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Nevada Nuclear Waste Storage Investigations Project

Installation of Steel Liner in Blind Hole Study

Kenny Construction Company
250 Northgate Parkway
Wheeling, IL 60090

Prepared by Sandia National Laboratories Albuquerque, New Mexico 87185 and Livermore, California 94550 for the United States Department of Energy under Contract DE-AC04-76DP00789

Printed September 1987

"Prepared by Nevada Nuclear Waste Storage Investigations (NNWSI) Project participants as part of the Civilian Radioactive Waste Management Program (CRWM). The NNWSI Project is managed by the Waste Management Project Office (WMPO) of the U. S. Department of Energy, Nevada Operations Office (DOE/NV). NNWSI Project work is sponsored by the Office of Geologic Repositories (OGR) of the DOE Office of Civilian Radioactive Waste Management (OCRWM)."

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A03
Microfiche copy: A01

SAND85-7111
Printed September 1987

Distribution
Category UC-70

INSTALLATION OF STEEL LINER IN BLIND HOLE STUDY

by

KENNY CONSTRUCTION COMPANY
250 Northgate Parkway
Wheeling, Illinois 60090

for

SANDIA NATIONAL LABORATORIES
P.O. Box 5800
Albuquerque, New Mexico 87185

UNDER SANDIA CONTRACT: 21-2633

Sandia Contract Monitor
Kenneth D. Young
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Projects Division

ABSTRACT

Lining of horizontally bored, waste-emplacement holes has been studied for possible use in underground nuclear waste repositories. The principal objective of this study was to develop and evaluate a technically feasible concept for installing a steel liner in a 37-in.-diameter borehole up to 700 ft in length. This report reviews the history of jacking such lines in place, surveys existing equipment, reviews the cost estimate for this procedure, examines welding technology for the application, and concludes with a critical review of the construction risk.

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1.0 INTRODUCTION

1.1 Background

The work described in this report was performed for Sandia National Laboratories (SNL) as part of the Nevada Nuclear Waste Storage Investigations (NNWSI) project. SNL is one of the principal organizations participating in the project, which is managed by the Waste Management Project Office in the Department of Energy's Nevada Operations Office. The project is part of the Department of Energy's program to develop a method to safely dispose of radioactive waste.

This report describes a system for installing a steel liner in a previously drilled, 37-in.-diameter, horizontal borehole up to 700 ft long. The report was prepared by Kenny Construction Company for Sandia National Laboratories under Contract No. 21-2633. The system is one of those considered early in the development of the conceptual design for the emplacement of nuclear waste in long, horizontal boreholes. The system is not the simultaneous drill and line concept used in the SCP-CDR design for the NNWSi project; the simultaneous drill and line concept is an outgrowth of the evaluations presented in this report.

1.2 Objectives and Approach

The principal objective of this study is to develop (and evaluate) a technically feasible concept for installing a steel liner in a 37-in.-diameter borehole up to 700 ft in length. The evaluation includes consideration of the costs and the availability of technology for use in the liner system. The approach taken in this report on a steel liner emplacement system consists of:

- developing a history of comparable projects constructed in the sizes that approximate the repository project;
- conducting a market survey of existing pipe jacking equipment and their capabilities;
- estimating liner installation time and cost estimates;
- estimating installation, manpower, and utility requirements including set-up, placing liner, transfer to next station, etc.;
- evaluating and demonstrating a conceptual liner welding system with welding time and cost estimates; and
- identifying new equipment development and procedures that should be addressed, recommended tests, or areas of concern.

The general approach used in determining the costs, choice of equipment, and manpower was based on existing construction technology and comparable liner installation projects.

2.0 **STEEL LINER INSTALLATION FEASIBILITY**

2.1 Objectives

The principal objective of this study is to provide a conceptual report detailing a system to install a steel liner in a 37-in.-diameter blind hole up to 700 ft in length. This system shall meet the following constraints and criteria:

- The installation unit must be compact, it must be capable of operating in a 20-ft-wide by 10-ft-high haulageway.
- The unit must comply with all mining codes and standards.
- The unit shall be readily transportable from one hole to another with minimum setup and demobilization time.
- The liner emplacement hole direction can be from 80° to 100° from the axis of the drift and from -10° to 10° elevation.
- The emplacement hole deviation will have no more than 6 in. in 100 ft with no more than 12 in. accumulated offset.
- The unit shall be capable of being lowered down an 18-ft-diameter shaft, either intact or disassembled into major components.
- The emplacement hole will be considered stable with the possibility of minimal rockfall within the hole.
- Liner shall be welded to provide a watertight joint.
- The blind end of the liner will be closed with a water-tight bulkhead.
- The liner will be assumed to be 0.5-in.-thick carbon steel (1020), containing no internal or external protrusions.

Additionally, the environment and rock properties are

Underground Environment

Ambient Rock Temperature	35°C
Air Temperature	20° to 35°C
Relative Humidity	Up to 100%

Rock Properties

- densely welded devitrified tuff;
- fracture spacing approximately 7 per ft in dense material;
- density 2.2 grams per cubic centimeter;
- unconfined compression strength 16,000 to 33,000 psi;
- uniaxial strain to failure approximately 0.41% to 0.97%; and
- rock may be saturated.

2.2 History of Comparable Projects

Pipe jacking has been an accepted construction technique since the late 1800s. The first concrete pipe jacked in place was accomplished by the Northern Pacific Railroad between 1896 and the 1900s.[1] The railroads were the first to jack pipe under railroad embankments, and in 1926 the first jacked installation using reinforced concrete pipe was completed.[2] In 1940, the Delaware, Lackawanna and Western Railroad jacked a 96-in.-diameter reinforced concrete pipe for 69 ft under an embankment to serve as a pedestrian underpass in Elmira, New York.[3] In recent years, pipe jacking has been employed in the installation of sanitary and storm drainage sewers in urban or environmentally sensitive areas. Reinforced concrete pipe is generally used for storm and sanitary sewers; steel casings are used as primary tunnel linings, which support earth loads before the installation of water mains, electric conduits, gas mains, and small-diameter sewers. The jacking of reinforced concrete pipe is addressed because of the comparable lengths and weights planned for the nuclear waste repository.

Reinforced concrete pipe jacking was recently employed on a project for the North Shore Sanitary District in Lake County, Illinois. The site was in a heavily congested

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[1] American Concrete Pipe Association, Concrete Pipe Association, "Jacking Concrete Pipe," 1980, pp 5-42.

[2] Ibid., "Development of Technology," pp 1-12.

[3] Ibid., "Expanding Industry," illustration 1.6, pp 1-12.

area and pipe jacking was used to minimize traffic and utility interference. The length of the project was approximately 14,000 lineal ft and the inside pipe diameter was 60 in. Two records were set on this Kenny Construction Company managed project: (1) a jacking run of 1,841 ft was completed from one shaft, and (2) a production rate of 164 ft in 9 1/2 hours was accomplished. The basic construction components consisted of rectangular shafts, in which the hydraulic pipe jacking frame and pipe launching pad was placed, reinforced concrete pipe (RCP), which serves as primary and final ground support, and a fully shielded, wheel-type tunnel boring machine.

A typical soft ground concrete pipe jacking cycle begins with the jacks at the access shaft fully extended. The tunnel boring machine then excavates 4 ft by thrusting off the concrete pipe within the tunnel. The jacks at the shaft are retracted and the next section of RCP is then installed. The shaft jacks push the pipe into the tunnel 4-ft or one-half the total length of the pipe. As this occurs, the propulsion jacks on the TBM are retracted and the TBM is set for the next excavation cycle. After excavation of the next 4 ft, the remaining length of pipe is pushed into the tunnel to complete the cycle.

