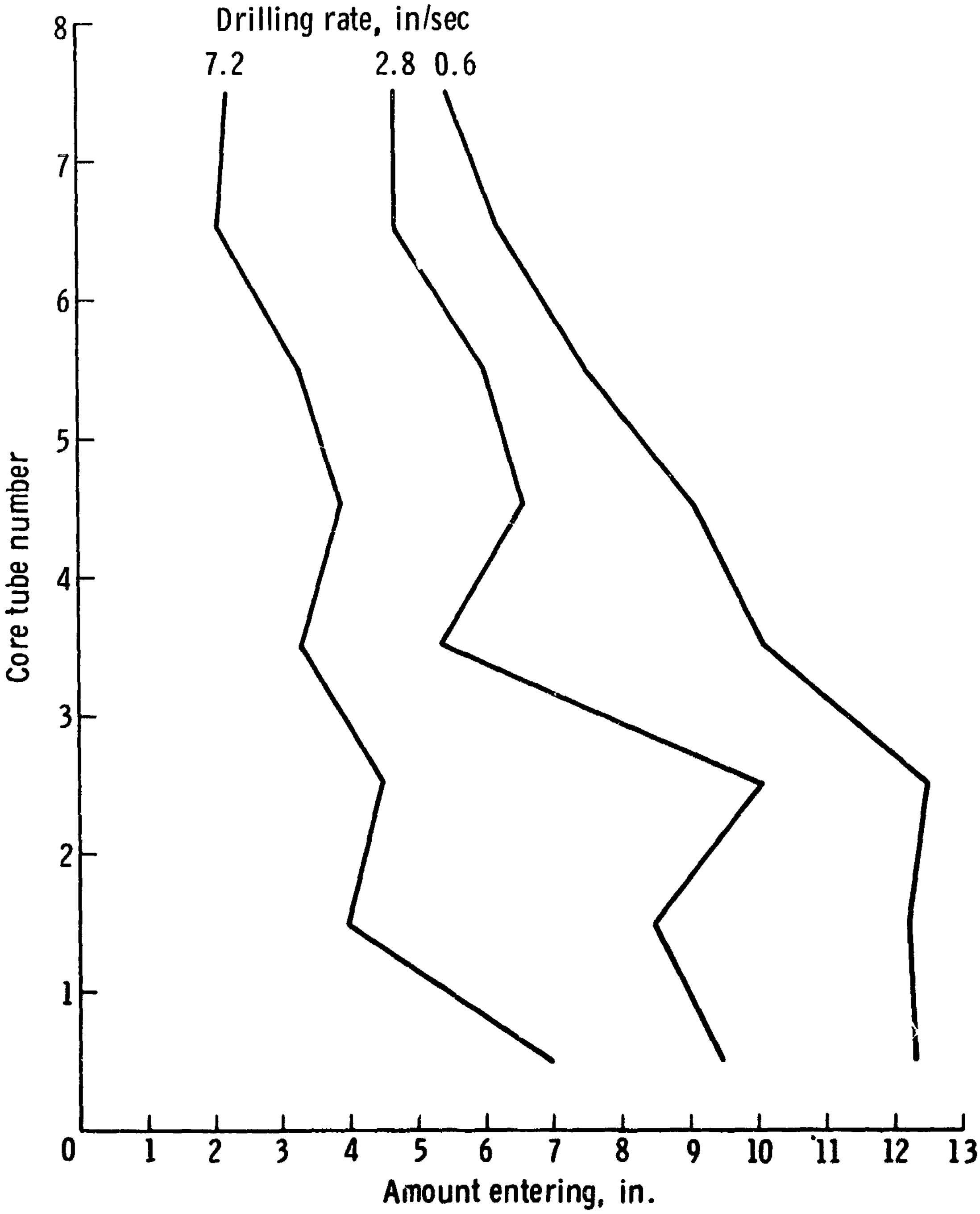

Figure 3. - Amount of sample entering the titanium core stem as each segment of core stem was emplaced into the MSC soil model.

