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[Technical Articles]

VACUUM METHOD FOR FIELD INSTALLATION OF PIPES AND CASINGS IN SANDY SOILS

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Abstract

Soil moisture-monitoring equipment is difficult to install in poorly consolidated sand or sediments using hand tools because the loose material tends to collapse. The technique described herein uses a 5.5-hp wet/dry vacuum cleaner, powered by a portable gasoline generator, to remove the soil while an operator pushes a conductor pipe or casing into the profile. After initiating the hole using a hand bucket auger, an open-ended metal pipe or polyvinyl chloride (PVC) casing is inserted vertically into the shallow hole. A smaller tube, or stinger, attached to a wet/dry vacuum is inserted into the pipe to extract loose material while downward pressure is applied on the pipe. Once the casing is installed, instrumentation such as lysimeters, gypsum blocks, or tensiometers can be placed at the desired depth and backfilled with native soil. The casing is then raised and the soil allowed to collapse around the equipment, or the pipe can be left in place for neutron probe access. Measurements of soil water content after an infiltration experiment demonstrated uniform downward movement with minimal preferential flow or soil disturbance as a result of the vacuum installation of gypsum blocks and a neutron access tube.

In many soil physics and contaminant transport studies, it is necessary to have moisture detectors, neutron access tubes, or other instruments buried in the soil profile for sampling purposes. Typically, an opening slightly smaller than the instrument to be installed is cored to the appropriate depth in the soil, and the instruments forced gently into the soil form a tight connection with the surrounding soil (Cassel and Klute 1986). The installation of equipment is difficult in areas of loose or collapsible material, such as sand dunes, because the instrument access holes do not remain open. One way to maintain access for equipment is to install a conductor casing in the loose soil, remove the soil material inside the casing, and then install the instruments. A hand bucket auger of a smaller diameter than the casing may be used to remove the inner material (e.g., a 7.6-cm auger inside a 10.2-cm casing). Thus, the size of the casing is restricted to something larger than the auger. The removal of loose, dry sand is very difficult, however, even with a sand-bucket auger.

Another technique for removing loose material from inside the casing or pipe utilizes suction or vacuum. This method has been used previously in laboratory settings and small-scale column experiments where a vacuum source was conveniently available (Kotarac-Carrillo 1996) although, to our knowledge, a specific method has not been reported. Very large, powerful vacuum machines have been used at some government field sites to collect radioactive soil (*T.L. Jones, pers. comm.*).

We used a combination of suction and downward pressure to install pipes or casings into which equipment could be installed at prescribed depths in the field. Our objective was to install a neutron access tube and gypsum blocks in a sandy, noncohesive soil at a remote site in order to monitor soil moisture changes with depth during wetting. The method used to install the equipment and results from an infiltration experiment are described.

MATERIALS AND METHODS

Study Area

The field site was located in a former oil field near Guadalupe in San Luis Obispo County, California. Sparsely vegetated sand dunes (designated "Dune land" in the soil survey and not further classified) along the coast were instrumented and investigated to determine the rate of infiltration and the direction of water movement through the vadose zone. The vegetation was predominantly a dune scrub community of coastal shrubs and grasses, including California sagebrush (*Artemisia californica*), coastal silver lupine (*Lupinus chamissonis*), coyote bush (*Buccharis pilularis*), deerweed (*Lotus scoparius*), and coastal buckwheat (*Ericameria ericoides* [*Haplopappus e.*]) (Holland and Keil 1995).

The morphologic data were collected and recorded during monitoring of well installation by Levine.Fricke.Recon Environmental Consultants (1996). The vadose zone was composed of fine to medium-grained, loose sand. The color was a light, yellowish brown (10YR6/4) throughout the vadose zone except for reddened bands at approximately 1.8 m. (Levine.Fricke.Recon 1996). The groundwater at this site was 2.6 m below ground surface during the field tests in September 1997 as measured by two piezometers near the test plot. The piezometers were installed using the vacuum installation methods described herein.

Average annual rainfall in the region is 30 to 36 cm, mostly during the winter. Intense, heavy storms have been recorded, particularly in El Niño years. The infiltration experiment was designed to simulate one of these heavy rains, which are believed to contribute to soil flushing and groundwater contamination. Because it is near the coast, temperatures in the area are mild, with average highs of 21.1 °C in the summer and average lows of 8.9 °C in the winter. Average annual temperature is 13.9 °C.

