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A STUDY OF TECHNIQUES AND THE DEVELOPMENT OF EQUIPMENT FOR DECANNING EBR-II FUEL ELEMENTS

by

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ABSTRACT

Remotely operated, semi-automatic machines, designed to effect the mechanical disassembly (i.e., decanning) of spent fuel elements from the Experimental Breeder Reactor-II, have been developed. The machines described are laboratory models which have successfully decanned simulated fuel elements. They are electrically or pneumatically operated and are capable of decanning three fuel elements per minute without the routine use of manipulators. Each machine is made up of functional units which are sequentially placed to eliminate handling between steps of the decanning operation and which are easily removable for replacement or maintenance.

In the first of the two machines described, pneumatically operated devices prepare the fuel element for a rotary shearing operation which cuts the tubing jacket along a helical circumferential path as it is being removed. The alternate machine removes the jacket by means of a series of shearing rolls. Both machines are served by auxiliary mechanisms, such as inspection jigs, fuel and scrap choppers, and transfer magazines. Improved versions of these machines or machines employing alternate methods still under development are to be designed for installation in the Fuel Cycle Facility of the EBR-II Plant.

INTRODUCTION

Equipment under development for use in the first step of the reprocessing of spent fuel from the Experimental Breeder Reactor-II (EBR-II) includes two complete machines which are intended to remove the ends, spacer wire, and tubing jacket of individual fuel elements, to separate these parts from the fuel and to chop the fuel into short lengths to facilitate charging into the melt-refining furnace.(1) This operation must be carried out with a minimum of fuel loss or mixing of the scrap with the fuel.

The equipment will be designed for installation in the shielded EBR-II Fuel Cycle Facility Cell,(2) which contains an inert dehydrated atmosphere* provided to prevent fuel or sodium fires and excessive oxidation of the fuel It is intended that the cell be operated without the use of the decontamination procedure normally practiced to permit personnel entry; therefore, all operations and process equipment repairs must be remotely handled. Primary actuation of these machines will be by pneumatic or electrical means, since only occasional use can be made of the manipulators and cranes, because the latter must be shared for other operations in the cell.

The following is a discussion of the problems involved, and a description of some of the tests made with laboratory equipment, before beginning the design of the prototype equipment for this facility. The object of this work has been to test and evaluate a number of basically different decanning procedures, in addition to developing specific equipment for the present requirement. This experience should be valuable in handling subsequent variation in the fuel due to damage or changes in design. The attempt has been made to decan the element, as designed, rather than to change it and to compromise the efficiency of the fuel.

OPERATIONAL REQUIREMENTS

The operating area which has been provided for the decanning process consists of one bay of the Fuel Cycle Cell, a usable area of approximately 12 by 12 feet. This area can be served by cranes and articulated manipulators which are provided to handle all transfers of material in and out of the locks and between various points in the cell. Due to the limited dexterity and availability of the in-cell manipulators, all routine machine functions must be accomplished by pneumatic, hydraulic or electrical actuators. Argonne Model 8 master-slave mechanical manipulators are provided in the adjoining air atmosphere cell where intricate operations, such as handling and inspecting individual fuel pins, will be carried out. Operations will be viewed through a three-foot square window placed directly in front of the machines. Auxiliary viewing, at an angle from the rear, can be done through two similar windows in the opposite wall of the cell. In addition, magnifiers or periscopes may be necessary for close viewing of certain operations.

The fuel element,(1) which is to be dismantled is shown in Fig. 1. It consists of a 0.144-in. diameter fissium alloy** fuel pin enclosed in a 0.009-in. wall-type 304 hard-drawn stainless steel tube The restrainer plug (top end) and the hanger tip (lower end) are heli-arc welded to the tube. The spacer wire is fusion welded to the tip and spot welded to the

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*95% argon, 5% nitrogen; 100 ppm oxygen, max.; 5 ppm water, max.

**A fuel containing nonradioactive isotopes of fission product elements in the abundance expected in the re-cycle process.

tube at the top. The 0.006-in. annular space between the fuel and tube ID is filled with sodium. Ninety-one of these fuel elements are contained in each subassembly, which is dismantled in the preceding operation in the air cell.

The ultimate condition of the fuel is not accurately known, but experiments with thermo-cycled and irradiated test fuel elements indicate that linear growth of the fuel during irradiation can cause a helical twisting of the fuel and jacket due to restraint of the spirally wound spacer wire. This increase in fuel length is accompanied by a corresponding decrease in diameter. It also increases slightly in hardness from its original value of about 45 Rc and becomes more brittle. Under unusual conditions damage to the element may include: tube perforations or bulging; bending or breakage of the hanger tip or spacer wire; or brittle fracture of the fuel pin due to mechanical or thermal stresses. Experiments also indicate that the physical properties of the stainless steel jacket will remain approximately the same after irradiation, except for a slight increase in hardness. This increase is minimized because of the high operating temperature (925°F). Previous studies(3) on type 347 stainless at lower temperatures (600°F) corroborate this evidence, since they also indicate only slight changes in physical properties and hardness, and a small decrease in ductility.

Repair procedure is based on the idea that the equipment will be made up of easily removable major units The unit, containing a damaged or malfunctioning part, may be moved to the adjoining air cell to be repaired by means of the master-slave manipulators or disposed of when repairs are not feasible. A duplicate unit may be installed to permit operations to continue with a minimum of delay, if desired.

Despite the low oxygen content of the cell atmosphere, it is desirable to carry out the decanning operation during the first hour of a shift in order to reduce oxidation of the fuel This will permit succeeding operations to be carried out during the remainder of the same shift period. It will be necessary for the machine to operate at the speed of three pins per minute to meet this requirement

DESIGN REQUIREMENTS

The ambient radiation level is expected to be too high to permit the use of organic materials in the construction of the apparatus. Calculations indicate the background level will be approximately 10^5 r/hr. Local levels will be 10^6 r/hr at three feet and 10^8 r/hr in close proximity to the fuel. At these levels organic materials are damaged so rapidly that every effort must be made to utilize inorganic substitutes.

The repetitive nature of the decanning operation will require the use of specific actuators and controls for each of the operations of the various units of the machine. The lack of manipulator sensitivity, coupled with the small size of the element and the distance at which the operations will be carried out, further emphasize the need for individually operated units. Since lubricants cannot be used, machine components which are lightly loaded or have low rubbing velocities must be selected wherever possible.

The wide possible variation in the condition of the fuel as it leaves the reactor puts severe limitations on the method ultimately used. It must be capable of accommodating variations in diameter, length, and straightness of the tubing, as well as fuel which has cracked, splintered, or powdered. Despite these variations, it must be capable of dependable operation with a very small possibility of scrap-fuel admixture or fuel loss.

