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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DATE
February 8, 1962

TITLE
FINAL REPORT GRAPHITE DISTORTION
"C" REACTOR

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FINAL REPORT

GRAPHITE DISTORTION

"C" REACTOR

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c. Insert special process tube with a number of small jacks corresponding with the drilled hole locations. The number and size of the holes would have to be commensurate with allowable stresses due to load to be lifted or moved.

d. Jack the load in the direction required. Holes located on the top at a process tube channel could be used to jack loads up. Side holes could be used to straighten out horizontal deflections in a process tube.

e. A quick-setting mix of graphite "mud" or "concrete" could conceivably be injected between filler logs while in a jacked-up position.

A combination of these operations on a sufficient number of tubes in a horizontal row could remove an appreciable portion of the deformation now in existence. We cannot, however, estimate the time required or the cost of such an operation.

If this technique as suggested should appear too costly to be performed on the complete stack, it might be more realistic to consider "jacking up" only the upper 50% of the stack to remove the sag from these process tubes, since they are the most seriously deflected tubes. This would at least extend the useful life of the tubes.

A similar "jacking" procedure might be accomplished by a thin flexible envelope if it could be introduced between the top surface of a process tube log and the underside of the filler logs. The

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INTRODUCTION

This report covers the efforts of the Laboratory in an investigation of the graphite distortion in the "C" reactor at Hanford. The particular aspects of the problem to be covered by the Laboratory were possible "fixes" to the control rod sticking problem caused by VSR channel distortion. It was also intended that the Laboratory effort would be somewhat of an independent look at the problem to verify some approaches taken by the IPD people at Hanford and to determine whether additional approaches existed which would warrant consideration.

Work currently under way at HAPO included investigation of materials which might be used as "sleeves" in the VSR channels. An additional material search by GEL was to be made.

APPROACHES TO PROBLEM SOLUTION

The investigative efforts by the Laboratory were essentially divided into three general areas:

1. Methods of restoring the missing or lost material by "graphite growing" techniques.
2. Methods of arresting the distortion at its present level or mechanically correcting the distortion.
3. Techniques which followed a "learn to live with the distortion" philosophy. Sleeving the channels with an appropriate material, for example.

RESULTS

1. Graphite Growing - Investigation of graphite growing means shows that it would be possible to manufacture graphite in place. It would

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not be effective, however, due to the extreme difficulty encountered in trying to control the location of deposition. Such a technique would also be most costly in performance of the deposit function as well as the down-time required to effect the means of making graphite deposits in place. Such an approach could well tend to equal the cost of re-stacking a pile. Efforts following an approach of this nature were quickly discontinued.

2. Mechanical Correction - Mechanical correction of the pile distortion is considered possible, but it also may be economically impractical. Consideration and thought has been given to "jacking" of successive layers by working through process tube holes. The same technique might be applicable for both horizontal as well as vertical distortion.

The general shape of the distorted pile, bulged outward on the outer faces, accompanied by "concavity" of VSR channel profile (i.e., bowing inward) indicates the presence of appreciable gaps between logs in rows. These gaps might possibly be utilized as space into which a process tube could be moved by the jacking technique starting from the center.

The technique suggested is as follows:

a. Remove existing process tube.

b. Insert right angle drilling tool and make a number of holes in the walls of the process tube log, either upward to the underside of the next filler log or laterally to the adjacent filler logs.

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presence of the shield donuts and gun barrel arrangement almost preclude this possibility, however.

Gross jacking on the faces which are bulged outward will not alleviate the problem due to the fact that the VSR channels are already bowed inward toward the reactor center. In fact, applying sufficient force to remove a face bulge might well contribute more VSR channel distortion than is now present.

3. Adaptive Solutions - "Living With Distortion"

a. Sleeves as a Temporary Fix

As work now underway at IPD indicates, sleeving of the VSR channels might well be a relatively simple solution to the problem, depending on the mechanism of distortion and the forces involved. Certainly it is a most attractive, immediately obvious solution which should be in-pile tested and evaluated as rapidly as possible.

In the Laboratory's investigation, only one material other than those already under investigation at IPD warranted consideration. This was pyrolytic-graphite. This information was previously given IPD and steps have already been taken to procure and test this material.

