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MOBIL RESEARCH AND DEVELOPMENT CORPORATION

RESEARCH DEPARTMENT

TECHNICAL MEMORANDUM NO. 67-14

THE USE OF SCREW FEEDERS AND SCREW CONVEYORS TO HANDLE SPENT SHALE - RETORT NO. 3

ANVIL POINTS OIL SHALE RESEARCH CENTER

Rifle, Colorado

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C. to JCK-WRB

The primary object of the Anvil Points Oil Shale Research Center TECHNICAL MEMORANDUM is to advise authorized personnel employed by the Participating Parties[1] that various activities are in progress or that certain significant data have been obtained within the Research Center.

These TECHNICAL MEMORANDA have been prepared to provide rapid, on-the-spot reporting of research currently in progress at Anvil Points. The conclusions drawn by project personnel are tentative and may be subject to change as work progresses. The TECHNICAL MEMORANDA have not been edited in detail.

[1] Mobil Research and Development Corporation, Project Manager

Continental Oil Company
Humble Oil and Refining Company
Pan American Petroleum Corporation
Phillips Petroleum Company
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THE USE OF SCREW FEEDERS AND SCREW CONVEYORS TO HANDLE SPENT SHALE - RETORT NO. 3

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FIGURES

THE USE OF SCREW FEEDERS AND SCREW CONVEYORS TO HANDLE SPENT SHALE - RETORT NO. 3

I. INTRODUCTION

Screw conveyors and feeders were selected to convey spent shale from Retort No. 3. The screw conveyor appeared to offer several advantages over conventional belt type conveyors previously used on Retorts No. 1 and No. 2 for similar service.

This report will summarize mechanical design criteria found necessary to properly specify screw conveyors for spent shale handling based on experiences at Anvil Points during Stage II of the Program.

Principal needs of an adequate spent shale handling system involve the following:

1. Retorted shale and dust must be properly confined during its travel to the disposal point to prevent pollution.

2. The conveying system must be capable of handling hot material to 1,000 F.

3. The conveying equipment must be capable of maintaining an oxygen free atmosphere to prevent ignition of hot spent shale.

4. Conveying equipment must be reliable in service. Emergency repairs must not extend beyond 30 minutes.

5. Suitable equipment is required to control the rate of shale flow from the retort.

6. Conveying and rate control equipment must also be capable of handling raw shale.

7. Spent shale handling equipment must be compatible with a retort lower seal system.

II. SUMMARY AND CONCLUSIONS

Screw conveyors and feeders were found to be entirely adequate to handle hot spent shale, meeting all the goals of the system needs.

In our judgment, screw conveyors will be most satisfactory for use on a commercial retort within their normal capacity ratings.

Reviewing larger capacity, commercially available equipment, screw feeders, used for rate control purposes, are capable of handling all sizes of shale and flows from retort sections to 400 square feet at the 500 mass rate; with 1/4 to 1 inch shale a screw conveyor is capable of handling sections up to approximately 400 square feet at the 500 shale mass rate; with 1/4 to 2 1/2 inch and 1 to 2 1/2 inch shale, a screw conveyor is capable of handling retort sections up to 250 square feet at the 500 shale mass rate.

The bottom pressure seal system used on Retort No. 3 is not feasible for larger capacity units due to size limitations of available equipment.

III. RECOMMENDATIONS

Experience at Anvil Points has shown that the incorporation of several design features will produce a reliable, long life screw conveyor system. These recommendations are based on needed revisions made to standard equipment purchased from national suppliers.

1. Select the conveyor diameter based on the largest dimension of shale to be handled rather than the nominal shale size.

2. Hardfacing of the outside edge and leading face of the screw flights is essential.

3. Use standard sizes and lengths of commercially available screw flights.

4. Flight couplings should permit disassembly of single flights without movement of adjacent flights.

5. Hangers should be of high grade steel with holding bolting locked in place.

6. Hanger bearings of chilled iron appear adequate but are the weakest link.

7. Flights require cut backs of three inches from the ends adjacent to hangers.

8. Offset entries and shaft hardfacing are required at conveyor inlets.

9. Screw feeders, heavily shafted, powered, and reinforced provide an adequate means of controlling the rate of shale flow from a retort. Raw shale and spent shale may both be handled with this type feeder. A baffle installed above the flight inlet which prevents a completely choked inlet, is desirable but not absolutely necessary.