In addition to the basic decanning operation, a number of preparatory steps must also be carried out These include: inspection, to insure trouble-free passage through the machine, loading into a container or magazine suitable for bulk transfer through the air lock between the air and argon atmosphere cells, removal of the spacer wire, the hanger tip, and the restrainer; after decanning, chopping of the fuel into convenient lengths; and finally baling or shredding the stainless scrap, for minimum bulk preparatory to disposal

DECANNING TECHNIQUES

Several methods of decanning have been used in the past on both aluminum and stainless steel-clad fuel elements Among these are included slitting operations by means of tools, cutters or rollers; turning operations; and the use of grinding or abrasive cutoff wheels.(4,5) Most of the foregoing methods are unsuitable in the present case since they produce a large number of small scrap particles which are difficult to keep separate from the fuel; they use liquid cutting lubricants or coolants; they involve the use of high-speed elements which depend heavily on the use of lubricants.

In an effort to find more suitable methods, a number of devices employing different principles of operation were built and tested. The most successful of these were

1 Vee-Roll Type. Several configurations, such as those shown in Figs. 3 and 4, have been tried They consist of two identical opposed rollers, heavily spring loaded to accommodate variations in element diameter, driven in contra-direction The fuel element is fed between the rolls, slitting the tube lengthwise in one pass The rolls work well when

freshly sharpened, but dull rapidly, and cuts become intermittent and incomplete. It is likely that improved action could be obtained by changes in the shape of the cutting edge and by the use of more suitable materials. However, this design is not favored, since it requires extremely high roll pressures (in excess of 1000 lb), which are likely to splinter or spall the fuel pin.

Several Vee-type cutters in series were also tried in an effort to reduce the load on the cutters. Each succeeding cutter had a smaller included angle and was set to cut several thousandths of an inch deeper than the preceding one. The results were no more satisfactory than for the preceding method, since it was almost impossible to maintain proper tracking of the rollers. This problem was evidently caused by work hardening of the material due to the action of the preceding rolls.

2. Notched Roll Type. The original laboratory model of the Vee-roll machine contained a second set of rolls with a square notch configuration, which was intended to shuck or strip the notched tube from the fuel and separate it. Tests indicated that this set of rolls seemed to have more effect than the cutters, and the following rolls were tried to check this point.

The notched roll (Fig. 5) is opposed by a slightly domed roll to prevent tight crimping of the scrap and consequent entrapment of fuel material. Cutting is accomplished by shearing the tube on each side of the fuel pin at a moderate pressure of 400 lb. This pressure, distributed over a much larger area than in the preceding cases, is much less likely to crush the fuel pin. This type of roll is far more dependable than any of the others tested.

Both of the preceding methods depend greatly on the integrity of the fuel pin, since the cut is interrupted at any gaps in the fuel larger than $\frac{1}{16}$ in. In addition, this second type cannot accommodate large variations in fuel diameter, any growth being sheared off, and reductions in diameter greater than 0.003-in. causing failure of the cut. However, this problem can be met by providing several slots of different sizes on the same rolls and by using the proper one after preliminary gaging.

3. Punch and Die Type. Method A, shown in Fig. 7, consists of a block bored to a close fit on the fuel pin and counterbored at the top to receive the tubing. Fuel is then pushed out by means of a plunger.

Method B, shown in Fig. 8, is similar, except that additional space is allowed to permit the tube to crumple progressively from the bottom as the fuel is pushed out through the opening in the bottom of the block. When the tube is completely compressed, continued travel of the inner plunger ejects the fuel.

One and one-half-inch lengths of fuel were satisfactorily stripped by these methods after having been soft soldered into the tubes to simulate bonding or local welding of the fuel to the tube. Pressures of approximately 625 lb were required to start stripping in Method B, but after the first tube convolution was formed the additional friction caused by it required an increase to 1000-1100 lb. This pressure is approximately the same as that required for Method A. Both of these methods require that preliminary preparation of the fuel include the circumferential slitting of the tube and breaking of the fuel while still enclosed in the tube. They require the handling of a much larger number of pieces of fuel and are also rather sensitive to pin diameter. Fuel growth will result in losses due to shearing on the edge of the opening, and reductions in diameter greater than 0.005-in. may cause jamming

4. Spiral Type. Drive rolls (Fig. 9), skewed with respect to the tube axis, drive the fuel element forward against a specially ground lathe tool bit in contact with the face of one of the wheels. The resulting shearing action removes the tube as the fuel passes through the machine. This method is insensitive to the condition, diameter, or presence of the fuel pin, since it is capable of stripping half hard tubing even when empty. It is capable of handling rods which have abrupt bends with angular deviations of as much as 10°, or which are bowed as much as $\frac{3}{4}$ in. in the total length. These deviations are limited mainly by clearances in the machine. However, this method will not handle tubes with large perforations or longitudinal splits. It is also necessary to cut ends cleanly to permit easy starting of the cutting operation.

DECANNING MACHINES

Two of the preceding methods were considered promising and advanced laboratory models were built, along with the auxiliary apparatus necessary to handle and prepare the fuel elements for the decanning operation.

1. Roll Decanner. The roll-decanning machine is shown diagrammatically in Fig. 2. It consists of a magazine, holding 25 fuel elements, which is loaded into a trigger mechanism that drops the elements singly into the Vee rests of the feed unit below. These units are actuated by pneumatic cylinders, which are controlled by the operator by means of solenoid valves located outside the operating cell area. The actuating fluid will be compressed, dehydrated argon, which is used to prevent contamination of the cell atmosphere through leakage. The cylinder of the feed unit is used to drive the fuel element to the right, into the dewiring rolls (Fig. 6), which cut the spacer wire welds and separate it from the tube which then passes on to the tip-removing cutter (at the left in Fig. 10). The tip cutter is made up of a pair of driven knurled rolls

above, and a movable head containing five tube cutting wheels, which is arranged to come up from below. The head drives the fuel element into contact with the driving rolls and causes it to rotate until the tubing is cut through. Five cutters, spaced $\frac{1}{8}$ in apart, are used because of the possible variation in the end position of the fuel within the tube. (The 0.400-in. expansion space makes the variation possible.) It is necessary for the fuel to extend slightly beyond the end of the tube, to permit proper separation of the scrap in the decanning operation. This can be seen at the right in Fig. 10. The small ringlets, formed by the multiple cuts, are then easily sheared and fall off separately. The final operation of the machine is to break the brittle fuel into $1\frac{1}{2}$ in. lengths. This is brought about by the action of a double-acting ram as the fuel passes through a hardened bushing (see view of chopper at the right in Fig. 14).

2. Spiral Decanner. The spiral-decanning machine is shown diagrammatically in Fig. 11 and in the corresponding photo (Fig. 12). It consists of a magazine, holding 25 fuel elements, which is loaded into a trigger mechanism that drops the elements singly into the shears. The right-hand shear (see close-up in Fig. 13), gaging from the end of the tip, cuts the tube and spacer wire immediately behind the lower tip (between the tip and the fuel). The left-hand shear cuts the tube and spacer wire at a point below the upper wire weld. The shear also crimps the main tube to prevent loss of the cut portion of the restrainer in subsequent operations. When the shears are opened, the tube and wire fall into the slotted feed rest (see Fig. 13), which allows the wire to fall free. In the event that the wire remains wound around the tube, a stripping die or orifice is provided to remove the wire as the tube and fuel are pushed through into the decanner.

