

SAFETY NEWS

1994

CONSTRUCTION



• A quarterly publication of the Construction Safety Councils •

SAFE EXCAVATION

ABSTRACT

For the last several years Concept Engineering Group, Inc. (CEG) has been perfecting the technology to excavate precisely, safely, and efficiently. This technology uses a combination of supersonic jets of air and high flow, pneumatic vacuum transport to dislodge and remove soil. The supersonic jets of air are extremely effective at penetrating most types of soil, but are harmless to non porous buried objects like pipes or cables. The pneumatic transfer system has several unique features which allow soil, which is not the traditionally easily vacuumed material, to be handled effectively. Combining these two technologies effectively offers industry improvements over the state of the art of traditional and vacuum excavating today and opens up significant new possibilities.

EXCAVATING TODAY

Traditional

The most commonly used tool today for general excavation is the backhoe or, in larger sizes, the hydraulic excavator. These units are productive, versatile, reliable, and available in many sizes and configurations. *Equipment Today* magazine does an excellent job publishing summaries of specifications for these machines. Yet despite their popularity, there are drawbacks and dangers, especially in an urban or suburban setting.

In a congested urban area, digging progress with a mechanical excavator is often slow because of the time and extra care required to maneuver around existing utilities or other buried substructures. A spotter is often necessary in the hole to guide the backhoe operator via hand signals. Often, too, the backhoe operator sits and waits while the man in the hole finishes by hand digging around a buried utility. In the real world other complications exist such as the "located line" turning out to be abandoned with the adjacent active line still buried and just waiting to be hit. Even though contractors have excellent systems like "One Call" to aid in locating buried utilities, numerous accidents continue to happen. The magazine *Underground Focus* is dedicated to below-ground damage prevention and compiles the numerous accidents across the U.S. associated with excavation. For example, the January/February, 1994, issue cites a report of some 610 damage incidents in Connecticut alone over a year period to September, 1993. According to *Underground Focus*, the total magnitude of the cost to U.S. industry from excavation damage to underground utilities is difficult to quantify, but clearly amounts to millions of dollars annually.

Vacuum Excavation

For line location, small hole repair, and maintenance work, many companies today are beginning to use vac-

uum excavation equipment. The gas industry alone spends an estimated \$1.8 billion on repair and maintenance work annually, 30% of which is due to excavation costs. Even a small savings in labor or pavement restoration costs per hole amounts to a substantial yearly savings for a company that has tens of thousands of annual openings.

Subsurface Utility Engineering (SUE) is emerging today as an engineering service for accurately locating and mapping underground utilities during the early development of a highway project. Physical locating is preferably done using vacuum excavation equipment. The Federal Highway Administration has estimated an annual \$100 million nationwide savings if SUE were to be used by all state and local highway agencies.

Most vacuum excavation units today have common features. About 2/3 of the units use an air lance as the means of soil excavation with air flows from 75 to 185 cfm at generally 100 psig. All of the units use a hose to vacuum the material into some type of soil hopper. One man generally operates the lance; while a second man positions and moves the hose. A positive displacement type of blower is predominate with air flows between 1,000 to 2,000 cfm and suction ranging to 15 inches Hg. Generally, the entire unit, sometimes with separate engines for the air compressor and blower, is mounted on the bed of a utility truck; although trailer or skid versions are available.

All of the units have some common problems too. Although an air lance is rugged and cheap to make (about \$40 for the pipe, fittings, and valve), it is a terribly inefficient way to turn compressed air into a digging tool. Vacuum hoses are prone to clogging and the hoppers are of a limited capacity.

NEW TECHNOLOGY

CEG for the last several years has been working on an improving the digging process using high speed, supersonic, jets of air coupled with high flow, pneumatic vacuum transport.

Supersonic Air Jets

Unlike the hard cutting edges of shovels, picks, digging bars, blades or buckets, only the high speed air of the jet contacts the soil. Supersonic jets of air are preferable for precise, safe excavation over these tools because they:

- Effectively penetrate and dislodge most types of soil, but are harmless to non-porous items like buried pipes or cables;
- Are two to three times faster than hand excavation and can excavate rocky types of soils where a shovel cannot be used;

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- Are powered by a standard, portable air compressor readily available in the construction industry;
- Can be sized for different air flow rates depending on the excavation rate required;
- Deliver at a minimum twice the momentum force per unit area to the soil than a conventional "air lance";
- Have been built to operate on compressed air as high as 250 psig, where the higher pressure "sharpens" the jet for harder soils;
- Can be used in multiples for larger excavations;
- Unlike water jets, introduce no liquid into the excavation which increases the volume of spoil for disposal or could freeze during winter operations.

Although supersonic nozzles have been designed and built for many years for rocket engines, air jet excavation nozzles are different. Unlike propulsion nozzles, the energy to accelerate the air comes from the release of its compression rather than from the combustion of a fuel. Because of their small size, particular attention must be paid to the effect of the boundary layer on the nozzle profile. Special tooling and computer-aided-machining is used to manufacture the nozzles. CEG has developed its own proprietary design method and CAD-CAM interface for its air jet excavation nozzles. CEG continues to refine and improve its design through detailed mathematical modeling and laboratory experimentation.