10. Conveyor casings made of an abrasive resistant material are necessary for long time service.

IV. DETAILED DISCUSSION

A. Description of Equipment

The spent shale conveying system for Retort No. 3 carries shale approximately 88 feet from the retort to its point of discharge into a canyon. Design capacity was for 20 tons per hour of three inch minus shale at 350 F. It consists of a screw feeder, two star feeders, followed by two screw conveyors (see Figure 1). On occasion, this equipment has conveyed shale at temperatures up to 1,000 F.

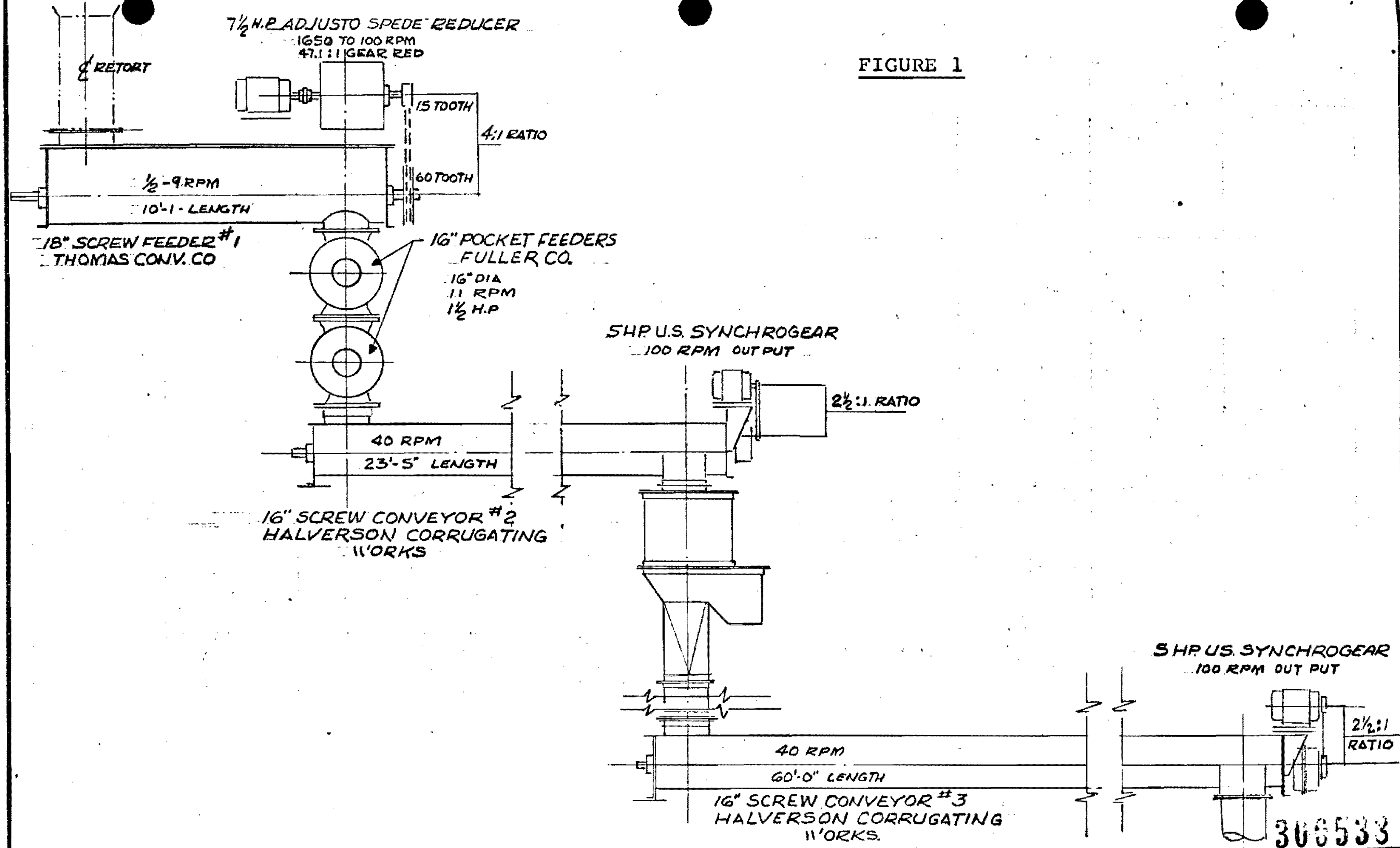
No. 1 screw, the rate control feeder, is an 18 inch diameter unit. It was designed and manufactured by the Thomas Conveyor Co., Inc. of Burleson, Texas. Details are shown in Figure 2. This screw has a nine inch flight pitch at the inlet and it opens to an 18 inch pitch beyond the inlet. (It operated at varying speeds less than 10 RPM.) Stellite was used by the manufacturer to hardface the flights. This conveyor has been satisfactory in all respects since being put into service.