The decanner drive rolls are skewed 15° with respect to the axis of the fuel elements. When they rotate, they impart a spiral forward motion which drives the fuel element against the tool. The tool (Fig. 9) is set 0 010 in. closer to the fuel centerline than the OD of the cutting roll. The cutting roll is similar to the serrated driving rolls except that the front face, which bears against the tool, is sharpened to form a cutting edge. The tool picks up the leading edge of the tube, shearing it against the cutting roll (Fig. 14) and separating it from the fuel. The fuel pin continues through the chopper bushing to be broken off by the ram as it moves back and forth The arm of the microswitch, located at the top center of the decanner, rides on top of the fuel element $1\frac{5}{8}$ in. ahead of the cutting edge of the tool. As the trailing end of the tube passes this point, the tool is withdrawn to allow the remaining portion of the tube, containing the sheared end of the restrainer, to be ejected from the machine by continued action of the drive rolls. Since it is attached to the tube scrap, it follows the former down the chute in the foreground into the scrap container The chopper guard, shown raised in the photo, channels the chopped fuel into the pan below the table.

Loading of the magazine, which is used with both machines, is accomplished by the master-slave manipulators in the air cell, using a simple funnel-type guide (Fig. 15). The magazine is placed under the guide preparatory to loading. Individual fuel elements, handled by a manipulator, are inspected visually or mechanically and dropped into the hopper until the magazine is filled. Levers, not visible in the photo, serve to cover the top opening of the magazine when it is removed from the guide, to prevent accidental loss of the fuel. Magazines are loaded into carts which carry them through the air lock into the argon cell, where they may be placed onto the machines by the manipulators.

CONCLUSION

It is planned to use both of the machines just described, or alternates still under consideration, because each has distinct advantages over the other as related to the condition of the fuel element.

The spiral decanner will be capable of decanning fuel elements which have sustained only slight external damage (to the casing) but with badly deteriorated fuel pins. This machine is made up largely of mechanisms which are slow moving or lightly loaded, and therefore likely to operate successfully without lubrication even at high cyclic rates. Since the fuel is expected to be in good condition normally, this machine will permit rapid decanning with a minimum of operator attention or corrective action by means of manipulators.

The roll decanner, in contrast, will handle fuel elements with a greater degree of external damage (bends, perforations, bulges, etc.) provided the fuel pin is intact and supplies sufficient backing for the cutting action. This machine, however, is likely to require more maintenance due to higher bearing loads and a greater number of rotating parts, and a greater amount of manipulative assistance by the operator.

Work is continuing on improvements in the basic operation of the machines, to achieve easier starting of the cut, more consistent operation, and better separation of the fuel and scrap. In addition, present models are being redesigned to improve serviceability by the use of a number of toggle clamps, snap-action fasteners, and twelve-point externally wrenched cap screws.

Tests on a number of graphite-base materials have been made by this Laboratory in order to select those which are satisfactory for use in an argon atmosphere of low humidity. Improved durability is expected as a result of the use of these materials as bearings, pneumatic piston seals, and piston rod seals, and by the use of ceramics as insulators for switches, connectors and other wiring devices.

An advanced model of the spiral-decanning machine is being installed in a controlled atmosphere box at ANL. It will be used to test durability, dependability, and to determine fuel yield, etc., when operated with unirradiated fuel elements. Results of this test will be utilized in preparing the designs for the prototype equipment.

ACKNOWLEDGMENT

The initial design of the roll-type decanner was developed by I. J. Bessette of the Central Shops Department, F. Bevilacqua* and L. W. Haaker.** Important contributions to the entire project have been made by N. A. Chiaramonte, N. G Avgerenos and L. H. Buczkowske of the Remote Control Engineering Division. The author is also indebted to engineers of the Reactor Engineering, Chemical Engineering and Metallurgy Divisions for helpful suggestions and data.

REFERENCES

1. Hampson, D C., Schraidt, J. H , and Malecha, R F., Equipment for Purification of Spent Reactor Fuel by Melt-Refining, Sixth Hot Laboratories and Equipment Conference, Chicago, March (1958)
2. Berstein, G. J , Graae, J. E A., Levenson, M., and Schraidt, J. H., Design for a Remotely Operated Facility for High-temperature Processing of Spent Reactor Fuel, Sixth Hot Laboratories and Equipment Conference, Chicago, March (1958).
3. Bailey, R. E. and Silliman, M. A., Effects of Irradiation on the Type 347 Stainless Steel Flow Separator in the EBR-I Core. ASTM-Third Annual Symposium on Irradiation Effects on Materials, February (1959).
4. Torgison, G I., SRE Fuel Decanner, Proceedings of the Fifth Hot Laboratories and Equipment Conference, Hot Laboratory Operation and Equipment, Vol. III
5. Culler, F. L and Blanco, R. E , Dissolution and Feed Preparation for Aqueous Radiochemical Separation Processes, Proc. of the Second United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland, September (1958), Vol. 17, p. 259.

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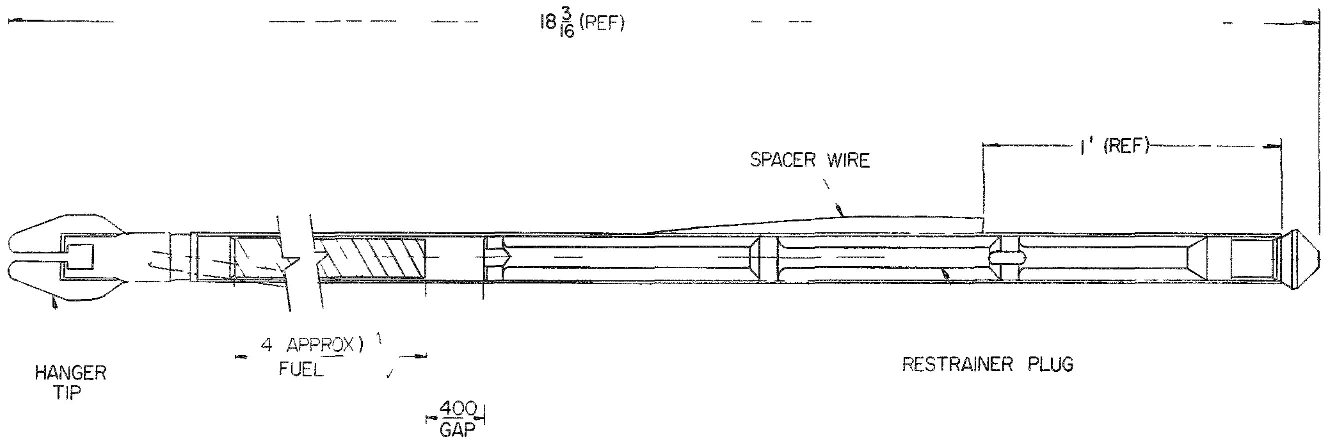