Installation of Equipment

The method used was to push a rigid tube or cylinder into loose soil or sand and to concurrently evacuate the cylinder from the surface using suction. The cylinder can be made of metal, polyvinyl chloride (PVC), or any rigid pipe or casing material. The diameter of the pipe depends on the strength of vacuum and installation depth. A shallow access hole about 10 cm deep is dug at the surface to situate the cylinder as it is pressed into the subsurface. Once the casing or pipe is in place, instruments can be lowered into the opening and backfilled if necessary.

In our case, a 7.5-cm diameter access hole was initiated using a hand-operated sand-bucket auger. For a neutron access tube, a 5.1-cm-diameter metal pipe was placed vertically in the access hole. A smaller tube, or stinger, was inserted into the pipe while the operator was standing on a ladder adjacent to the vertical pipe or casing. Our stinger was a 1.5-m length of 2.5-cm schedule 40 PVC pipe attached to a wet/dry vacuum source via a 5-cm-diameter flexible hose (Fig. 1). The end of the stinger was cut diagonally to a point to help loosen the soil. The vacuum source we used was a 5.5-hp wet/dry vacuum cleaner (Shop Vac Corp., Chicago, IL) run off a portable, gasoline-powered generator. The Shop Vac had a bucket capacity of 18.9 L (5 gal). Dry and wet sandy soils were removed easily and quickly from the inside of the pipe in the upper 2.4 m of an established, vegetated sand dune in the central coast area of California. The soil was collected in a clean 18.9-L bucket fitted with a bulkhead lid. Two openings in the lid provided access to the vacuum and to the stinger in the soil (see detail inset in Fig. 1). When one bucket was full, the vacuum was shut off and a new bucket attached to the bulkhead lid. This operation required only a few seconds and allowed soil from different layers or depths to be kept separate in case they were to be returned to the hole.