One important feature of the screw feeder is that it was designed to operate with a 1 psig internal pressure in a very dusty atmosphere. Shaft seals were in standard packing glands and made of braded asbestos and graphite rope packing. This seal operated satisfactorily.

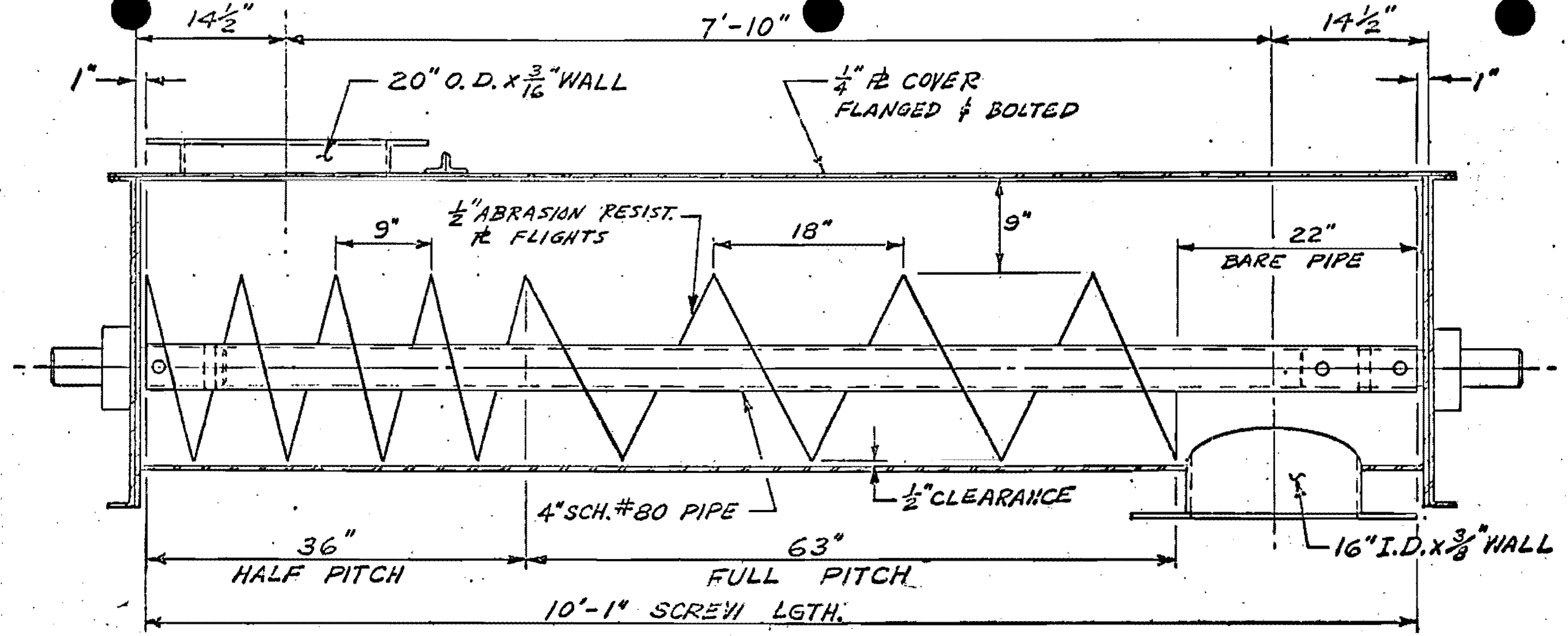
Shale from the screw feeder drops into two 16 inch star feeders mounted in series. These feeders were used to create a pressure seal for the retort. Vent gas was injected between the two feeders, the rate being controlled by a pressure balance across the top feeder. This gas leaks through the lower feeder and out through the spent shale train. It also blankets hot shale in an inert atmosphere thereby preventing combustion in the conveying equipment. Internal baffles were installed above each rotor to prevent shale from jamming as the rotor closed on the casing. Six vane rotors were employed for this service to provide adequate sealing. A four vane rotor vane will create a pulsing gas flow condition at this point. These units were purchased from the Fuller Company and are the largest six vane units of standard design. The use of this type equipment is limited to approximately the capacities used for Retort No. 3.