The most serious draw back to channel sleeving is the lack of information and data on the forces involved in channel distortion, and thus the force that a sleeve must resist in operation.

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From the information and data sent to GEL for use in this investigation, there is no conclusive indication as to what the magnitude of force might be. There is data that indicates that the forces will probably be random in nature from very low to extremely high. For example, in some of the VSR channel distortion plots there is evidence of "slip" of a whole layer of logs relative to an adjacent layer. This would indicate an excessively large shear force on a sleeve if one were present. In some cases, log end protrusion into a channel has resisted relocating forces of high values, again indicating a possible high crushing or collapsing force on a sleeve section. It is also possible that an obstruction prevents return of the log and there is really no crushing force at all.

Ideally, in sleeve selection, one would prefer to establish a design limit and this in turn suggests force measurement. While it might be possible to make a force measurement across a slip plane, there is no assurance that the force would occur at the time the measurement was taken. The force could easily occur as a random thing rather than a steady state condition. Further, the forces will unquestionably vary in magnitude from point to point. It is doubtful that sufficient force measurement data could be obtained to be useful in determining the sleeve material structural require-

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ments. The approach taken by IPD people in selecting a number of the best possible materials from both the nuclear and mechanical properties and testing such materials in the reactor itself is therefore a reasonable one.

It must, however, initially at least, be considered a temporary fix; initially because there is no way of knowing if the sleeve strength will be sufficient to prevent further deformation of the VSR channels over a period of time.

b. <u>Sleeves as Permanent Fix</u>

The only way in which sleeves can be considered a permanent fix for VSR channel distortion, other than pure structural stiffness, would be to accompany their use with a removal of major means of force transmittal in the stack, the keys.

All evidence submitted to GEL for use in this investigation shows that the log ends which creep into a channel fail in one of two modes: 1) pure tension as a result of key loading in the keyway, or 2) bending, as by the control rod "wiping" the end of the log on the way by after being displaced to one side of the channel. Note that the filler log end has no support in bearing for the width of the process tube log adjacent to the VSR channel. This type of log end breakage obviously cannot produce sleeve damage since it cannot occur with a sleeve in place. Only that log end breakage which occurs as a result of direct tensile load, with the log end continuing to move into the channel as a result of the tensile loading or as a result

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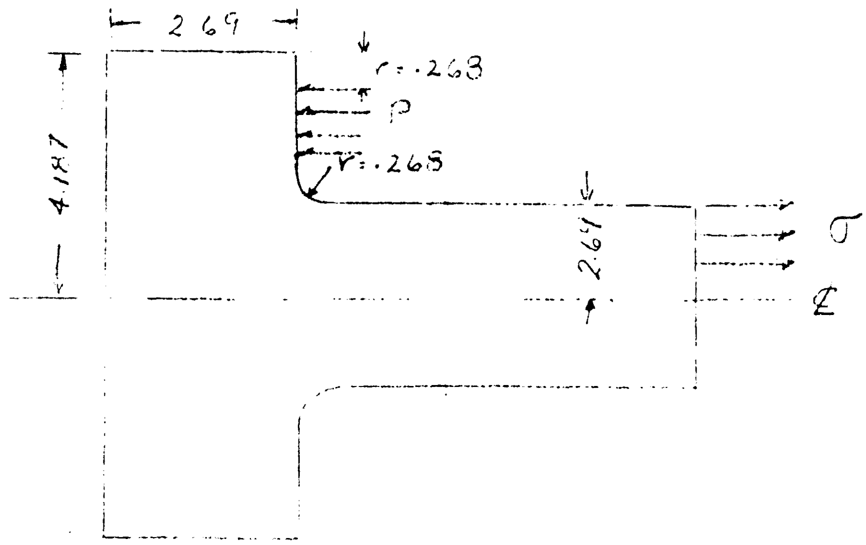
of vibrational "walking" forces can produce sleeve damage by crushing.

If it is assumed that the resistance required to stop the vibrational walking of a single log would be relatively low, it is possible to establish an order of magnitude of collapsing force which a log end could apply against a sleeve. In any one key-log end relation, the maximum tensile force that the log end can resist is a function of the area at the "root" of the keyway, and the stress concentration factor which in the case of the sharp corner specified on the drawings will be extremely high.