The fully shielded tunnel boring machine is equipped with a conveyor system which loads the excavated material into rail-mounted muck cars. The muck train consists of muck cars propelled by a battery-operated locomotive. The muck trains are designed with capacities equivalent to one excavation cycle. Normally, four to five muck cars are provided per train. Two sets of muck cars are used so that one train can be dumped while the second, empty train is taken back into the heading. The typical muck haulage cycle begins with a full train being pushed by the locomotive from the tunnel heading. The cars are deposited in the tail tunnel, leaving the access shaft open. Empty cars are then spotted on the rail within the jacking frame, and once all cars are in position, the locomotive pulls them back into the tunnel heading in preparation for the next excavation cycle. The full cars are pushed back into the access shaft and hoisted to the surface until the next set of full cars is spotted in the tail tunnel, completing the cycle.

On the Lake-Cook Road tunnel project, the pipe jacking frame consisted of four 200-ton jacks. Each jack had an 8-in. bore and a stroke of 114 in. Figure 1 shows the jacking frame system set-up within the rectangular access shaft. Average jacking runs were approximately 1,000 ft, which yield an average dead load of reinforced concrete

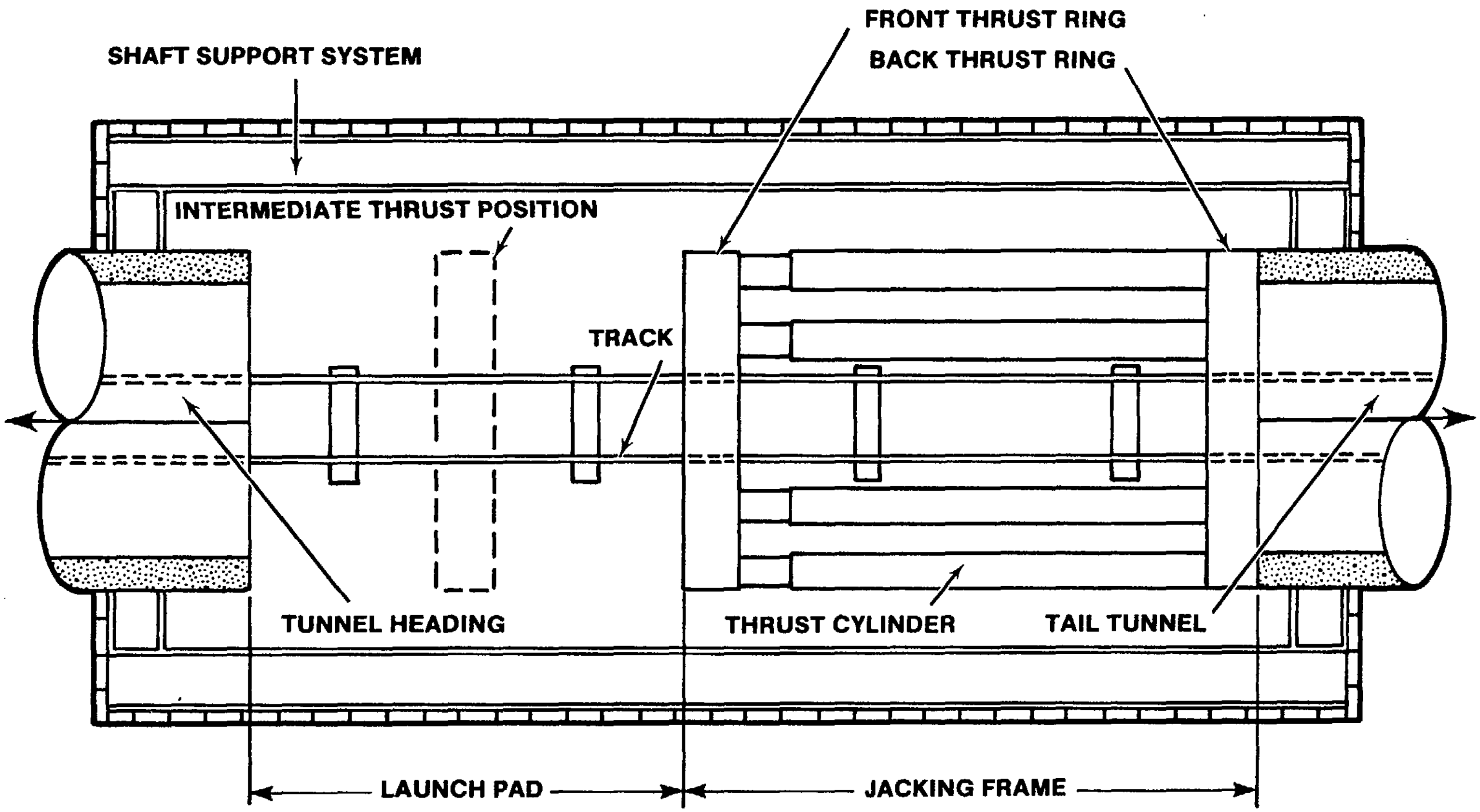


Figure 1. Jacking Pipe From a Rectangular Shaft

pipe equal to 765 tons. To reduce friction loads and thus axial loads on the RCP, the excavated diameter was slightly larger than the outside diameter of the pipe. This annular space was filled with a bentonite slurry which acts as a lubricant and also supports the earth around the pipe. The bentonite slurry was mixed in a pumphouse at the surface and pumped to a manifold system carried within the pipe. The slurry was pumped into the annular space through nipples cast into the RCP by the pipe manufacturer.

Reinforced concrete pipe jacking, in association with tunnel boring machine excavation, has been successfully employed for diameters ranging from 42 in. through 120 in. For pipe sizes smaller than 42 in., hand excavation or continuous flight augers have been successful.

Pipe jacking has also been employed with steel casings used as the primary ground support. The most common excavation system used consists of a cutterhead attached to a continuous flight auger. The cutterhead normally extends 4 in. beyond the lead edge of the steel casing, and continuous augers installed within the casing move the spoil from the cutterhead to the shaft. The most commonly used length of steel casing is 20 ft. The majority of horizontal boring machines produced today consist of a base section which includes the jacking system, track system, casing push ring, and the power package, which includes an engine transmission and coupling device to accept the auger's hex drive shaft (Figure 2). Depending upon the size and length of casing being installed, the jacking system may consist of one hydraulic cylinder or as many as four hydraulic cylinders. The stroke on these cylinders is typically between 4 ft and 5 ft. To jack a 20-ft length of steel casing, the jacking system is moved forward along the track assembly after completion of each full stroke of the cylinders. The jacking component has grips or "dogs," which clamp the system to the track assembly to resist the thrust. After the 20 ft of casing is jacked its entire length, the jacking assembly is moved back along the track to its initial position and another cycle is begun. Typical diameter of steel casings installed in this manner range from 8 in. to 60 in.

