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REMOTE CONTROLLED UNDERGROUND MINING SYSTEM

Final Report: Preliminary Design and Concept Plans

By
John C. Haspert

Work Performed Under Contract No. FG01-82CE15130

Underground Systems
Arcadia, California

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1000 INDEPENDENCE AVE., S.W.

WASHINGTON, D. C. 20585

CONTRACTOR

JOHN C. HASPERT, DBA
UNDERGROUND SYSTEMS
P.O. BOX 1252
ARCADIA, CA 91006

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FORWARD

The contents of this manual discuss a proposed mining technique for pitching and/or gaseous deposits of coal in a seam structure having a surface outcrop. The technique is referred to as, 'Remote Controlled Mining System'. Discussion format presents 3 Sections in this manual to its review.

Section I provides an introduction to the Concept; summarizes the technologies that are brought together providing the mining technique with its operational requirements; identifies the importance that each of the individual technologies bears in the concepts plan, and the exact manner through which they contribute to the complete mining plan.

Section II discusses pertinent hardware assemblies and the particular function of each that provides key operational support to the mining technique. A portion of the discussions treat the preliminary design of specific hardware required by the mining technique; the Mining (drilling) Rig and all the accessory equipment necessary to the mining and transfer of mined material to the adit at an outcrop. Other portions discuss a suggested equipment operational procedure addressing, in particular, the means and the manner by which the Mining Rig provides the handling technique to the heavy and bulky hardware components required by the mining system during the process of extending a mine bore or withdrawing from it.

Section III presents a compilation of engineering data necessary to the preliminary design process of hardware capable of providing and sustaining a mining operation of the nature proposed in this manual, and a broad preliminary review of mine production cost on a cost per ton of mined coal basis.

S U M M A R Y

The proposed mining technique has the potential to mine coal from underground horizontal or pitching seams in the 9-foot thickness range at an estimated cost ranging from \$7.987 to \$10.152 per ton. The estimate is established on conclusions drawn from:

1. The anticipated mining rate, in terms of tons per hour, that the mining system's hardware is expected to achieve as an average.
2. The approximate cost of the mining hardware amortized on a production service life expectancy of 4,000,000 tons.
3. Logistics pertinent to continuous mine production, requiring the operation of two Mining Rigs simultaneously with operating crews totaling to 9 men per shift.
4. The angle of the mine bores into pitching seams extend, whenever possible, to no more than 30° from the horizontal.
5. Mine Bores extend to maximum feasible or permissibles length. A bore length of 2,500 feet is considered feasible.
6. Gas recovery from the mine bores can be accomplished with relative ease. The value of this, however, has not been determined since its handling as a 'recoverable' requires investigation on hardware assemblies necessary to its processing, and the volume that must exist to invite a commercially attractive effort.

POSITIVE ANALOGIES:

The estimated mine production costs (cost per ton mined) decrease as the mine bore diameters increase. The limitation, however, that exists on these scales, considering the maximum diameter to which a mine bore might be developed, has not been established.

NEGATIVE ANALOGIES:

The projected economies associated to the mining technique are sensitive to and deteriorate as:

1. The mine bore diameters are scaled down (reduced) from that considered in this investigation.
2. The mine bores are shorter than the feasible or permissible at a given mine site.
3. The angle from the horizontal at which the bores are planned extends over 30° . This becomes critical as the angle approaches 30° . 40° angles should be considered prohibitive until field experimentation has been conducted and data on, i.e., 30° angle bores can be evaluated.
4. The margin of permissible error in defining specifications for the system's underground working hardware is limited, concerning particularly;
 - 4.1 The Mine Bore Support system; the structural specifications required to withstand overburden pressures that exist at a given mine site where an application of the mining technique is planned.
 - 4.2 The Drive Stem; its structural specifications and the haulage capacity those specifications allow.

PROBLEM AREAS:

A terse summary of these is as follows:

1. Initial capital investment for the mining system's hardware requirements are somewhat higher than hardware costs associated to other mining techniques.
2. Expertise in the coal industry, required for the operation of the mining system's hardware is considered to be very limited or nil.

3. The above referenced items tend to bear a negative impact within the coal mining industry. Response to an extensive number of inquiries made, seeking development interest within the industry, declined leadership in field research proposals.

TANGENT INTERESTS:

The investigation supported by the grant project does not include data on the potential economic impact that the surface based mining system poses in contrast to overhead costs or direct heading costs common to current underground mining operations. This can be expected to be favorable, especially in the areas of ventilation, life and health insurance, supervision, and mine maintenance. An investigation on impact that the development of the mining system may have in these areas is encouraged to entice involvement by private enterprise.

The investigation on the mining system completed thus far does not include a plan for modification to hardware or the application of it that would permit an underground setup from where remote controlled mining could be accomplished. Investigation of this potential application is encouraged.

An investigation of the system's potential to mine metallurgical coal from seams ranging down to 30' in thickness is recommended.

SECTION I

MINING TECHNIQUE -- TECHNOLOGIES INVOLVED

1. INTRODUCTION

REMOTE CONTROLLED UNDERGROUND MINING SYSTEM (Horizontal or Pitching Seams)

The concept identifies a mining technique which can mine ores or minerals from horizontal gaseous seams or from seams pitching at an angle from the horizontal in a remote controlled manner.

The concept's application to the mining of coal from pitching seams is unique since techniques which permit this are currently extremely limited and most often do not support a profitable mining operation.

The technology involved is a remote or a surface based control mining method, and provides feasibility to the underground mining of:

- Mining seams ranging to over 15 feet in thickness. (The investigation covered by this manual considers, specifically, a 9 foot thick seam.)
- Mining up to 70% of the coal deposit in a seam.
- Mining gaseous deposits of coal safely without exposure of manpower to hazard.
- Mining seams extending up to 60 degrees from the horizontal.
- Methane recovery from gaseous deposits.
- Mining metallurgical coal in horizontal or pitching seams ranging down to approximately 30 inches in thickness.

The mining capacity in terms of tons per man shift, and correspondingly, the mining costs per tonnage produced, relate to the thickness of a seam more than to any other mine site condition, due to the impact of labor cost.

The concept considers rotary mechanics as the 'mining action', developing parallel and adjacent bores which, by virtue of the guidance system the concept employs, allows consideration of bores extending several thousand feet in length.

