TECHNOLOGY UTILIZATION

MECHANICAL SYSTEMS

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

Compilations are now published in one of nine broad subject groups:

SP–5971: Electronics – Components and Circuitry

SP–5972: Electronics Systems

SP–5973: Physical Sciences

SP–5974: Materials

SP–5975: Life Sciences

SP–5976: Mechanics

SP–5977: Machinery

SP–5978: Fabrication Technology

SP–5979: Mathematics and Information Sciences

When the subject matter of a particular Compilation is more narrowly defined, its title describes the subject matter more specifically. Successive Compilations in each broad category above are identified by an issue number in parentheses: e.g., the (03) in SP–5972(03).

This document is one in a series intended to furnish such technological information. Divided into three sections, this Compilation presents information on several mechanized systems. Section 1 contains articles on robotics. Section 2 contains articles on industrial mechanical systems, including several on linear and rotary motion systems. Section 3 discusses several mechanical control systems, such as brakes and clutches.

Additional technical information on the articles in this Compilation can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA has decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Contents

Section 1. Robotics

TERMINAL-POINTER HAND CONTROLLER
FOR TELEOPERATOR APPLICATION

Hand Controller

The man/machine interface is the most difficult task in the development of teleoperator systems. All currently used systems have one or more disadvantages, such as complexity, inaccuracy, slowness, or bulkiness. A newly-designed hand controller has many of the advantages of one of the best systems, an exoskeletal master. There is spatial correspondence between the operator and the end effector, control functions are all located in a single place, and movements in all three directions may be controlled accurately. However, unlike the exoskeletal master, the hand controller is small and compact. It is operated with a single hand and has a dead-man switch, which locks all motions when the controller is released.

The manipulator control is shown in the figure; it has three degrees of rotational freedom and a linear-advance control. Rotational motions correspond to wrist movements. The manipulator control has been incorporated in a two-dimension-of-motion model using a transmitter and a receiver to eliminate wiring from the intermediate system to the slave arm.

There is a one-to-one correspondence between the angular orientation of the hand controller and the angular orientation of the end effector. An intermediate subsystem, either a computer or a mechanical analog, transforms the input command motions from the hand controller into individual command motions for the joint.

Source: C. D. Pegden and E. L. Saenger of
URS/Martix Co.
under contract to
Marshall Space Flight Center
(MFS-22860)

Circle 1 on Reader Service Card.

1

ADVANCED ACTION MANIPULATOR SYSTEM (ADAMS)

Slave Kinematic Arrangement
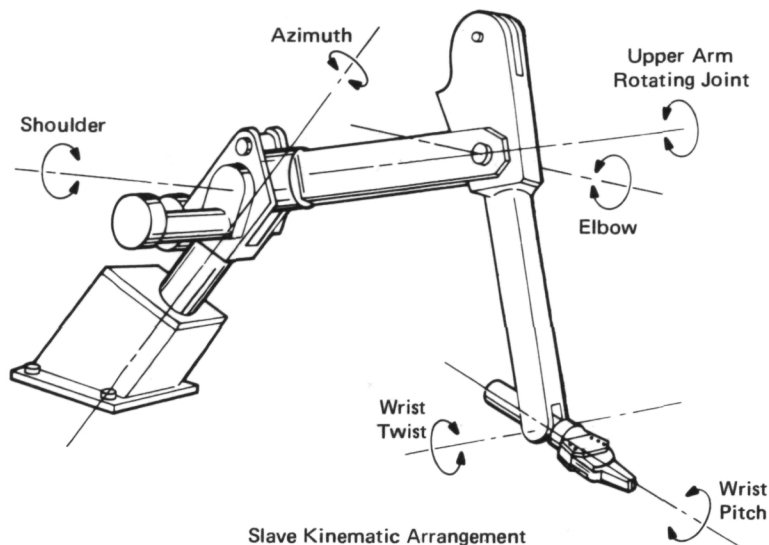
Hands and arms, man's most indispensable and versatile tools, are easily injured in hostile environments. For this reason, explosive, radioactive, and other hazardous objects are sometimes handled with mechanical manipulators. A typical manipulator system is operated with hands and arms and should reproduce as closely as possible their agility, sensitivity, and freedom of motion. Unfortunately, most manipulators are very complex and expensive. Therefore, recent emphasis has been to cut their cost and complexity with a token compromise in performance.

One recently developed low-cost manipulator called the Advanced Action Manipulator System (ADAMS) offers improved performance over other models in its category. It features larger force and reach capabilities and is readily convertible for underwater use. The system, built as a unique kinematic arrangement, provides an extremely large working envelope. The arms are designed so that appropriate seals may be added for shallow, underwater operation. The system has six degrees of motion (see figure): the azimuth joint, the shoulder joint, the upper arm rotating joint, the elbow joint, the wrist pitch, and the wrist twist. Its other features include:

1. A load capacity of 6 lb (2.7 kg).
2; A slave arm positional accuracy of 0.1 in. (2.5 mm).
3. A reach capacity of 3.5 ft (1.05 m).
4. A maximum arm speed of 30 in./sec. (0.75 m/sec).

In addition, the arms are of conventional aluminum welded construction for light weight. Stainless steel is used where added strength is needed.

The drive mechanisms of the system are operated with electronic controls and employ permanent-magnet servo motors with attached planetary gearheads. One motor gearhead combination is used for the shoulder and elbow motion, the other is used for the wrist motion. The potentiometers are packaged internally for protection and to minimize the profile. They are spur-gear driven off the motor shaft.

Two main sets of counterweights are included with the system. They extend behind the shoulder approximately eight inches (20 cm). The sum of the two sets eliminates the shoulder joint imbalance. Adjustments of these counterweights between the right-hand and left-hand manipulators provide balance about the tilted azimuth axis.

The servo controls include an operational amplifier output stage to drive the motors. A power conditioning card feeds ±8.1 V to the potentiometers and ±6.2 V to the operational amplifier. In addition, a lag network within the amplifier provides the servo compensation. Finally, gain between the master and slave is controlled by a stepping rotary switch which changes the master input resistance to the operational amplifier.

Circle 2 on Reader Service Card.

A PROPOSED REMOTE MANIPULATOR SYSTEM: A CONCEPT
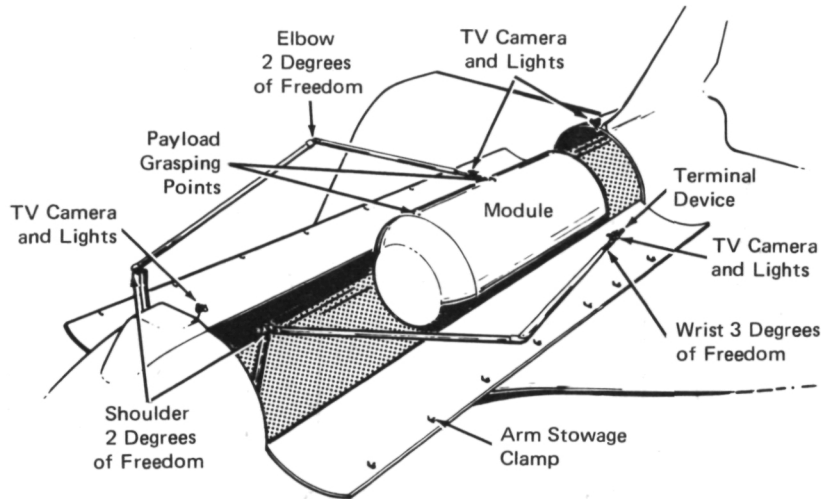
In recent years, remotely operated mechanical arms have become an object of interest to many industries involved in some phase of routine production or assembly. Ideally these arms should perform a wide variety of tasks, require little operator training, and be adaptable to automatic control.

A manipulator control system, proposed for use on the space shuttle, meets these requirements and has many features that would be of interest in several applications. The system has a variable ratio, mixed mode, bilateral, master-slave control. The arms (shown in the figure as proposed for a space shuttle) consist of a shoulder with two degrees of freedom, an elbow with two degrees of freedom, a wrist with three degrees of freedom, and a terminal grasping device. An operator can be readily trained to use the geometrically similar master control that allows parallel control of all the degrees of freedom. Feedback is provided by TV cameras attached near the shoulder, near the terminal grasping device, and at the end of the shuttle opposite the arm.

The system has several features that allow it to efficiently perform a wide range of tasks.

A low sensitivity mode provides a one-to-one ratio between angular movements of the master and the slave. This mode is suitable for moving a load over large distances and for other operations which do not require precise coordination.

A high sensitivity mode has an eighteen-to-one ratio of angular motion between the master and the mechanical system. This high ratio provides a degree of control accurate enough to allow an operator to perform delicate and exact manipulations without extensive practice.

The system is provided with positional and coordinate indexing. At the high master-to-slave angular ratio, more than the full range of movement on the master control may be required to achieve the desired motion by the slave arm. If the master control has reached the end of its play, the slave arm may be position indexed, or held in position, while the master control is returned to the other extreme position from which further motion can be directed. Coordinate indexing maintains geometrically parallel control upon switching the camera used for feedback. In addition, coordinate indexing can be used to operate the arm in direct relation to some device or operation as may be required in an automated process.

Finally, the system may be programed to automatically perform predetermined tasks such as those that are often required on assembly lines.

Circle 3 on Reader Service Card.