2.3 Market Survey of Existing Equipment

2.3.1 Equipment Manufacturers Contacted

Lampland Equipment, Inc.
Brownsdale, Minnesota
Milwaukee Boiler Manufacturing Co.
Milwaukee, Wisconsin

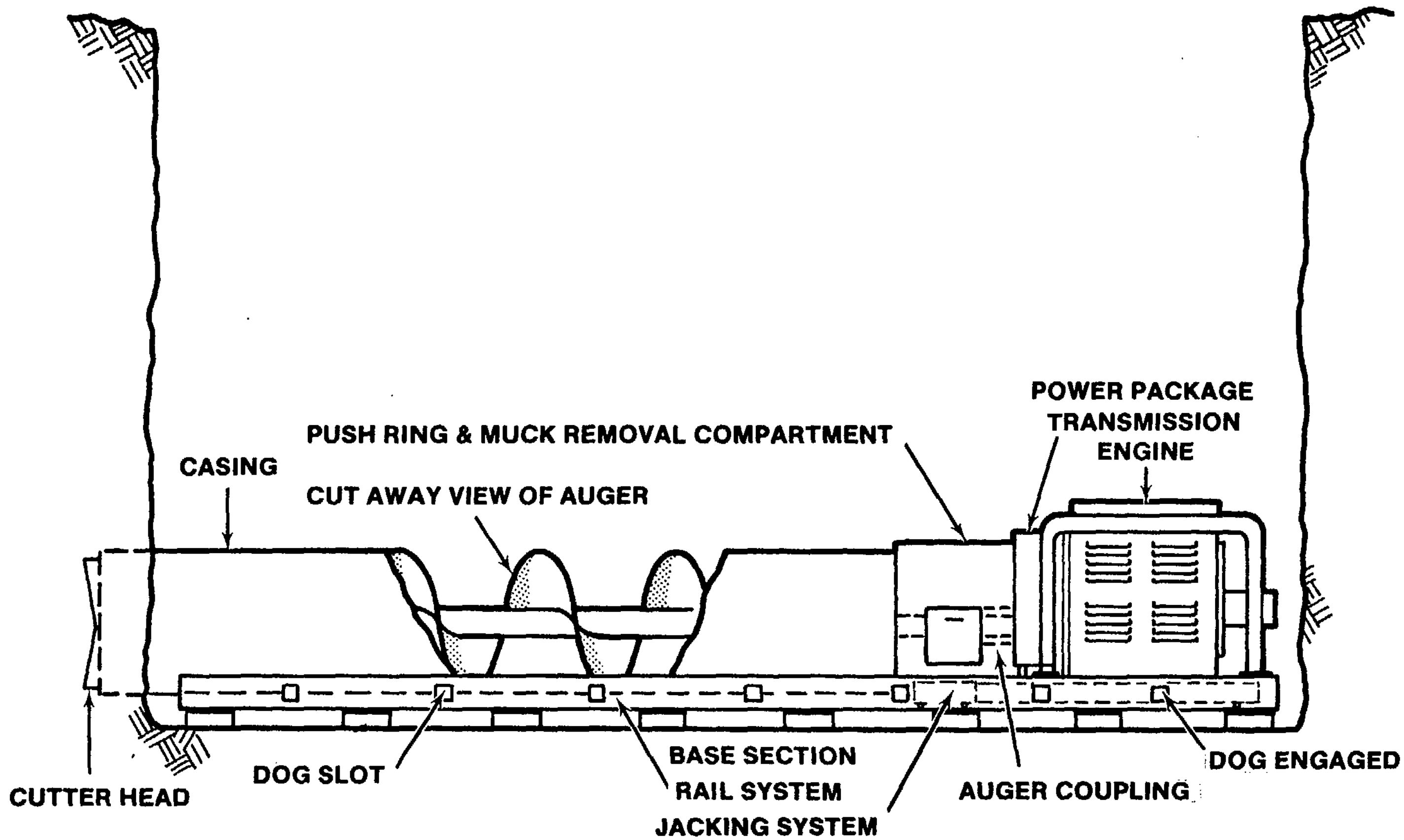


Figure 2. Jacking Steel Casing With Auger Excavation

Carl W. Decker, Inc.
    Detroit, Michigan
American Augers, Inc.
    Detroit, Michigan
Calweld, Inc.
    Sante Fe Springs, California
Richmond Manufacturing Co.
    Ashland, Ohio

Each of these manufacturers is based in the United States and has participated in the fabrication of equipment of similar type to that needed in the liner emplacement for this project. Numerous foreign companies are currently marketing similar equipment; however, firms resident in the United States were given a favored opportunity to provide a quotation. Of the firms contacted, three responded with literature and price quotations.

Lampland Equipment
  Total Price (excluding carrier)....$76,370.00

American Augers
  Total Price (excluding carrier)...$125,000.00

Richmond Manufacturing
  Total Price (Diesel Power System
  excluding carrier)....$63,400.00

The equipment furnished by Lampland Equipment and American Augers are custom designed for this particular project using existing components as much as possible. The price of equipment from Richmond Manufacturing consists entirely of standard equipment with no modification for the atmosphere or environment in which it will be used.

2.3.2 Equipment Capabilities

Each of the equipment packages proposed by the manufacturers is capable of jacking 700 ft of 36-in.-diameter, 1/2-in.-thick casing. The amount of thrust provided ranges from 200 tons to 250 tons. Each of the units is capable of being lowered down an 18-ft-diameter shaft with minimal reassembly.

The jacking equipment quoted by both American Augers and Lampland Equipment is powered electrically, minimizing the amount of ventilation which is necessary in a mine environment. Section 2.7 further outlines equipment capabilities and actual choice of equipment.

2.4 Liner Installation Time and Cost Estimates

2.4.1 Typical Installation Sequence

Principal steps to install the steel liner in the prebored horizontal blind hole are

- o Move-in equipment, which consists of pipe jacking frame and carrier, steel casing transporters, mobile crane, and electric transformer.
- o Set up pipe jacking frame on proper line and grade at prebored hole. Adjust and block thrust end of frame against opposite wall.
- o Place initial length of steel casing on launch pad and install light and camera. Jack into hole.
- o Place subsequent steel casings and weld joints. Continue until desired length of casing is emplaced.
- o Place and weld bulkhead at end of casing. Remove light and camera.
- o Retract all jack frame cylinders to transport position and move to next site.

2.4.2 Liner Installation Schedule

Table 1 shows the schedule necessary to emplace the steel liner in a prebored hole 700 ft long. Based on the figure, the schedule is

o	Moving, set-up, and machinery maintenance	16.0 hrs
o	Complete set-up and final alignment of jacking frame	4.0 hrs
o	Place initial steel casing, install light and camera within casing, jack into hole	4.0 hrs
o	Place subsequent steel casings, weld joint, and jack into place (684 LF, 43 Sections) jacking/16 ft section =	0.183 hrs
	welding/joint =	0.670 hrs

- Total/Section = 0.85 hrs x 43 sections = 36.55 - Use: 40.0 hrs
- Place & Weld Bulkheads at blind end of casing if required = 8.0 hrs
- Total/700-ft hole = 72.0 hrs

Table 1

LINER INSTALLATION SCHEDULE

Description	Day 1	Day 2	Day 3
Move equipment and set up, review bored hole alignment survey	8		
Equipment maintenance	8		
Complete set-up and final alignment of jacking frame	4		
Place initial casing (16 ft), install lights and camera, jack into place	4		
Place subsequent steel casings (43 sections), weld joint, and			
Jack into place		8	
Jack into place		8	
Jack into place		8	
Jack into place			8
Jack into place			8
Place and weld bulkhead at blind end of casing			8

2.4.3 Basis for Liner Installation Cost Estimate

As a basis for the cost estimate for a demonstration of this technology, the Nuclear Test Site, Nevada, was chosen as the generic site. All labor rates, material prices, and equipment freight rates coincide with existing agreements and rates currently established for this area. It has been assumed that a minimum of six holes, approximately 700 ft long, will have casings installed. This will minimize the effects of a typical "learning curve."