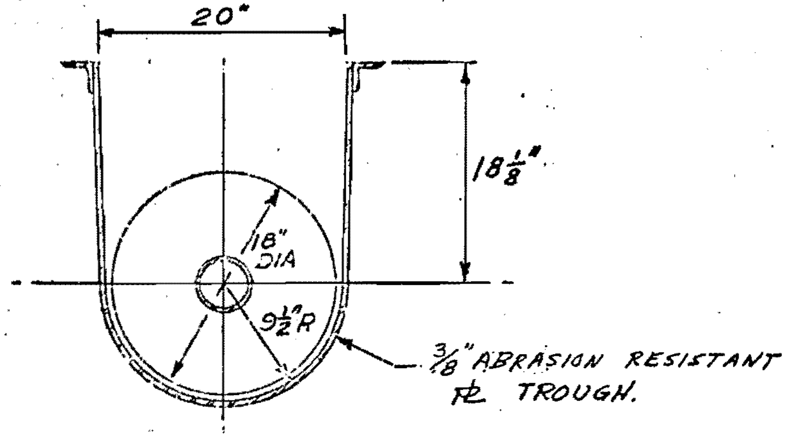
Two sixteen inch standard, fully enclosed, screw conveyors in series moved shale from the discharge of the star feeders into the canyon east of the retort structure. These units were found to be undersized when handling 1 to 2 1/2 inch and 1/2 to 2 1/2 inch raw shale. Structural damage occurred to the hangers. They were satisfactory when handling 1/4 to 1 inch shale. A 24 inch screw would be recommended for

FIGURE 1



NO.	DATE	PRINT ISSUE TO	ANVIL POINTS OIL SHALE RESEARCH CENTER RIFLE, COLO. PROJECT MANAGER-SOCONY MOBIL OIL CO., INC.	SCALE ¼ = 1'-0	SPENT SHALE CONVEYORS RETORT #3 GAS COMBUSTION PROCESS
			JOB NO. / CHARGE	DRAWN BY K. LARSON	
				STARTED 8-25-67	
				COMPLETED 8-25-67	LOCATION
			APPROVED / PROCESS [signature] / DESIGN [signature] / SAFETY	DIMENS.	DRAWING NO. RE 97





TYP. TROUGH SECTION

GENERAL NOTES:

1. 3" OF FACE OF FLIGHT ON CARRYING SIDE TO HAVE STELLITE HARD SURFACE, & 2'-0" OF INLET END OF PIPE TO HAVE HARD SURFACE.
2. UNIT TO BE SEALED FOR 1 P.S.I.

FIGURE 2

NO.	DATE	PRINT ISSUE TO

ANVIL POINTS
OIL SHALE RESEARCH CENTER
RIFLE, COLO.
PROJECT MANAGER-SOCONY MOBIL OIL CO., INC.

JOB NO.	CHARGE		
APPROVED	PROCESS: HSB	DESIGN: HSB	SAFETY

SCALE: ¾" = 1'-0"
DRAWN BY: J.R. Hamilton
STARTED: 8/25/67
COMPLETED: 8/25/67
DIMENS.