As a mining system, it is a blend of several proven technologies 'borrowed' from other industries. These are:

1. Directional hole drilling as used by the Oil Industry.
2. A foolproof guidance system. The mining mechanism receives guidance from a steel pipeline placed to be the guiding member to the direction of the mine bore. The steel pipeline is part of the directional hole drilling assembly, the technology referenced in item 1 above; and which precedes the 'final and full' diameter mining of a planned bore.
3. A totally mechanized tunneling machine type Miner.
4. A ground support system referred to as pipe jacking, a technique known as 'inch-worming' in the tunneling industry.

Pipe jacking and the inch-worming technique provide the means to mine support synchronous with the mine's heading advance. The support system is mobile, and is retrievable from a 'mined out' bore.

None of the basic technologies which are blended into the mining technique require the development of new drilling techniques or special mining tools. All of the hardware used in the mining system has proven performance records established in other industries.

The Mining Rig, which provides the control means to the mining tools, is of a special nature. Its design and operational specifications are directed to semi-automate the handling of the 'mining hardware' and thereby influence

man shift mine productivity to a maximum value. This is expected to net the lowest possible underground mining costs, on a cost per ton basis, the mining system can achieve in the specific areas of mining interest which motivate its research and engineering development; and secure a competitive advantage in several areas over current systems used for the underground mining of coal; specifically, in the areas of safety and ventilation costs.

2. BRIEF DOCUMENTATION OF THE MINING SYSTEM

2.1 ILLUSTRATIONS -- MODE OF OPERATION

The brief summary following identifies the concept and its development format.

Figures*1 and*2, following, offer an illustration of the mining technique in an ore or mineral deposit declining at an angle, for example, of approximately 14 degrees from the horizontal.

As a mining system, a series of parallel closely spaced bores are planned. Each planned bore would have a probe hole drilled prior to its mining. See Fig. 1 of the drawing. Each planned bore would contain a string of drill pipe, left in place after the probe hole is drilled, to serve as the guidance member/system to the mining machine's Mining Head. See Fig. 2 of the drawing. Logistics pertaining to the handling of the mining hardware encourage adaptation of the system to stage work on two bores simultaneously. A probe hole for one of the planned bores would be drilled while an adjacent, previously drilled, probe hole is in the process of being mined out to its final diameter. Thus, the full bore mining hardware in recovery process from a 'mined out' bore can be directly placed to mining in a 'new' bore. The technique would eliminate multiple handling operations, and influence higher man shift productivity.

A laboratory scale model of the Mining Head and the internally flighted Drive Stem is at hand, and demonstrates the basic approach of the technique; The means by which a mineral or ore is mined and transferred from the heading.

*These figures are reductions of a Drawing on the Mining System. The Drawing is included in the detached packet, and is identified as Assembly Plan 1.0.1.

FIG. 1 ILLUSTRATION OF DRILLED PILOT HOLE

FIG. 2 'Illustration of Pilot Hole Being Reamed.'

SEE DESIGN PLAN 10.1--ENLARGED VIEW

MINING PLAN

FIGS. 1 & 2

UNDERGROUND SYSTEMS	
WEST DIRECTION	AT ANA CAL
REMOTE-CONTROLLED UNDERGROUND MINING SYSTEM	
DATE	CONCEPT
DATE	DATE
DATE	DATE

The technologies referenced above, when blended into an operational procedure, provide a mining technique for an underground, horizontal or pitching seam of mineral or ore, in the manner illustrated in Figures 1 and 2. The significance and requirement of each is as follows:

Drilling of a probe hole -- This employs the oil industry's directional hole drilling technique with drilling media (water or mud). In the process, a log is developed of all the pertinent data such as gas environment, base and overburden-geological makeup, the mineral or ore seam's material strength, ground water structures, and the geometry of the deposit to the desired depth to which mining is planned.

Guidance System to the mining operation -- The pilot hole 'drilling string' (drill pipe) is left in the hole it drilled after the drilling operation is completed. The 'planted drill string' becomes the guideline to the Mining Head of the mining equipment.

Mining via tunneling technology -- The Mining Head, placed on a directional course through the 'drill string' guidance system, is energized rotationally and with drilling thrust through a Drive Stem with a portal or surface based power plant.

Mineral or ore transportation -- (From the mine heading) The Drive Stem, which delivers the mining energy to the Mining Head, is equipped with internal flighting, and, as it rotates, the material contained therein is 'augered' from the mine heading to the mine portal.

Mine support system -- Steel Mine Support Collars are made to follow the Mining Head as it advances, via the pipe jacking technology, commonly referred to as 'inch-worming'. The technique provides mine support as the mine heading advances, and permits removing the support system after the mine's depth or length extension has been reached.

Gas Recovery -- The Mining Plan and technique allow the recovery of mine gases without jeopardy to the operating crew or to the planned mine bore and productivity. A string of Drive Stem members extend from a surface based power plant and provide rotational drive to the Mining Head. These provide the technical means through which mine gases are 'drained' off at the surface or mine bore adit.

3. SUMMARY DOCUMENTATION OF ESSENTIAL HARDWARE FUNCTIONS

Discussions following identify specific equipment assemblies required by the mining system. The purpose of each and the specific manner in which its function contributes to the mining system is noted. The specific equipment assemblies are:

1. The Pilot Hole Drilling Rig (provides the means to placing a planned mine bore's guidance system);
2. The Mining Head;
3. The Drive Stem (provides the means to transport the mined mineral);
4. The Mine Bore Support System;
5. The Gas Monitoring and Retention System; and
6. The Mining Rig (provides the control means to equipment assemblies 2 thru 5).

3.1 Pilot Hole Drilling Rig -- Guidance System

The drilling of the pilot hole is primarily the means to provide guidance to the full bore mining operation. The drill pipe or the outer caisson, pending the hardware drilling assembly requirement, becomes the guideline for the full bore Mining Head.

3.1.1 Background Information On Directional Hole Drilling

Figure 3 illustrates the 'directional hole' concept. It is the means to providing a pilot hole through a mineral or ore deposit. Fig. 4, following, illustrates

FIG. 3

Cutaway showing Dyna-Drill assembly

Illustration of the "Bent Deflecting and Orienting Sub"
used to control rate of curvature

directional hole drilling hardware and the technique developed for the oil well drilling industry. The hardware the industry uses is commercially available. A directional hole drilling assembly consists primarily of:

1. The drilling bit.
2. A down-hole motor.
3. Non-magnetic drill collars.
4. The hole deflection assembly.
5. The drill pipe extending to a surface based drilling rig.
6. Hole direction surveying equipment.
7. A drill rig and a mud or water circulation system.