A PROPOSED HAND-TOOL ASSEMBLY FOR ROBOTS

Figure 1. Allen Wrench   Figure 2. Wirecutter
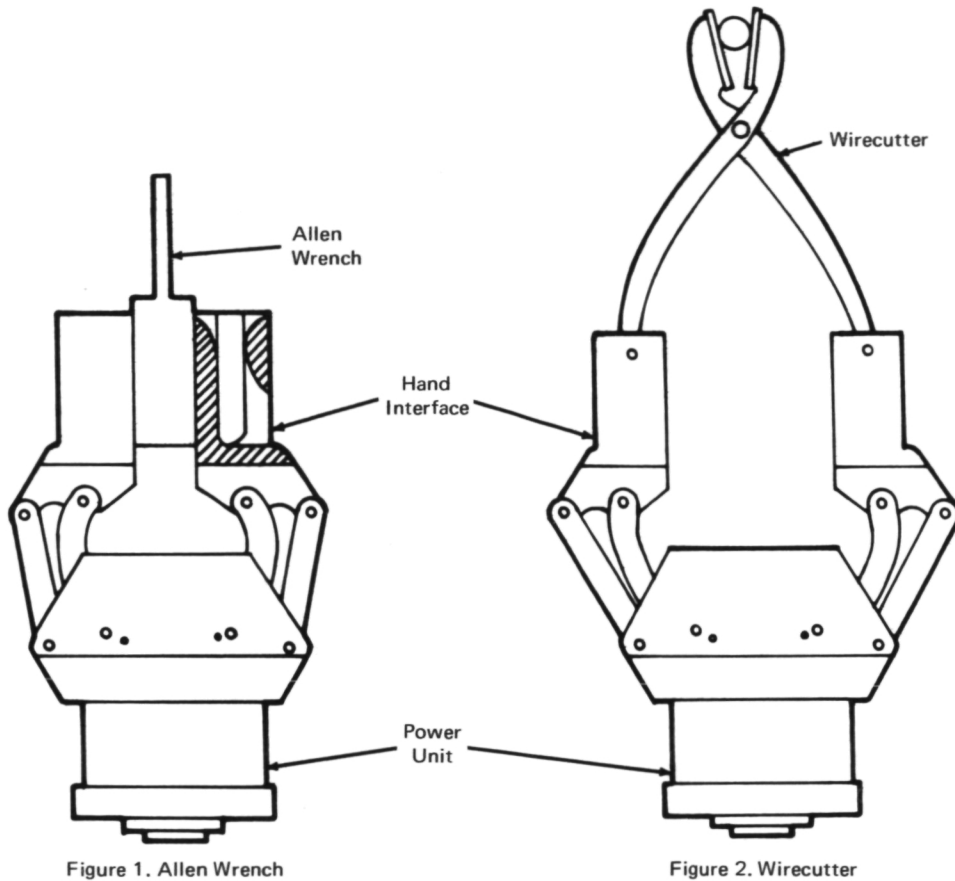
Terminator Kit Assembly With Hand Tools

In general, robots and remote manipulators cannot hold, operate, and release hand tools. Some types of hand tools can be fitted with makeshift brackets that allow the robot to hold them, but hand tools that open and close cannot be used without considerable modification to the robot.

A proposed end effector (that part of the robot which does the task) will grasp, hold, operate, and release modified tools. The end effector is packaged as the Terminator Kit Assembly (TKA) and includes all the features that a mechanical manipulator needs to use hand tools for maintenance, repair, or assembly work.

It includes a tool box, a hand interface, and a power unit. The tool box holds the hand tools and, on command, releases them to the hand interface which accepts and operates them. The power unit supplies the "muscle" for the assembly. Figures 1 and 2 depict the assembly with two different types of tools. The same handle geometry may be used for most tools.

Source: D. H. Dane and H. T. Blaise
Marshall Space Flight Cneter
(MFS-22266)

Circle 4 on Reader Service Card.

RECOGNITION SYSTEM FOR CLASS II ROBOTS
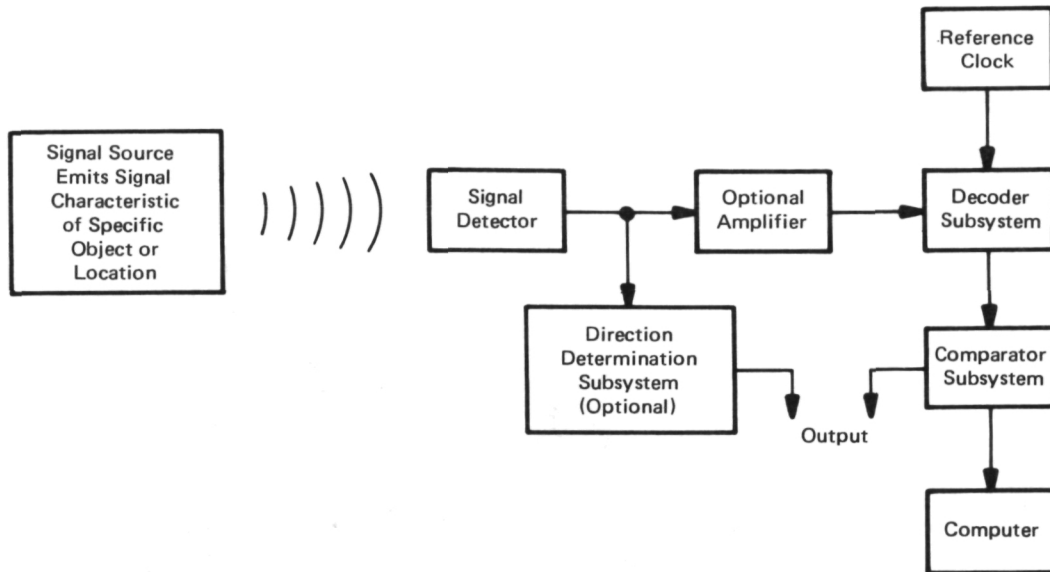
Class I robots are designed to function in an unknown environment. Class II robots, on the other hand, are intended to function in a specific environment. Class II robots thus entail the concept of organism/environment design rather than organism-oriented design. Because of this it is possible, through appropriate planning of the environment, to provide such robots with the ability to recognize selected environmental features. This can be achieved by associating with such features infrared, visible, or ultraviolet sources which emit coded identification signals.

Numerous means of coding exist, among the simplest of which is frequency or pulse-rate encoding. The receiver is located on the robot and may incorporate a means for determining the direction of the signal source (see figure). Several such means exist, most of which (including both passive direction finding and active pointing systems) are based on an extended detector located behind a slit or an aperture. The output of the receiver is amplified if necessary, and the frequency or pulse rate is extracted either by counting or by active filtering.

Both digital and analog implementation are feasible; however, the digital system offers more flexibility. The binary output of the counter is compared with stored binary words, and an indication is provided if equivalence is established. The counter is gated on and reset with timing pulses provided by the system clock. The information in storage need not consist of fixed words corresponding to known objects/locations but may consist of a recognition algorithm, which combines the robot's current state with its past history to generate a recognition code against which decoded incoming signals can be matched.

This system is superior, for Class II robots, to the three major techniques of robot control used by prior art. It has inherently greater resolution than do systems based on radio or radar signals. Its data storage and processing requirements are small compared to those of systems which are dependent on totally self-contained methods of position-data acquisition via comparison with a computer-stored map. And finally, it produces results presently unobtainable by systems which attempt to implement various pattern recognition methods.

Circle 5 on Reader Service Card.

Section 2. Mechanical Systems - Rotary and Linear

PORTABLE BEVELING TOOL
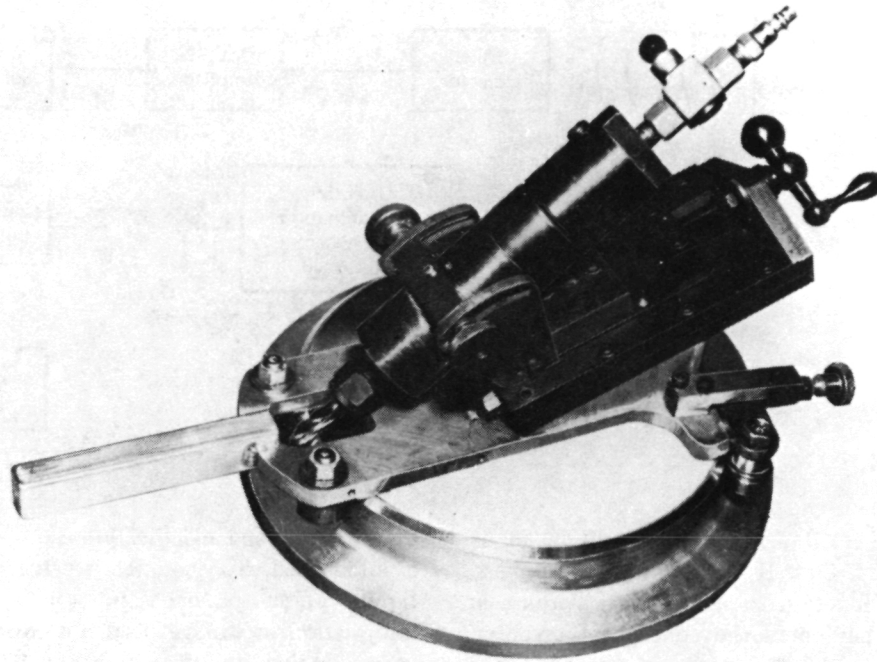
Currently, the fabrication of an elbow assembly requires mating the flange and elbow by fusion butt welding. This requires scarfing a 40 degree bevel on the outer edges of the abutting end surfaces of the components. When done manually, it is time consuming and does not produce uniform results or consistent quality.

A portable beveling tool has been designed to semi-automatically bevel the end surfaces of tubular or cylindrical components.' As shown in the figure, the tool is positioned with respect to the flange by means of four roller elements and held rigid by the base. Also mounted on the base is an air driven motor with a cutting element attached to its shaft. The cutter extends through the aperture where it makes contact with the workpiece. To adjust the cutter angle in relation to the workpiece a pair of calibrated scales are provided. Their position is locked in place by means of two knobs.

In operation, the tool, adjusted for the desired cutting angle, is placed on the workpiece as shown in the figure.

The rear roller spring is adjusted to avoid any erratic movements. A source of compressed air, controlled by a valve, is attached to the motor. By means of the feed screw handle, the rotating cutter is slowly moved until it makes contact with the flange. The entire tool assembly is then rotated around the perimeter of the flange. To facilitate the rotating process a handle is provided on the base.

To bevel the inside edge of the flange an end mill type cutter can be used. By controlling the feed screw adjustment, the depth of cut is limited.

Source: R. H. Snowden of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-16863)

Circle 6 on Reader Service Card.