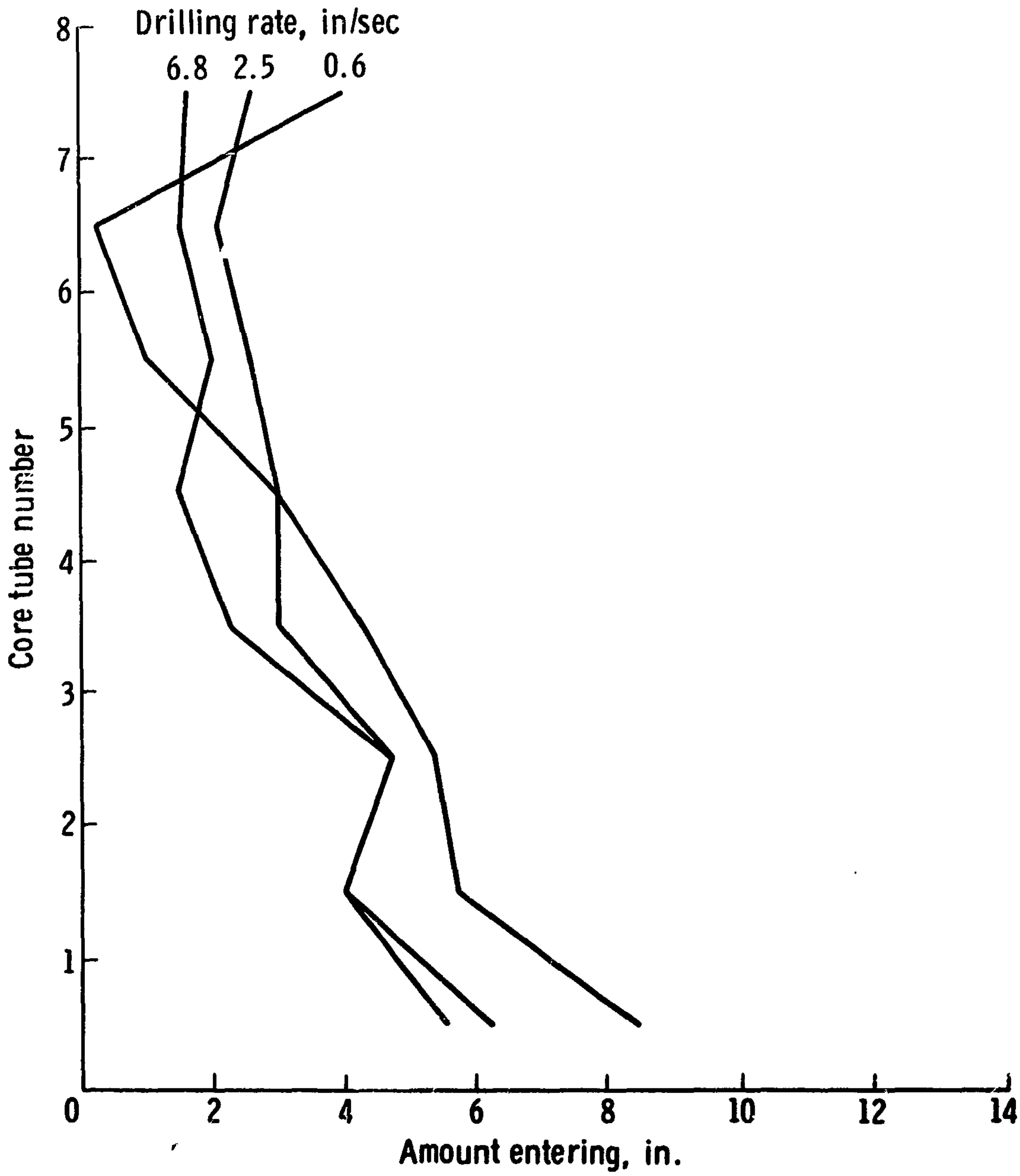

Figure 4. - Amount of sample entering the titanium core stem as each segment of core stem was emplaced into the Denver soil model.