Fig 1 EBR-II Fuel Element

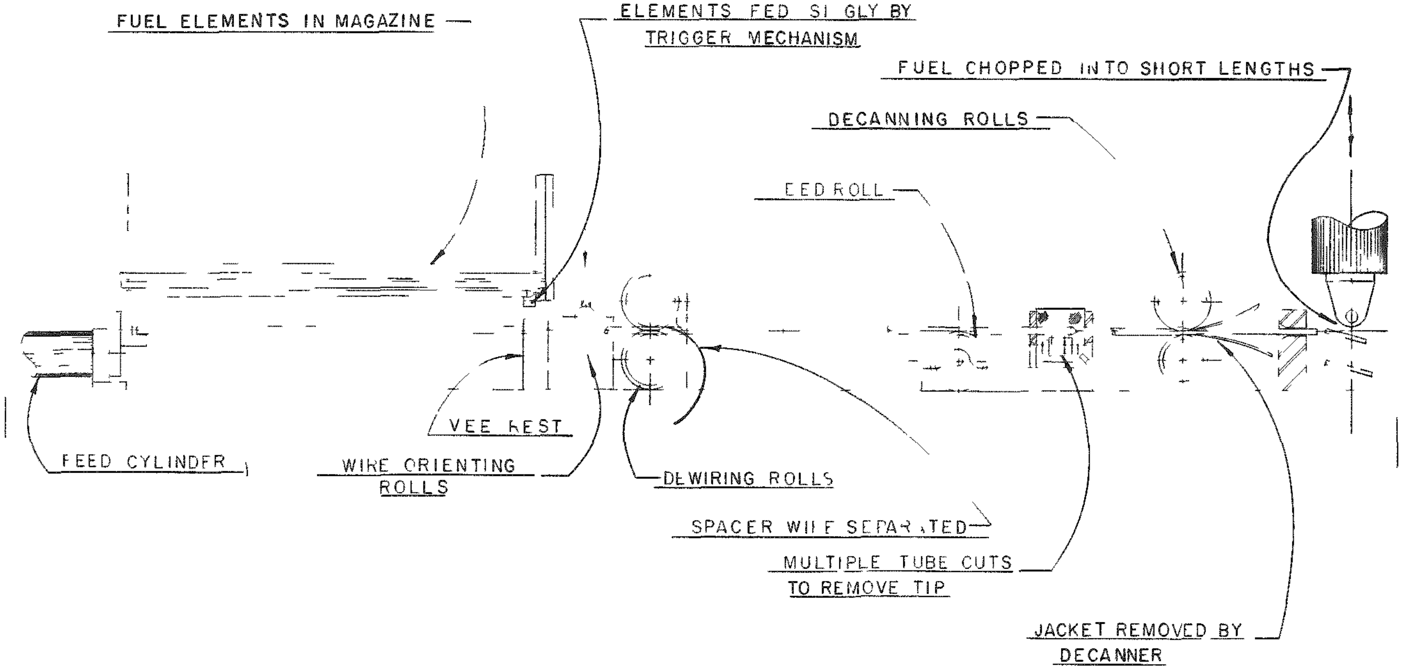

Fig 2 Roll Decanning Operation

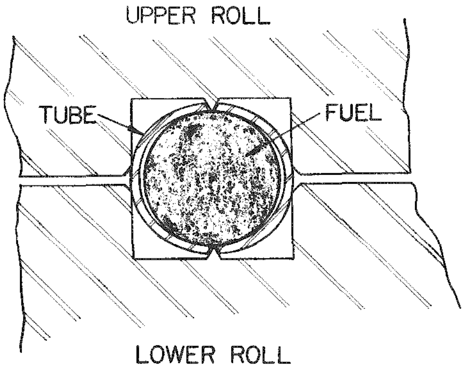

Fig. 3. Vee Type Rolls

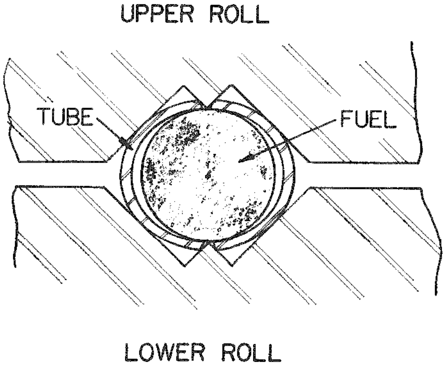

Fig. 4. Vee Type Rolls

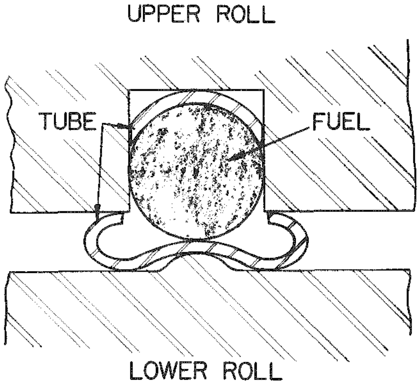

Fig. 5. Notched Rolls

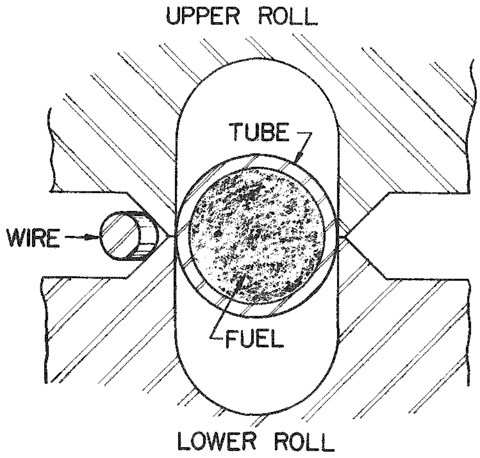

Fig. 6. Dewiring Rolls

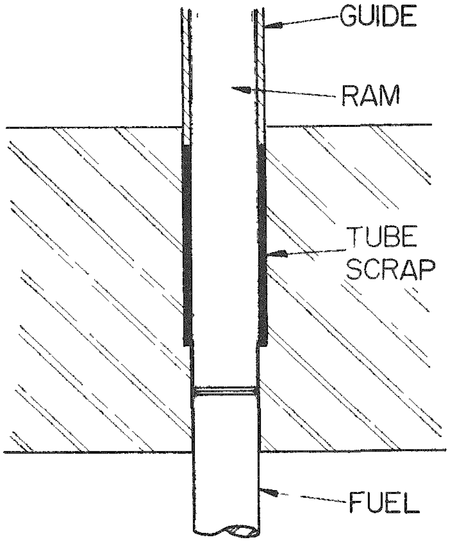

Fig. 7. Punch and Die Method "A"