MACHINE FINISHES BALLS TO HIGH DEGREE OF ROUNDNESS
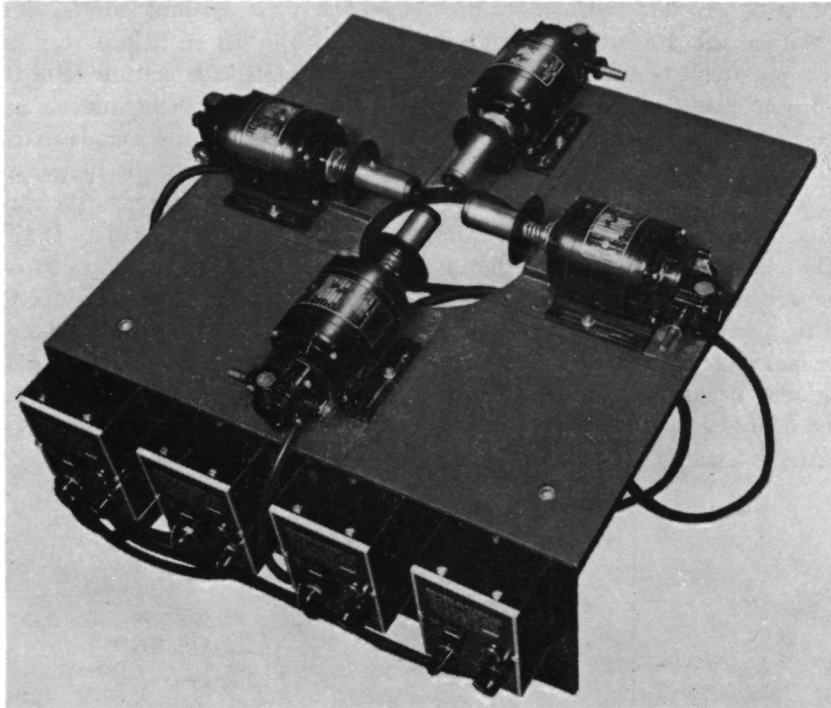
The machine shown in the figure will finish a ball to roundness (sphericity) within 12.5 nm (half a microinch) from any type of hard material. Machines used previously would produce a ball with accuracy of only 125 nm (five microinches) roundness. Grinding and polishing of the ball to this tolerance are accomplished by lapping elements on four to six motor-driven spindles.

Four spindles with lapping elements used for grinding and polishing a relatively small ball are positioned around a circular opening in an aluminum platform which is supported by one solid-metal side and two leg brackets on the opposite corners. The spindles holding the polishing laps are adjustably spring-loaded to ensure constant contact pressure on the ball and are driven by four electric motors mounted on the platform. Individual motor controls are mounted on the side of the platform and allow variation of the speed and direction of spindle rotation, which results in a random motion of the ball. It is this random motion with respect to the polishing laps that effects the high degree of uniform roundness in the ball.

The grinding-lapping compound drips onto the ball from a container positioned directly overhead (not shown). The excess compound and the abraded ball particles are collected in a container below the opening in the platform. For a heavier and larger diameter ball, a fifth spindle is used to support the ball from below; this spindle is driven by an electric motor mounted on an angle arm beneath the platform. When the fifth spindle is used, a ring channel beneath the spindle catches the compound and material removed from the ball, thus preventing coating and clogging of the motor. A sixth spindle and motor may be mounted directly over the ball to provide a faster finishing rate and improved roundness.

Circle 7 on Reader Service Card.

REVERSIBLE MOTOR AND HELICAL GEAR COMBINATION PROVIDES
POSITIVE BIDIRECTIONAL LINEAR AND ROTARY MOTION

A novel combination of standard mechanisms provides a new tool for soil particle size reduction which is readily adaptable to remotely controlled usage. A helical gear train driven by a reversible motor is combined with an auger/cylinder grinder. The marriage of these two mechanisms allows the soil particles of a sample to be reduced in size; and by reversing the motor, residual or unwanted soil particles may be purged from the system easily. The reliability required for efficient remote-control usage demands a simplicity of design. Thus it is desirable to lower the auger (allowing the purged sample to escape) and reverse its rotation using a minimum of additional mechanism. The new design accomplishes this by taking advantage of the natural end thrust characteristics of a helical gear train.

The driver helical gear is driven by a reversible motor. The driven helical gear turns the shaft of the conical auger. The end thrust of this helical gear forces the conical auger shaft into the up position as shown in Figure 1. As the soil sample enters the inlet port, the particles fall down the inner wall of the cylinder, attempting to fall through the clearance space between the auger and the cylinder. The rotary motion of the auger tends to lift the particles of soil and recirculate them. The constant abrasion due to recirculation breaks up the particles until they are small enough to escape through the clearance spaces. Upon obtaining the desired amount of processed soil, the motor is stopped. The relatively-weak compression spring maintains the auger in the up position.
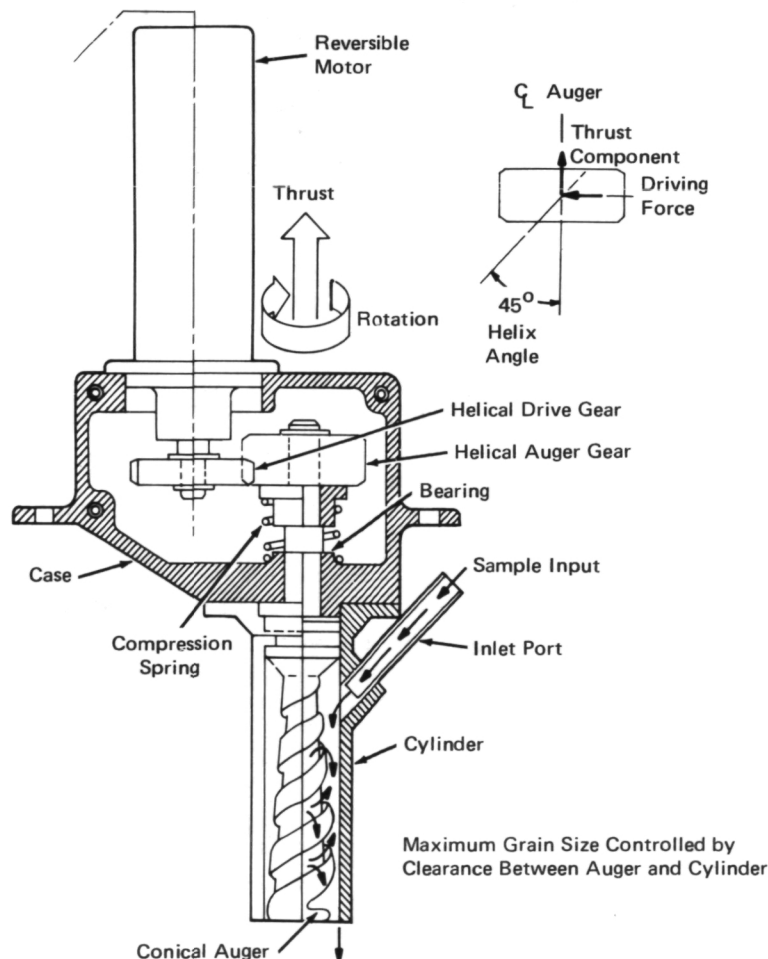

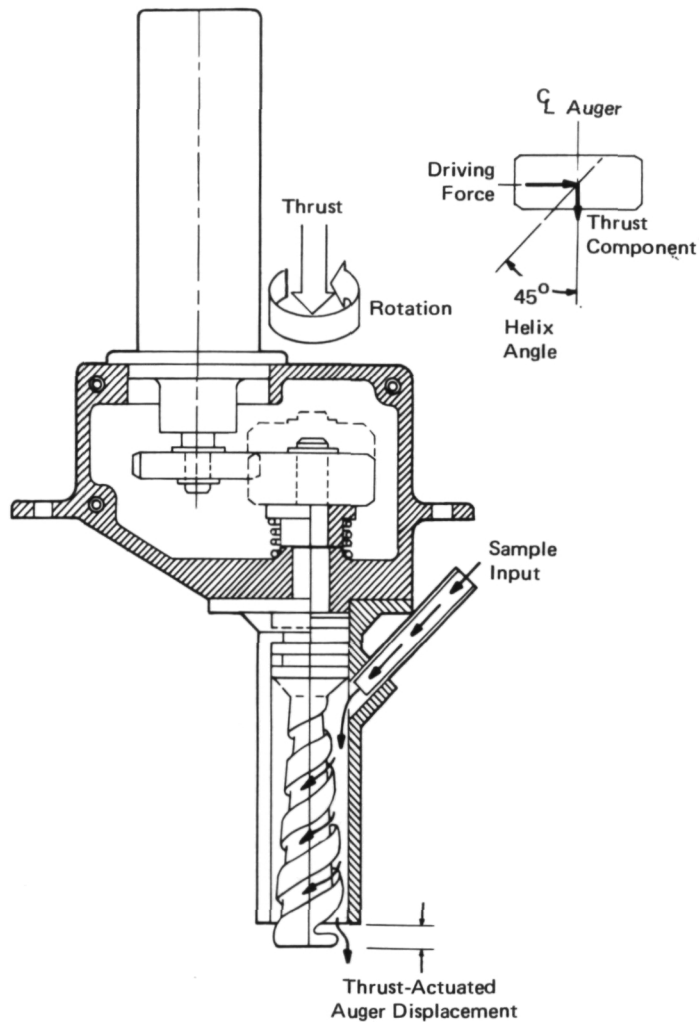Figure 1. Soil Processor in Processing Mode

Figure 2. Soil Processor in Purge Mode

Residual soil may be purged from the processing unit as shown in Figure 2. The motor is reversed, reversing the rotation of the driven helical gear. The end thrust of the gear overcomes the weak compression force of the spring, causing a downward movement of the conical auger. The centrifugal force of the rotating auger, combined with the expulsion action of the auger flutes, completes the purge. Thus, as used in this device, the helical gears eliminate the need for an auxiliary purging mechanism. Stopping the motor, the compression spring forces the auger to the up position; and the processor is ready to reuse.

This tool may prove useful in soil survey and soil evaluation work performed by building or construction firms. Another possible use may be in the chemical processing of dry or slurried products, where reversal or clearing of flow would be required.

Circle 8 on Reader Service Card.

MOTOR/DRIVE COUPLING WITH SELF-ACTUATED LINEAR PRETRAVEL

The small soil grinder shown in Figures 1 and 2 eliminates a secondary mechanical system previously required for purging the system at the completion of each cycle. It provides a low-friction, purely-axial, camlike displacement of the auger, activated simply by reversing the motor. Since the drive motor and the auger are coaxial using this method, the motor bearing also can serve as the upper carrier bearing for the auger.