Operationally, a drilling fluid under pressure (pure water or a mud mixture) is pumped by high pressure pumps through the drill pipe to the down-hole motor which, through a rotor and stator assembly, delivers rotational drive to the drilling bit. The high pressure fluid introduced through the drilling pipe, after passage through the down-hole motor, is directed through the drilling bit at a pressure level and velocity sufficient to remove the drilled cuttings from the bottom of the hole and force them through the annulus to the surface.

The drilling fluid further provides a means to monitoring intrusive materials that may be embedded in a mineral deposit; and the formation's gas and pressure, if any. The drill stem providing the mud circulation to and through the drill bit does not rotate the bit, but does provide the drilling thrust to it. The illustration in Fig. 4 shows the principal mechanism in one of the current commercial systems, which enables 'hole deflection', as necessary, to achieve a controlled direction of the probe hole's development.

The oil field industry, in drilling directional holes, uses equipment assemblies referred to as 'whip stock', 'bent shoe' and 'bent sub'. The whip stock becomes a permanent fixture in a well bore, that is, it cannot be moved forward once it has been set in place. The bent shoe and bent sub, on the other hand, can advance forward with the advance of the drilling bit.

The non-magnetic drill collars are required to enable the placement of surveying instruments into the bore, which indicate the bore's direction of development and provide the 'intelligence' required to apply a correction to the direction, should it become necessary.

In oil field work most of the directional hole drilling requirements have been in relatively firm and stable type earth formations. Driving a pilot through a soft material, such as coal, however, requires that special consideration be given to the turbulence caused by the high pressure, high velocity, mud system flowing through and around the drilling bit and on upward to the surface of the bore. Mud pressure and high velocity flow, required as drilling mechanics, have the capacity to erode and break down the wall surface of a bore. This can be a critical situation since the tools that are placed into the bore to effect a directional change in the drilling line of the drilling bit are prone to become malfunctional because the wall surface of the bore may have deteriorated, thus eliminating the anticipated firm base against which a deflection tool must support itself.

In softer materials, such as coal, the drilling rate in terms of feet per hour is at a fairly high value. The hole wall erosion problem may tend to eliminate itself while the bit is advancing since the turbulence which creates the erosion

problem is constantly advancing at a rate faster than erosion can progress and create the problem. It is reasonable to assume that drilling a hole in a straight line through coal will permit drilling rates above 50 feet per hour, resulting in very minor hole erosion problems.

The hardware assembly proposed for application in the Remote Controlled Mining System, discussed in this manual, is modified to some extent, primarily because of the 'soft' nature of coal. The modification to safeguard against erosion related problems is shown in Assembly Drawing No. 11.0, included in the packet of drawings accompanying (detached) this manual. The modified hardware assembly, and its pertinent features, are discussed in detail in Section II of the manual, Div. 4.2, entitled, "Alternate Technique and Hardware Specifically Designed For Drilling Probe Holes In Coal Seams".

3.2 GUIDANCE SYSTEM

The top side of Figure 1 illustrates the plan for a probe hole, drilled to a planned length, through the center of a mineral deposit. The drill pipe, extending from the drill bit to the portal, as stated earlier, is left in the drilled hole.

The Mining Head, which is discussed in paragraphs following, is equipped with a bushing through its diametrical center. The bushing, at the start of the mining operation at the portal, is made to engage with the drill pipe and remains engaged with it as the Mining Head advances. Thus, the Mining Head, through its engagement with the probe hole's drill pipe, is always advancing without leeway to wander 'off course'. The system eliminates the need for further guidance attendance at the mine heading and constitutes a 'foolproof' method to guidance of the mining machine's Mining Head.

3.3 MINING HEAD

The Remote Controlled Mining System (RCMS) discussed in this manual considers a mining technique wherein a series of parallel bores are extended through the center of a coal seam. To gain lower mining costs (cost per ton mined), it is important to extend bores the maximum distance that either the mine site and coal structure or the mechanics of the mining system will permit. Longer mine bores translate directly to lower mining costs on a per ton basis since less time is lost to moving the mining equipment, and more time is allowed to mining production.

The mining action at a bore heading is accomplished with a tunneling machine type Mining Head as illustrated in Figure 5. It can be of several design configurations. Its principal purpose is to dislodge the mineral or ore at the heading in a rate controlled manner and then feed the mined consist into an inner compartment of the Mining Head from where its transfer to the portal through the Drive Stem's internal flighting starts. The Mining Head, in most instances when a soft or low strength mineral or ore is considered, will include design provisions for a bulkhead configuration having entry ports which control the rate of loose material flow from the heading to the inner compartment. A laboratory scale model of the concept demonstrates this. The mining tools providing the mining action, in most instances, would consider the Disc Cutter shown in Figure 5.

In the interest of mining production, the Mining Head of the mining system must perform in a dependable manner and provide days of maintenance free service, since it would become self-defeating if the Mining Head of the System would have to be withdrawn from a bore before the total planned depth of the bore has been reached.

- Typical Tunneling Machine type MINER can be designed:
- to permit large diameter drill stem drive to Cutter-head.
 - to permit guidance via small diameter drill pipe placed during the probe hole drilling operation defining the seam's pitch angle and its thickness.

FIGURE 5

Carbide tipped mining bits common to coal and potash mining machines, now used by the industry, may also be considered, but only in deposits that are known to be free of high strength material intrusions, and where a good order of homogeneity in the mineral deposits exists. These bits are sensitive to high impact or shock loading, giving cause to bit failure at a time when an exchange for a new bit could be time-consuming and costly.

The Disc Cutters have a proven performance history developed for the construction industry. They have been used extensively on tunneling machines and on rotary drilled shaft sinking operations. They are not readily destroyed by impact and shock loading, and, in medium rock strength range materials, have a substantial service life before replacement becomes mandatory.

Although there is some resemblance in the configuration of the Mining Head proposed for the RCMS with drilling heads developed in the past for certain types of tunneling machines, some sharp and distinctive differences do exist. Mining Heads for conventional tunneling equipment are primarily responsible for the extraction of material from a bore heading. Auxiliary support hardware working either in conjunction with, or independent of, the Mining Head provides means for the removal of the extracted material from the heading area. Furthermore, the Mining Head of a tunneling machine is driven by a power plant relatively close to it, and the operating engineers are also generally in the vicinity of the heading so as to be able to observe the operation of the Mining Head and the support equipment. By contrast, the RCMS has its power plant and the operating crew, the miners, positioned above ground. It and the operating crew are always at an operational area remote from the mine bore heading.