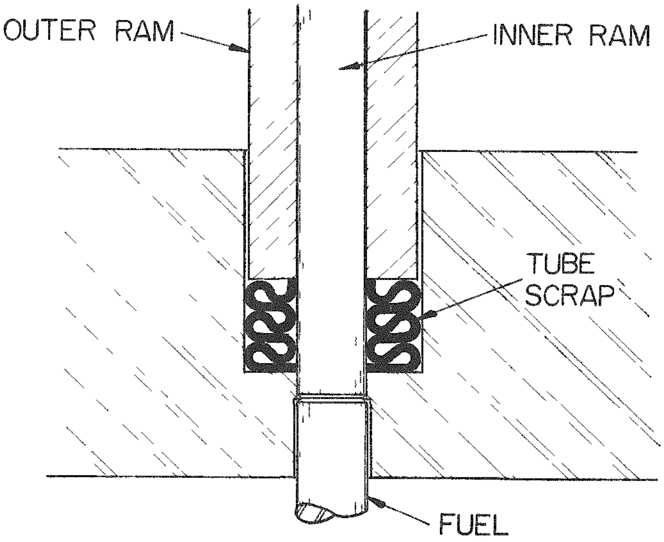

Fig. 8. Punch and Die Method "B"

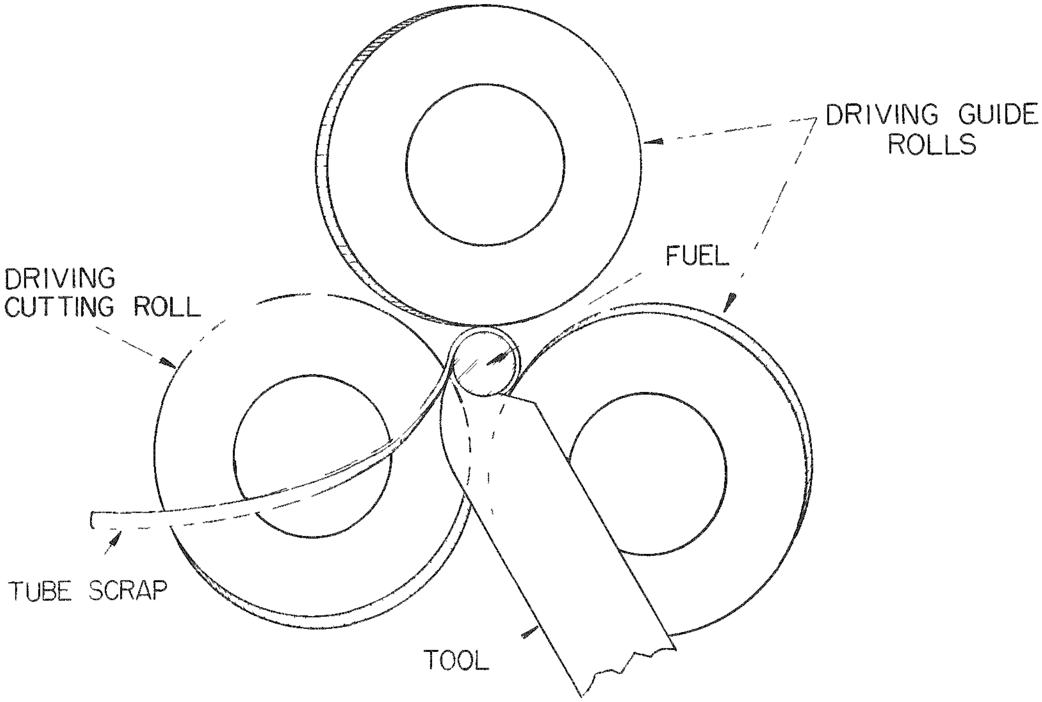

Fig. 9. Tool and Drive Rolls in Operation

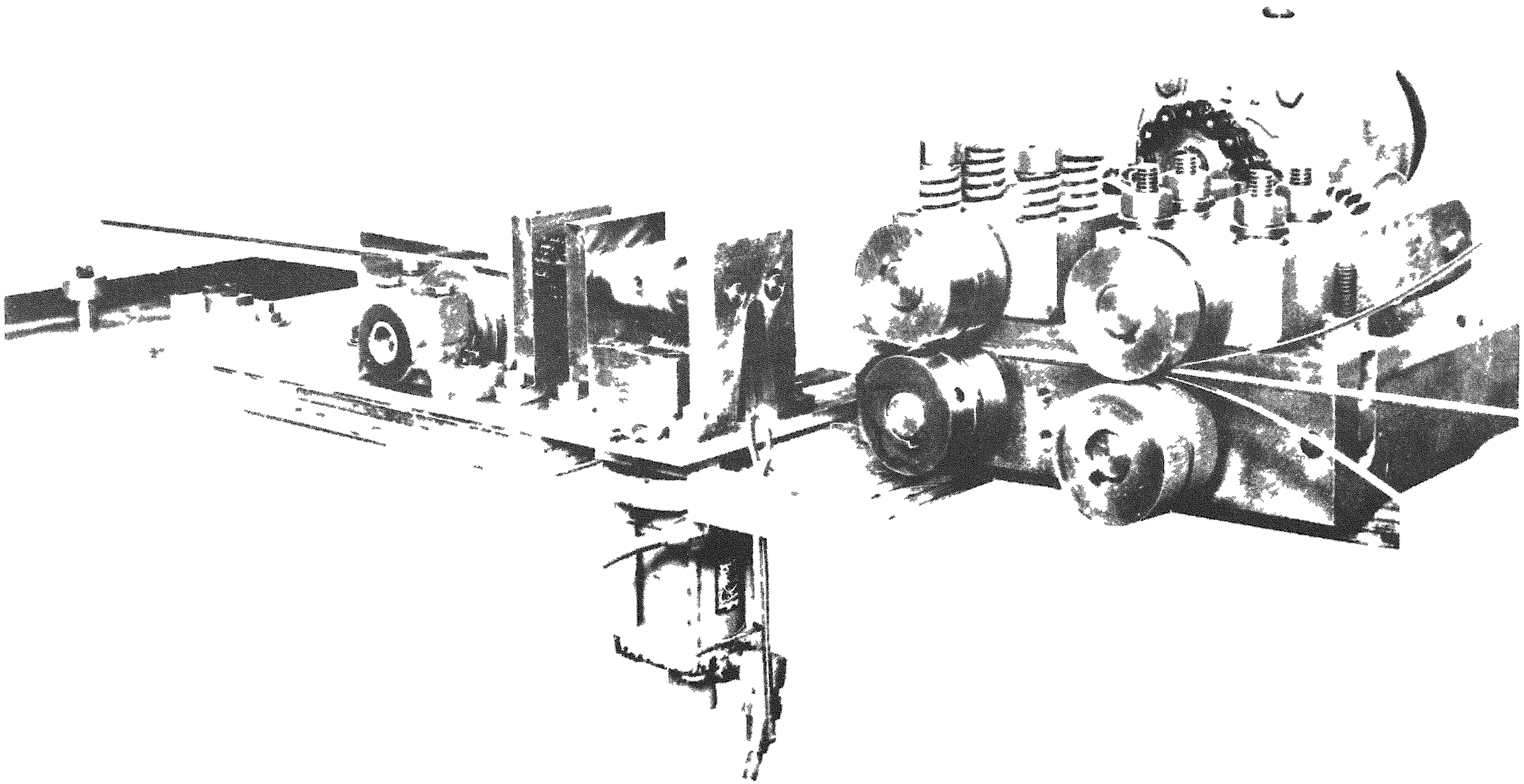

Fig 10 Roll Decanning Machine
(Shown in various stages of the operation)