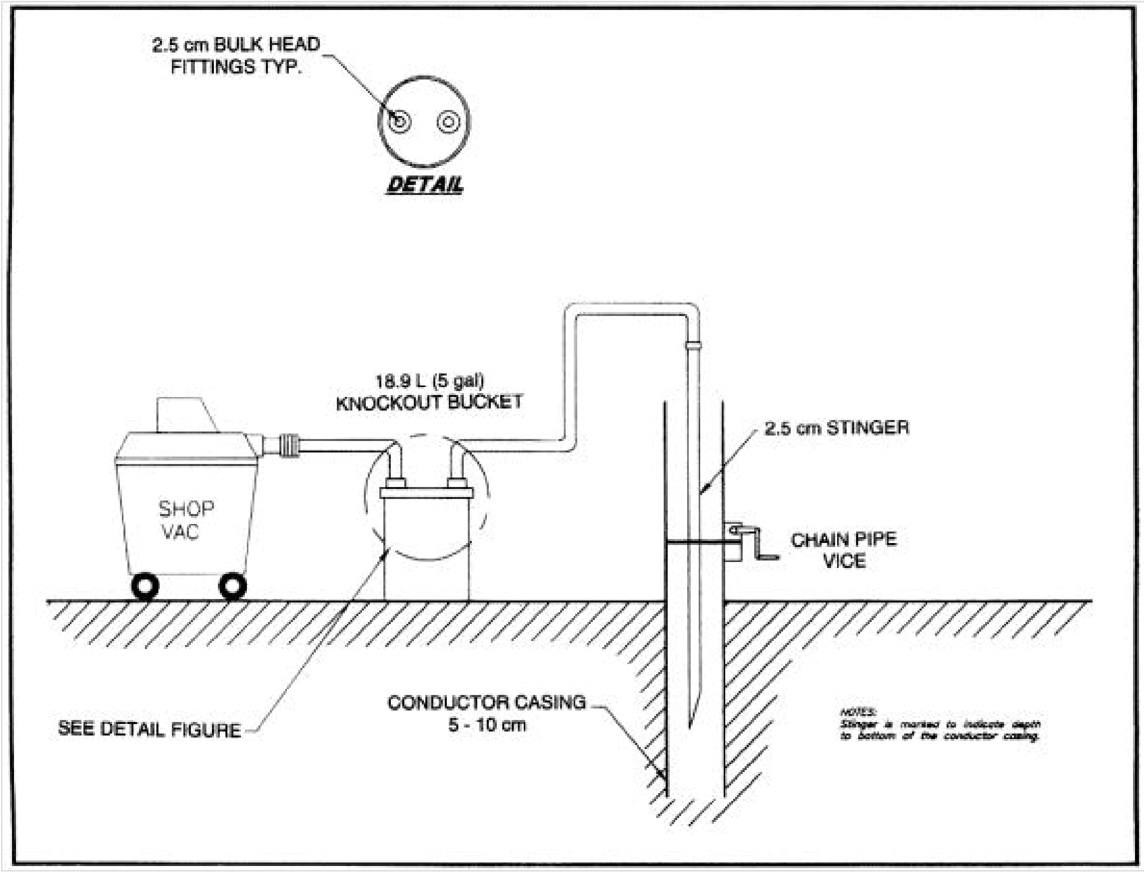

Fig. 1. Schematic representation of the equipment used in the vacuum method of pipe or casing installation in a collapsible sand or soil.

A chain-pipe vice secured to the pipe was used to exert downward pressure on the pipe or casing. A ladder or a stepstool was placed next to the vertical pipe to maintain the installer's balance and to prevent sideways insertion of the pipe into the ground. Although other gripping equipment may also hold onto the pipe tightly enough to either push or pull the pipe into the ground, we found that the chain-pipe vice worked the best. Plywood boards on which to stand or place the ladder reduced surface soil disturbance and helped stabilize the ladder. It is also helpful to drill a hole in the plywood to help guide and support the pipe as it enters the ground. The combination of downward force while removing the soil at the tip of the inserted pipe created a tightly packed access tube.

The installation of the neutron access tube required < 15 min. After installation, we cleaned the inside of the pipe with an absorbant rag taped to the end of a long pole.

Gypsum block placement involved the installation of a 10.2-cm-diameter PVC casing to 2.4 m depth using the same method as described above, except that multiple buckets were required to hold the removed sandy soil. Once the casing was in place, gypsum blocks were inserted into the access hole and placed one per depth, ranging from 0.3 to 2.4 m at 0.3-m intervals. The instruments were then covered with soil that had been vacuumed from the hole. The soil was backfilled into the hole and packed around the instruments, using a 1.9-cm rod, as the casing was raised slightly and eventually removed altogether allowing contact between the undisturbed soil and the backfilled installation area. Caution must be used while packing the soil around the instruments to prevent damage and wire breakage. To complete the installation, a paste of hydrated bentonite was spread around the edges of the protruding instruments and tubes to prevent excess water entry along the access hole and instruments.

The gypsum blocks were not calibrated for soil moisture content at this site. Instead, we used the resistivity readings directly and assumed a positive relationship between water content and resistivity. The gypsum blocks were treated as "wet-dry switches," where readings of 85 or more indicated wet conditions and readings < 35 indicated dry conditions.

Infiltration Study

A 1.6-m double-ring infiltrometer was installed in a vegetated dune soil on a 3.3- by 3.3-m level area. The inner ring was 1 m in diameter. The soil around the infiltrometer, to a distance of 0.5 m (2.6 m total diameter), was drip irrigated to limit lateral movement of the water applied to the infiltrometer. Water was applied to field-dry soil to determine its movement and redistribution in the vadose zone. Drip irrigation of the border area around the infiltrometer was initiated about 3 h before the water was added to the inside of the infiltrometer by hand sprinkling.

Twenty-five centimeters of tap water infiltrated in <1 h and resulted in minor, short-lived (<10 min) ponding. The plot was covered with plastic tarps immediately after water application to prevent evaporation, and soil water content was monitored with neutron attenuation and gypsum blocks (Gardner 1986). A covered control or nonirrigated plot was also instrumented with gypsum blocks and monitored for moîsture changes over time.

Data from gypsum blocks placed at every 0.3-m depth were read with a SoilMoisture meter (Soil Moisture Corp., Santa Barbara, CA). The water content was monitored with a field-calibrated CPN Hydroprobe neutron detector at 0.3-m intervals to 2.1 m depth in a 5.1-cm aluminum neutron access tube installed in the center of the infiltrometer. Readings were recorded every 15 min until the wetting front reached 2.1 m.