A sleeve-type coupling, with two helical slots 180° apart cut through its outer wall, is attached to the motor output shaft. The shearpin follower is inserted through the slots, the guide bushing, and the auger shaft. For the corresponding mode (Figure 1), the initial rotation of the motor drives the shearpin follower up the slot and moves the auger to the extreme upward position. At this point the pin bottoms out, delivering the full torque of the motor to the auger. A local flat in the top of the slot removes the thrust loads and provides positive location of the auger as long as power is applied.
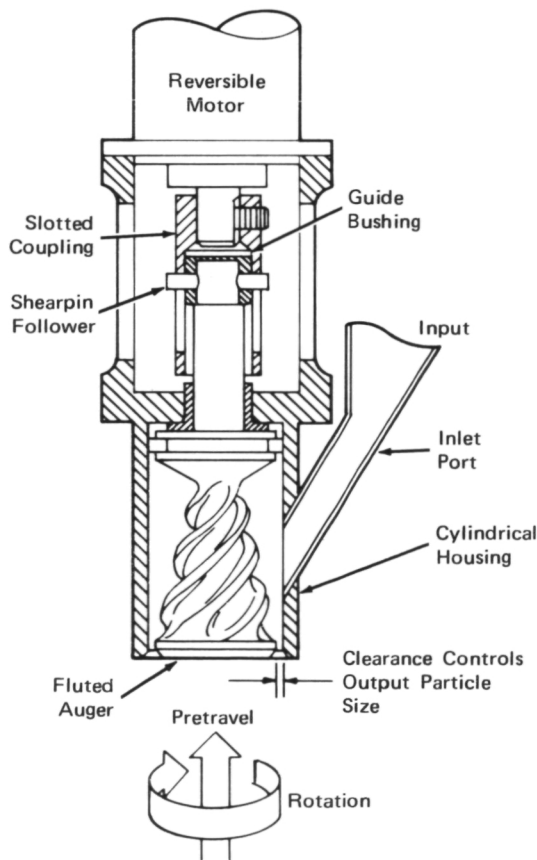

Figure 1. Soil Grinder in Processing Mode
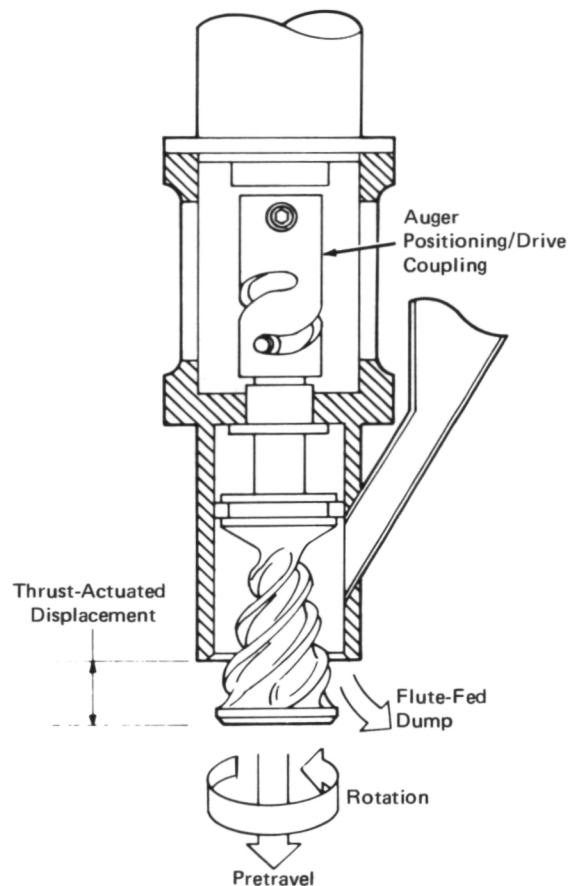
Figure 2. Soil Grinder in Dump Mode

Once a sufficient amount of sample has been processed, the motor is stopped and its direction is reversed. The initial rotation drives the pin down the slot and moves the auger down and out of the housing (Figure 2). The pin then bottoms out, and the auger rotates and dumps any material that is still in the inlet port.

The device is readily adaptable to miniaturized applications where linear pretravel might be required for gear engagement. On a large scale, it could be used with a fluted dump valve in storage bins for granular solids such as grain, where unagitated flow might clog the dump port.

Source: J. Timbrook of
Martin Marietta Corp.
under contract to
Langley Research Center
(LAR-10790)

No further documentation is available.

IMPROVED SYSTEM FOR MEASURING SPEED OF ROTATING MACHINERY
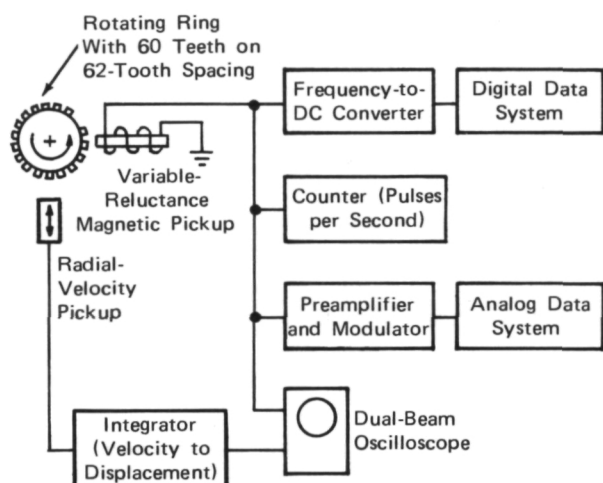
A conventional method of monitoring the speed of rotating machinery is to use a gear with 60 teeth and a magnetic pickup as a sensor to indicate the number of teeth per second passing by it. The number of teeth passing by in 1 second, as indicated by an electronic counter connected to the pickup, equals the speed in revolutions per minute. When a vibration or stress problem is under investigation, it is customary to use an additional 1-tooth gear and a second magnetic pickup to provide a rotational reference point for the vibration or strain sensor. Use of the two gears and two magnetic pickups with their associated equipment constitutes a redundancy and requires an inconvenient arrangement.

A gear is now designed that combines both functions and does not require duplicate electronic equipment to provide an indication of speed and a reference position.

The gear is designed with spaces for 61 or 62 teeth, but only 60 are included in the finished gear. The 1- or 2-tooth gap constitutes a reference point that can be detected electronically, and the convenient count of 60 per revolution is retained. Since the gear is only a minor part of the speed-measuring system, existing equipment can be used without modification.

The diagram illustrates a typical application of the speed-measuring system, when used in conjunction with a velocity pickup, to detect the radial motion resulting from unbalanced forces acting on a rotating body. For this purpose, the gear notch is related to the position of the magnetic pickup and a vibration sensor by installation on the machine. The electronic counter provides a real-time display of machine speed in the form of pulses per second or revolutions per minute. The output of the magnetic pickup can be converted to a proportional dc voltage, using conventional frequency-to-dc converters, and presented visually by a digital voltmeter. Alternatively, for recording speed in analog or real time, the output is first conditioned by a preamplifier and modulation system.

As indicated in the diagram, the phase relationship of a radial displacement relative to the notch in the gear can be presented visually during a test with the aid of a dual-beam oscilloscope. One beam displays the output of the tooth sensor while the other displays a vibration or strain signal. In the instance depicted by the diagram, a radial velocity pickup provides an indication on one beam of the oscilloscope of the magnitude-time relationship of the displacement while the other beam provides a reference mark corresponding to the notch in the gear.

This system can be calibrated by adding a known unbalance at a known position on the rotating mass and noting the effects on the oscilloscope. Any unbalance caused by the lack of symmetry of the gear is neutralized in the usual manner prior to installation as a test device. The notched gear could be permanently installed in any rotating machine to measure speed and to provide a method of locating rotational position.

No further documentation is available.

HIGH-AMPLITUDE SINUSOIDAL PRESSURE GENERATOR
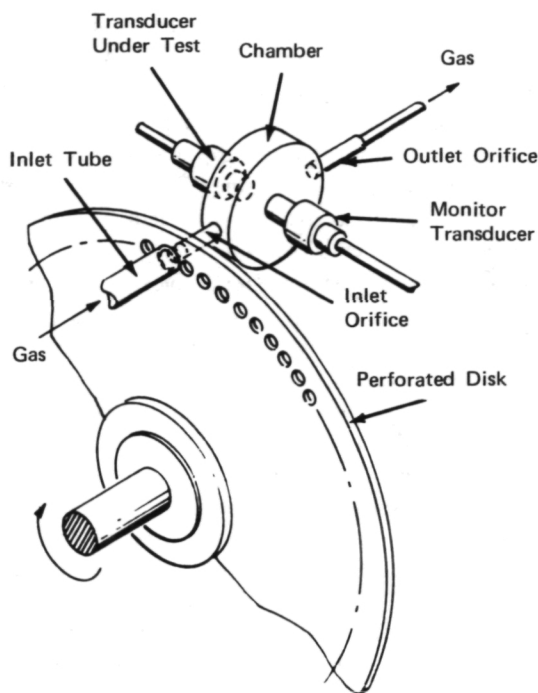
Inlet-Area-Modulated Sinusoidal Pressure Generator

A sinusoidal pressure generator capable of generating large-amplitude, high-frequency pressure fluctuations at high average static pressures has been built and tested. The generator is capable of producing pressure oscillations as high as 120%, 18%, and 12% of the mean chamber pressure at frequencies of 1, 10, and 15 kHz, respectively. Mean pressure of the chamber can be varied from 15 to 1500 psia (0.1×10^6 to 10×10^6 N/m^2).

The generator is an inlet-area-modulated, gas-flow-through device using a rotating disk. It is similar in operation to a sinusoidal pressure generator previously described in NASA Tech Brief 66-10031. However, the newer generator varies the area of the inlet to the chamber rather than the outlet area, and thus is able to produce the high amplitudes described above. Also, this generator uses hydrogen gas for operation rather than helium. Hydrogen offers higher frequency and better waveshape capability because of its higher speed of wave propagation (speed of sound). The dynamic pressure at a given frequency and average chamber pressure are also highest for hydrogen because they are a function of the gas constant and the specific heat ratio.

The inlet-area-modulated generator is illustrated in the figure. Pressure oscillations in this type of generator are produced by controlling the gas flow into and out of a chamber. The pressure in the chamber is sensed by the test transducer and by a standard transducer. Sinusoidal pressure variation is obtained by varying the mass flow through the chamber in a sinusoidal manner as a function of time. This is done by varying the flow area to the chamber by rotating a circular disk, with holes located along a circle near the disk periphery, against the inlet nozzle throat. Rotation of the disk alternately blocks and opens the flow area.

Pressure differences across the chamber are minimized by keeping the chamber dimensions smaller than the wavelength of the sinusoidal oscillation being generated. Thus, pressure wave propagation phenomenon is minimal. The chamber pressure change is therefore quasi-steady and is an expansion-compression phenomenon.

