THE RELINING OF SAICCOR'S EFFLUENT OUTFALL

BERNSTEIN, MARK
AHRENS, HUGH P.L. (MEMBER ASCE)
SMART, MICHAEL D.

ABSTRACT

This paper describes the method employed to refurbish an existing marine outfall which was deteriorating rapidly. It reviews the repair options that were available and how each was investigated and rejected until the best solution was obtained. Finally the execution of the project is described in detail through each stage to successful completion.

1.0 INTRODUCTION

The SAICCOR rayon pulp mill at Umkomaas on the east coast of South Africa was commissioned in 1954 with an initial capacity of 100 tons of pulp per day and is currently producing 1 200 tons of pulp per day.

During 1964 and 1965, investigations into the provision of a sea outfall were carried out and in 1967, a rubber lined steel pipeline of 914 mm internal diameter designed to discharge a little over 100 000 m^3 per day of effluent at 50°C into the Indian Ocean through a diffuser system located 2500 m offshore in 20 to 25 m of water was commissioned. The outfall consisted of a landline delivering effluent from a pumping station on the south bank of the river to a sealine which was located north of the Umkomaas River mouth.

The landline was made up of three separate sections as follows:

(a) Pumphouse to bridge

This was a 117 m long section of buried pipe terminating in a 9 m high vertical leg discharging into a bend on a bridge over the Umkomaas River.

(b) Bridge section

This consisted of 8 No 25 m long self supporting pipes spanning between the existing bridge piers.

Bernstein, M. Consultant to Campbell, Bernstein & Irving
Ahrens, H. Partner of Campbell, Bernstein & Irving, Overport, South Africa
Smart, M. Engineer with Campbell, Bernstein & Irving

(c) Bridge to the sea outfall

This consisted of a 200 m length of buried pipe from the end of the bridge to a 90° bend at the beach which is the start of the sealine.

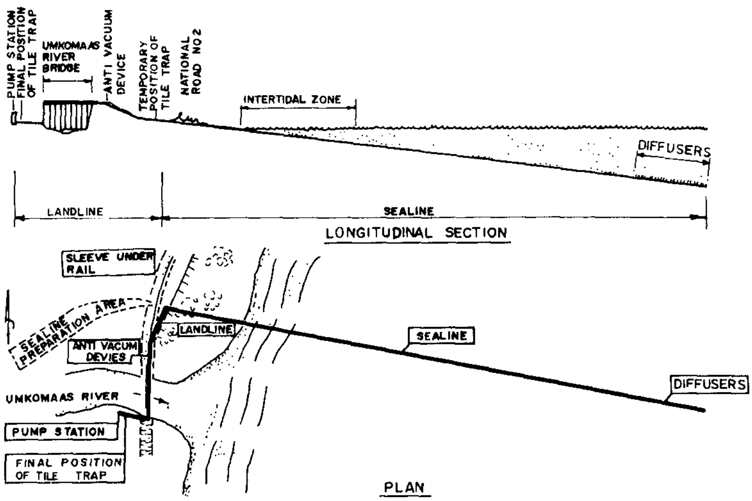


FIGURE 1

The 2000 m long sealine was made up of 97,5 m flanged lengths with a 100 mm thick concrete weightcoat. It terminated in a 300 m long diffuser section containing 48 No vertical outlets ranging in diameter between 100 mm and 137 mm.

An examination of the pipeline at the end of 1971 revealed some deterioration of the rubber at the invert and there were also signs of blistering up to 25 mm diameter under the pulp scale which had built up to a thickness of about 25 mm. It was considered that most of this deterioration was caused by the passage of heavy grit in the effluent and equipment to reduce this was installed.

Further inspections at regular intervals revealed a reduction in the rate of deterioration. Although the friction factor was building up at a rapid rate, it was decided not to attempt to remove the scale because this was undoubtedly offering protection to the lining.

An inspection in 1978 revealed that tiles from the pump station sump lining had broken away and entered the pipeline through the pumps. These 150 x 150 x 37 clay tiles accumulated at the bottom of the 9 m high riser to the bridge until they broke roughly in half and were carried up the riser and through the main pipeline.