NO. 1 SPENT SHALE SCREW FEEDER
(18" SCREW FEEDER)
RETORT NO. 3

LOCATION
DRAWING NO. RE 96

future handling of large shale as shale with one dimension as long as eight inches will pass through the screening plant.

B. Hardfacing of Flights

All of the flights for the No. 2 and No. 3 screws were ordered as industrial standard size, carbon steel with no hardfacing. They have a tapered cross section with a thickness of the inner edge next to the conveyor pipe about twice the thickness of the outer edge. These thicknesses were approximately 1/2 inch and 1/4 inch respectively.

Some wear had been noted after three months of service and a marked increase was noted during the next month on the flights for No. 3 screw. Screw No. 2 showed less evidence of wear for these periods. Wear is evidenced by a reduction of overal diameter and/or a thinning of the outside edge.

After five months of service, the leading (working edge) of each flight for No. 3 screw was hardfaced with three adjacent passes parallel to outside edge of flight and starting close to the outside edge. The hardface alloy used was Amsco 60.

Subsequent inspections of No. 3 flights showed increased wear despite the hardfacing. The original flights were then replaced after seven months of service.

New flights for conveyor No. 3 were hardfaced at Anvil Points. One pass was laid down parallel to the outside edge of the flight, then a lace-pattern of radial passes was laid down, starting at the parallel pass near the outside edge and running radially for a depth of 2 to 2 1/4 inches. The hardface alloy used was Stoody No. 2134. In subsequent inspections of these flights the only signs of wear have been a slight "polishing" of the hardface.

After removal of the old flights from No. 3 screw, some measurements, noted below, were made of their wear. Since these flights were originally 16 inches in diameter, it will be noted that the wear ranges from a minimum of 1/4 inch up to two inches on the diameter for a period from October 1966 to June 1967.

Flight No.	Installation Date	Measured Diameter June 1967
1	October 1966	14 1/2 to 15 1/2
2	October 1966	14 1/2
3	October 1966	14 1/2 to 15
4	October 1966	14 1/2 to 15
5	October 1966	14 to 15

Since increasing wear had been noted on No. 2 screw, replacement flights were installed after eight months of use. These flights were hardfaced, as on No. 3, using Stoody No. 2134. Subsequent inspections indicated a very slight "polish" of the hardface.

C. Screw Diameter Selection

A review of industrial conveyor standards used to determine screw diameter is of interest in relation to the possible effect that actual shale size has on such diameter and ultimate conveyor performance. For oil shale, the loading classification selected was Class III (15% full), handling "highly abrasive lumpy materials which must be carried at a low level in the trough to avoid contact with hanger bearings or interference with hanger frames". The maximum lump size for a 16 inch diameter conveyor is given as 3 1/2 inches, where the size represents 25% of the total. The maximum RPM is 45 - 40 RPM was used at Anvil Points. Handbooks rate shale as a Class II A material which would have permitted operation with a trough 30% full. 1/4 to 1 inch shale easily falls into this category. Large oil shale probably falls between the two ratings.

Maximum demands are placed on the conveyor systems at startups. For a period of about 12 hours minimum these systems must handle raw shale with an upper limit maximum of 2 1/2 inches, which will pass through the screener. However, shale is seldom, if ever, even fairly uniform in size, so that a 2 1/2 inch piece, although passing through the screens could be, and often is, 6 inches to 8 inches long. These larger pieces caused much of the structural damage described in Section G - Hangers. In In such case, then, a larger conveyor diameter up to 24 inches is a better selection for the 1/4 to 2 1/2 or 1 to 2 1/2 inch shale fractions.

D. Flight Modification

As manufactured, for standard flight sections, the flight actually covers the full length of the conveyor pipe, to which it is attached. In a multi-flight conveyor, such as No. 2 and No. 3 screws, when flights are connected with coupling shafts at the hangers, the horizontal distance, measured at the hanger, between flights, is only three inches. Shortly after startup in 1966 a series of failures to hangers and bearings occurred in both No. 2 and No. 3 screws. It was finally concluded that pieces of raw shale were getting "hung" up between the flights and the hangers and causing these failures. 1 to 2 1/2 inch shale was being tested.