The need for calibrating pressure transducers under these conditions was prompted by studies of high-frequency combustion instability in rocket engines. Other needs have also arisen, such as the quieting of advanced aircraft engines, experiments with fluidics, and the upgrading of internal combustion engine technology.
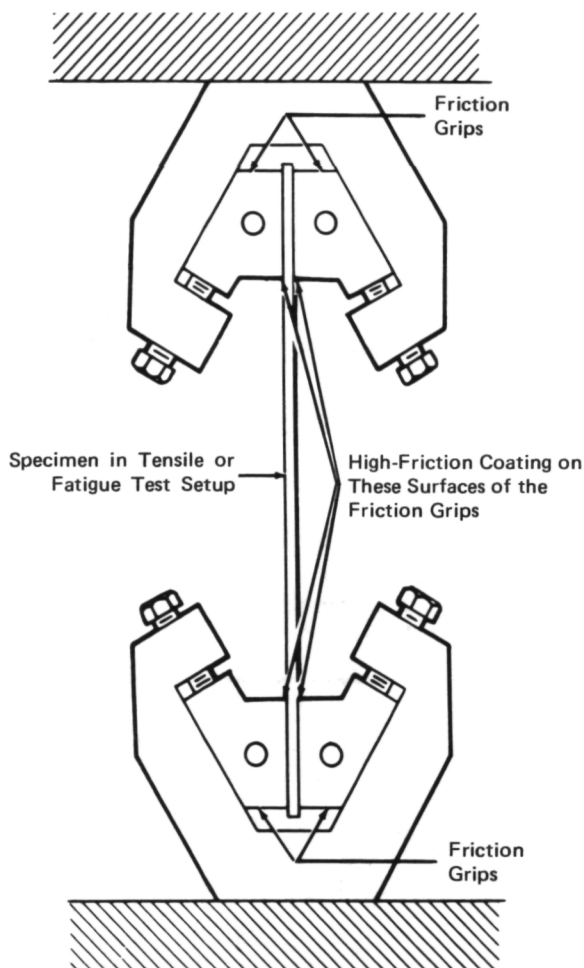
HIGH-FRICTION MECHANICAL GRIPS

Friction
Grips

Specimen in Tensile or
Fatigue Test Setup

High-Friction Coating on
These Surfaces of the
Friction Grips

Friction
Grips

Wedge-Shaped Grip With Plasma-Arc-Sprayed Coating

Mechanical-grip friction surfaces are usually machined to a high-friction finish by multiple serrations. The high-friction finishes produced by this method may be relatively expensive.

Plasma-arc spraying offers a method of preparing the required surface at a greatly reduced cost.

Such high-friction surfaces may be prepared at a greatly reduced cost by using plasma-arc spraying. A coarse-grained, tungsten carbide bonded-nickel coating is applied by plasma-arc spraying. This coating has been used successfully on wedge-shaped mechanical test grips.

The test grip shown in the illustration demonstrates plasma-arc-sprayed coatings. These grips were proof tested to a 150,000-pound (670,000-newton) pull. This indicates that they may be used for 100,000-pound (450,000-newton) laboratory tests.

No further documentation is available.

HYDROGEN-OXYGEN POWERED INTERNAL COMBUSTION ENGINE

Because of a need for an intermediate-level power source, a program was initiated to convert the combustion of hydrogen and oxygen to useful power in an internal combustion engine. As a result, a five-hp single-cylinder internal combustion engine was built. Operating on gaseous hydrogen and oxygen, the engine was tested at 4000 rpm for longer than 100 hours. In appearance, the engine closely resembles a conventional two-stroke cycle, internal combustion engine.

In operation, the hydrogen and oxygen, under high pressure, are injected sequentially into the combustion chamber. First hydrogen at 300 psi, then oxygen at 800 psi, is injected to form a hydrogen-rich mixture. This specific mode of injection eliminates previous difficulties of preignition, detonation, etc., encountered with carburated, spark-ignited, hydrogen-air mixtures. Ignition at startup is by means of a palladium catalyst, and after warmup is by autoignition. The best measured brake specific fuel consumption (hydrogen and oxygen) attained to date is 1.6 lb/hp-hr. Based on

the results of these tests, prototype development is considered completed.

This innovation should be useful in areas where poisonous exhaust gases pose a severe problem.

The following documentation may be obtained from:
National Technical Information Service
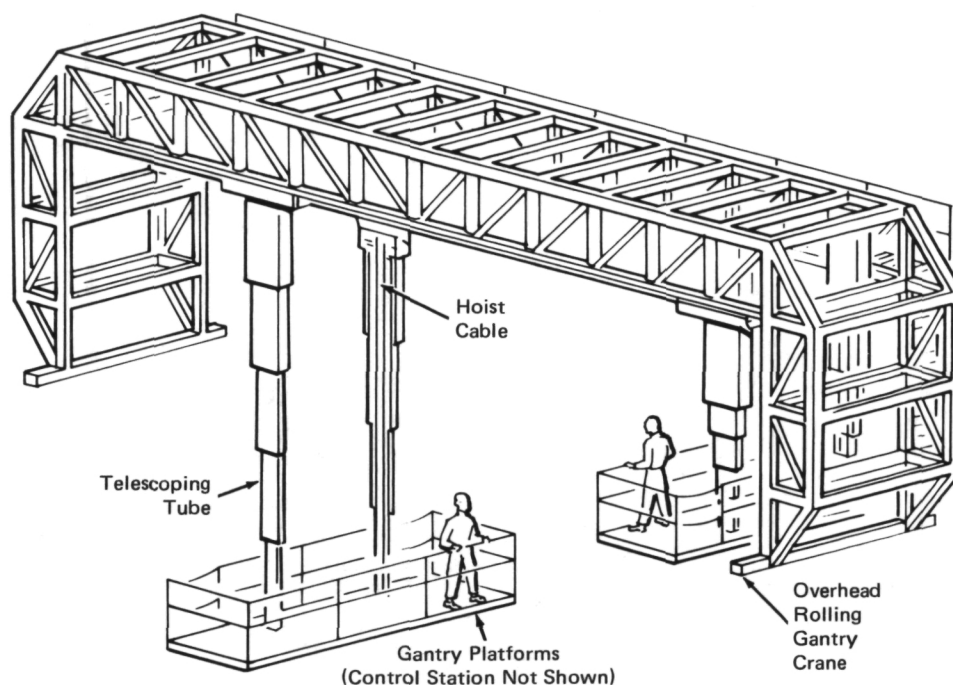Springfield, Virginia 22151
Single document price $3.00
(or microfiche $2.25)
Reference: NASA-CR-255 (N65-28954), Development of a Hydrogen-Oxygen Internal Combustion Engine Space Power System

Source: N. Morgan and H. Cameron of
Vickers, Inc.
under contract to
Lewis Research Center
(LEW-90264)

Section 3. Mechanical Systems - Control

TELESCOPING OVERHEAD GANTRY PLATFORM

Telescoping Gantry Platform

The cable-operated gantry platform shown in the figure is suspended from an overhead rolling crane by telescoping tubes that permit three-dimensional positioning for maximum access to large structures. The telescoping tubes provide a highly rigid platform, and controls on the platform provide an operator with axial, vertical, and lateral positioning capabilities.

The platform would reduce the need for a clutter of special-access platforms in large equipment manufacturing and repair concerns. In the unlikely event that hoist or cable should fail, the telescoping tubes would lock and prevent the platform from dumping people and equipment.

Source: J. M. Hines, D. F. Holcomb,
and J. Zitko of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-19419)

Circle 9 on Reader Service Card.

IMPROVED HALF-REVOLUTION CLUTCH

Direction of
Driven
Rotation

Indexing
Detent

Output
Shaft

Black Dot on Ear

Indexing
Pawl
Slot

Rotary Solenoid

Drum for
Spring

Torsion
Spring

Orange Dot

Lug

Control Pawl

Control Detent

Drum for
Spring

Control Sleeve

Input Shaft

Direction of
Driver
Rotation

Black Dot on EAR
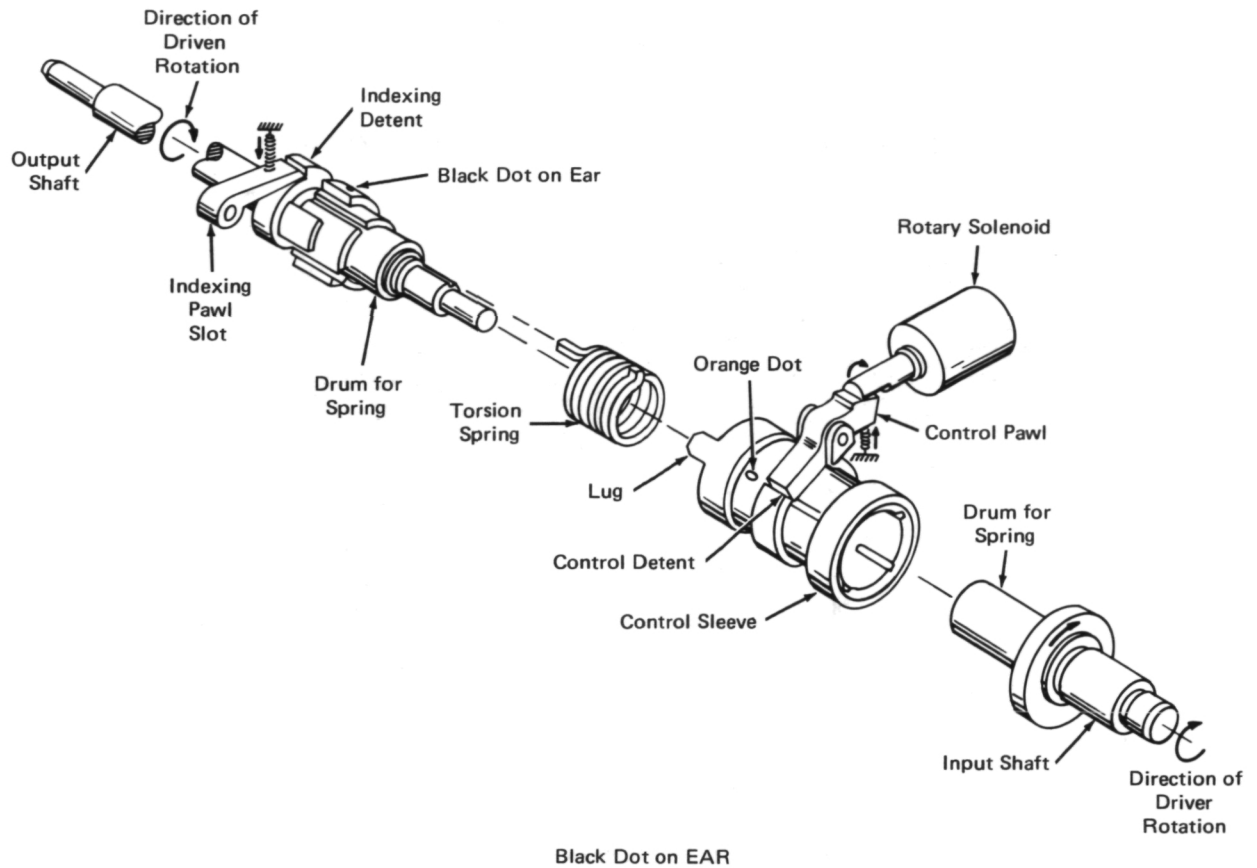
A new solenoid-controlled spring clutch (see figure) has several novel features that make it highly reliable. A chromium-alloy coating is deposited over those surfaces susceptible to wear, such as the drum areas that are in contact with the torsion spring and the control and index detents; and the control and index pawls are coated with a nickel alloy. The clutch has an ingenious arrangement of slots that allows controlled and positive adjustments. Once adjusted, the clutch does not have to be readjusted during its entire useful life.