Following reports of further deterioration and damage to the lining within the pipeline as a result of the movement of tiles, a series of shut-downs was arranged and inspections of the accessible sections of the pipe were made during early 1981.

Photographs were taken which revealed that the build-up of pulp was severe and, in certain areas, debris mainly in the form of broken tiles had built up and become cemented by the pulp. Attempts to clear away the debris mechanically proved largely ineffective because of the lack of suitable facilities to transport the debris over any distance in the time available.

Later in that year, leaks were detected on the land section of the pipe north of the bridge and these were sealed using external clamps. A further internal inspection using television equipment was made of that section of the pipe and the resulting picture was not encouraging. It was realised that the repair or replacement of the pipe was a matter of urgency and SAICCOR, working with its Consultants, pressed ahead with investigations into various alternatives.

2.0 ALTERNATIVE SOLUTION

Investigations revealed that the following were the only alternatives available:

(a) a new pipeline estimated to cost more than R10 million requiring 15-18 months for construction,

(b) relining of the existing pipeline with 800 mm OD plastic pipes estimated to cost R2,5 million but requiring only a few days to construct once pipes were available and site preparations completed.

The latter alternative which had obvious attractions also had attendant risks of blockage due to:

(i) pulp accumulated on pipe walls,
(ii) rubber lining which may have been loosened by debris passing through the pipeline,
(iii) accumulations of cemented debris which had been observed during inspections,
(iv) the configuration of the existing pipeline which was known to have been moved into a flat S-curve shortly after laying.

A study of each of these problems revealed that they were not insuperable and it was agreed that there were emergency measures which could be taken provided that a jam did not occur within the surf zone which was inaccessible to divers.

3.0 RELINING

3.1 PHILOSOPHY

A simple philosophy was evolved in which the existing pipeline would be regarded as a "hole in the ground or in the sea" which could be exploited for either the receipt of a new internal liner or as an anchor for a new pipeline if this had to be laid external to the existing pipeline in the event of a jam.

The following main factors emerged from the ensuing study:

(i) that the gap between an existing 914 mm internal diameter rubber-lined steel pipe and an 800 mm external diameter plastic pipe should be adequate to prevent jamming as a result of pulp accumulations,

(ii) that, if jamming did occur outside the surf zone, the causes could either be removed by divers who would cut holes under water in the existing pipeline or alternatively, a large hole would be cut to permit a connection to be made between the section of liner already completed and a new pipeline which would be clamped to the extension of the existing pipeline,

(iii) that an experiment would be carried out by lining the short landline section before embarking on the more formidable task of lining 2 000 m of underwater sealine.

It was obvious that the entire operation was primarily dependant upon the passage of the liner through the 500 m long surf zone which was inaccessible to divers and it was accordingly decided to carry out an inspection of this section and clear any debris before proceeding further with the project.

The hot dark coloured effluent in the surf zone section was displaced by cold seawater and divers traversed the entire surf zone in order to inspect the interior of the pipe. This was a formidable task requiring great physical endurance and courage but it was completed without incident and divers reported that there was no loose rubber or piles of debris in this section of the pipeline. It is also of interest to note that two heavy stainless steel props which had been used to secure plates internally over leaks had also disappeared having been carried away by the pumped effluent. As a result of the favourable report by divers, it was decided to proceed with the re-lining proposal.

3.2 MATERIALS

It was apparent that only semi-rigid pipes could be used particularly in the case of the sealine where the liner had to be introduced in one continuous length of 2100 m. Jointing was therefore of prime importance because, in addition to constructional requirements, the liner could only be anchored at the shore end which would result in the full frictional force of about 20 tonnes being transmitted by tension through the joints.

Many relining materials were investigated including the following:

(i) Stainless Steel

Stainless steel had proved reliable against chemical attack but was extremely costly and inflexible so that the use of this material would be restricted to use on the land only.