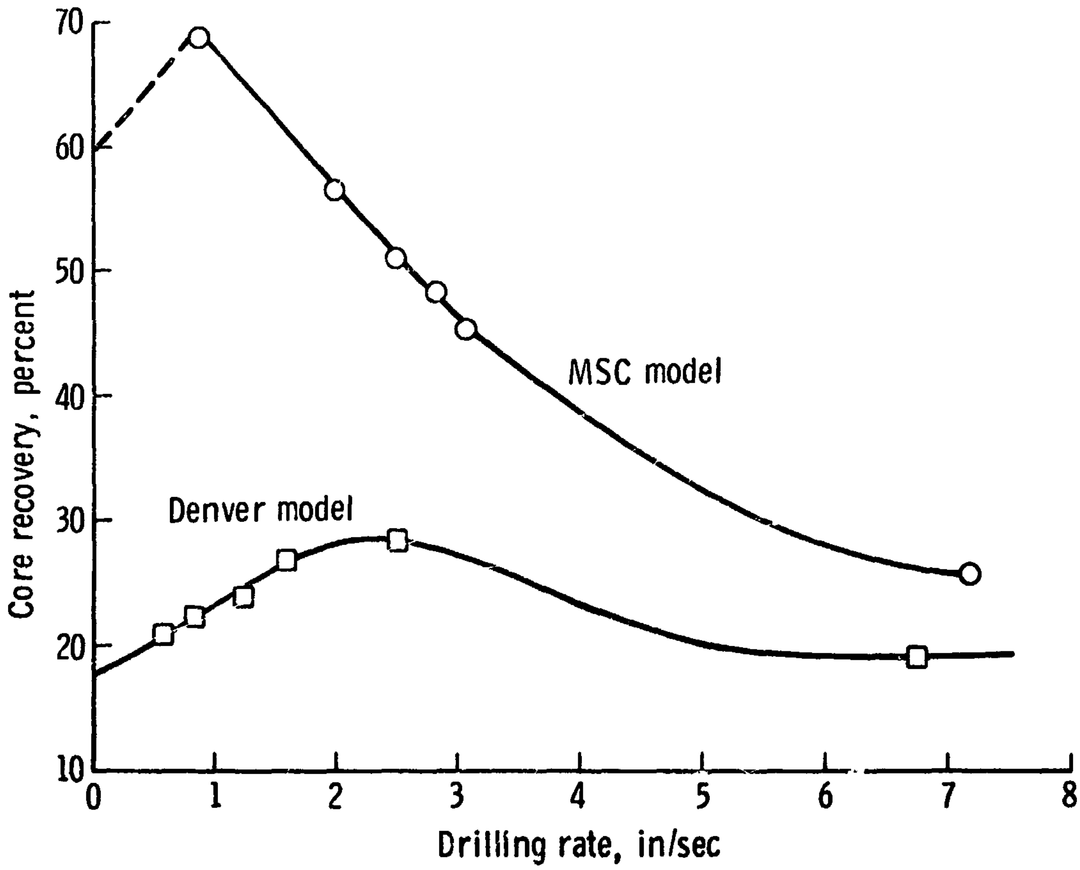

Figure 5. - Percentage core recovery (for eight s.em sections) as a function of the drilling rate.

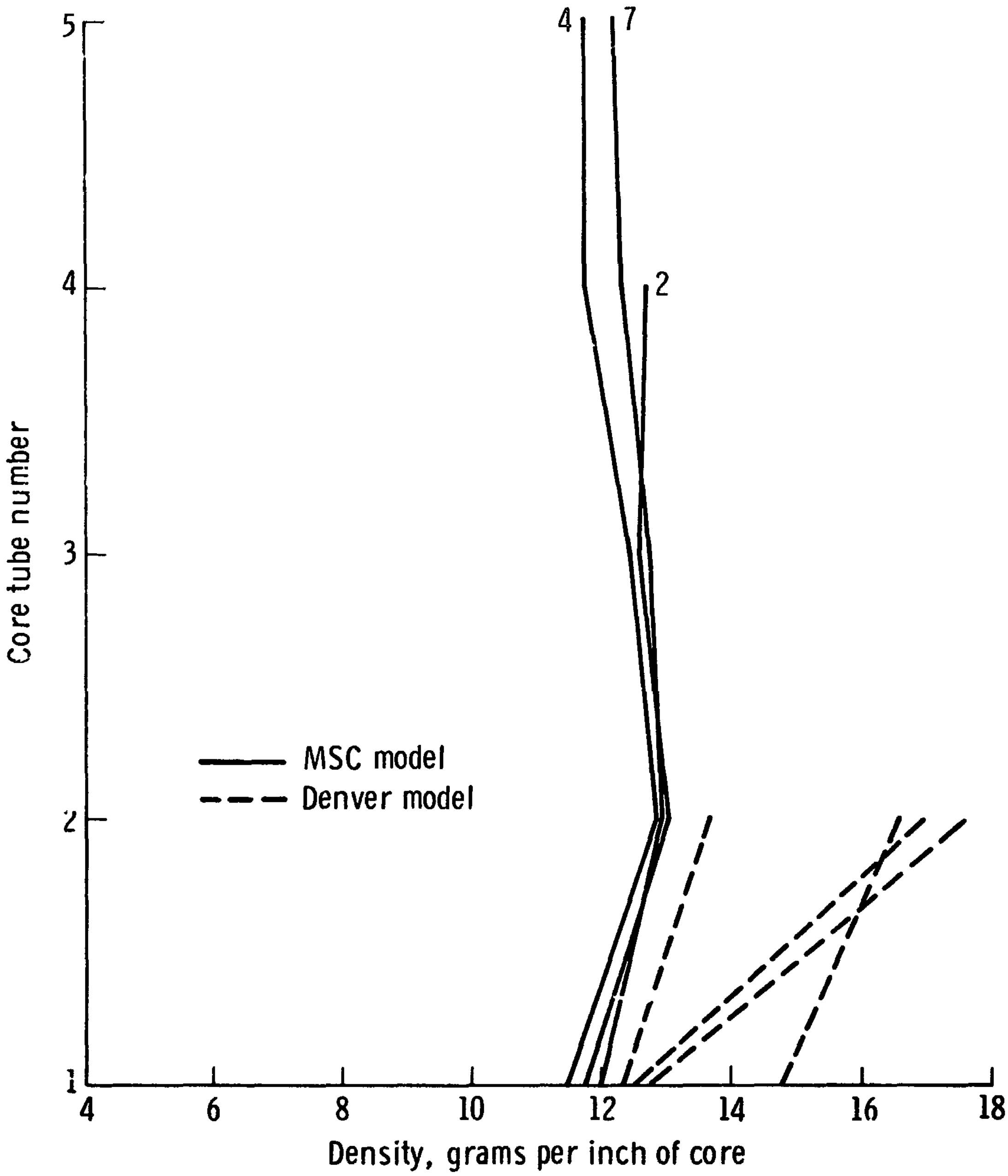

Figure 6. - Density of core sample recovered in each stem section from the MSC model when eight stems were emplaced. Note that density is maximum in tube section 2 in all three tests plotted.