A helical spring that wraps around two in-line shafts (input and output) provides the torque for the clutch. Rotating the input shaft in the direction of the helix causes the springs to wind tighter so that torque is transmitted to the outer shaft. A solenoid is used to control the clutch: momentary solenoid operation removes the pawl detent, thus permitting the spring to grip the input shaft. Declutching is automatic after one-half revolution, at which time pawl detent recurs. Declutching also can occur after one revolution by applying a holding current to the solenoid for a period equal to half a revolution. In addition, by applying a constant holding current to the solenoid, the clutch can operate in a continuous mode.

No further documentation is available.

SPRAG SOLENOID BRAKE

The sprag solenoid brake (see figures) produces approximately ten times the braking torque of similarly sized solenoid brakes and is not limited to low or medium shaft rotation speeds. The locking mechanism consists of a double set of sprags arranged alternately so that every other sprag wedges between the inner shaft and the outer housing to prevent rotation in one direction, while the remaining sprags wedge in a similar manner to prevent rotation in the opposite direction. The control member is keyed to rotate with the socket member. The sprags are mounted in the socket member so that a spring, which goes through the sprags, will pull them into contact with the outer housing, thus preventing rotation by the previously described wedging action. The sprags are disengaged when the wedge-shaped control member is forced between each set of sprags pushing them apart and away from the outer housing.
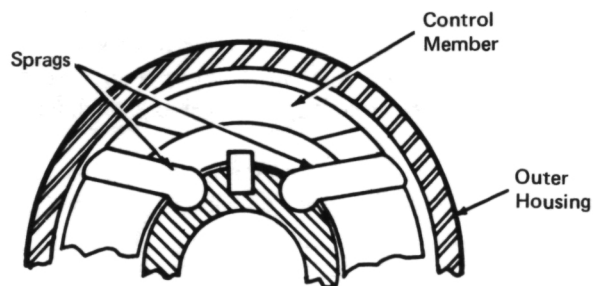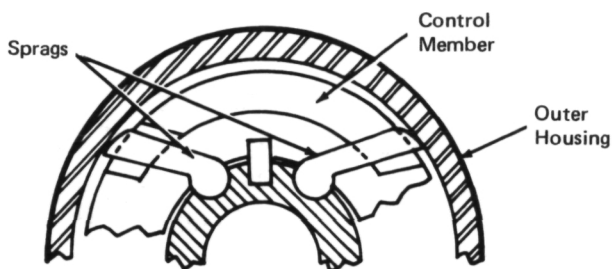
Figure 2. Brake in Locked Configuration

The control member is spring loaded to push the sprags apart and hold them away from the outer housing when no power is applied to the solenoid (see Figure 1). This allows the socket member and shaft to rotate freely. When power is applied to the solenoid, the control member is pulled in parallel to the shaft which allows the sprags to make contact with the outer housing (see Figure 2). In this manner, the sprags act as brakes to halt rotation of the socket member and shaft.

Thus, braking occurs when power is applied to the solenoid; otherwise there is free rotation. The reverse case, free wheeling with the power on and braking with the power off, can be accomplished by changing the control member to push the sprags apart when power is applied.

Figure 1. Brake in Freewheeling Configuration

Source: P. H. Dane
Marshall Space Flight Center
(MFS-21846)

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PULSE-MODULATED FLIGHT CONTROL ACTUATOR
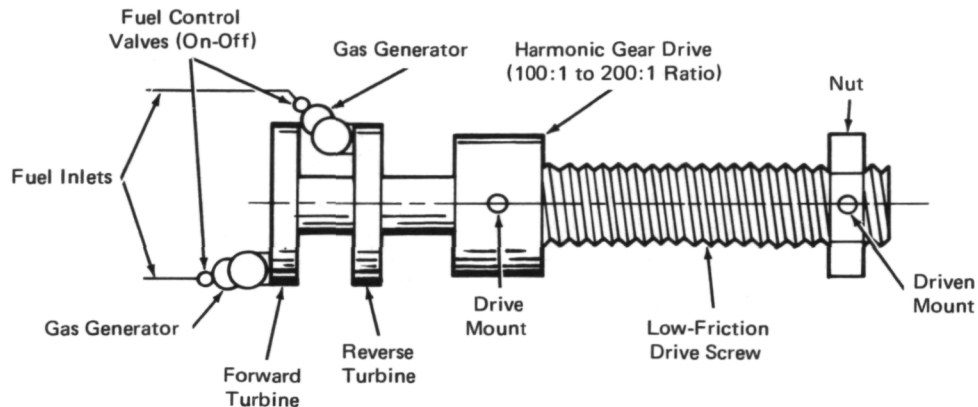
Mechanical Flight-Control Actuator

Modern large, or high-performance, aircraft utilize fully-proportional control systems to transmit pilot control motions to the aerodynamic control surfaces. Extensive mechanical and hydraulic linkages are used to tailor the control response to the desired level and to simulate, as closely as possible, the feel normally achieved in small aircraft with plain push-pull control wire systems. The evolution of large aircraft has made it increasingly more difficult to achieve this proper feel, particularly through all flight phases.

The continued increase in aircraft size and the difficulty in achieving proper pilot feel have led to the concept of "fly by wire." In such control systems, all pilot interface is provided through electronic computer systems. In some systems, computers are utilized to generate artificial control system feel. The control motions of the pilot are received by the computer, and appropriate signals are sent to the flight control (aerodynamic) surfaces to achieve proper aircraft response. Simultaneously, proportional signals, which simulate the correct feel, are fed back to the pilot operated actuating mechanisms.

A new device makes the fully-proportional control systems, as used in the past, unnecessary. The new system interfaces with the computer output signals, and a reversible power train is used to move a mechanical actuator. Separate power turbines are used to drive the screw assembly in each direction. The screw and the

power supply are mounted on one surface, and the nut assembly is mounted on another surface (see figure). Movement is achieved by turning on the solenoid valve which controls the flow of fuel to a gas generator. As gas is generated, it drives the turbine rotor which drives the power screw and moves the nut assembly. When the nut assembly is correctly positioned the solenoid valve is turned off.

This type of device is presently used to move flaps and various other devices on aircraft, but not flight control surfaces. Thus, present units are of the low-power and slow-response type. By using high-power-level turbines and fast-acting on-off valves, the present units can be used for flight control systems of the "fly-by-wire" type. Other methods for supplying power, such as hydraulic motors (or turbines) or electronic motors, could achieve the same effect.

The new system, by replacing the more-complex proportional system presently in use, improves the reliability of flight control. Furthermore, reductions in weight and cost should be achieved.

No further documentation is available.

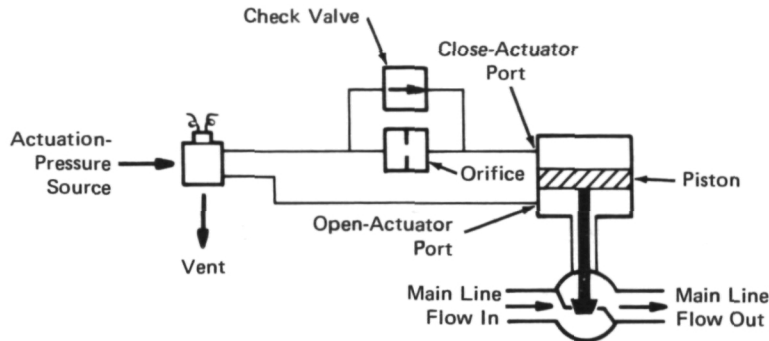# SYSTEM FOR ONE-WAY TIMING OF PNEUMATIC-OPERATED VALVES

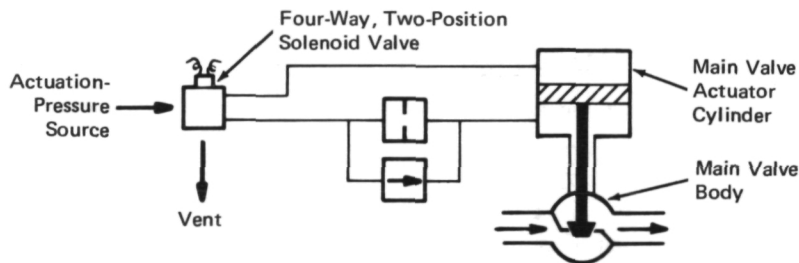Figure 1. Slow-Opening and Fast-Closing Valve Actuation System

Figure 2. Fast-Opening and Slow-Closing Valve Actuation System

A system has been developed to control, independently, the opening and closing times of a cylinder-operated valve. Previously these times were controlled by adding one or more orifices in the actuation-pressure supply lines. This required the valve travel time to be increased for both the opening and the closing strokes. This new system utilizes a check valve in parallel with one of the orifices to allow the stroke time of the valve to be increased in one direction without slowing down the stroke time in the opposite direction.

The orifice that controls the valve stroke time is sized to be compatible with actuation pressure, actuator volume, actuator fluid media, and desired stroke time. In a fast-closing and slow-opening valve, the orifice and the check valve are arranged in parallel in the line between the four-way solenoid valve and the close-actuator port (Figure 1). This allows the close side of the actuator piston to be pressurized rapidly, since the supply pressure is flowing through both the orifice and the check valve; at the same time, pressure is vented from the open side of the piston through the four-way solenoid valve. The opening time of the valve is longer, however, since the close-side of the piston is vented through only the orifice as the open side of the piston is being pressurized. In a fast-opening and slow-closing valve, the orifice and the check valve are placed in the line to the open-actuator port and the operation is reversed (Figure 2).

Circle 11 on Reader Service Card.