Services and equipment necessary, but not included are

- o electrical, water, compressed air, and ventilation from surface to liner installation sites;
- o unloading of equipment and materials at site;
- o lowering and assembly of equipment at bottom of shaft; and
- o shaft service for men and materials during installation of liners.

2.4.4 Liner Installation Cost Estimate

The cost estimate is broken into five sections, which include labor cost, materials cost, equipment operations expense, supervision and overhead costs, and equipment purchase costs.

(1) Total Labor Cost

The typical crew for the complete installation process consists of

Heavy-Duty Repairman/Welder		2 people
Jack Frame Operator		1 person
Mine Vehicle/Boom Operator		1 person
Laborer		1 person
	TOTAL	5 people

Nine shifts are needed to install 700 ft of steel casing in prebored hole, Table 1. Number of Manhours: 9 shifts x 8 hours/shift x 5 people = 360 manhours.

Crew Costs

		Wage	Vac.	Total	Fr. Benefits
Welders	2 ea	17.01	0.60	2x17.61= 35.22	2x6.05= 12.10
Jack Frame	1 ea	16.91	0.60	17.51	6.05
Boom Oper	1 ea	16.91	0.60	17.51	6.05
Miner	1 ea	13.89	2.15	16.04	4.26
	Crew Total			**86.28**	**22.41**
Electrician	1 ea	19.49		19.49	6.29

Cost/Shift (Normal Crew)

	Labor	Fr. Ben.	Prem. O.T.*
8 hrsx86.28 =	690.24	9hrsx22.41= 201.69	1hrx1.5x86.28 =129.42

Pure Labor =	690.24
Prem. O.T. =	129.42
Fr. Ben. =	201.69
Payroll Taxes=9.65% x (690.24 + 129.42) =	79.10
WC/GL & Umb. =9 hrs x 86.28 x 34.37%	266.89
Total	**1367.64**

5 people/shift=
273.47/person/shift

Cost/Shift (Electrician)

	Labor	Fr. Ben.	Prem. O.T.*
8 hrs x 19.49 =	155.92	9hrsx6.29 56.61	1hrx1.5x19.49 =29.24

Pure Labor =	155.92
Prem. O.T. =	29.24
Fr. Ben. =	56.61
Payroll Taxes = 9.65% x (155.92 + 29.24) =	17.87
WC/GL & Umb= 9 hrs x 19.49 x 34.47% =	60.29
Total	**319.93**/person/shift

Labor cost/700-ft liner = 9 shifts x $1367.64/shift = $12,308.76

Additional Electrician during setup and maintenance shifts: 2 shifts x $319.93/shift = $639.86

TOTAL LABOR COST/700-FT LINER = $12,948.62

TOTAL LABOR COST/6 EACH - 700-FT LINERS = $77,691.72

***NOTE:** Premium overtime included at 1 hr shift to compensate for travel to and from miner installation area.

(2) Total Materials Cost

Steel Casing (36-in. outside diameter, 1/2-in. wall thickness, carbon steel (1020), prebeveled ends, F.O.B. jobsite)

700 ft x $61.61/LF =	$43,127.00

Blind End Bulkhead Plate (1/2-in. thick, 1020 carbon steel)

1 ea. x $36.03/ea =	$ 36.03

Welding Wire (Dual Shield II-70, .045 diameter)

700 LF/16 ft per joint = 44 joints 44 welded joints x $9.89/joint + 10% waste =	$ 478.68

Weld Shield Gas (75/25; Argon/ Carbon-dioxide

44 welded joints x $3.00/joint + 20% Waste =	$ 158.40
Total Materials Cost/700-ft liner =	**$43,800.11**
Total Material Cost/6 each - 700-ft liners =	**$262,800.66**

(3) Total Equipment Operations Expense

Jacking Frame and Carrier

Parts and Hydraulic Oil 30% of Shift Time - 30% x 6 shifts x 8 hrs/shift x $7.24/hr =	$ 104.26

3-Ton Low Profile Diesel Powered Truck with Scrubber and PTO Hydraulic Boom

9 shifts x 8 hrs/shift x $5.35/hr =	$ 385.20

Liner Transport Wagons (2 ea)

6 shifts x 8 hrs/shift x 50% x 2 ea x $1.15/hr =	$ 55.20

Welders & Wire Feeds (2 Sets)

7 shifts x 8 hrs/shift x 80% x 2 sets x $1.07/hr =	$ 95.87
Total Equipment Operations Expense per 700-ft liner =	**$ 640.53**
Total Equipment Operations Expense/6 Each - 700-ft liners =	**$3,843.18**

NOTE: This amount does not include any expense for electrical, ventilation, or other utilities supplied by the mine site.

(4) Supervision and Overhead

Based on six installations - four-week duration

Supervision (incl. insurance, tax, and benefits)

Project Manager	4 wk x 1933 =	$7732
Superintendent (swing shift)	4 wk x 1610 =	6440
Superintendent (graveyard shift)	4 wk x 1610 =	6440
Project Engineer	4 wk x 1288 =	5152
Safety Engineer	4 wk x 966 =	3864
Timekeeper/Clerk	4 wk x 805 =	3220
Subtotal		**$32,848**

General Accounts

Office Supplies	1 mo x 600 =	$ 600
Engineering Supplies	1 mo x 300 =	300
Legal & Audit	Lump Sum =	10,000
Safety & First Aid	1 mo x 600 =	600
Telephone	1 mo x 1000 =	1,000
Small Tools (Direct Pure Labor x 10%)	=	3,914
Subsistence - 5 people x	1 mo x 750 =	3,750
travel-home office - 2 people x 2 trips x 1000/trip	=	4,000
Moving Expenses -	5 men x 2000 =	10,000
Safety Training	1 mo x 400 =	400
Federal Express	1 mo x 320 =	320
Subtotal		**$34,884**

Insurance

Car Insurance	4 cars x $50/month =	$ 200
	Subtotal	**$ 200**

Equipment

Fuel, Oil, and Grease - Cars - 4 ea x $450/mo x 1 mo =	$ 1,800
Subtotal	**$ 1,800**

Plant Installation

Office Trailer - Install & Remove =	$ 8,000
Subtotal	**$ 8,000**

TOTAL SUPERVISION AND OVER-HEAD/6 EA-700-FT LINERS = $77,732

(5) Equipment Purchase Costs

Liner Welding System (Subsection 2.6.3)	$11,327.90
Jacking System (Subsection 2.7	119,700.00
3 Ton Low Profile Diesel Powered Truck with Scrubber & Hydraulic Boom	52,000.00
2-Axle Transport Wagons-3 ea @ $2500	7,500.00
Video Camera and Monitor	1,400.00
Lighting	2,650.00
Ventilation Equipment for Welding Bulk-head of Blind End of Liner	2,500.00
TOTAL EQUIPMENT PURCHASE COST =	**$197,077.90**

2.4.5 Cost Summary

The total cost based on a pilot program of six each 700-ft liners, excluding home office G&A, and fee is

o Labor Cost	= $ 77,691.22
o Materials Cost	= 262,800.66
o Equipment Operations Expense	= 3,843.18
o Supervision	= 77,732.00
o Equipment	= 197,077.90
TOTAL COST	**= $619,144.96**

The total cost per each 700-ft liner = **$103,190.83**
The following Figure 3 illustrates the average total cost/each 700-ft liner installed for various numbers of liners and differing amounts of equipment.