From "Stress Concentration Design Factors" by R.E. Peterson (John Wiley, 1953, page 121), the stress concentration, σ_{max}, is 10 for a T Head of the following configuration:



The end of a graphite log is equivalent to the one-half of the "T" head shown above the center line.

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The values for Peterson's variables are:

$D = 4.187 \times 2 = 8.37$ in.

$d = 2.69 \times 2 = 5.36$ in.

$m = 2.69$ in.

$r = .050\ d = .268$

The value of $r = .050\ d$ is the smallest radius included in Peterson's curves. For the following values of Peterson's parameters

$m/d = 2.69/5.36 = .5$

$D/d = 8.37/5.36 = 1.56$

$r/d = .050$

the stress magnification σ_{max}/σ is 10.

However, the radius of 0.268 inch is much larger than the actual radius in the notch of the log. The actual stress concentration factor is thus much greater than 10. For a corner with zero radius, the stress concentration factor approaches infinity.

Assuming a tensile strength of 2000 psi in the direction of the grain, the load, P, required to break the end of the log with a keyway radius of .268 (see above) would be $2000 \times 4.187 \times 2.69/10 = 2250$ lbs. The actual load required to break the end of the "C" pile log would be much less than 2250 lbs because the stress concentration factor is obviously much larger than 10. If a factor of 100 is assumed reasonable, then the breakage force is 225 lbs, a relatively low force.

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Assuming a shear strength of 1000 psi in the key, the force required to shear off a section of key would be 2 x 2.25 x 1000 or 4500 lbs. This is far greater than the force required to fracture the end of the block. Thus, in general, the end of the graphite log will fracture before the key will shear, leaving the end of the log free to advance into the VSR channel. If the vibration and inclined plane forces are ignored or considered reasonably low in value, and if the major forces are considered to be those which are generated via core graphite shrinkage, transmitted through the keys, then the above numbers represent the maximum and minimum collapsing forces which a sleeve would see from a single log end. Since we are only interested in a maximum, it would be that represented by the double shear load of a key (4500 lb if 1000 psi is an acceptable shear strength) since the log end would first break and continue to be driven into the side of the sleeve by the key until the key failed. Once the key sheared, no further driving force is available from shrinkage alone.

It should be noted that the above applies only to single log ends moving into a channel and not layer slippage (offsets) and general overall curvature.

Should it be considered desirable to remove possible sources of log end breakage, it appears possible to cut the keys surrounding a VSR channel.

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Key Cutting - Tool Concept

In order to cut the keys, it is necessary to utilize a tool which can work from a VSR channel. A concept of the tool is shown on Figure 1. The concept embodies the general features of a saber saw, with a 90 degree bend in the blade. It should be understood that the tool shown is not intended to be a detailed design but is a feasible concept which could be utilized.

Basically, the tool consists of an air motor driving a swashplate or similar mechanism to convert rotary motion to linear blade motion. The blade is made of spring steel and is fed through a 90 degree bend guide mechanism. The motor blade-drive mechanism is mounted on a slide, which permits retraction and extension of the blade. Above and below the cutting assembly are positioning clamps which extend radially to anchor the unit in the VSR channel. The cutting unit is bearing mounted relative to the clamps so that the extended blade can be swung in an arc through a key. The actual cutting stroke of the blade is kept short, to allow the blade to penetrate the crack area between filler logs, once the blade is extended into the gap over a process tube log and a cut started.

The blade extension is manual permitting the operator some degree of "feel" for blade insertion. A "vacuum cleaner" connection would of course be needed with the device for dust control.

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Typical usage would be based on dimensional locations of each gap from a reference point (determined during borescoping) and positioning the tool in the channel relative to these dimensions. The blade would then be extended into the gap between process tube logs and filler logs, and the clamps actuated. When anchored, the cut is started and the tool swung through sufficient angular displacement to assure severing a key.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this investigation and the complex nature of the problem, it is obvious that there is no inexpensive simple solution to the problem (operating at reduced power levels and low production rate are considered expensive). It is also concluded that the approach of sleeving the channels is the best probable temporary fix. It must be considered temporary until evaluation can be made to ascertain its usefulness as permanent fix for the VSR channels.