Under a caption entitled, "Mining Head Configuration and Mechanics" in Section II of this manual, discussion treats the particular design and functional characteristics the RCMS' Mining Head must have.

3.4 DRIVE STEM -- HAULAGE MEANS

The Drive Stem, as used by the mining system, must provide two functions; namely, deliver rotational drive power from the Mining Rig's Power Plant to the Mining Head working on the face of a mine bore, and convey the mined consist from the face to the portal of the mine bore. Unit lengths are joined together to provide a continuous 'string'.

Most current drilling operations use Drive Stem members which are either threaded or use bolts as the 'connection' means. For oil field drilling, the drill string providing the drive power to the drill bit is made up of joints of pipe having a threaded connection. Some shaft sinking operations use Drive Stem units, which are bolt connected, as the means for transmitting rotary power to large diameter drill bits. Threaded connections for joints of pipe larger than, for example, 12 inches in diameter are costly to manufacture, whereas bolted connections are time-consuming in their assembly and disassembly requirements.

Conventional means, as noted above, in connecting the individual units end to end are not considered adequate in an operation such as mining, because of time lost to the mechanics in joining the large diameter units. To gain the desired advantage of maximum mining production, the preliminary design plans for the mining system's equipment needs propose a Drive Stem and a 'quick' connection means ideally suited to the mining technique. This is discussed in detail in Section II under the caption entitled, "Drive Stem Units, Configuration and Mechanics".

Figure 6 illustrates a typical Drive Stem. It may range from one foot to over six feet in diameter, pending the mining bore diameter. It is flange connected and receives its 'drive' power and the drilling thrust component for the Mining Head from a portal or remote positioned power plant.

Transport of the mined mineral or ore from the mine heading is achieved through the spiral flighting assembled to the inner compartment of the Mining Head, and the internal flighting of the Drive Stem, as illustrated in Figure 7.

Equipment designed, considering a one-to-one basis of Mining Head rotation to Drive Stem rotation, is expected to satisfy mining efforts with bores ranging to approximately 9 feet in diameter and declining up to approximately 10^0 from the horizontal. Bore diameters greater than, or in that diameter range, but declining at a steep pitch, can be mined and the material removed at a desired rate by recourse to a planetary drive between the Drive Stem and the Mining Head. The planetary gear drive will allow ratios of 1 to 1.5, 1 to 2, etc., of Mining Head to Drive Stem.

Assembly 4.1, drawing 4.1, included in the packet of drawings accompanying this manual, illustrates a proposed 9 foot diameter Mining Head having a .736 to 1 ratio when rotating (Mining Head to Drive Stem). It is discussed in greater detail in Section II of the manual under the caption entitled, "Drive Stem Configuration and Mechanics".

FIGURE 6
TYPICAL DRIVE STEM - UNIT

CONVEYANCE CONCEPT

FIG. 7

3.5 MINE BORE SUPPORT SYSTEM

The mining system requires that the mine bores are sheltered against collapse or caving as the bore headings advance, and that the mine bore support system be retrievable after the bore has reached the planned depth of the mining effort.

Providing support to the mine bore, synchronous with the heading advance, can be achieved through hydraulic jacking of circular steel collars extending from the Mining Head to the portal. They are hydraulically jacked forward in incremental groups, and the groups in cyclic phases. The technique is referred to as 'Inch-Worming' by the industry. Case histories of pipe jacking projects completed in the past are referenced in the Appendixes.

The design format of the mine bore support system considers 2 basic types of Collars. One of these is referred to as an Anchor Collar, and the other as the Mine Support Collar. Both units provide shelter to the mine bore against caving, with an exceptional difference as follows:

- : The Anchor Collars anchor to the mine bore wall and, in addition, provide thrust to the forward or backward movement of the Mine Support Collars.
- : The Mine Support Collar, by contrast to the Anchor Collar, is functional only as a device to shelter the mine bore against caving. It cannot anchor itself to the mine bore wall. When mining is in progress, all of the collars in the mine bore are forced to movement in concert with the heading advance, through thrust applied to them by the Anchor Collars.

Functionally, the movement of Collar No. 1 is controlled by the movement of the Mining Head and provides the 'intelligence' source to the controlled movement of the rest of the Mine Support.

The Mine Support Collars are dispersed at a suggested ratio of 9 to every Anchor Collar. They are fabricated re-enforced steel cylindrical shells, designed with particular concern on the overburden pressures which they must withstand. Design details and a suggested manufacturing plan are presented as assembly 2.1 on drawing Nos. 2.1.1 and 2.1.1.1, and discussed in Section II of this manual.

A typical arrangement of the Anchor Collars and the groups of Mine Support Collars positioned between them is shown in Fig. 9, and is discussed further below. Their recovery from or their entry placement into a mine bore are a similar operation. The cyclic sequence of movement inside the mine bore to accomplish either is also brought to discussion in Section II of this manual, under the caption, "Anchor Collar -- Operational Mechanics".

Fig. 8 is an illustration of a typical Anchor Collar. Mine bore wall gripping pads, positioned to engage the roof and floor side of the bore, can be noted. Enlarged views of the Anchor Collar, its basic design format and a suggested manufacturing plan, are presented as assembly 2.2 on drawing No. 2.2 (3 sheets) and discussed in Section II of this manual.

TYPICAL ANCHOR COLLAR UNIT

FUNCTION:

One group of Hydraulic Cylinders, housed inside the Anchor Collar, provide thrust to the Anchor Shoes extending them radially, thereby forcing them against the mine bore wall.

Another group of Cylinders, also housed inside the collar, provide linear thrust to either Sub -A- or Sub -B- pending the operator's desire to advance the Mine Support System or to withdraw it from a mine bore.

The phantom lines and arrows indicate direction of thrust the Anchor Collar's cylinders provide. See Assembly Drawing No. 22 for further operational and design details

SEE ASSEMBLY PLAN I.O. 6
FOR FUNCTIONAL DETAILS

MINE SUPPORT COLLAR--JACKING PLAN
FIG. 9

Limit Switches, sensitive to the movement of the Mining Head and the cyclic movement of the first Anchor Collar following the Mining Head, provide intelligence to the hydraulic circuitry which controls the cyclic jacking of all the other groups of collars extending to the mine's portal. The technology provides the means through which a chain of collars extending several thousand feet in length can be moved into or out of a mine bore, without over-stressing the ends of the collars.