(ii) Glass Reinforced Plastic (GRP)

Although this material had been successfully used in relining operations, it was considered that the jointing procedure was too slow and could not be rigidly controlled to obtain uniformity and reliability. The local cost was also somewhat high and production capacity limited.

(iii) Polypropylene (PP)

This material which was manufactured locally would have been capable of withstanding the chemical attack and could meet the temperature requirements. The wall thickness proposed by the manufacturers was however considerable and some concern was expressed regarding the reliability of welding such thick walled pipes in the field.

(iv) High Density Polyethylene (HDPE)

These pipes could also be manufactured locally but were unsuitable for the high temperature of the effluent.

(v) Ultra high molecular weight high density polyethylene (UHMWHDPE)

This material was only available from the United States of America. At that time there was only one manufacturer with the expertise, equipment and experience of re-lining existing pipes of the size under consideration. Although more expensive than

local products, the reduced wall thickness permitted greater flexibility and the use of a proven welding technique. The supplier also offered the services of an experienced technician to carry out the fusion welding of the pipes and to supervise the handling of the pipe on site.

3.3 DIAMETER AND CAPACITY

Ultra high molecular weight high density polyethylene was therefore selected for the material of the liner and 800 mm was chosen as the outside diameter. This allowed a 57 mm annular space which would provide adequate flexibility during relining and would ensure a somewhat better capacity than the existing pipeline in its "aged" condition.

The coefficient of friction for new rubber lined steel pipes would be about 0,013 in the Manning formula but, as a result of pulp adhering to the internal surface, the existing pipeline had a measured co-efficient of 0,023.

It was considered however that a co-efficient of 0,020 could be achieved by light pigging and this figure was used for comparative calculations of capacity.

The Manning co-efficient for new plastic pipes was given as 0,007 and it was assumed that, if pulp built up on the plastic surface, it could be easily dislodged with regular pigging. It was nevertheless decided to use a conservative 0,010 for comparative calculations.

Table 1 shows comparative friction heads per 1 000 m of the existing pipeline and of a new 800 OD plastic liner for flows of 3 000, 3 500 and 4 000 m^3/h.

TABLE 1 : FRICTION HEADS PER 1000 m

TYPE OF PIPELINE	NETT INTERNAL DIAMETER	FRICTION HEAD in m per 1000 m at		
		3000 m^3/h	3500 m^3/h	4000 m^3/h
Rubber-lined steel	914 mm	4,60	6,27	8,19
Plastic Pipe 800 OD	738,8 mm	3,59	4,89	6,39

Allowing for a possible 500 m extension of the pipeline for a new diffuser at a later date, total heads for various flows would be as shown in Table 2.

TABLE 2 : TOTAL FRICTION HEADS

TYPE OF PIPELINE	TOTAL FRICTION HEAD in m at FLOWS of		
	3000 m^3/h	3500 m^3/h	4000 m^3/h
Rubber-lined steel	13,43	18,28	23,88
800 OD Plastic Pipe	10,64	14,49	18,93

It will be seen from TABLE 1 that the smaller plastic pipe has a lesser unit frictional head than the larger rubber-lined steel pipe whilst TABLE 2 shows that, even with an additional length of diffuser, the total head in the new smaller diameter plastic pipe would be less than that in the existing larger pipe because of the reduced friction.

It was concluded therefore that the lined pipeline would have a better capacity than the original pipeline.

PRESSURE DIAGRAM

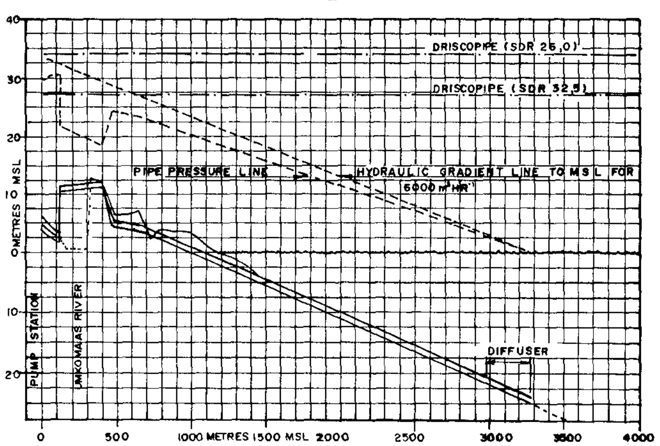


FIGURE 2

3.4 TIME FACTOR

It was important to minimise the times of stoppages because of the considerable loss of production involved and the difficulty of stopping and restarting operations at the pulpmill.