As a result, it was decided to cut back the end of each flight three inches along the shaft at the hangers to provide clearance as the flight closed on the hanger. A short piece of pipe or rod was welded to both the cut edge of the flight and the conveyor shaft to strengthen the flight at this point. This modification served to eliminate the close clearance between flights and hangers as the causative factor in the failures noted.

A further modification is required to the flight at the discharge chute end. Good conveyor practice for a 16 inch conveyor requires that the flight be cut back so that it ends on the conveyor shaft a horizontal distance of three inches short of the centerline of the discharge chute.

E. Conveyor Chute Modification

Unusual wear was noted in the No. 3 screw on the flight and the conveyor shaft in the area of the inlet chute. It was agreed, after review, that free falling shale, discharged from No. 2 screw, was the cause. By modifications to the chute just above the entry into the trough the shale was redirected so as to fall tangentially into the trough in the direction of the feed, thus greatly minimizing the impact effect of a straight fall. The shaft was also hardfaced at the entry to minimize erosion.

F. Flight Bearings

In the following table, are listed dates of replacement of bearings, hangers and coupling shafts on No. 3 screw conveyor, which is a five flight conveyor.

Turnaround Date	Bearings	Hangers	Coupling Shafts
4/3/67	*No. 1, 2, 3, 4	No. 1, 2, 3, 4	No. 1, 2, 3, 4
6/6/67	No. 1, 2, 3, 4	No. 3, 4	No. 1, 2, 3, 4

*These are numbered in the direction of travel of spent shale.

Replacement bearings has been the outstanding maintenance item on the No. 2 screw conveyor. There are indications that the incidence of replacement of bearings is roughly associated with the shale size, i.e. more replacements can be anticipated with 1 to 2 1/2 inch shale as against 1/4 to 1 inch shale. However, the need for a larger diameter screw for the larger shale is judged to be the operative factor.

Bearings are plain chilled iron, three inches inside diameter and in two halves, i.e. upper and lower, and are as recommended for this service. Grease type bearings, in which grease is admitted through a hole in the top half of the bearing, were also tested, with no significant gain in life.

No. 3 conveyor has been much more troublesome from the standpoint of replacement needs than No. 2 conveyor, although No. 2 conveyor handled hotter spent shale. Possible reasons for this may be in two areas, i.e. (1) water was originally injected into the No. 3 screw between No. 2 and No. 3 hangers creating a wet and dusty atmosphere and (2) the No. 3 conveyor is a five flight unit, less rigid than the No. 2 conveyor. Flights are shaft connected and retained in split bearings suspended in the trough by hangers attached to the top sides of the trough, and the result is a sort of "articulated" motion of the screw. It is surmised that this motion comes about due to the (1) number of flights in series, (2) spasmodic movement of shale, and (3) the fact that the inherent design of the trough is not "stiff enough" due to its length to resist this motion and maintain fairly accurate alignment of the screw. Consequently, this motion can cause unusual wear conditions at each hanger bearing, resulting in unusual demands on the bearings.

Referring to the table above, the chilled iron bearings installed on April 3 turnaround were removed during the July 6 turnaround and inspected. Wear was observed to be very slight and not measurable. Wide range shale was tested throughout most of this period.

The table above lists those replacements made only at principal shutdowns or where new flights were isntalled. In addition to those listed, it is estimated that probably seven to nine bearings were replaced on No. 3 screw at various times, most of these shortly after the program started, with the remainder scattered at various intervals since. Most of these replacements were necessary when hangers bent when testing 1 to 2 1/2 inch shale. Many bearings were made in the machine shop on an emergency basis. Wear decreased when a shipment of factory bearings of the proper material was available.

G. Hangers

Hangers have been the second most outstanding maintenance item on No. 3 screw. Most of the hanger failures occurred early in the program. A larger diameter conveyor would have lifted the hangers out of the shale and prevented most of the failures. Relieving the flights back three inches on each side of the hangers helped cut down the hanger failures considerably.

As noted in the table above however, problems still occurred on occasion with hangers. Hangers No. 3 and No. 4 of No. 3 conveyor were replaced on June 6 turnaround. Each of these was found to be broken at a point of high stress concentration due to a sharp 90° bend. Also, No. 2 hanger on No. 3 conveyor was replaced on the August 14 turnaround.

