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HYDRAULICS & PNEUMATICS

THE MAGAZINE OF FLUID POWER AND MOTION CONTROL SYSTEMS

FLUID POWER IN ACTION:

Mobile Equipment

Designing with air

Cartridge valves

SAE Show preview

Ideas & Applications:
Air powers Dextrous Hand

is sent to the controller. The controller then activates an electric motor to move the governor to a lower setting, reducing engine speed to approximately 1300 rpm. Actuation of any joystick or travel control instantly returns the governor to its original position. Engine speed increases in accordance with the position of the governor control lever. If constant engine speed is needed, the operator can turn off the AESC.

Straight-line travel — when implements are operated while the vehicle is traveling, a crossover valve directs one pump to provide flow for *both* left and right track drives. Equal flow is routed to each track to maintain travel in a straight line, but travel speed is reduced. The second pump provides flow for the implements in this situation. This feature provides advantages in material-handling operations, such as log sorting in a sawmill yard or landing, and fine grading during ditch cleaning operations.

Load sensing — pumps increase flow based on pressure in the return line from the open-center valves. As this pressure decreases — due to increased flow to implements, swing, or travel circuits — it signals the pumps to stroke to increase their flow rates.

Horsepower summation — to use total engine output more effectively, the horsepower summation control circuit provides greater hydraulic power to each circuit and offers faster implement speeds and stronger, faster pivot turns. Each pump can use up to 87% of the engine horsepower. When operating a function that requires flow from only one pump, power is diverted from the other pump to increase flow to the working circuit. Thus, single-function operation such as swing, bucket, and one-track turning are much faster, which affords quicker cycle times and higher production.

Hydraulic cylinder snubbers — hydraulic cylinder snubbers are incorporated in the rod end of the boom cylinder and both ends of the stick cylinder. Snubbers cushion the hydraulic shock encountered at the end of a cylinder stroke. This prolongs cylinder life and helps reduce noise.

Telerobotic excavator operates in hazardous environments

In 1983, Kraft TeleRobotics, Inc., Overland Park, Kans., began work to develop a new capability for remote manipulators called *force feedback*. Its goal: to provide equipment operators with a physical and mental dimension of feeling — by enabling them to experience the movements and forces acting on a distant manipulator. The experience creates a mental illusion or *telepresence*, as if the manipulator were an extension of the operator's own arm. Use over time has demonstated that, compared to remote control with only visual clues, force feedback enables the manipulator operator to perform more complex tasks with less risk of damage to the work site, manipulator, or tooling.

Force feedback technology is a key factor in the operation of Kraft's Haz-Trak. Designed for use at hazardous and nuclear waste sites, the Haz-Trak is a remotely operated, microprocessor-controlled, hydraulically actuated excavator that also is fitted with a dozer blade for grading, backfilling, and leveling operations. In addition, special tools can replace the excavator bucket so the machine can perform material-handling functions such as barrel and drum moving.

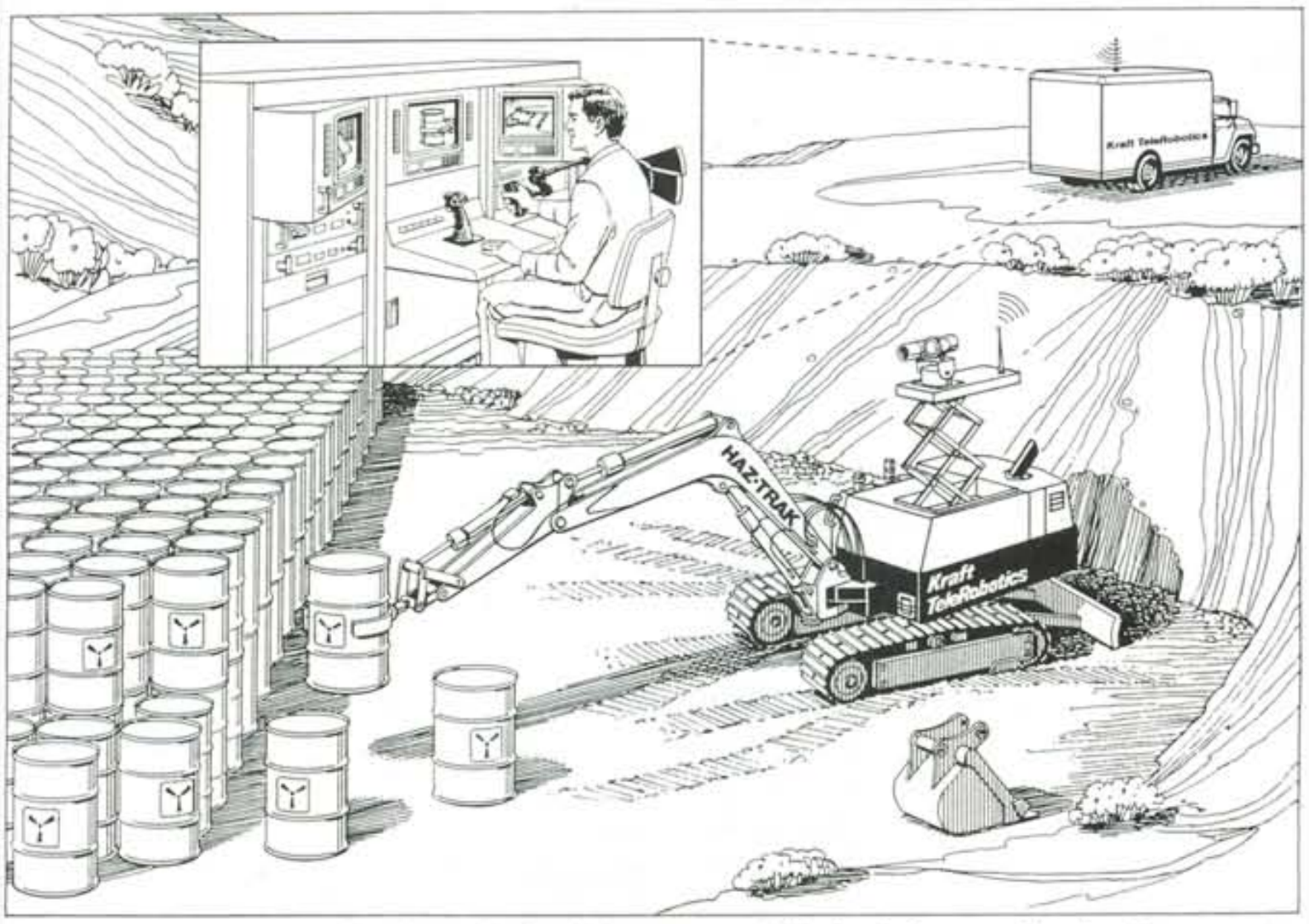
The hydraulic system on the diesel-powered Haz-Trak is fairly conventional. A variable-displacement piston pump supplies the system with 25 gpm at pressures to about 2130 psi. The 17.2-gal reservoir has a 3-μm pressure filter, a 10-μm return-line filter, and a wire-mesh suction strainer to protect the hydraulic system.