An analysis on overburden pressures that the Support Collars must withstand, and the influence these have on the Support Collars' design requirements, are discussed in the Appendix following entitled "Overburden Impact On Mine Bore Support Systems". The analysis considers 5 basic types of earth formations, and draws conclusions on the structural requirements the Support Collars of varying diameters must have to withstand the burden pressure.

Mathematical formulas are at hand which aid the Support Collar designer in determining the cross-sectional area the Support Collar must have to withstand collapsing pressures a given overburden would pose. Geological data on a given mine site is very important. It is necessary for the designer to have it available in order to calculate the overburden pressure as it would exist with a given bore diameter and the earth formations around it.

Overburden subsidence and earth formations 'closing in' on a bore from all directions is a common and expected circumstance in many soft earth formations. It is a function which relates to both the size of a bore and the element of time after the bore exposure has been made. In the framework of the mining technique, it would not be the purpose to remain in a mine bore any longer than would be required to reach the planned depth of the mine. Reverse jacking of the Support Collars providing their removal would, as a normal procedure,

start shortly thereafter. The time span from when the mine bore is started, through the removal of the support system, will be in terms of days. The function of ground subsidence, or swelling, is generally observed in terms of weeks or months of exposure. Thus, the recovery of the mine Support Collar will be of no greater significance than their entry thrust into a mine's bore, other than the requirement of higher jacking pressures as the bore angle from the horizontal increases.

It is expected that moving the mine support system into and out of mine bores will require operational techniques suitable to the geometry of the mine bore. For example, a mine bore developed into a coal seam dipping at 5° from the horizontal will require that the Anchor Collars provide a thrust base from which forward thrust can be developed for the movement of the mine Support Collars. In contrast, a mine bore developed into a coal seam dipping at 30° from the horizontal will require that the Anchor Collars provide the control means by which the 'free' forward movement of the mine Support Collars is held in check. The mechanics of the Anchor Collars, and the hydraulic control on their individual functional hardware components, permit either type of 'mining operational requirement' referenced above.

The energy system to the mobile mine support system, discussed above, is hydraulic. Its power plant is positioned at the portal. It can be designed to move a string of collars extending several thousand feet in length, at select rates ranging from one foot to over 30 feet per hour. Parameters as to its size requirements (gallons per minute and working pressure) are scaled to the capacity of the drive stem to transfer the mined material from the mine heading to the portal. The drive stem's capacity to remove mined material from the mine bore heading determines the rate at which a mine bore heading can advance, and subsequently the rate at which the mine support system must advance.

3.6 GAS MONITORING & RETENTION

In Division 3.1, entitled, "Probe Hole", a discussion on the purpose for a pilot hole through the seam structure to be mined is offered. The primary purpose of the pilot hole, as noted, was to permit the placement of a small diameter pipeline which becomes the guidance technique and hardware to the full and large bore mining operation.

During the process of drilling the pilot hole, areas in the coal seams having a high gas content will be probed and can be logged for gas intensity and formation pressure. Some gas will be released during the drilling operation of the pilot hole and will surface in mix with the circulation water used by the drilling operation. Released gases in mix with the circulation media, if in sufficient quantity, can be captured from the circulation fluid as it is delivered to the 'mud' tanks following its flow up the annulus of the pilot bore.

When 'full bore' mining is in progress, the plan anticipates the greatest percentage of gases released at the mine bore heading, to find an escape pattern through the Mining Head of the machine. Its entry there into the inner compartment of the Mining Head is not restricted. After entry, it would have further unrestricted flow up to the adit through the large diameter Drive Stem, which delivers rotational drive to the Mining Head. Gases released following the heading's advance have access to enter the mine bore's support system and, once in that confinement, would also have unrestricted flow to the adit of the mine bore.

Confinement of the released gases is maintained from the mine bore heading, on through the mining system's hardware, up to an exhaust station housed on the

Mining Rig positioned at the adit. The exhaust station on the Mining Rig is supported with a power driven turbine with capacity to develop a slight negative pressure, inside the confining mining hardware assemblies, should it become necessary, to keep the flow rate at a measure adequate to safely handle and dispose whatever volume of gas that may be released while mining is in progress.

Assembly Plan 1.0.4 illustrates the general configuration of the hardware assembly to accomplish this. Drawings of Assemblies 5.1 and 6.1 illustrate the pertinent hardware assembled on the Mining Rig necessary to facilitate the plan's function. The assemblies are discussed in detail, on purpose and function, in Section II of this manual, under the caption, "Coal and Gas Gathering and Transfer System". The drawings of Assemblies 5.1 and 6.1 are contained in a separate packet accompanying this manual.

3.7 MINING RIG

Drilling rigs for a wide range of bore sizes are currently being manufactured. These are in two classifications, of which one is designed specifically for drilling vertical holes, and the other for driving horizontal holes. The vertical hole drilling rigs range from the type used for water wells and oil field type holes, which are relatively small in diameter, to rigs specifically designed for drilling large diameter holes such as mine shafts serving needs for ventilation, haulage and access to underground mining operations. Vertical hole drilling rigs for boring small and large diameter holes have the capacity to drill holes extending at an angle from true vertical. In the small hole drilling rig classification, these are sometimes referred to as slant hole drilling rigs. Shaft drilling rigs are generally designed to permit drilling either a true vertical or a hole extending a limited number of degrees from the true vertical. All of the vertical hole drilling equipment, with very few exceptions, has the power plant, providing the rotational drive to the drilling bit, positioned on the floor of the drilling rig. The rigs are designed to operate from a 'surface ground' setup.

Rigs designed to drill horizontal holes are classified as either a conventional type mineral mining machine or a tunneling machine, and are made to work in an underground setup. The principal difference in the two types of machines is that the tunneling machine is generally used for drilling the stronger earth formations and in a heading area range greater than that common to mineral mining machines. Both equipment types have the power plant, which provides the drilling or mining energy, positioned immediately behind the drilling hardware.

The drilling rig (mining rig) required with the Remote Controlled Mining System is a blend of a shaft drilling rig and a tunneling machine. As noted above, shaft drilling rigs can only develop bores extending from the vertical. Whereas, the requirement of the Remote Controlled Mining System is that the bores be extended horizontally or at an angle deviating from the horizontal. A shaft drilling rig has in its hardware assembly 'elevators', 'Kelly', 'traveling block', 'circulation swivels', and 'tongs', all of which provide the means for the placing of new joints of drill pipe (or Drive Stems, as they are sometimes referred to) onto a string assembly of these units extending from the rig floor to the drilling bit below. In any vertical hole drilling operation, the influence of gravity has a minor impact on the handling facilities or the procedure for handling heavy joints of drill pipe and/or Drive Stems. A drilling rig designed to drive a horizontal bore, as is the requirement with the Remote Controlled Mining System, requires a great deal more attention on the means and technique used to place new joints of Drive Stem units onto a string assembly of the units as the bore advances, or in removing them as the Mining Head or drilling bit is withdrawn from the bore. The time allotted to the task must be held to a minimum or the mine production potential is severely jeopardized.