LINEAR ACTUATOR SYSTEM
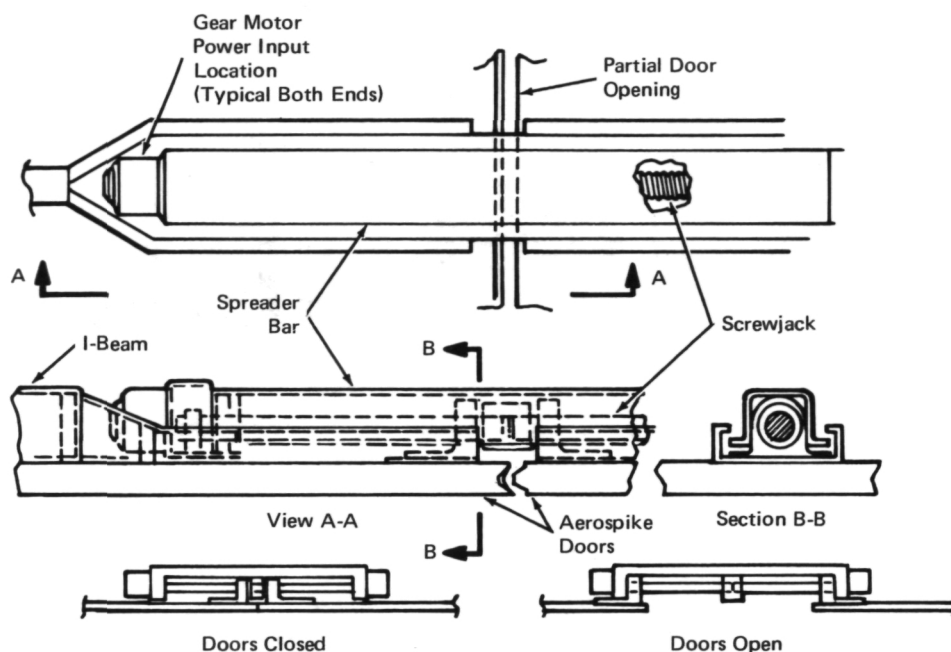
Door Actuator Mechanism

The linear actuator system shown in the figure is designed to open and close doors or to raise and lower weights using a modified standard screwjack system. The actuator mechanism is comprised of a spreader-bar assembly that houses, at each end, a gear motor that drives a screwjack. The figure shows the system with the doors open and the doors closed. Either one of the electrically powered gear motors can open the doors if the other motor fails.

The system originally was designed to open each pair of doors in a circular array of sixteen doors which opened in the form of an expanding hoop. Therefore, spherical bearings were mounted in the door fittings and at the screwjack tie to the spreader bar to prevent any twisting of the screwjack, due to changing aline-ment as the doors opened and closed. However, the system can be installed in other configurations to permit a weight saving in comparison to standard compression-loaded screwjack systems.

Circle 12 on Reader Service Card.

LOCKING DEVICE FOR ANTENNA DEPLOYMENT MECHANISM

Cam Surface
Detail

Antenna Rib
Stowed

Antenna Rib
Deployed

Inner
Ball Bearing

Hub

Machined
Sockets
3 Near Top
3 Near Bottom

Locking Ball
(1 of 3) Shown in
Upper Position

Central
Support

Lifter

2 in.

Cam Surface
(See Detail)

(Rotation of This Member Causes
Cammed Surface to Press Balls
into Machined Sockets on
Central Support)
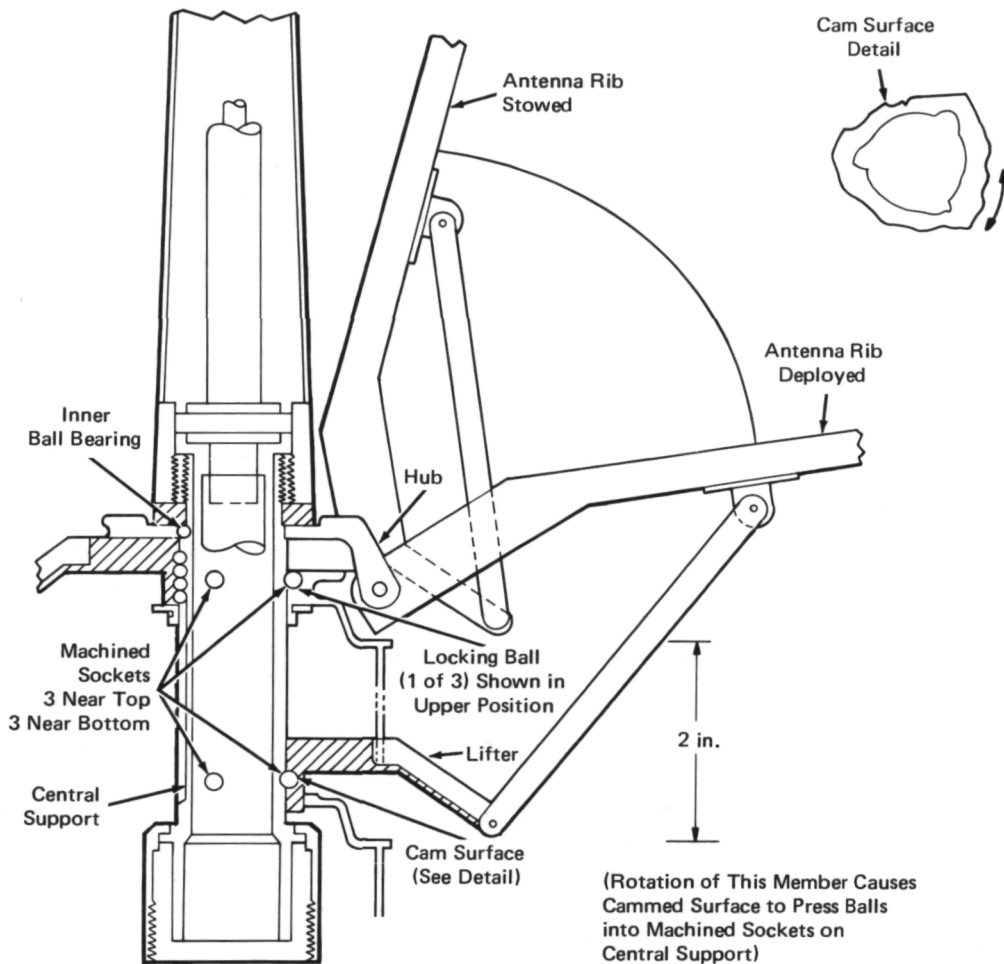
Deployment Mechanism and Locking Device

A hand-operated locking mechanism for positive antenna positioning is shown in the figure. Overcenter camming is used to effect deployment. Ease of operation and positive-torque locking are incorporated into the design.

The mechanism operates as follows: As the antenna approaches the end of its travel, torque applied to the grip handle depresses the locking balls into machined depressions in the central support. This torquing function adds a linear push or pull to the grip handle, causing it to be moved to the limits of its travel. The peripheral movement of the grip during the locking operation is approximately 2.54 cm (1 in.); the downward or upward movement of the grip is approximately

0.3 cm (1/8 in.). Thus the closing load is divided by a factor of 8. This meets the performance requirement of having less than 10 pounds of operating push and requiring no more than 5 cm (2 in.) of linear movement of the grip. The device can be locked only in the terminal position.

Source: R. H. Schirmer of
RCA Corp.
under contract to
Johnson Space Center
(MSC-13744)

No further documentation is available.

CLOSURE DIAPHRAGM WITH POWERED CUTTER
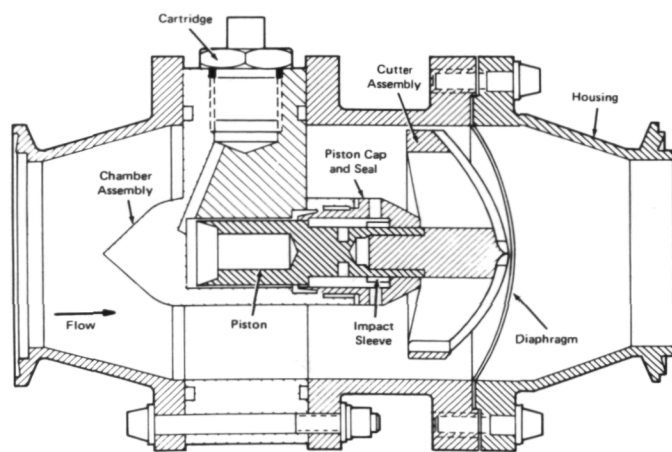
Closure Diaphragm with Powered Cutter

A device for isolating cryogenic or corrosive liquids, while maintaining a hermetically sealed closure, incorporates a gas-powered piercing/opening technique. The device consists of a domed closure diaphragm, a cutter assembly, an actuator, and an electrically-initiated gas generator cartridge (see figure). The diaphragm is retained in the outlet by a series of concentric Vee-shaped ridges and grooves in the clamping flanges. To assure zero peripheral leakage, the clamping flanges may be seal welded after assembly. Due to the piercing/cutting technique used to open the diaphragm, the thickness of the diaphragm should be chosen to withstand a pressure difference of about twice the normal pressure of the system.

The cutter consists of six radial cutter blades and a peripheral hexagonal ring. The cutter blades are formed on a radius complimentary to the diaphragm radius, so that the cutting action occurs at a constant angle of $10°$ throughout the cutting portion of the stroke, straightening the diaphragm segments and distributing the shearing energy load uniformly. Upon actuation, the cutter cuts the diaphragm into six pie-shaped segments, after which further penetration of the cutter into the diaphragm causes the peripheral ring to force the segments outward and to hold them against the outlet housing. This forced deployment of the diaphragm segments, which does not rely upon fluid-dynamic forces, is an important improvement over conventional-type cutter assemblies.

The actuator which drives the cutter consists of a cylinder, a piston, a piston cap and seal, and an energy-absorbing impact sleeve. The actuator contains two metal-to-metal, chevron-type, dynamic sealing surfaces to isolate the actuating combustion products from the fluid flow passage. One sealing surface is machined on the piston crown to provide the primary seal against the cylinder wall; the other seal is machined in the piston cap and seal to provide a second seal against the piston trunk. Both seals are dimensioned to attain an interference fit in the elastic stress range. The materials used in the cylinder, the piston, and the piston cap are selected to maintain the seal-bearing pressure throughout the temperature range from room temperature to 20 K ($-423°$ F), while providing the necessary hardness differences to allow nonlubricated operation.

The actuator impact sleeve is a cylinder made of annealed copper which fits loosely on the piston rod, with a large clearance in the bore of the piston cap. The sleeve undergoes plastic deformation when arresting the piston at the end of the actuation stroke, absorbing much of the kinetic energy in the process. The sleeve can be compressed to half its original length in absorbing the excess energy after deployment of the diaphragm segments.