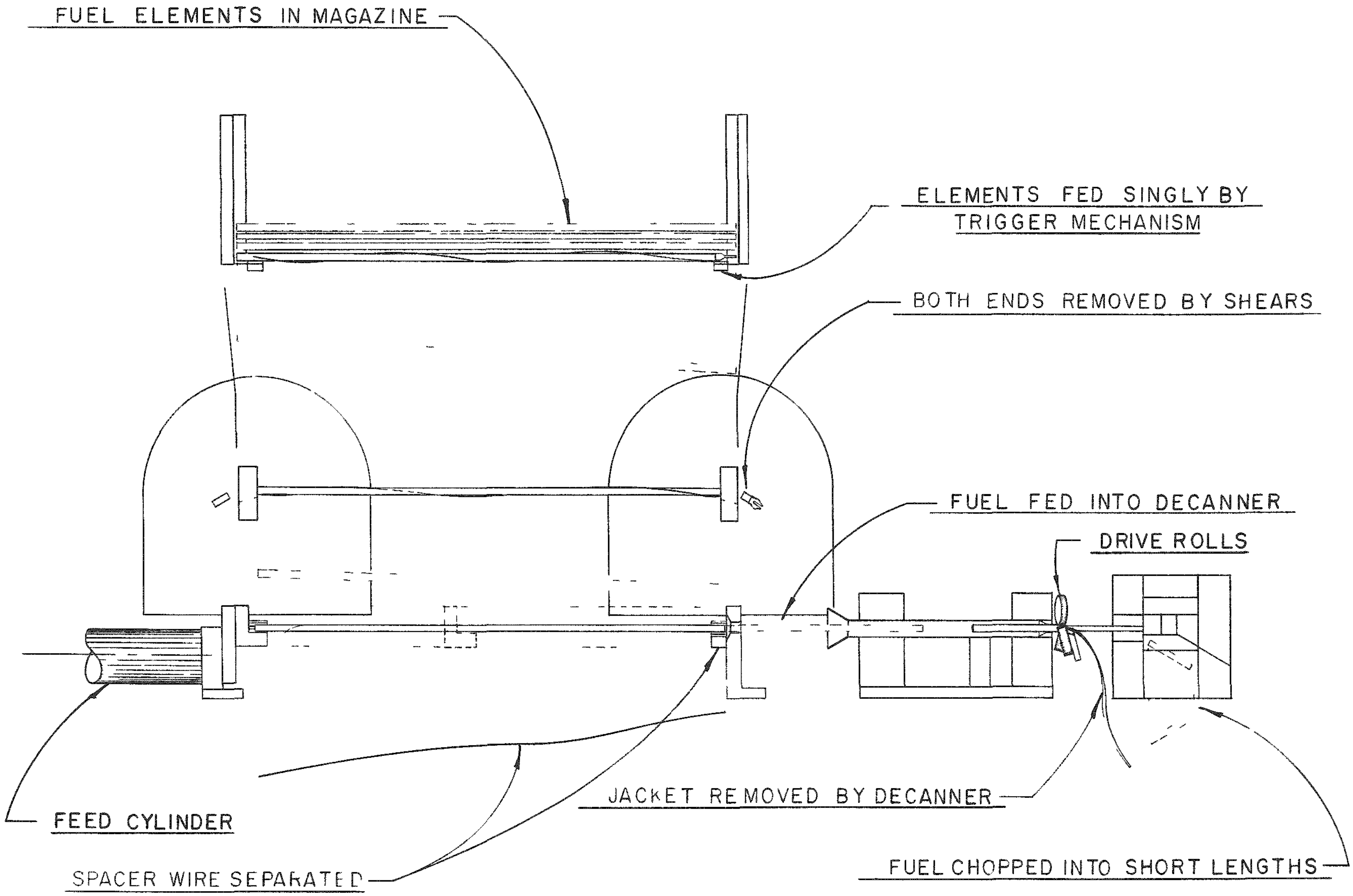

Fig. 11. Spiral Decanning Operation

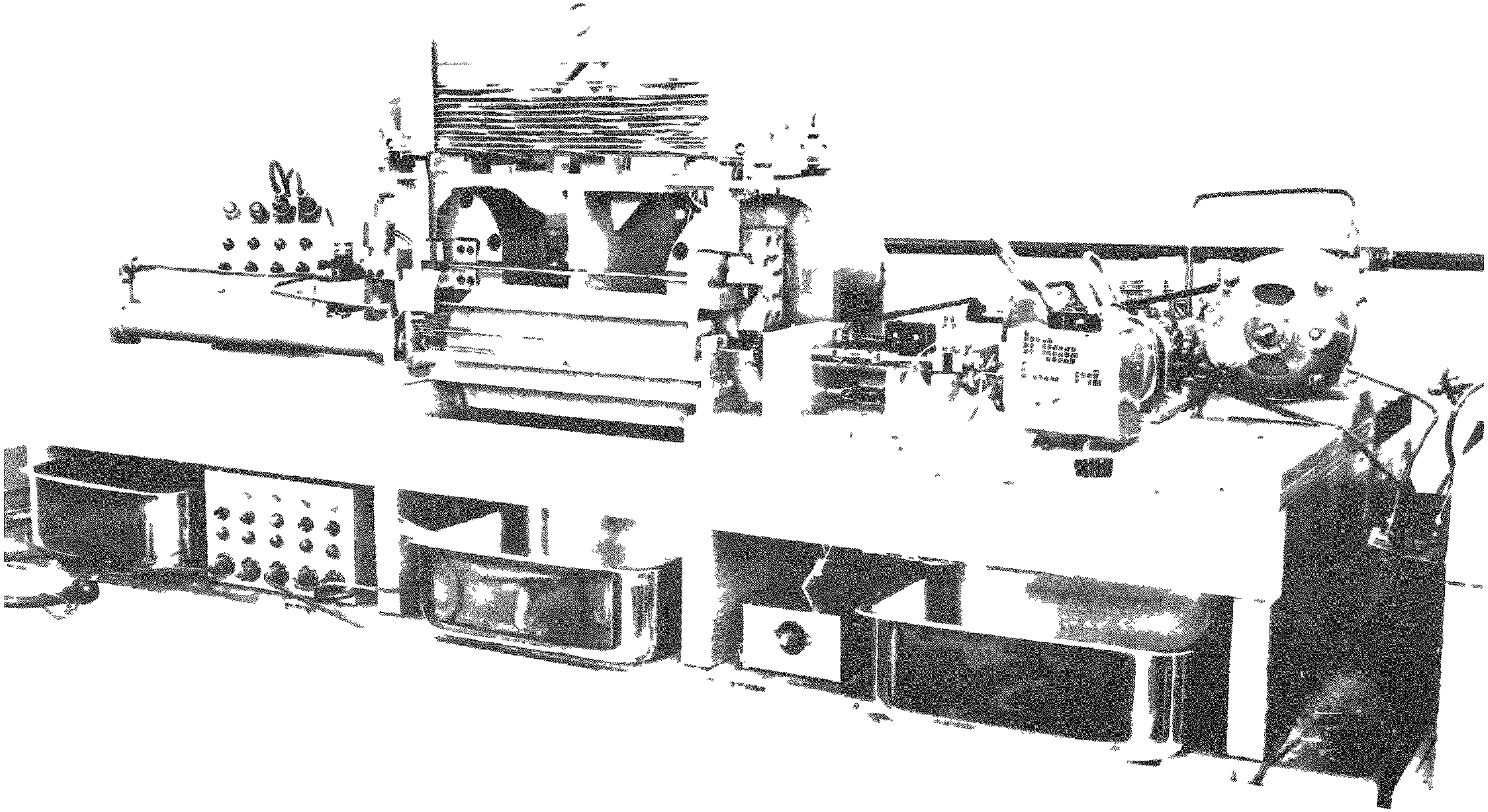

Fig. 12. Spiral Decanning Machine