2.5 Personnel and Utility Requirements

To expedite the installation of the six, 700-ft long steel casings, using one set of equipment, the following personnel and utilities will be required.

The crew necessary to move the equipment from liner site to liner site, to set up the system, to maintain the equipment, and to install the steel liners consists of

Heavy Duty Repairman/Welder	-	2 people
Jack Frame Operator	-	1 person
Mine Vehicle/Boom Operator	-	1 person
Laborer	-	1 person
Total	-	**5 people**
Electrician (setup & maintenance)	-	**1 person**

Working three shifts per day yields a work force of 15 people performing installation with two electricians needed during maintenance and setup. In addition, a supervisory staff of six is indicated. Additional support, not included in the estimate, would consist of a shaft hoist operator, man hoist operator, and two top laborers to service the underground crew during installation and setup. Working three shifts per day yields 12 support personnel. This crew could also be used to service the drilling operations.

Utility requirements include ventilation and electrical power. The ventilation is determined as the greatest value of

A. 200 CFM x No. of People + Diesel Machine Requirements
No. of Men = 5 Standard Crew + 2 Supervisory Personnel + 3 inspectors = **10 people**

Mine vehicle requirements = **3,000 CFM**

Total CFM = 10 people x 200 CFM/person + 3,000 CFM = **5,000 CFM**

B. To provide enough ventilation, especially during welding procedures, a velocity of 30 FPM is required. Therefore, the CFM needed is equal to 30 ft per minute x the cross-sectional area of the haulageway, 10 ft x 20 ft.

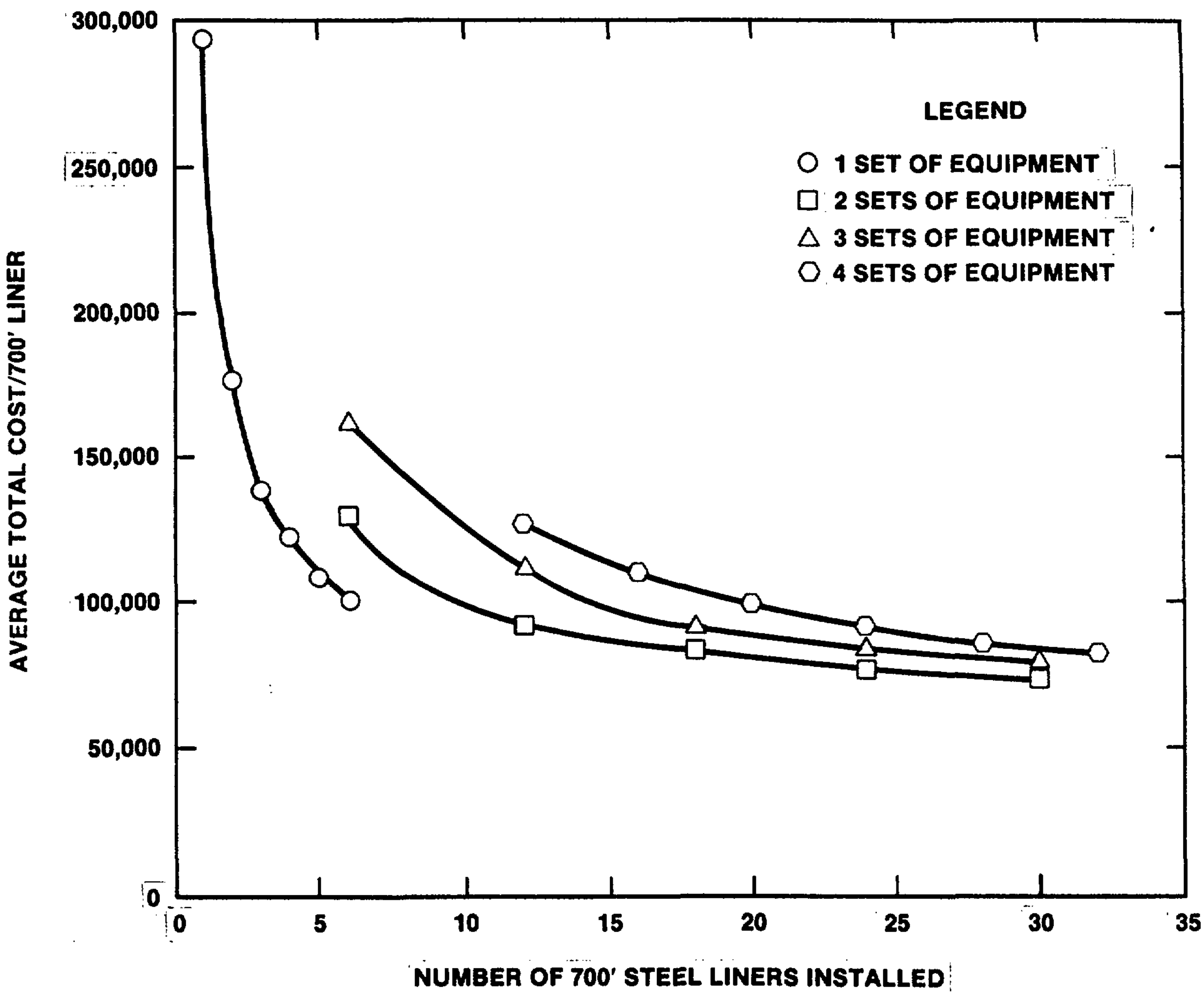


Figure 3. Average Total Cost/Each 700-Ft Liner

Total CFM = 30 FPM x 200 square feet
= **6,000 CFM**

Using the greatest value yields, a ventilation requirement of at least 6,000 cubic feet per minute.

The electrical power needed to service the equipment is 400 amperes, 480 volts.

2.6 Liner Welding System Feasibility

2.6.1 Welding Procedure

The task is to develop a liner welding system for jointing sections of 36-in. diameter, 1/2-in. wall, carbon steel (1020). The welded joint shall have no internal or external protrusions and must also be watertight. Areas of concern include the actual joint design, the welding procedure, and the weld materials.

The joint design chosen is the 45° "V" bevel butt joint (see Figure 4). The root opening will be a maximum of 1/16 in. with a land of 1/16 in. To expedite welding within close tolerances, we have chosen to have the joints of each section of liner machined to these specifications before delivery to the work site. The price for liner contained in Section 2.4 reflects this requirement. The 45° bevel is suitable for either vertical-up or vertical-down position welding. The 1/16-in. landing specified will aid in eliminating internal protrusions of the final weld.

The welding procedure and materials chosen for this application are the flux cored arc weld (FCAW), using .045-in. Dual Shield II-70 electrode with a shielding gas of 75% Argon/25% Carbon Dioxide (see Appendix B). The semi-automatic process is to be used. This procedure was recently used by McDermott International while laying 28 miles of 18-in.-diameter pipeline offshore for the Emirate of Ras Al Khaimal, United Arab Emirates.[4] The FCAW process provided a low-hydrogen process, speeded production, reduced the possibility of sulfide stress cracking, and reduced slag defects. The flux cored electrode provides high tensile strength and impact toughness, which are important attributes in maintaining the structural integrity of the welded joints during the jacking process.

[4] Welding Journal, August 1985, p. 55.