Section II, following, discusses the primary requirements and the design plans for a drilling rig that will provide the proposed Remote Controlled Mining System disclosed in this manual, the hardware assembly basic and most important to its feasibility.

SECTION II

PRELIMINARY DESIGN PLANS--MINING HARDWARE--

ALTERNATIVE MINING PLANS--

LISTING OF PLANS, DRAWINGS AND NOMENCLATURE

1.0 NOMENCLATURE & SUMMARY OF PRELIMINARY DESIGN PLANS

GENERAL

The series of drawings prepared to illustrate the concept of the Remote Controlled Mining System and the required hardware to make it functional are discussed in this Section. The drawings are detached from this manual and submitted as a separate packet. They are categorized in two groups. One group is referred to as 'Preliminary Design Plans' and have numerical designations ranging from 1.0.1 through 1.0.7. These present illustrations of the mining concept plan; the preliminary design plans for the mining hardware and the required functional specifications it must have; and 'mining approach' alternatives when planning an application of the technique in steeply pitching seams. The second group is referred to as 'Assembly Drawings'. These illustrate the hardware required by the mining technique. Major assemblies are identified with assembly numbers ranging from 1.1. through 15.1. Each of the major assemblies is supported with drawings of its sub-assemblies. A listing of all the drawings, Preliminary Design Plans and Assembly Drawings, is included at the end of this section under the heading "Nomenclature and Definitions".

The major assemblies and the basic numerical designation plan for them is as follows:

- : Mining Rig - - - - - 1.1 thru 1.9
- : Mine Support System; Support and Anchor Collars - - - 2.1 and 2.2
- : Drive Stem - - - - - 3.1
- : Mining Head - - - - - 4.1
- : Coal and Gas Gathering & Transfer System - - - - - 5.1 and 6.1
- : Coal Conveyor System - - - - - 7.1

: Hydraulic Hardware - - - - -	8.1
: Electronic Hardware - - - - -	9.1
: Pilot Hole Drill String Accessories - - - - -	10.0
: Probe Hole Drilling Accessories - - - - -	11.0
: Down-Hole Motor - - - - -	12.0
: Rock Bit - - - - -	13.0
: Probe/Pilot Drill Rig - - - - -	14.0
: Drill Pipe Magazine - - - - -	15.0

The Preliminary Design Plans are discussed below.

The major assembly drawings of the mining system's necessary hardware are discussed in Division 2.0 of this section. A good number of drawings are self-explanatory and include notations, where deemed necessary, to assist interpretation.

1.1 MINING/ASSEMBLY/EQUIPMENT PLANS

The Preliminary Design Plans illustrating the mining technique; particular pertinent hardware functions and the hardware's interrelationship as a working system, and its basic design configuration are referenced below. These are:

Plan 1.0.1

This plan illustrates the mining system's technique. It is an enlargement of Figures 1 and 2 shown and discussed in Section I under the caption "Illustrations--Mode of Operation". Definition of the technology and procedures are noted on the drawing to assist its interpretation.

Plan 1.0.2 is an illustration of alternate approach plans to mining from a steeply pitching seam of coal. It is discussed in Division 3.2 in this section of the manual.

Plan 1.0.3 is an illustration of a Probe/Pilot Hole Drilling Rig. It poses specific design features ideally suited to the requirements of the mining system. The functional requirements are discussed in Division 4.4 in this section of the manual.

Plan 1.0.4 is an illustration of a 'Full Bore' mining rig. It poses specific design features providing the means to handle the heavy hardware components required by the mining system and to control them when mining. Its functional requirements are discussed in Division 2.0 in this section of the manual.

Plan 1.0.5 illustrates and provides detail on the working mechanical relationship between the Mining Head and components of the mine bore Support System in the immediate heading vicinity. It illustrates specifically the hydraulic and associated operational details pertinent to the functions of the Mining Head, its advance movement and how that is controlled and regulated by the Drive Stem String and the Mine Bore Support System. Notations are made on the drawing to assist interpretation of the proposed assembly procedure of the pertinent hardware referenced above, its operational requirements, and the sequential order in which it must function to achieve automation.

ADVANCING A MINE BORE:

The mechanics of the Mining Head and interrelated functions of support hardware connected with it, which enable synchronization of the advance rate of the Mine Support System to that of the Mining Head, are discussed below. To aid comprehension the following should be noted:

1. The Mining Head (Assembly 4.1) is spline connected to a Load Cell Housing (Sub-assembly 3.1.7), which contains Load Cells (Units 3.1.7.1). These are sensitive to resistance the Mining Head encounters while advancing.
2. The Mining Head receives its drilling thrust from pressure exerted by the Drive Stem string on the Load Cells.
3. The rate of advance of the Mine Support System, Anchor Collars 1, 1A, 2, 3, 4, 5, 6, etc., and the Regular Mine Support Collars positioned between them must synchronize with the advance rate of the Mining Head. Sub B is part of the Mine Support System. It is the leading sub-assembly component of Anchor Collar No. 1, and the only unit of the Mine Support System in contact with the Mining Head. It is positioned immediately behind the Mining Head and houses some of the hardware necessary to achieve synchronization. The Servo Unit and microprocessor in control of the hardware is housed on the Mining Rig.
4. The Load Cell Housing is in functional contact with a Servo Controlled Valve (shown as item 8.1.2 on the Assembly Plan Drawing) housed by Sub B of Anchor Collar No. 1.

5. The Valve (8.1.2) controls the advance rate of Sub B, and through connection with a Servo Unit (housed on the Mining Rig), provides functional control to Valve 8.1.3. This Valve provides advance control means to the rest of the Mine Support System.