RESULTS AND DISCUSSIONS

Soil moisture monitored by gypsum blocks in the nonirrigated control plot did not change over time (Fig. 2). Beneath the surface of the test plot, the wetting front was sharp and well-defined as measured by both gypsum blocks and neutron attenuation (Figs. 3 and 4). The change in soil water content at specific depths over time indicate that water did not enter the access hole or run directly down the edge of the neutron access tube, so the backfilling and bentonite seal were effective.

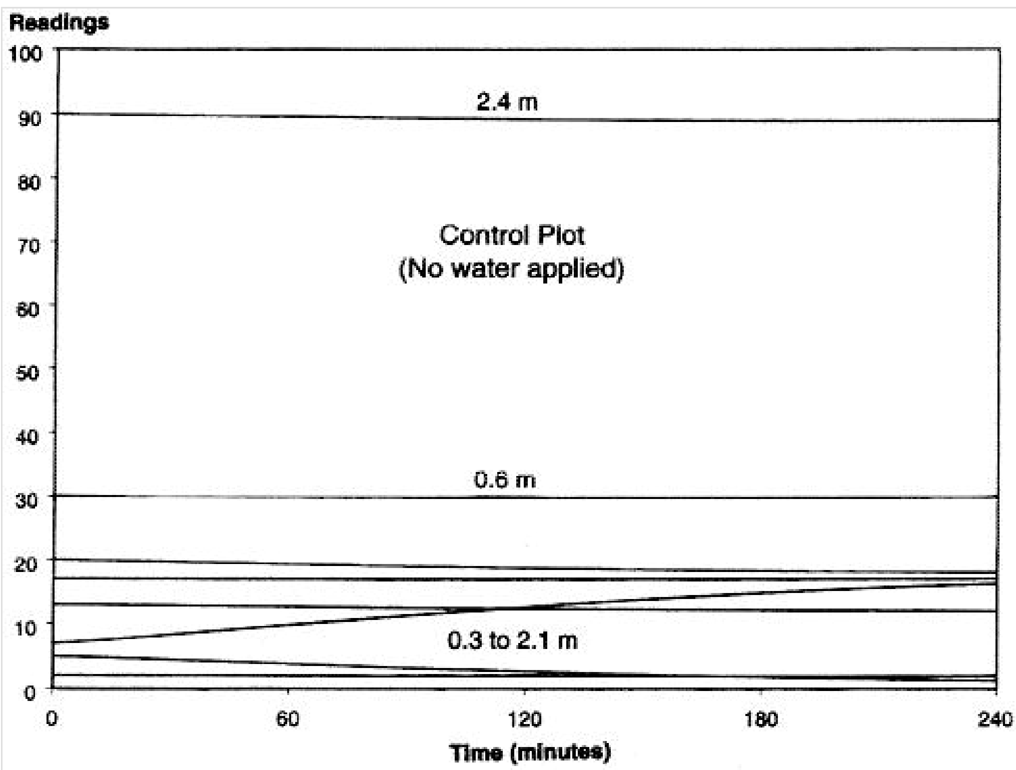

Fig. 2. Uncalibrated gypsum block readings taken with a resistivity meter over time in the control or nonirrigated plot at various depths below the surface.