(Showing fuel in various stages of the operation)

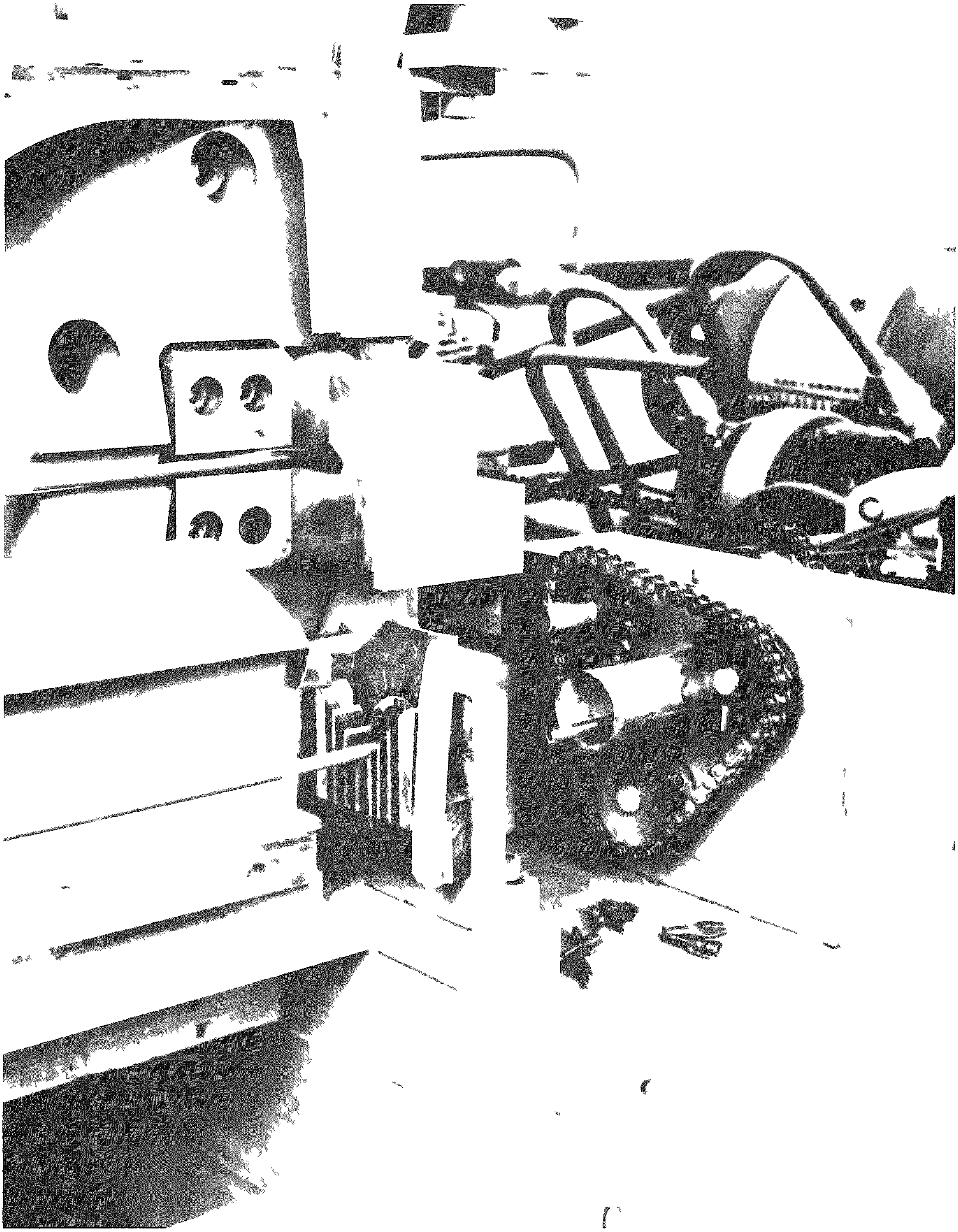

Fig 13 Shear and Feeder Rest
(In Operation)