Compared to an air lance, a tool with a supersonic nozzle has many important advantages. Compressed air exiting from the open end of a pipe nipple in an air lance expands suddenly to atmosphere in a unfocused, complicated manner. A properly expanded supersonic jet will have more kinetic energy and more focused momentum than the air stream from a lance. In practical terms this means that a supersonic jet can do more work and move more material than an air lance for a given size of compressor. For example, considering a standard portable air compressor of 175 scfm at 100 psig, the wasted fuel costs for an air lance are about \$50 for every 100 hours of use. Viewed in another way, to do the same work, the size of the compressor can be reduced using a tool with a supersonic nozzle resulting in a substantial initial capital equipment savings.

Pneumatic Vacuum Transport

Pneumatic vacuum transport naturally matches air jet excavation for a number of reasons. Like the air jets, only the suction air stream contacts the soil. The high speed jets of air effectively break up the soil into fractional inch particle sizes which are readily transported by the vacuum. When used concurrently, the jets overcome the traditional problem in suction systems of initially moving the material off of the surface by imparting an initial motion to and aerating the soil particles. In addition a vacuum system:

- Can remove material from a small diameter, deep excavation (pot hole) where a hand shovel or a backhoe bucket cannot;
- Pulls any dust at the excavation face into the system rather than releasing it into the open air;
- Can be filtered to various degrees depending on the



material being excavated and the site regulations;

- Can be made in various sizes to match the soil excavation rate;
- Can remove other material, such as water, from the excavation.

Yet, pneumatic vacuum transport of soil has its own unique set of characteristics and problems. Soil types vary widely in grain size, particle shape, packing, moisture content, grading, plasticity, organic matter content, etc. Soils, in general, are not the free flowing material most conventionally moved by pneumatic transport. Existing vacuum excavation units attempt to deal with the clogging problem in different manners.

All of the current vacuum excavation units use simply a vacuum hose to convey the material from the excavation to the hopper. Two types of hose are commonly used: a cheap, corrugated, underground drainage type plastic hose, or a heavy wall, rubber vacuum hose. The light, cheap hose can be slung over a laborer's shoulder, and is so flexible that there are typically many severe bends in the hose. These bends lead to serious clogging problems and high suction losses. The frequent clogs are cleared either by rapping the hose with a mallet or replacing the entire hose, both of which take time away from the digging. The other type of heavy rubber hose is too expensive to be discarded. Descended from sewer

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sucker types of trucks, typically the heavier hoses are used along with water jets. The water provides lubrication to allow the material to slide along the inside of the hose. Because of their high weight this type of hose is supported from a fixed boom which is raised or lowered hydraulically, but moved by hand from side to side which can be difficult and fatiguing.

All of the units, also, suck the soil into some type of hopper. Tank sizes vary with about 70% of the units having a volume less than about 40 cubic feet. In all cases the tank size limits the amount of work that can be done before the process has to be interrupted. The larger the tank, the more space is taken up on the unit and the greater the cost of the tank since it must be designed to take the full vacuum capacity of the system. When the vacuum excavator tank is mounted on the truck and the spoil cannot be put back in the hole by local regulation, the truck itself needs to leave the work site when its tank is full.

NEW EQUIPMENT

Soft Trencher

Based on CEG safe excavation technology and pneu-



matic transport experience, CEG, with support from Battelle, Columbus, and sponsored by the Electric Power Research Institute has recently completed an advanced trenching machine for the installation of electrical transmission cable in urban areas. The Soft Trencher development was undertaken by EPRI's Electrical Systems Division Underground Transmission Program as part of its effort to reduce the construction costs of underground electrical transmission facilities. The mission of the Soft Trencher is to provide a safer and more effective means

to trench in a urban and suburban environment. This self-propelled, rubber-tired vehicle:

- Has the flexibility to dig trenches up to 6 feet wide by 10 feet deep;
- Has a target excavation rate 25% faster than a backhoe;
- Uses interchangeable excavating heads for different types of soils each with multiple CEG supersonic air jets for excavation;
- Has a telescoping boom with lift/lower, slew left/right, and extend/retract motions for material pick-up;
- Utilizes a multi-stage vacuum and filter system for soil separation;
- Continuously discharges spoil via a conveyor into a truck;
- Operates from a remote, portable box with proportional joysticks to allow the operator to move about the excavation as needed;
- Provides an operator's seat with conventional steering wheel, accelerator, and brake pedal for travel around site.

The Soft Trencher has successfully completed preliminary testing in Pittsburgh and will be going through field trials prior to commercialization. The Soft Trencher is attractive for any utility or contractor trenching in an urban or suburban area for any of a number of different utilities including electrical distribution cable, gas pipe, water pipe, telephone cable, television cable, or other communication cables.

Low Cost Hand Held Air Tool

Concept Engineering Group is continuing development of additional safe excavation equipment. A low cost, general purpose, hand held air jet tool is planned to be introduced in the spring of 1995. To be operable from any standard portable or truck pto compressor that can run a paving breaker, the ergonomically designed tool will be useful for general excavation or cleaning. As stated earlier as opposed to a commonly used home-made air lance, the CEG tool will be lighter, safer, and more energy efficient. With a highly focused stream of compressed air, the tool will pay for itself in reduced fuel costs.

SUMMARY

With an emphasis today on safety, the use of vacuum excavation techniques should grow. Concept Engineering Group is at the forefront of safe excavation developing and improving air jet performance and pneumatic soil transport. □

*Richard D. Nathenson, P.E.
Concept Engineering Group, Inc.
Pittsburgh, PA*