The construction work was therefore designed and planned to have stoppages of only 21 hours for the landline and 34 hours for the sealine.

4.0 CONSTRUCTION

4.1 PREPARATION FOR PROJECT

The preparatory work required in order to achieve the least possible stoppage of factory operation was a most important part of the project and required several months of intensive effort and the massing of considerable resources. Everything that could be done without causing interference with the flow of effluent was completed well in advance of the relining operations. Main items requiring special attention were as follows:-

4.1.1 The sea end of the pipeline was opened and the diffuser ports were blanked off. Pumping at maximum flow rates was then used periodically to flush debris from the pipeline. Divers made frequent inspections at the outlet and reported considerable discharges of debris and pulp.

4.1.2 Wherever relaying was possible as an alternative to relining, this work was completed well in advance of the relining operation.

4.1.3 Specials were manufactured and anchor blocks and foundations were constructed in advance.

4.1.4 Scaffolding was erected at the south end of the bridge where the lining operations would take place at a height of some 9 m above the roadway.

4.1.5 Where connections were to take place below ground level sheet piling was driven to ensure safe access.

4.1.6 A large site was prepared for the receipt and storage of the 12 m long pipes and a welding machine was set up on that site to enable the pipes to be welded into 500 m lengths in readiness for the relining operation. Arrangements were made for the welded joint between the 500 m long sections to be carried out speedily during the relining operation.

4.1.7 As this site was on the side of a main railway line away from the sea, a 2 m diameter concrete culvert was jacked under the railway in order that the stored lining could be fed into the existing sealine.

4.1.8 A system of winches mounted on tracks was set up so that the new liner could be pulled through the concrete sleeve and pushed into the pipeline.

4.1.9 Divers and fully equipped vessels were commissioned to standby during the operation in order to open the pipeline and clear any jam should this occur or alternatively, to lay the new pipes alongside the existing pipeline in the event of it not being possible to insert the entire liner. A pinger was purchased for installation in the end of the pipe to assist with location of the pipe end in the event of a jam.

4.1.10 Food kitchens, emergency power equipment, and a mass of special tools and equipment was assembled in case of need.

4.1.11 Rigid timetables and lists of duties were established in order to implement a number of alternative plans in case problems should arise.

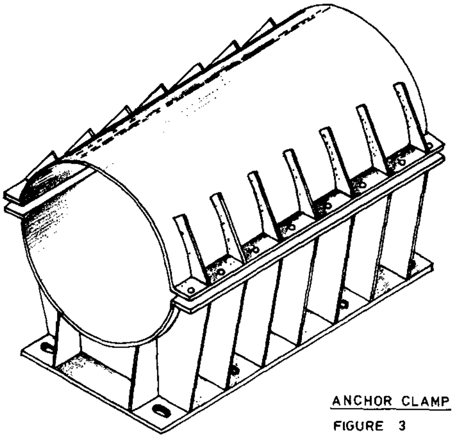
4.1.12 Special equipment and protection was set up to cope with inclement weather.

In effect, the whole exercise was planned as an emergency operation with plans to meet any contingency and it was significant that no contingency arose during the operations for which there was not a plan prepared well in advance.

4.2 PRELIMINARY WORKS

4.2.1 The section from the bridge to the sea outfall was constructed first and this involved the laying of a plastic pipe in a new position adjacent to the existing pipe. The north end of this new pipe was connected to a tile trap combined with a pig port adjacent to the 90° bend at the start of the sealine. This tile trap remained in this temporary position to trap any further debris which might find its way into the line after commissioning of this section of pipes so as to avoid further accumulations of broken tiles in the sealine.