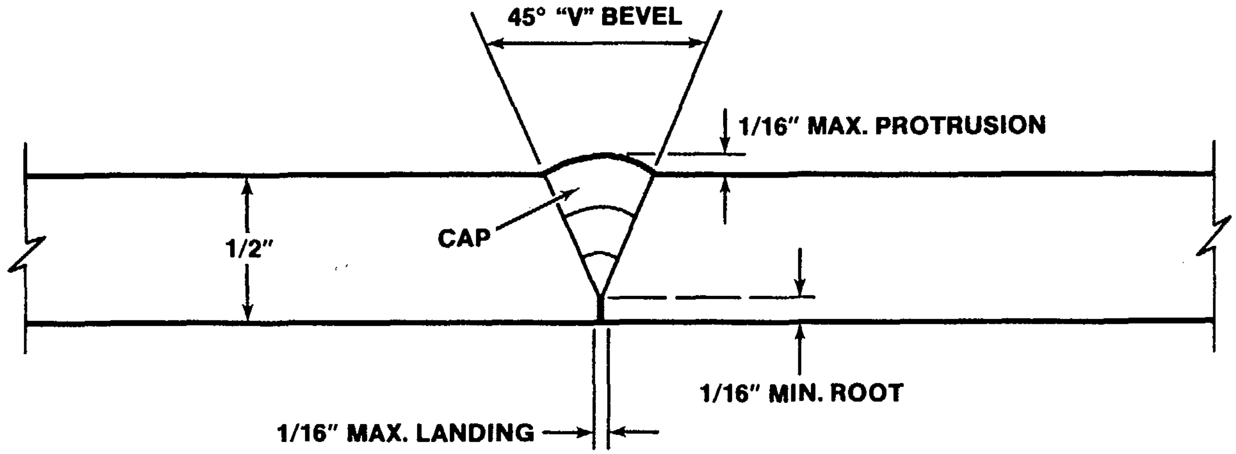


Figure 4. 45° "V" Bevel Butt Joint

2.6.2 Weld Test

To confirm our decisions on welding procedure and materials, a test was conducted. The test was undertaken on August 1, 1985, in shop conditions (Figure 5). The only deviation from the prescribed procedure was that the joint was a 37° "V" bevel instead of the final design of 45°.

The test results are

WORK DESCRIPTION	TIME STARTING	TIME ENDING	DURATION
First Joint			
Set-up Welder	9:45 am	9:55 am	10 min
Tack Weld	10:07	10:12	5 min
Continuous Weld - 1st Pass	10:12	10:36	24 min
Remove slag	10:36	10:38	2 min
Continuous Weld - 2nd Pass	10:38	11:13	35 min
Remove slag	11:13	11:17	4 min
Continuous Weld - 3rd Pass (Cap)	11:17	11:54	37 min
Remove slag	11:54	11:56	2 min
		TOTAL	**119 min**
Second Joint			
Tack Weld	1:52 pm	1:57 pm	5 min
Weld & Remove Slag-1st Pass	1:57	2:13	16 min
Weld & Remove Slag-2nd Pass	2:13	2:38	25 min
Weld & Remove Slag-3rd Pass (Cap)	2:38	3:06	28 min
		TOTAL	**74 min**

The first joint weld test was concluded to acquaint the welder with the procedures necessary to produce a joint of satisfactory quality. Numerous discussions and observations interrupted the actual production. The completed joint had no internal protrusions (Figure 6). The cap weld protruded a maximum of 1/16 in. (Figure 7), which would cause no detrimental effect. Total weld depth averaged 1/2-in. in total thickness.

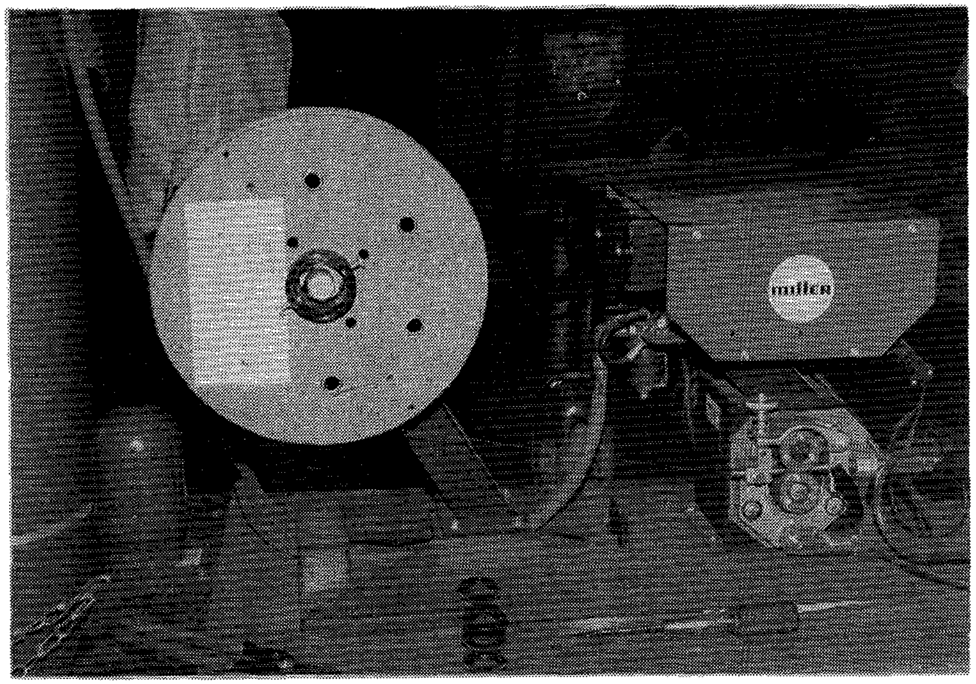


Figure 5. Welding System Showing Wire Spool and Line Wire Feeder

Figure 6. Test Program Weld With No Internal Protrusions

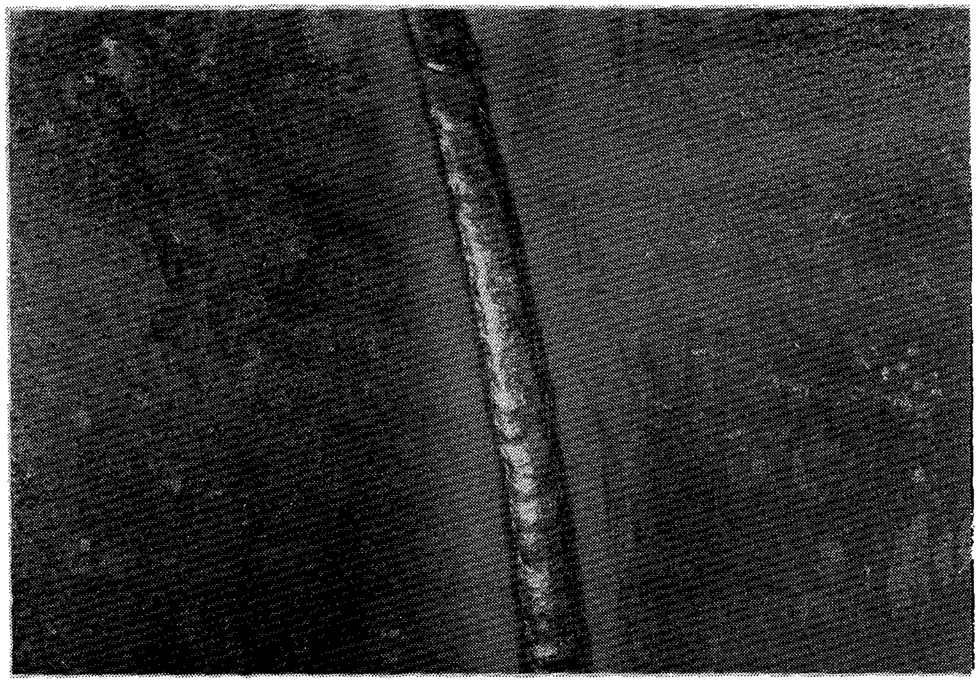


Figure 7. Illustration of Final or Cap Weld, Average External Protrusion of 1/16 In.