There are other problem areas, however, besides the VSR rod sticking. Specifically, this is process tube sag, particularly in the upper rows. The rate of deflection increase may be plotted, and is determined to be on the order of an inch per year. In a relatively short time, it is predicted that this will begin to produce tube failures in "C". (They have already appeared in "H".)

It is the Laboratory's recommendation, therefore, that, along with the sleeving of the VSR channels, an intensive effort be made to find ways and means of restoring process tube alignment.

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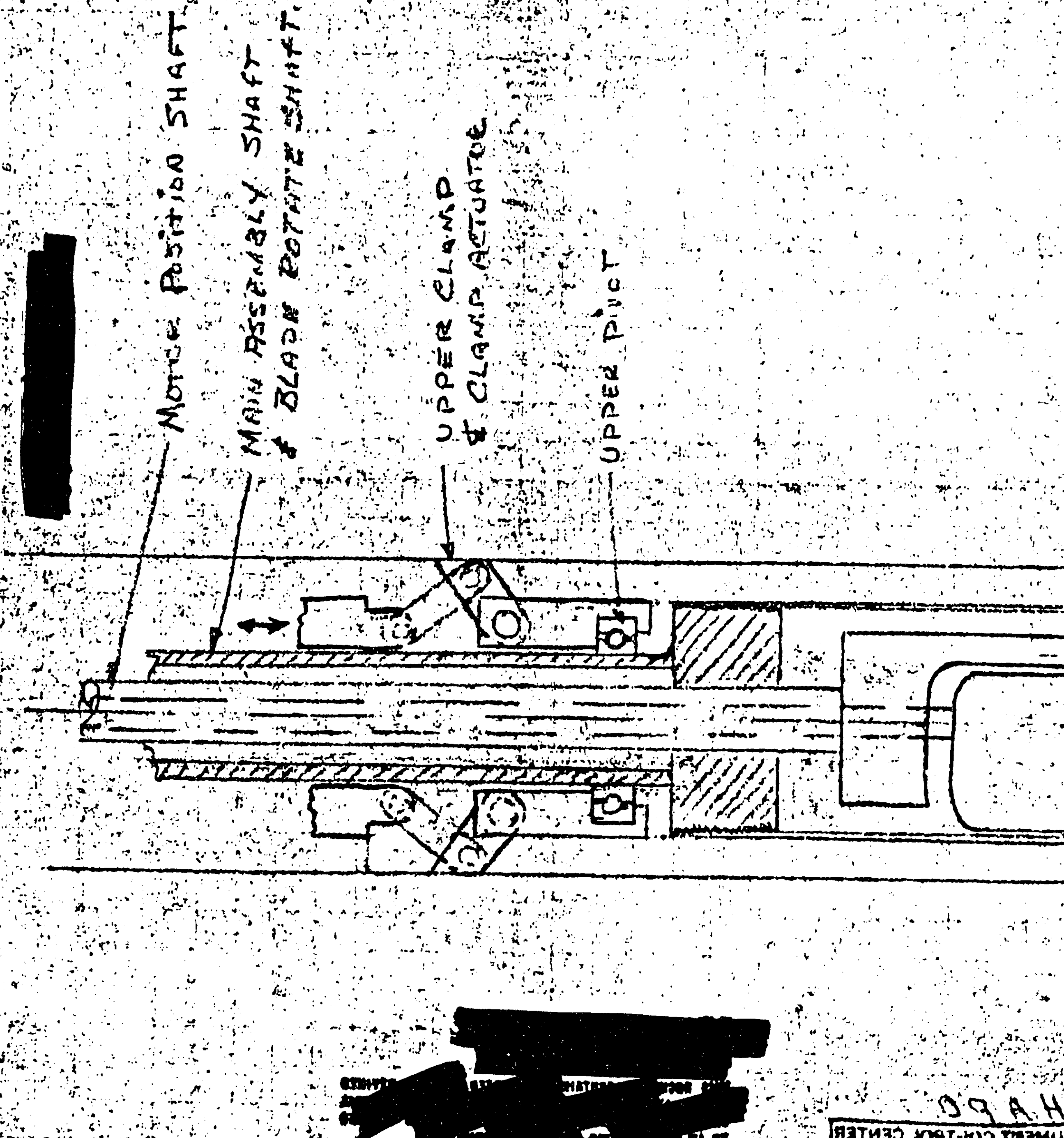