Two independently controlled hydraulic motors drive the machine's tracks, making counter-rotational steering possible. A hydraulic motor can rotate the machine's upper structure through 360°. Cylinders provide the excavator boom with four degrees of freedom: swing, elevation, crowd or dipper, and bucket curl. When the excavator is used as a material-handling machine, special hydraulic tools are mounted on the arm in place of the bucket. These tools may provide one or two additional degrees of freedom, such as yaw and roll.

Jet-pipe servovalves control all hydraulic actuators. Control electronics for the vehicle, excavator or material-handling arm, and viewing system is housed in an environmental enclosure located in the turret area. Communication between the distant master controller and the on-board electronics is accomplished over a fiber optic or RF telemetry link.

In the center bay of the control console, a fully proportional, displacement-type, 2-axis joystick controls vehicle speed and direction. Moving the joystick forward or back causes the vehicle to move forward or back at a speed proportional to joystick displacement. Twisting the joy-

Telerobotic Haz-Trac system remotely controls downsized, 6800-lb excavator with maximum digging radius of 15 ft, 5 in., that can travel at speeds to 2 mph.



Operator sees remote site through viewing system which includes two fixed color cameras for peripheral vision and single hydraulically actuated, pan-and-tilt-mounted color camera with auto-iris, auto-focus, and zoom. Material-handling attachments are operated remotely by force-feedback master/slave controller kinematically similar to human arm.

stick about its vertical axis, while moving it forward or back, causes the vehicle to turn left or right. Twisting the joystick while in its center OFF position causes the vehicle to counter-rotate about its own axis. A trigger switch mounted in the joystick serves as a safety interlock; the switch must be depressed to initiate any vehicle motion commands.

Force feedback comes into play when operating the machine as an excavator or material handler. The operator uses a Kraft KMC 9100-MC controller as the man/machine interface. This device is a compact, six degree-of-freedom, force-reflecting master which bilaterally controls the remote excavator arm. Kinematically similar to the human arm, the master controller provides a high degree of dexterity. The master/slave arrangement operates as a position-controlled, closed-loop servo system. Movements introduced at the master control by the operator's arm are duplicated by the slave excavator arm; forces felt at the machine arm are reflected at the control. A fully intersecting wrist design reduces cross-coupling and further enhances the intuitive operator interface.

The master controller is counterbalanced to minimize effort and has potentiometers at each of six joints to provide master positional information to the microprocessor. Five axes are electrically actuated to impart force back to the operator. The custom electric actuators produce high force reflection with very low back-drive characteristics. Low force thresholds and excellent system fidelity result in a high level of sensitivity for the operator, with little fatigue. When an optional end-effector — such as a barrel handler — is installed on the excavator arm, a trigger potentiometer incorporated into the terminus-style hand grip provides proportional control of gripper closing force.

Among other important characteristics, Kraft's microprocessor-based control system has the ability to:

- scale down the master-to-slave relative-motion ratio for precise end-effector control
- offset the master position relative to the slave for operator comfort
- establish motion boundaries or individual joint restrictions — using software — to prevent impact with peripheral equipment, and
- teach the excavator arm a routine or sequence electronical and save it in rugged bubble-memory for later automatic execution.

Cylinder offsets excavator boom for close-in digging

The LS-1600 excavator — smallest in the C Series II line built by Link-Belt Construction Equipment Co,. Lexington, Ky. — is especially designed to perform at jobsites with limited working space. Where buildings or other obstructions prevent the 15,000-lb machine from working directly over a trench, its 3-piece boom can be offset hydraulically to the right or left up to 44 in. from centerline — enabling the operator to dig along foundations, pipelines, etc.

Boom-offset cylinder is pinned between lugs on base section and tip section of 3-piece boom on side outboard from operator. Offset rod — seen along operator's side of boom midsection — pins between same two attachment points on opposite side of boom.

To offset the boom, the operator first unlocks and then depresses a spring-centered pedal in the cab that activates a 3-position, spring-centered directional control valve by means of a push/pull cable. This valve routes flow from a variable-displacement piston pump to an offset cylinder mounted along the boom. Pushing the pedal forward retracts the cylinder to offset the boom away from the operator; pushing the pedal to the rear extends it to offset the boom toward the operator. When the pedal is released, the valve shifts to its blocked center position to maintain the offset cylinder at the selected displacement. HP