The second joint weld test was conducted on a production basis with minimal interference. A single welder/mechanic performed all necessary steps. As indicated by the test results, a single welder can produce a completed joint in 74 min. The quality of weld was similar to that of the first test and was again satisfactory for the type of joint necessary in the actual liner installation.

To expedite installation, two welders should be working on opposite sides of the steel casings, yielding an average weld period of 37 min.

2.6.3 Welding Equipment and Costs

The equipment necessary to perform the welding procedure consists of a DC-constant potential welding power source, a semi-automatic digital wire feeder, a hand torch with adaptor assembly to feeder, regulator and flowmeter, and an internal pipe clamp. The internal pipe clamp is a device which expands within the joint to assure trueness to round and secures the two pipe sections in position.

The price of this equipment is

1 Ea: #085-209 Miller Electric System ... $2,940.00
- Consists of: CV Deltaweld 450 amp source
- 230/460/575 volt-3 phase
- S-52 D digital feeder & control
- Control cables and .035 drive rolls
- Wire protective cover

1 Ea: Tweco Supra 350-15 ft. Assembly.... $ 296.95
- Consists of: 350 amp hand torch
- Adaptor assembly to feeder
- Spare Parts Kit

1 Ea: Victor HRV Regulator & Flowmeter... $ 99.50

TOTAL/SET... $3,336.45

2 Sets Required - 2 sets x $3336.45/set = $6,672.90
1 Ea: Internal Manual Clamp for 36-in. Pipe = $4,655.00

TOTAL WELDING EQUIPMENT = $11,327.90

2.7 New Equipment Development, Tests, and Areas of Concern

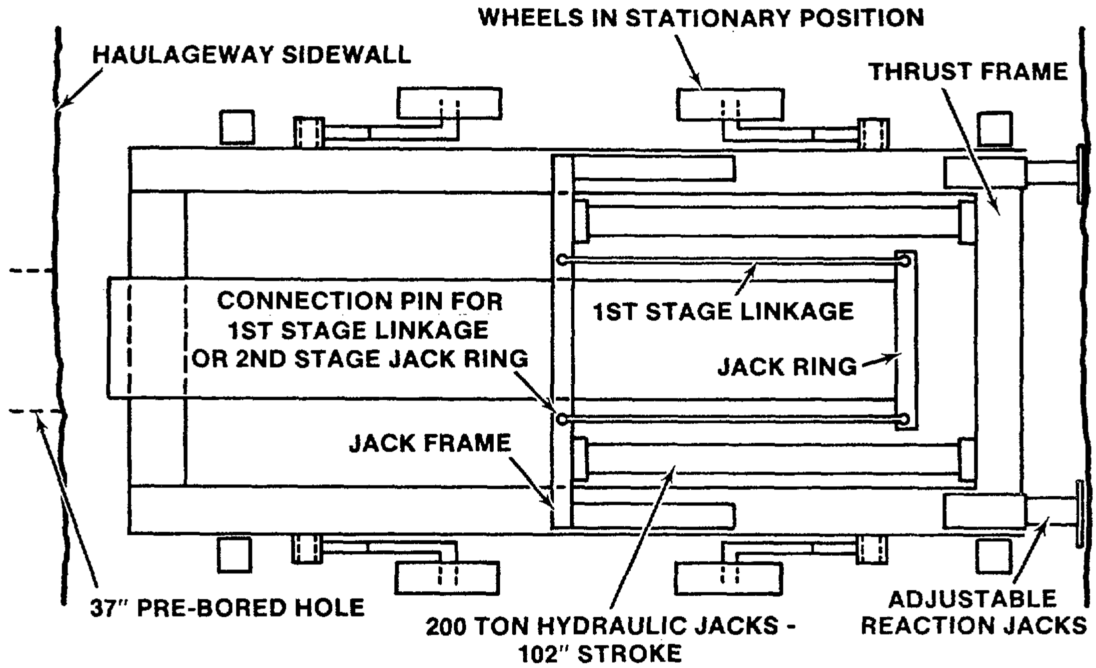
To expedite the most efficient and economical scheme for the installation of the steel liners in prebored holes, questionable facets need to be addressed. Among these requirements are new equipment development, tests, and specific areas of concern.

2.7.1 New Equipment Development

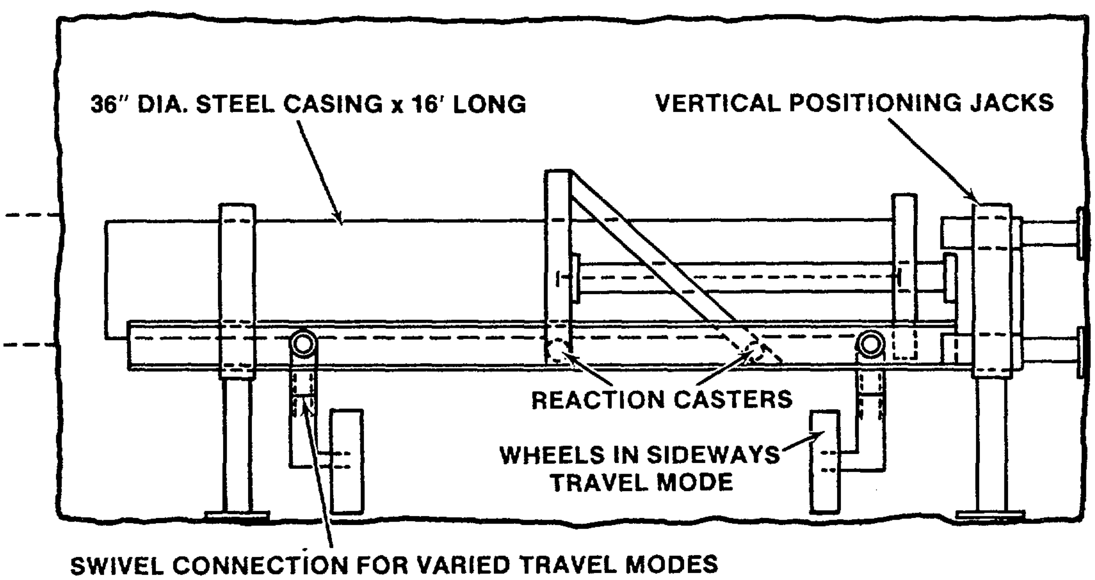
The primary equipment used in the installation of the 36-in.-diameter steel casing consists of the jacking frame and welding equipment. Both units are composed of components currently manufactured for use in the existing construction market. However, it is believed that improvements can be made to each of these particular units, which would be beneficial in the installation scheme.

The jacking units quoted within the market survey consist of components from equipment supplied for projects which both auger and jack steel liners. The major drawback to this type of equipment is the short length of stroke and the need to recycle the jack reaction frame after each 4-ft to 5-ft stroke. Other problems arise such as the limitation of length of liner to be placed being only 10 ft by one manufacturer and the overall length of 19 ft by another manufacturer. The 10-ft length limitation would add additional joints, which need to be welded, an approximate 57% increase in the most time-consuming process. The 19-ft total length is impractical in the efficient mobilization and setup of the jacking frame.