Very few hanger replacements have been required for the No. 2 Conveyor.

These hangers are Jeffry Std. No. 226 with 1/8 inch grease pipes connecting to top half of the bearing. Due to vibrations it has been found expedient to tackweld nuts and bolts in place after hanger installation. Several hanger failures occurred due to loosening of holding bolts.

H. Coupling Shafts

These are three inch diameter, and are hardened steel, as required for use with chilled iron bearings. On the June 6 turnaround new coupling shafts were installed on the No. 3 screw when installing five new hardfaced flights. These sections were very difficult to remove and reinstall. Designs are available which will permit disassembly without removal of adjacent screw flights. Measurements were made of the replaced shafts and following noted:

Hanger No. 1 and No. 2 shafts - approximately 1/32 inch radial wear

Hanger No. 3 and No. 4 shafts - approximately 1/16 inch radial wear

These figures represent total wear for a period of slightly more than two months. It does not represent steady wear over a continuous operating period, since there were approximately seven shutdowns over this period. This wear rate is high with respect to needed shaft life.

I. Drive and Tail Shafts and Bearings

At the time of installation of new flights on both No. 2 and No. 3 screw conveyors, detailed examination of both drive and tail shafts showed no evidence of wear, and were not replaced. These shafts are held securely with set screws to the steel collar of Dodge Type E Pillow Blocks with Tapered Pillow Bearings which absorb radial and thrust loads of the conveyor. The pillow block is externally mounted outboard of the trough seal and is grease lubricated. On examination, no wear was detected.

J. Trough End Seals

This consists of a packing gland body (mounted on the trough ends) containing the graphite and asbestos packing. The packing gland end plate, with tape-up bolts, acts as a follower and is inserted into the packed gland and body. The bolts tightened to suit. Occasionally, as the packing wears, the take-up bolts are adjusted so that the seal is maintained.

K. Casing (Trough) and Cover

The trough is angle type, that is, with a reinforcement angle running along the outside of each side of the top edge. This stiffens the trough and provides a mounting flange for the bolts to secure the cover, with bolts on about 12 inch centers. Trough shell original thickness was 1/4 inch in November 1966 which is heavier than handbook recommended of thickness (3/16 inch) for our service. Using a Sonoray instrument, shell thickness measurements were made at two locations to determine wear. The first location was directly underneath the centerline of the flights. On both No. 2 and No. 3 screws, several measurements were made along the trough and no wear was detected. The second location was on the "travel" side of the trough, i.e. that side where the material builds up along the trough due to action of the flights, and directly opposite the centerline of the flights. These measurements each represent an average of four or five similarly located points

Conveyor Casing Wear

	February 1967	March 1967
Conveyor No. 2 Shell	.240"	.223"
Conveyor No. 3 Shell	.210"	.225"

While it would appear these two latter measurements should logically be reversed, the difference between them is within the percentage of accuracy of the instrument used. At any rate, the indications are definite that some wear is taking place at this location.

Trough covers come in standard 12 foot lengths. However from the standpoint of inspection of hangers and bearings, and/or necessary replacemnts, complete removal of all covers are required for adequate inspections, etc. At Anvil Points, modifications to the covers were made, so that only two foot lengths of covers, centered at each hanger, needed to be removed.

It is necessary to use covered conveyors to prevent air from reaching hot spent shale. Ignition will occur. The inert blanketing gas, in this case, was the seal gas injected between the two lower star feeders.

Spent shale is also very dusty. Covered conveyors are necessary to confine this dust until it is at the disposal point. Retorts No. 1 and No. 2 used high speed enclosed belt conveyors to move shale from the retorts to the weigh bins. This system was very unsatisfactory as dust would blow or fall off the belt and fill the enclosure. Screw conveyors are ideal from this standpoint as the system is self cleaning.

When shutting down a retort under emergency conditions, it is often necessary to convey shale at temperatures up to 1,000 F. Belt type conveyors are unsuitable for this service. No problems were experienced with the screw type conveyor in handling shale at these temperatures.