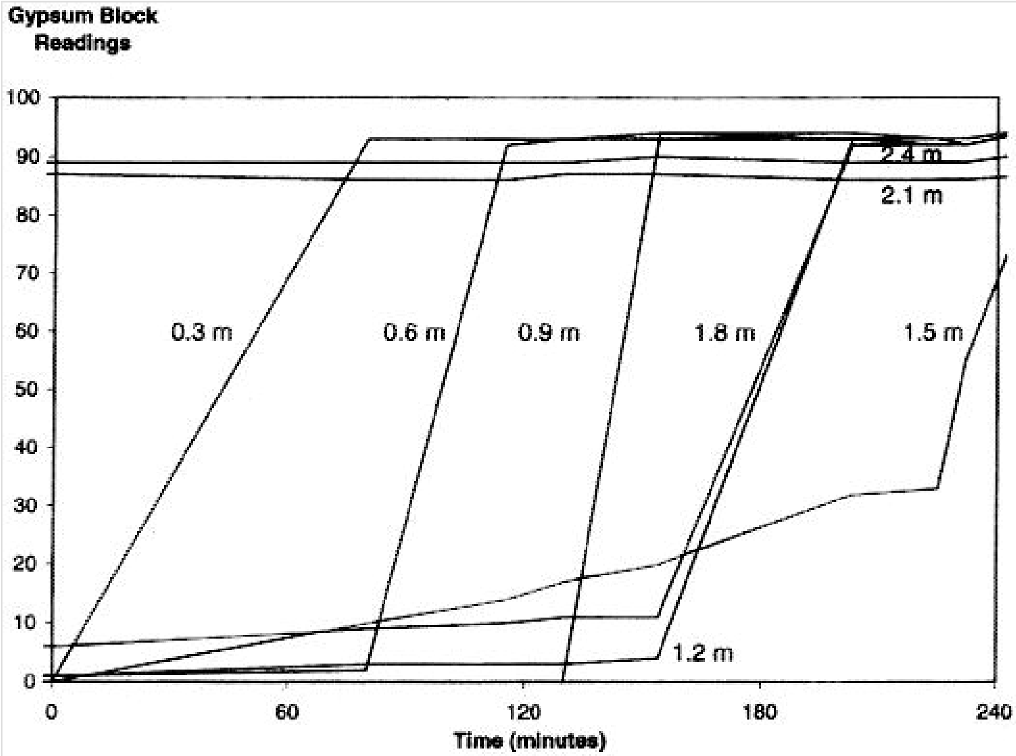

Fig. 3. Uncalibrated gypsum block readings taken with a resistivity meter over time after 25 cm of water were applied at the surface through an infiltration ring. High resistivity readings correspond to high soil water contents and visa versa.

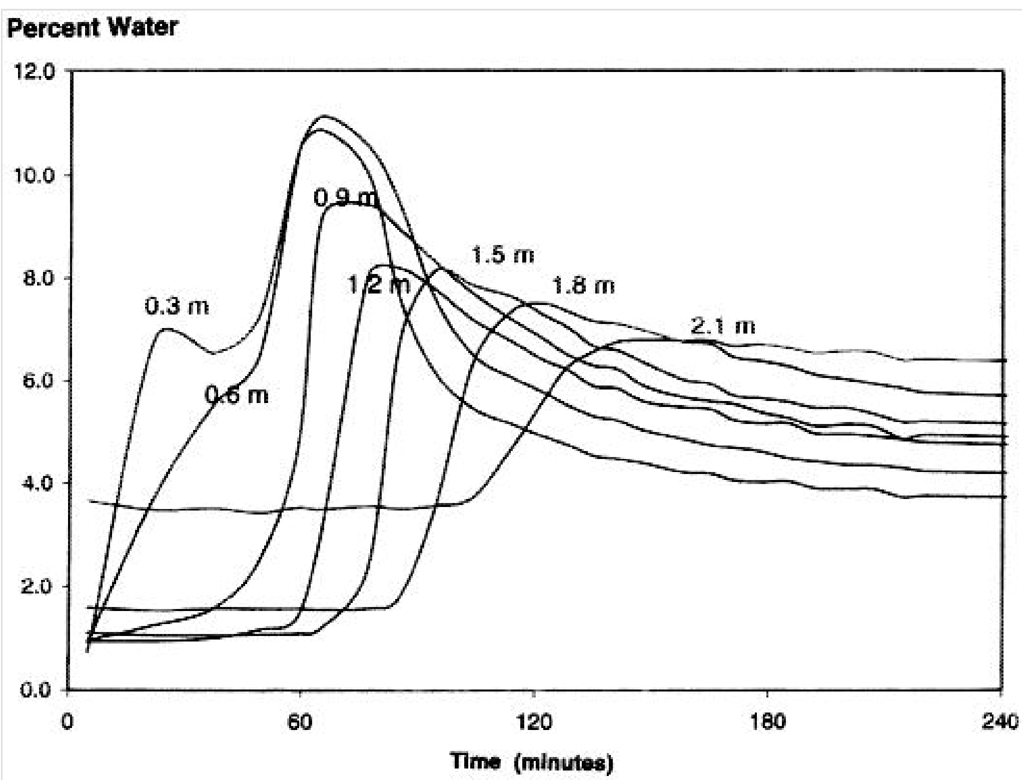

Fig. 4. Gravimetric soil moisture content, measured by neutron attenuation at several depths, during and after application of 25 cm of water to the test plot.