6. Both Valves 8.1.2 and 8.1.3 are made functional through a master control Valve (8.1.5). The Mining Rig operator has manual control of this Valve. In one selected positioning of its spool, the hydraulic fluid is directed to flow through Valves 8.1.3 and 8.1.2, and thereby provide advance movement to the Mining Head and the Mine Support System. An alternate positioning of the Valve's (8.1.5) spool, by the operator, directs the hydraulic fluid through Valve Unit 8.1.4 only. This Valve, also under Microprocessor and Servo Unit control, provides the cyclic jacking pressure required alternately by the jacking cylinders of Anchor Collar groups 1, 2, 4, 6, 8, 10, 12, etc., and 1A, 3, 5, 7, 9, 11, etc., to accomplish a retreat movement of the entire Mine Support System and the Mining Head from the Mine Bore.

LOAD CELL FUNCTION: ADVANCING A MINE BORE

When the pressure in the Load Cells (3.1.7.1 units) declines, the heading material is softer than anticipated. As a result, the Load Cell Pressure Sensing Bar (8.1.1) in contact with the Load Cell Housing Assembly (3.1.7), and also with the Servo Controlled Valve (8.1.2), provides 'intelligence' to the Valve to increase the volume of fluid (pressure compensated) to the Thrust Cylinders (2.2.5), thereby increasing the rate of advance of Sub B, to synchronize with the rate of advance of the Mining Head, (Assembly 4.1). Conversely,

when the pressure in the Load Cells increases, the heading material is stronger (harder) than anticipated. And again, the mechanics of the Load Cell Pressure Sensing Bar in contact with the Load Cell Housing Assembly and the Servo Controlled Valve (8.1.2) provide 'intelligence' to the Valve to reduce the volume of fluid (pressure compensated) to the Thrust Cylinders (2.2.5), thereby reducing the rate of advance of Sub B, to synchronize with the rate of advance with the Mining Head (Assembly 4.1). This functional relationship between the Load Cell Housing Assembly and Sub B of Anchor Collor No. 1A will prevail unless the Operator elects to increase the Load Cell pressure on the Mining Head. This is accomplished by providing or allowing the Drive Stem String to bear against the Load Cell Housing Assembly with greater force, which, in turn, provides a greater normal loading to the Mining Head's Disc Cutters, thereby increasing the rate of advance of the Mining Head, synchronizing it with the advance rate of the Mine Support System, of which Sub B is a part.

RETREATING FROM A MINE BORE:

During a retreat maneuver from a 'mined-out bore', the Mining Head is generally not required to rotate. The principal function is to remove the Mine Support hardware, the Anchor and regular Support Collars, from the bore. As noted above, the Master Control Valve (8.1.5), and flow control from it to the Microprocessor Controlled Valve (8.1.4), accomplish this. Additional functional detail of the Anchor Collars are noted on the Drawing of Preliminary Design Plan 1.0.6. This plan identifies all of the Anchor Collars placed into a mine bore into two groups

which alternately receive hydraulic jacking pressure to induce movement to the entire Mine Support System. The group arrangement of the Anchor Collars provides that all the odd numbered collars, starting with No. 1 directly behind the Mining Head, comprise one group, and the even numbered collars, including and starting with Collar No. 1A, 2, 4, 6, etc., comprise the second group.

Other details important to the function of the Mine Support System and its hardware components, the Drive Stem String and the Mining Head, can be noted on Assembly Drawings 2.1, 2.2, 3.1 and 4.1. These Assemblies and Drawings of their component sub-assemblies are noted in the 'Nomenclature', Division 5.0, in this section of the manual.

Plan 1.0.6 is an illustration of the Mine Bore Support System and its functional plan. The functional plan is discussed in Division 3.5 of Section I in this manual and also in notations entered on the drawings of Plans 1.0.5 and 1.0.6.

Plan 1.0.7 is a diagrammatic layout of instrumentation and computer controlled hardware providing automation to the Mining Hardware; and of the plan providing manual control on the Mining Rig's support functions, namely the handling of the heavy hardware components requiring placement into or withdrawal from a mine bore.

2.0 MINING RIG --(PRELIMINARY DESIGN PLAN 1.0.4)

Discussions below on the Mining Rig address the following:

1. The preliminary design plan of the Mining Rig.
2. The Operational Plan.

Plan Drawing 1.0.4 illustrates the design features of the Mining Rig and the general configuration it will have. The design features accomplish the major requirements necessary to the mining technique, which are:

1. Provide the base from which energy can be directed to a mine heading, extending underground and remote from the Rig, and, in the process, provide control and operational means to the accessory equipment which provides the mining action and supports the mine bore against collapsing as the heading advances.
2. Include self-contained and automated means which will enable the handling of heavy joints of pipe, such as the Drive Stem units and the mine bore Support Collars, at a minimum expense of time and without the assistance of standby equipment and labor.

A review of the referenced assembly plan (see detached), and discussions following, will identify details on the operational features of the Mining Rig and the manner in which semi-automation is achieved in the handling of the heavy hardware components such as the Drive Stem units and the mine bore Support Collars.

The pertinent features of the Mining Rig as set forth by the design plan are:

1. The Rig base, which provides the housing means to all of the sub-assemblies having to perform a specific function.
2. A Kelly Rail, which in turn provides:
 - 2.1 for the establishment of the angle from the horizontal at which the mine bore will be developed; and
 - 2.2 the means by which the Drive Stem units and the mine bore Support Collars are handled for either assembly to or disassembly from the string of these units extending with the mine bore.
 - 2.3 housing to the Kelly and guidance to its movement. (Back and forth on the Kelly Rail as becomes necessary in the mining process to facilitate the handling of the Drive Stem units and the mine bore Support Collars.)
 - 2.4 housing to the Kelly drive system which delivers rotational drive to the Kelly, which in turn must provide rotational drive to the Drive Stem Assembly and the Mining Head.
3. Support equipment (sub-assemblies) which provide the means to the handling and placement of Drive Stem Units and Mine Bore Support Collars by the Kelly Rail Assembly referenced in item 2 above.
4. The power plant and associated Hydraulics which provide hydraulic drive to:
 - 4.1 the Kelly functions.
 - 4.2 the movement of the mine support system (pipe jacking technique referred to as 'inch-worming').

- 4.3 miscellaneous hydraulic controls and operational tools requiring drive power.
5. An assembly referred to as "Kelly Rail Torsion Lock", identified in the design drawings as Sub-assembly No. 1.8. The assembly provides the means through which the mining energy transmitted through the Kelly is stabilized. The assembly prevents torsional deformation to develop on the Kelly Rail, due to torque developed by the Kelly's function.
 6. The operator's control system.
 7. Wheel assemblies providing means for towing.
 8. Leveling Jacks and foundation pads necessary to provide rig 'setup' stability; to assure adequate ground support to the burden pressure due to the equipment's weight.