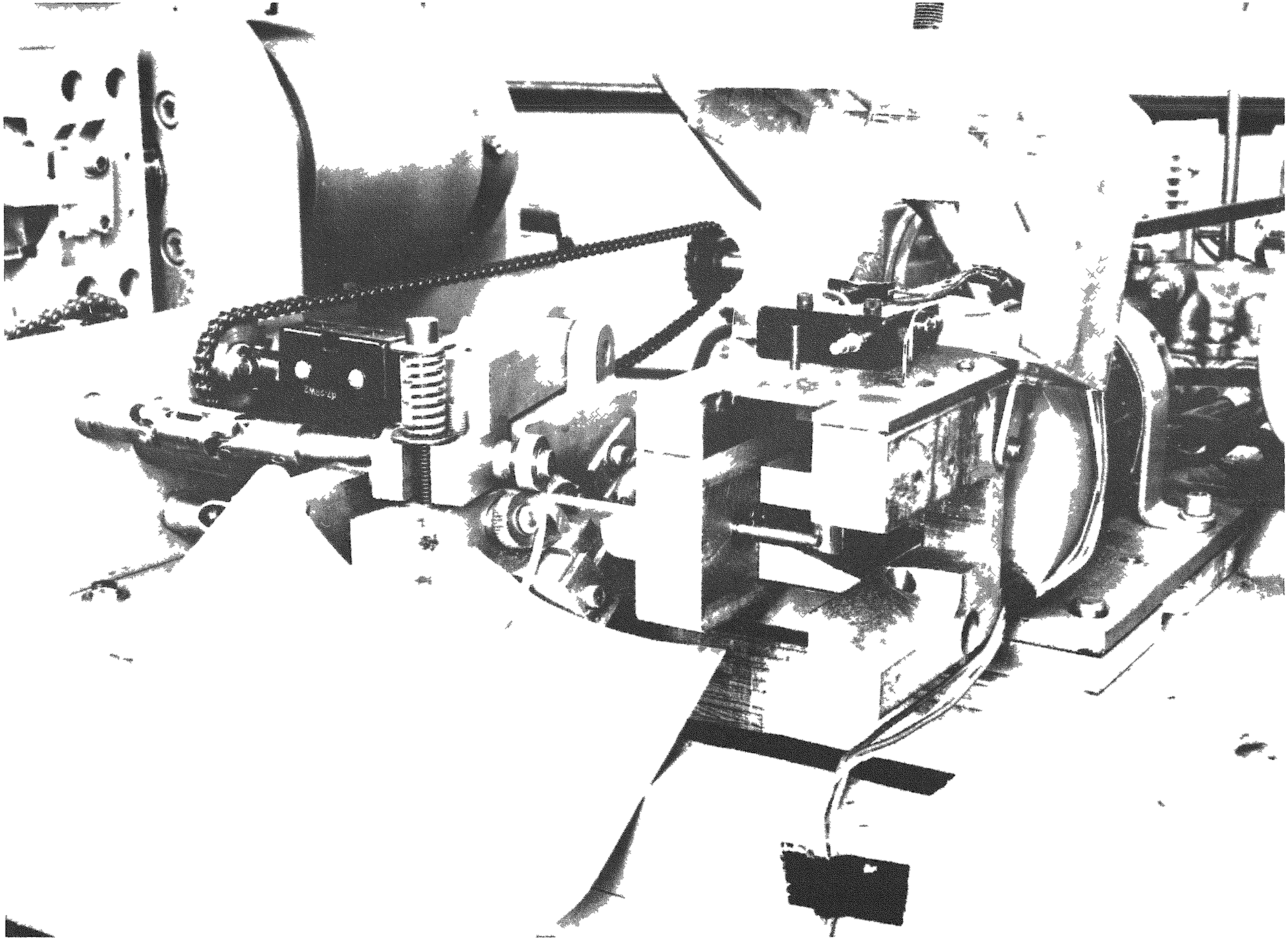

Fig 14 Decanning and Chopping Units
(In Operation)

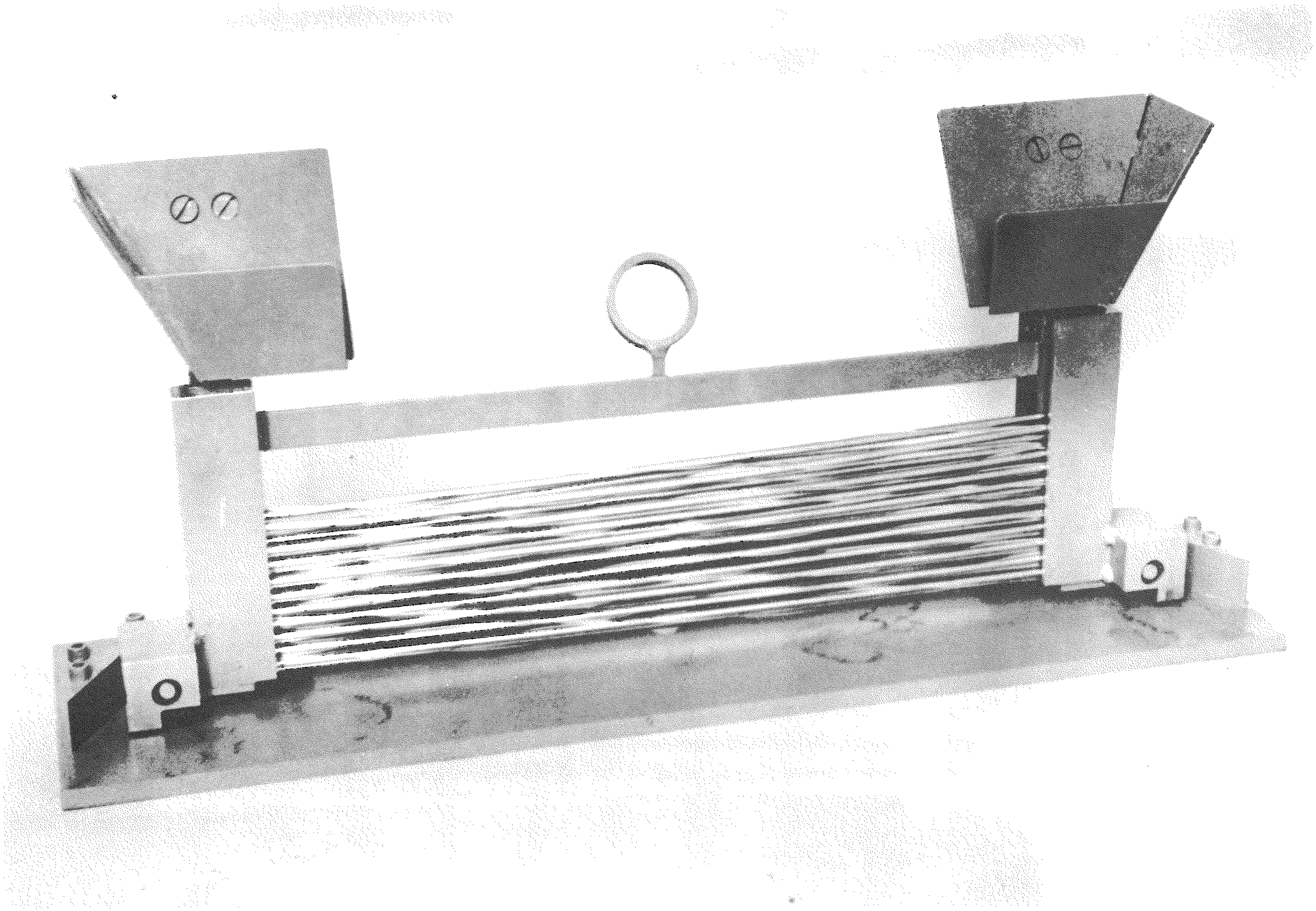

Fig. 15. Magazine Loader