Each end of this new pipeline was restricted by means of heavy anchor clamps. Details of the anchor clamps are shown in Figure 3 and a feature of these clamps was the arrangement provided to allow for adjustment of lengths and location should this be necessary. The holding down plate was drilled with oversize holes and large rectangular washers were fitted. These large washers allowed reasonable movement within the bolt holes and, after final tightening of the bolts, the washers were welded in position.



ANCHOR CLAMP

FIGURE 3

The whole of this section, except for the two ends, was backfilled before the first mill shut so as to hold the pipe in place and to provide a platform on which the liner pipe could be laid out in readiness for winching into the bridge section.

At the south end of this section, provision was made for the connection to the bridge section after relining by sheetpiling a portion of the existing line which had to be removed later to provide a gap for the insertion of the liner. All necessary preparatory work for connecting the liner to the newly laid pipeline was thus prepared in advance.

4.2.2 The section of the landline from the pumphouse to the bridge was constructed between the two mill shuts. Due to the complexity of the route, part of the pipeline was replaced using a plastic pipe buried adjacent to the existing pipe with stainless steel fabricated fittings being used to tie in at the pumphouse and bridge ends. The final connections were made during the second mill shut.

4.2.3 During the landline operations, the liner for the sealine was being made up into approximately 500 m lengths ready for introduction into the sealine.

As the liner was to be pushed into the sealine by using a system of clamps and winches, preparations were made to receive a hydraulic clamp mounted on rails and two sets of winches for moving the clamp backwards and forwards.

4.3 MILL SHUT NO. 1

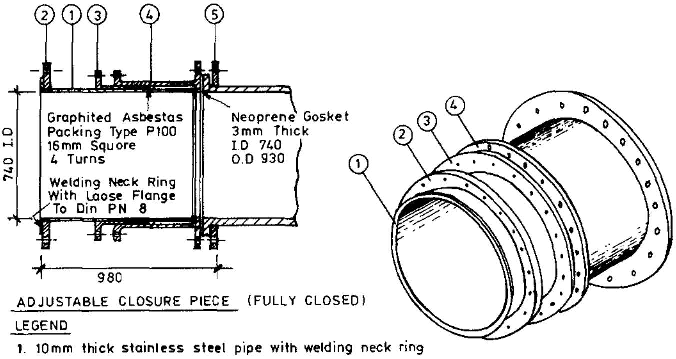
4.3.1 The bridge section was relined during the first mill shut by pulling the liner into the existing pipes which were retained as structural beams. The liner was pulled from the south end of the bridge using a system of winches which would pull against the southern most flange of the pipeline and not introduce any load on to the bridge structure itself. The liner was introduced at the north end once an existing air valve, bend and length of pipe had been removed.

A sample length of plastic pipe was pulled through as a sizing piece to confirm that the liner could negotiate a 4° bend which was known to exist in that section of the pipeline. Once this test had been cleared, the new liner was pulled into position. The actual pulling operation was completed in about 1,5 hours.

The front end of the line being pulled was notched to form a conical nose while the tail end was fitted with a stub-end and loose flange. This flange was pulled hard up against the flange of the existing steel pipe. A new flanged stainless steel air valve tee was bolted to this and was then anchored to a concrete base so that the north end of the liner was effectively locked into position.

The gap between the air valve tee and the previously laid plastic pipeline was closed with a section that comprised a length of plastic pipe, a specially designed stainless steel anti-vacuum fitting and an adjustable stainless steel closure piece to ensure an accurate fit.

This closure piece is shown in Figure 4 and comprised a temporary stuffing box which was welded up after commissioning. The anti-vacuum device consisted of a NORVAL type reflux valve with a stainless steel screen and diaphragm designed to allow air to enter the pipeline and prevent the creation of an air vacuum which could cause collapse of the plastic pipes.



ADJUSTABLE CLOSURE PIECE (FULLY CLOSED)

LEGEND

1. 10mm thick stainless steel pipe with welding neck ring
2. Loose carbon steel flange
3. Stainless steel packing compressor
4. Stainless steel outer sleeve
5. Loose carbon steel flange

FIGURE 4.