Power for the actuator is provided by an electrically-initiated pressure cartridge. The opening time of the device is approximately 0.75 millisecond. It can be used in normal temperature applications for handling hazardous fluids or gases, or in high-temperature environments such as nuclear (liquid metal) and superheated steam systems.
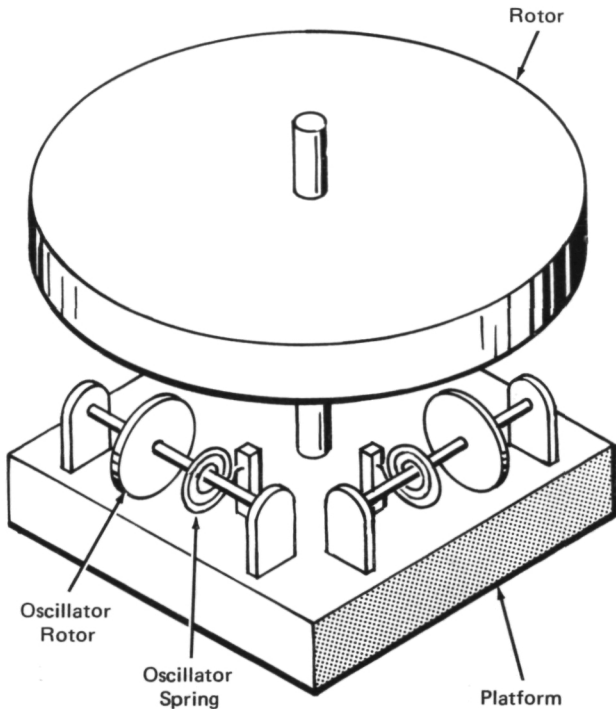
PASSIVE DUAL-SPIN MISALINEMENT COMPENSATOR

Passive Dual-Spin Misalinement Compensators

The satisfactory performance of a dual-spin space-craft attitude control system requires a precise alinement of the bearing axis within the rotor, such that it is coincident with the rotor principal axis of inertia and contains the rotor center of mass. If the initial conditions of the system are such that the system momentum is not alined with the axis of rotation of the rotor, then the dual-spin spacecraft will assume a coning motion similar to the free precessional motion of a gyroscope. A suitable damping mechanism can be used to remove the precession energy so that the platform will remain inertially fixed.

The misalinement compensator allows the system to assume a motion such that the platform remains inertially fixed in the presence of rotor misalinements. Such compensators do not perform the function of a precession damper. The system would still experience precessional motion and require a damping mechanism, or some other device for the dissipation of precession energy, to achieve the desired motion. Typical damping mechanisms must respond to the precession frequency and dissipate energy to be effective. The misalinement compensators must respond to the frequency of rotation of the rotor and need not dissipate energy to be effective.

The accompanying figure shows the essential components of the system. Each rotary oscillator consists of a symmetric rotor, mounted to the platform by a low-friction suspension, in conjunction with a rotary spring joining the rotor to the platform. The compensation system requires two such rotary oscillators. Their location on the spacecraft platform is arbitrary, except that they should have their axes of rotation perpendicular to the bearing axis of the spacecraft rotor and perpendicular to each other. It is assumed that the platform rotor is symmetric about its nominal axis of revolution.

The torque that must be exerted on the platform in order to cause it to remain inertially fixed in spite of the disturbances introduced by a misalined rotor has constant magnitude, is perpendicular to the bearing and has components which vary sinusoidally (with equal amplitude and 90° out of phase). If the ratio of the rotary moment of inertia of the oscillator rotor to the stiffness constant of the attached spring is properly chosen, then the angular motion of the oscillator will be sinusoidal at the required frequency; and the resulting torque transmitted to the platform by the rotary spring will have the desired property.

Assume that a compensator of the type described is mounted on each of the two platform-fixed axes mentioned above and that the motion of the system starts from an arbitrary set of initial conditions. Although under such conditions the analysis of a dual-spin space-craft with a pair of compensators is complex, it has been shown analytically and verified by computer simulation that the compensators will quickly assume a motion whereby they produce compensating torques on the platform and the platform will assume an inertially fixed orientation.

TWIN-SPOOL TURBOPUMPS FOR "LOW" NET POSITIVE
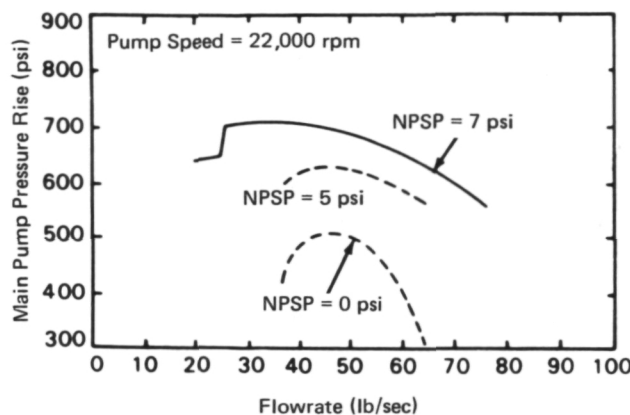## SUCTION PRESSURE OPERATIONS

Figure 1. Effect of NPSP on Single-Spool
Turbopump Performance

Rocket engine turbopumps capable of operating at low to zero net positive suction pressure (NPSP) would improve rocket engine performance and reliability. Specifically, the need to pressurize propellant storage tanks could be at least simplified or possibly eliminated. [NPSP is the margin by which total pressure in the pumped fluid exceeds its vapor (saturation) pressure, as measured in the supply tank. Low or zero NPSP is achieved when the absolute pressure in the supply tank approaches or equals the saturation pressure of the fluid.] Figure 1 indicates the reduction in performance of a conventional single-spool turbopump as the NPSP is reduced to zero.

A separately driven low-speed inducer is capable of handling the pumped fluid at low NPSP and raising its pressure to an adequate NPSP before it is ingested by the main pump inlet. The twin-spool turbopump (Figure 2) incorporates the inducer and a main pump, each separately driven at different speeds through a coaxial shaft arrangement. The inducer can operate at low speed for low NPSP, and the main pump can operate at high speed to generate high pressure. This arrangement results in a minimal envelope and requires no external control for the inducer.

The twin-spool turbopump is a modification of a single-shaft turbopump in which a centrifugal pump is driven by a two-stage impulse turbine. The single-shaft turbopump is modified to add an in-line low-speed inducer immediately upstream of the main pump inlet and an inducer drive turbine immediately downstream of the main turbine, with the inducer drive turbine extracting its power from the main turbine exhaust. The inducer and the inducer drive turbine are mechanically connected by a shaft that is coaxial with the hollow shaft connecting the main pump and the main turbine. Both the inducer and the main stages are supported by their own rolling-element bearings.

A twin-spool hydrogen turbopump for pumping liquid hydrogen at zero NPSP has been developed and tested. This turbopump operates satisfactorily over its entire operating range with zero NPSP at the inlet of the low-speed inducer. The stall margin of the pump does not drop when the pump is operated at low positive suction pressures. The twin-spool turbopump makes the fuel system pressure rise insensitive to variations in tank pressure, thus hydrodynamically decoupling the tank from the engine.
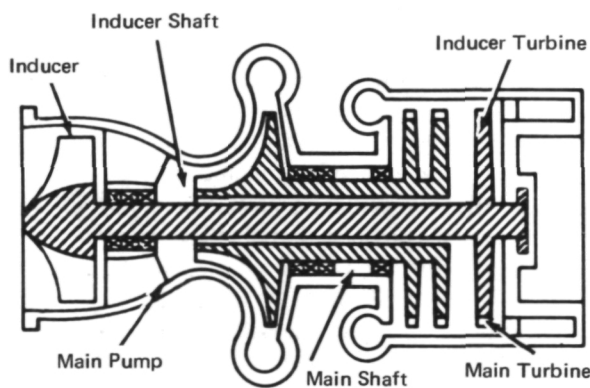

Figure 2. Twin-Spool Turbopump Schematic

The twin-spool turbopump can be used in pumping applications where low NPSP is desired. A computer program which accurately predicts both steady-state and transient operating characteristics of the twin-spool hydrogen turbopump has been developed. This computer program is available from: COSMIC, 112 Barrow Hall, University of Georgia, Athens, Georgia 30601. Reference: LEW-11079.

The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $6.00
(or microfiche $2.25)
Reference: NASA-CR-72540 (N69-36246), Investigation of Twin-Spool Turbopump Performance

Source: O. I. Ford, W. E. Campbell,
and E. K. Bair of
Aerojet-General Corp.
under contract to
Lewis Research Center
(LEW-11105)

Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

Terminal-Pointer Hand Controller for Teleoperator Application (Page 1) MFS-22860
        and
Advanced Action Manipulator System (ADAMS) (Page 2) MFS-22022
        and
A Proposed Hand-Tool Assembly for Robots (Page 4) MFS-22266
        and
Machine Finishes Balls to High Degree of Roundness (Page 7) MFS-21448
        and
Sprag Solenoid Brake (Page 17) MFS-21846

Inquiries concerning rights for the commercial use of these inventions should be addressed to:

> Patent Counsel
> Marshall Space Flight Center
> Code CC01
> Marshall Space Flight Center, Alabama 35812

**A Proposed Remote Manipulator System: A Concept** (Page 3) MSC-14245

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

> Patent Counsel
> Johnson Space Center
> Code AM
> Houston, Texas 77058

Recognition System for Class II Robots (Page 5) MFS-22286

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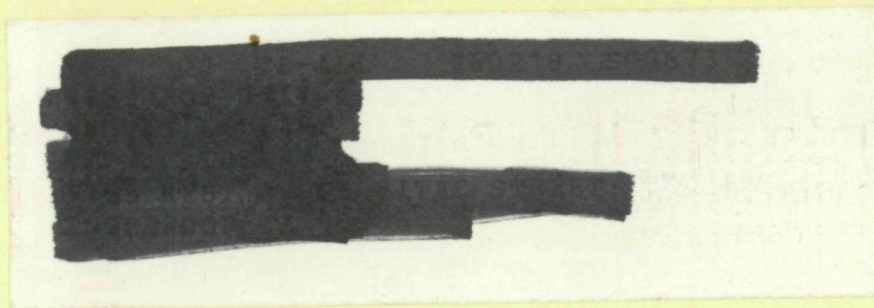
*"The aeronautical and space activities of the United States shall be
conducted so as to contribute . . . to the expansion of human knowl-
edge of phenomena in the atmosphere and space. The Administration
shall provide for the widest practicable and appropriate dissemination
of information concerning its activities and the results thereof."*
—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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