It is common industry practice for contractors involved in reinforced concrete pipe jacking to custom build jacking frames to meet their specific needs. Figure 8 illustrates a jacking unit which would meet the specific requirements of this project. The proposed unit is capable of jacking 16-ft lengths of steel casing in two steps. The first step utilizes a linkage system to jack the initial 8 ft. The links are disconnected and the jack ring is attached directly to the jack frame, and the final 8 ft can then be jacked. Figure 9 illustrates the equipment placement within the haulageway.



PLAN VIEW



PROFILE

Figure 8. Customer Liner Jacking System

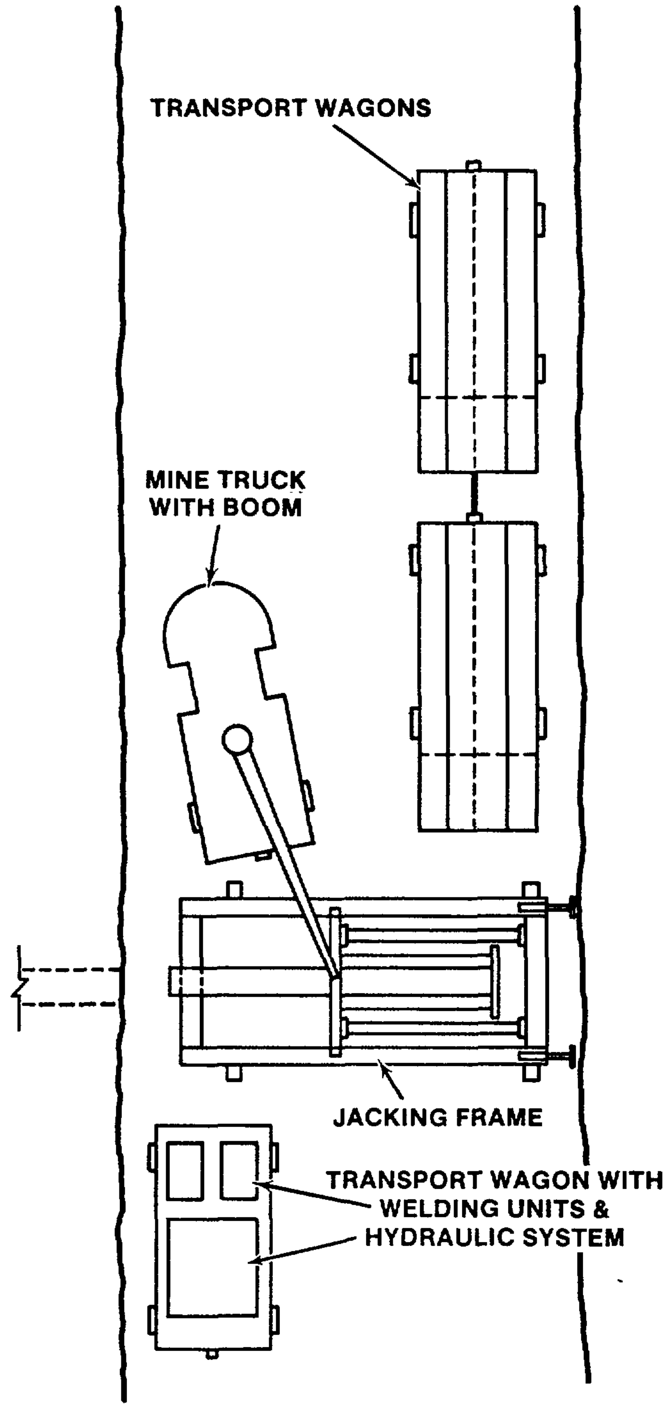


Figure 9. Emplacement Equipment Within Haulageway

The electrically driven hydraulic power system is commercially available and would be mounted on a two-axle flatbed trailer along with the sets of welding machinery. The estimated cost of the total jacking system is $119,700.

The liner welding system, used for purposes of this report, is the semi-automatic type, which requires two welders to hand place the weld. Fully automatic welding in recent years has become popular, but because of limitations expressed by manufacturers' representatives contacted, this method was not used. The opinions expressed were that the side-to-side oscillation necessary in the final weld passes could be better controlled for the quality of weld necessary by hand guided techniques. If a fully automatic system could be found which could produce the quality of weld essential for this project, a savings in labor cost could result.

2.7.2 Tests

The process of jacking steel liners is common to existing construction techniques; however, normal jacking operations are carried out within shafts seldom deeper than 100 vertical ft. To establish actual costs, it is suggested that a pilot program be demonstrated within an existing mine with conditions similar to those anticipated of an actual repository site. A minimum of six prebored holes would be needed to aid in evaluation of the actual time and costs related to the installation of the 36-in.-diameter steel casings. Upon completion of each liner, a pneumatic or hydrostatic test should be conducted to evaluate the watertight criteria.

2.7.3 Areas of Concern

The primary areas of concern include the alignment of the prebored hole, stability of the hole, and the -10° to $+10^{\circ}$ deviation from the horizontal axis.

The alignment of the prebored hole is critical to the liner jacking process. Deviation will cause additional frictional and lateral loads to be applied to the steel liner. Excessive deviation could cause excessive jacking pressures and structural failure of the liner. Small deviations could be compensated for with the addition of guide shoes on the leading edge of the liner, holding the liner in the center of the hole and preventing the liner from cutting into the prebored surface.

The stability of the prebored hole is also important to the successful installation of the steel liner. Minimal rock fall will need to be removed ahead of the leading edge of the liner to prevent the liner from becoming wedged within the hole. Excessive rock falls occurring around the casing after only partial installation could cause the steel liner to become frozen within the hole.

The -10° to $+10^{\circ}$ deviation from the horizontal axis causes problems with the installation of the 36-in.-diameter liner in that the rear end of the jacking equipment will contact either the haulageway roof or invert. A maximum deviation of two degrees would prove more desirable.

These areas of concern could be negligible if geologic conditions are favorable and if the deviation from the horizontal axis is limited to 2°.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The principal objective of this study was to develop (and evaluate) a technically feasible concept for installing a steel liner in a 37-in.-diameter borehole up to 700 ft. in length. This objective has been met as evidenced by the detailed discussions presented in Section 2.0. The principal conclusions and recommendations drawn from this study are:

- Current technology exists to efficiently install 36-in.-diameter steel liners within prebored long horizontal blind holes.
- Experience in jacking concrete pipe indicates that the weight and length of liners to be installed pose little or no problems in the selection of equipment. The custom manufactured jacking system is both capable and economical for the liner emplacement.
- All restraints and requirements set forth for the system in Section 2.0 can be met; however, for the most efficient placement of liners it is recommended that the deviation from the horizontal axis be limited to 2°.
- To eliminate any extreme procedures, such as tapering of joints and welding from within the liner, care should be exercised during borehole excavation to assure proper alignment.

The proposed liner emplacement system consists of components currently manufactured for use in the existing construction market. It is suggested that a pilot program be demonstrated in underground conditions similar to that anticipated for a repository site if further consideration is given to this concept.

As mentioned in the background section of this report, the liner section considered in this report is one of those considered early in the development of the designs for the horizontal emplacement concept. The simultaneous drill-and-line concept used in the Site Characterization Plan Conceptual Design is an outgrowth of the evaluation presented in this study.

APPENDIX

This report contains no data from, or for inclusion in, the RIB and/or SEPDB.

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