To achieve a seal at the south end of the bridge, the notched end of the pipe was cut off square and a specially designed sleeve was inserted and bolted between the steel pipe flanges. Once the pipe was commissioned, the plastic liner would expand and seal itself against a neoprene ring around the sleeve.

4.3.2. The divers' inspection of the 500 m surf zone section was carried out during the relining of the bridge section. Water which had been stored in a dam on the beach was pumped into the sealine via a manhole on the beach. Once the pipeline had cooled sufficiently, three divers entered the pipe and began the inspection. Only one diver traversed the full 500 metres, the other two divers stopping off en route to assist in handling the air lines, communication cable and safety lines necessary for the lead diver. This magnificent team effort was completed in about 6 hours, and the information obtained from the survey enabled the decision to proceed with the second mill shut to be made with confidence.

4.4 MILL SHUT NO. 2

4.4.1 When the time for the second mill shut arrived, it was necessary to carry out two preliminary operations before the relining could commence. First the tile trap was disconnected and physically removed from its temporary foundations. This exposed the open end of the pipe entering the sleeve under the national road.

Rails for the winch assembly designed to pull the liner pipe into the sea outfall were bolted to the concrete foundation of the tile trap so that the task of winching the pipe from the assembly yard, through the railway culvert and into the sealine, could commence. This winch assembly consisted firstly of a hydraulic clamping device which was mounted on rails and which gripped the pipe with sufficient force to transmit the winch pulling force to the pipe. The hydraulic clamp had a travel of 12 m and was pulled by two winches capable of exerting a total pull of 40 tonnes. On completion of its 12 m travel, a return winch, mounted over the culvert under the railway pulled the hydraulic clamp, which was now in the open position, back to its starting position. The clamp would then be closed and the main winches would repeat the cycle and pull the hydraulic clamp back over the 12 m track.

Next an existing bend and portion of an adjoining length of steel pipe were uplifted on the beach side of the road as the bend was too sharp for the passage of the semi-flexible liner. In order that the total anchoring force required to restrain the completed liner would not be restricted to a single flange at the beginning of the section, an additional anchor block was constructed in advance on the beach side of the main road. This was provided with a clamp to which the liner could be bolted when completed.

The first 500 m of liner moved into the pipe with ease and a speed approaching 10 m per minute was initally achieved. This rate gradually decreased and, towards the end of the operation, the speed had reduced to about 1,5 m per minute whilst the force induced by the winches had gradually increased to a maximum of 16,3 tonnes.

Including brief stoppages to weld the 500 m lengths together, the lining operation continued for 21 hours until the end flange of the liner was set against the flanged end of the existing sealine as the first anchor. The liner was then clamped to the anchor block previously provided on the beach to act as a second anchorage. The sea end of the liner was left loose to accommodate the 18 m of expansion anticipated when hot effluent was re-introduced into the pipeline.

4.4.2 Whilst the sealine was being relined, the tile trap was moved to its new and final position adjacent to the pump station and the new pipeline laid between pumphouse and the south end of the bridge was connected into the system.

The gap between the relined sea outfall and the new pipe previously laid up to the tile trap during the first mill shut was closed with a stainless steel bend anchored to the tile trap foundation and connections made by using the same adjustable closure piece described previously.

5.0 CONCLUSION

The operation was carried out with relative ease largely because of the advance planning of the exercise. Although not all precautions taken in anticipation of problems were required, they were necessary in order to minimise the heavy risks involved in a major operation of this type.

The system has been in successful operation for over 12 months and the pumps are handling the total effluent quantity effectively at a reduced pumping head.

It is believed that this is the longest large diameter pipe relining ever attempted and it was completed in a total shutdown time of less than 60 hours at a cost of about 25% of a replacement pipeline. Its success heralds opportunities for the renewal of many ageing pipelines which would otherwise require costly and disruptive replacement.

6.0 ACKNOWLEDGEMENTS

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