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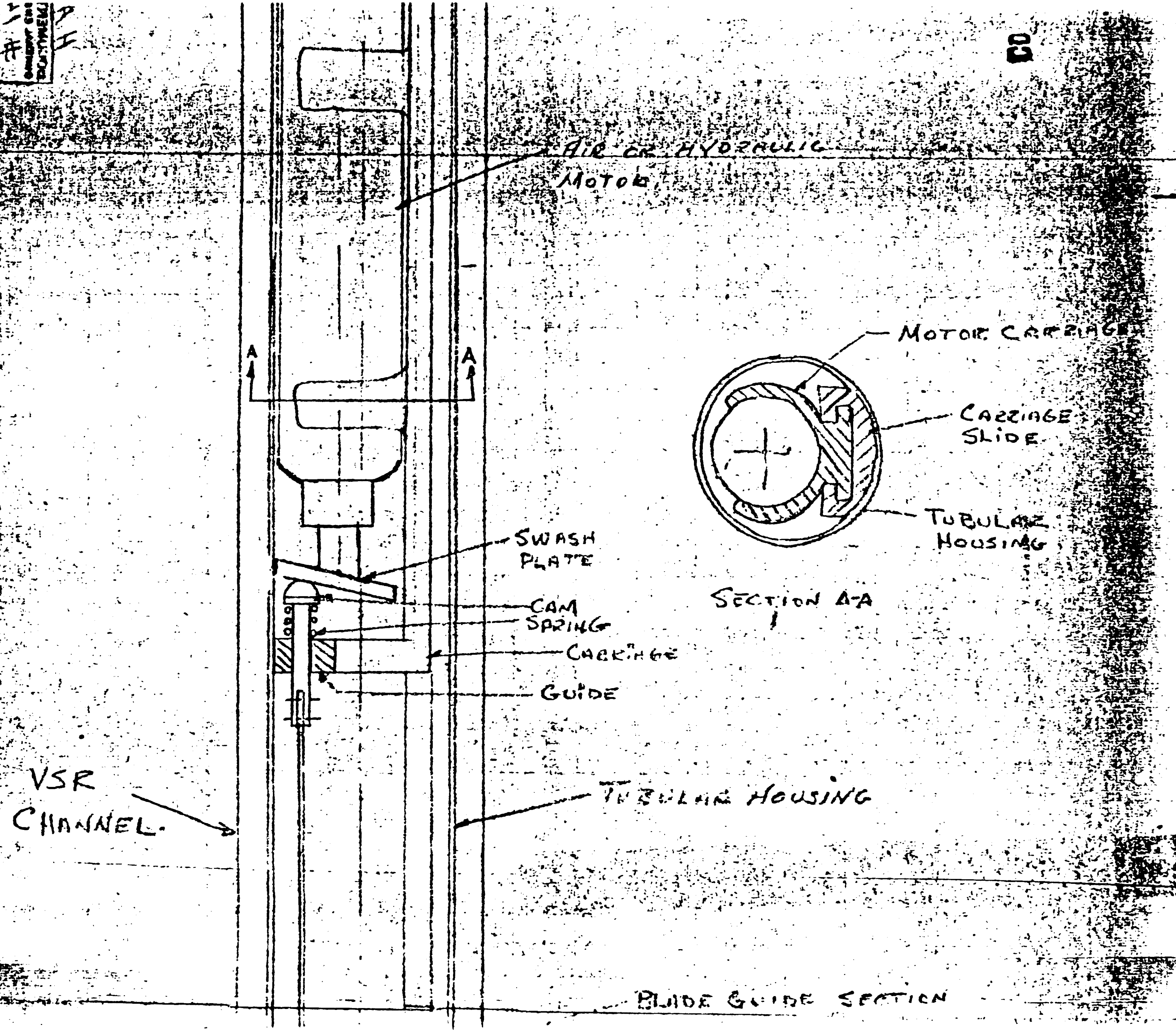
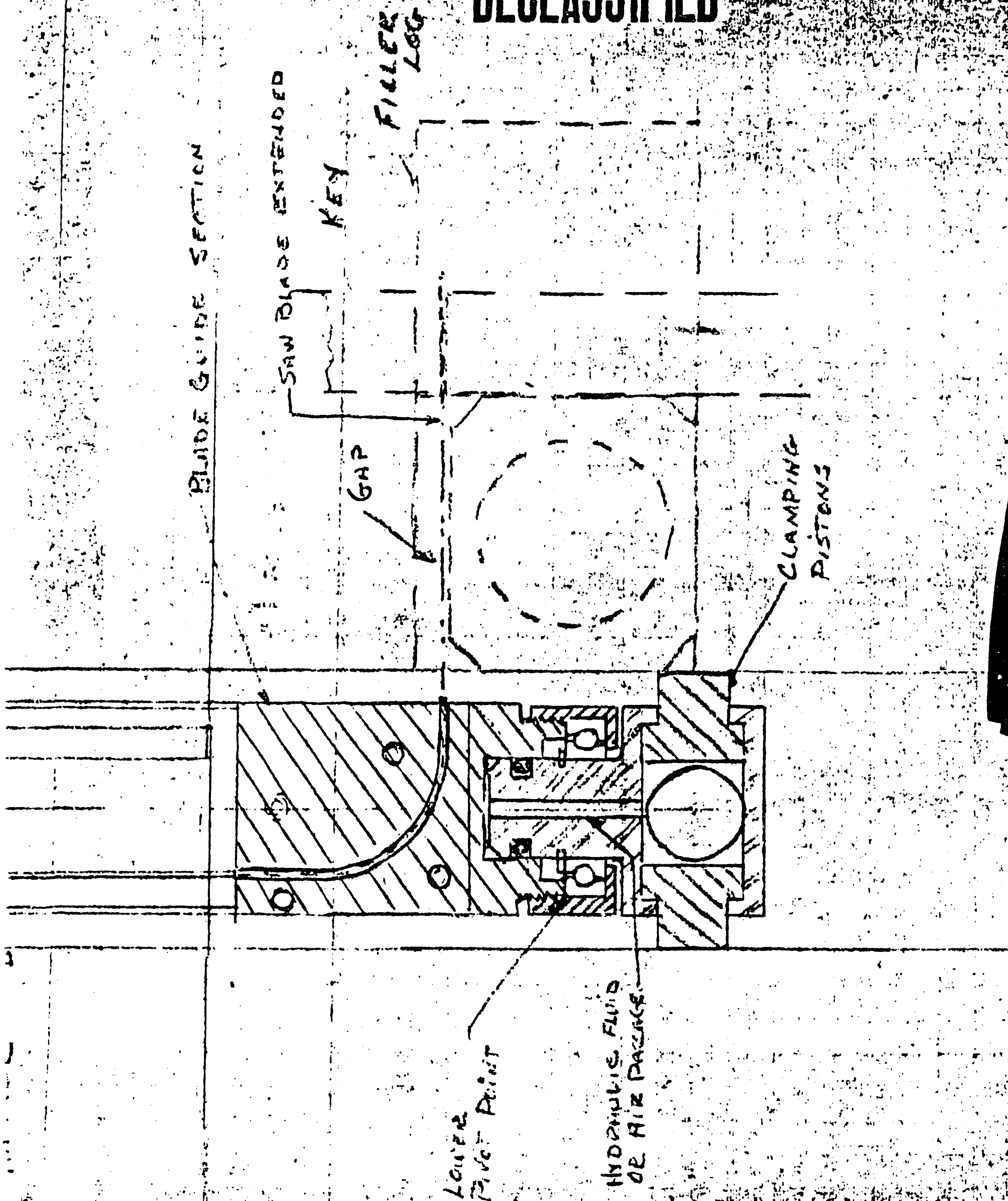


RETRACTABLE SABER SAW FIG.

HW GEL 1



RETRACTABLE BLADE
SABER SAW - 90° OFF SET
FIG 1

JAN 12 1962
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