The wetting front was detected at a rate of 0.4 to 0.5 m hr^{-1} in the upper 1.2 m of the soil profile (Fig. 3). The highest rate of water movement and the only anomaly in the data occurred at the 1.8-m depth after an elapsed time of 200 min. The gypsum block at this depth became saturated before the block at 1.5 m, which was the last to record high water content (Fig. 3). This may have occurred in response to preferential flow to 1.8 m around the 1.5 m block or because the wetting front intersected a change in soil texture, which may have initiated fingering around the gypsum block. Additionally, the gypsum block itself may have been slow to saturate. Primarily, however, water movement through the vadose zone was monitored effectively by the gypsum blocks installed using the vacuum method.

The measurement of water content over time using neutron attenuation indicated that water did not travel along the tube or accumulate in pockets around it (Fig. 4). The wetting front was difficult to monitor in the upper profile but moved through the lower zone, from 1.2 to 2.1 m, at a rate of about 1.2 m hr^{-1}. Neutron attenuation detected changes in water content faster than the gypsum blocks and had a larger sphere of detection. Backfilling or packing around the gypsum blocks during installation may have reduced the rate of saturation of the blocks compared with the relatively undisturbed soil around the neutron access tube. The water content at 2.1 m remained constant at less than 4% until nearly 2 hours after the water was applied to the soil surface. Thus, the pipe was apparently installed uniformly and tightly within the soil profile, and preferential flow of water through the vadose zone did not occur within the sphere of neutron detection.

CONCLUSIONS

An innovative method for installing access tubes or conductor casing in unconsolidated, collapsible material such as dune sands has been presented. The casings may be used to keep sandy soil from collapsing until instruments are installed at various depths and surrounded by packed soil. Instruments such as gypsum blocks, piezometers, or tensiometers may be installed using this technique which combines downward force and suction to remove the loose material within the inserted pipe or casing.

Monitoring changes in soil water content at depth over time indicated that this method is effective for installing instrumentation commonly used in hydrology and soil physics field experiments. Water or contaminant movement through loose, poorly consolidated soil material such as dune sands can be observed with equipment installed using the procedures described.

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IMAGE GALLERY

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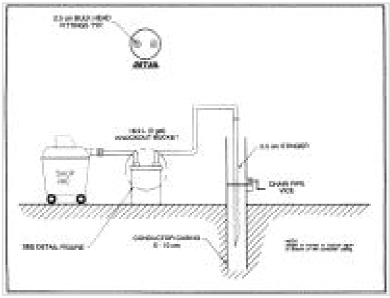

Fig. 1

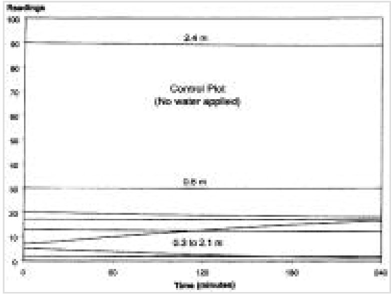

Fig. 2

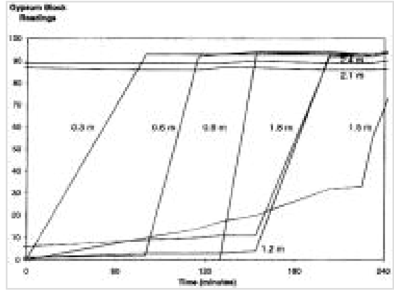

Fig. 3

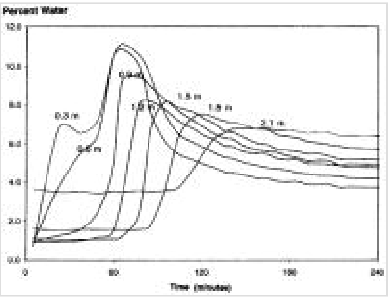

Fig. 4

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