The view on the bottom side of the Assembly Plan Drawing shows a typical attitude of the Rig developing a mine bore extending at an angle of approximately 15° from the horizontal. The illustration identifies only the base of the Rig's main housing framework (1.4.1), and a unit referred to as the Kelly Rail (Assembly 1.1.1).

The Kelly Rail and its function permit developing mine bores in a range extending from the horizontal to approximately 40° from the horizontal. This is accomplished by providing a pivot point on the front side of the Rig at which the Kelly Rail

is anchored to the main housing. The opposite end, or the back side of the Kelly Rail, is equipped with a hydraulic drive system which, when energized, moves it in a radial arc starting from the horizontal and extending upward to an included angle of 40° . Details on the Mining Rig's main housing, shown in Assembly Drawing 1.4, illustrate a design feature referred to as Beam H. The Beam is equipped, on its outer flange side, with multiple strands of sprocket gear chain extending the full length of the 40° arc. The back side of the Kelly Rail is equipped with sprocket gears which are in engagement with the sprocket chain. The sprocket gears on the Kelly Rail are given rotational drive by a hydraulic motor (Hagglund) referenced as item 1.1.3.1.

The upper view on design plan 1.0.4 shows the Kelly Rail and an assembly referred to as Kelly Assembly (identified as Assembly 1.2). The Kelly Assembly, as noted elsewhere, provides the means of delivering rotational drive to the Drive Stem members driving the Mining Head. The Kelly Rail (Assembly 1.1.1) is equipped with gear racks. The Kelly Assembly is equipped with gears which engage with the gear racks. It is hydraulically powered and, through the referenced gear and rack arrangement, can be made to move back and forth on the Kelly Rail a distance of approximately 30 feet.

The Kelly Assembly, aside from delivering rotational drive to the Mining Head, also provides mechanization necessary to the discharge of the coal and gas in transport from the mine bore. The part of the Kelly Assembly that provides this function is shown in drawing of Assembly 5.1 and is discussed further in pages following.

The above discussion identified the relationship between the Mining Rig's main housing framework; the Kelly Rail, which provides the means for developing mine bores at angles ranging from the horizontal to approximately 40° from the horizontal; and the Kelly Assembly, which delivers rotational drive to the Mining Head and houses the mechanism necessary to the final discharge of coal and gas being brought to the surface in the mining process. Aside from these mining related characteristics, the Mining Rig is equipped with self-contained means necessary to the handling of the accessory equipment, namely; the Mine Support Collars and the Drive Stem members. With means to semi 'self-servicing', it is anticipated that the Mining Rig will be available to a mining program approximately 75% of its on-site time.

The particular manner, and the associated hardware assemblies which provide the Rig with means to be 'self-servicing', are as noted below.

A Collar Loading Carriage, identified as Assembly 1.6.1, is housed and supported on an I-Beam type rail, identified as Assembly 1.5.1, which is part of the Mining Rig's main housing framework. The Collar Loading Carriage has a component assembly referred to as a Collar Support Carriage, and identified as Assembly 1.1.2 on the design plan drawing 1.0.4. It is the purpose of the Collar Loading Carriage to receive either an Anchor or a Mine Support Collar, with an internally contained Drive Stem member, and through a power winch and line system transport that assembly to a position directly underneath the Kelly Rail. (The positioning of an Anchor or Mine Support Collar on the Collar Loading Carriage is illustrated in phantom outline on the drawing.) The Rig's mechanization plan provides that after the Collar Loading Carriage has arrived at a position underneath the Kelly

Rail, the Kelly Rail is lowered to a horizontal attitude and given to straddle the Anchor or Mine Support Collar housed on the Collar Loading Carriage. When in that attitude, Collar Carriage Cylinders, referred to as Sub-assembly 1.1.2.1, and Support Grapples, referred to as Sub-assembly 1.1.2.2, engage with the Collar Support Carriage (1.1.2). After the engagement is complete, the Collar, now totally contained by the Collar Support Carriage, is also in containment by the Kelly Rail and free of the Collar Loading Carriage. The Crowd System, identified as Assembly 1.3, which is housed on the Kelly Rail, contains a Sub-assembly, referred to as Crowd Ring Sub-assembly 1.3.2. The Crowd Ring, through hydraulic drive (from attached cylinders, Sub-assembly 1.3.2.1) can be made to engage with the upper end of either the Anchor or Mine Support Collars. The engagement between the Crowd Ring and the Collars provides the means to holding the unit collar and controlling its movement. After the engagement is made, the Kelly Rail and the Collar (now supported by the Collar Support Carriage) can be made to raise and attain the desired angle of the projected mine bore. The exact operational procedure suggested for the Mining Rig's handling of the accessory mining equipment is discussed in this section of the manual under the caption entitled, "Handling Procedure of the Mining Accessories By The Mining Rig". Discussions under that caption suggest directions to the Mining Rig's operator with regards to the details required to either the placement of the Anchor and Mine Support Collars into a mine bore, or retrieving them via the Mining Rig's mechanization plan.

The illustration on the top half of preliminary design plan drawing 1.0.4 illustrates a suggested conveyor system positioned adjacent to the Mining Rig. It provides the means to the transfer of the mined coal into a 'coal loading'

hopper. The hopper is planned, sizewise, to permit truck loading through its underneath side. Also shown is the suggested manner by which the mine gas is directed from the Cowling Assembly (5.1), housed on the Kelly Assembly, to a downstream processing station referred to as a gas transport system (Assembly 6.1). The gas transport system consists primarily of a turbine type pump which can be used to influence the exhaust flow of the gas entering the Cowling System.

Discussions on plans enabling the monitoring and containment of gases which may exist in certain mines is discussed in Section I of this manual entitled, "Gas Monitoring And Retention", and in paragraphs following in this section of the report in discussions on the drawing of Assembly 5.1 entitled, "Coal And Gas Gathering And Transfer System".

The Mining Rig's main housing framework should be equipped with a system of Leveling Jacks to assure that its setup at a proposed mine bore site is level and can be held stable. These are shown as Sub-assemblies 1.4.6.

Mobility, moving the rig from one bore to an adjacent bore, is planned through provision of wheels which will engage with the ground only after the Leveling Jacks have been retracted. The wheels are shown as Sub-assemblies 1.4.12.

Expertise required in the manufacture of the specific type of drilling rig required by the mining system is not considered to be critical or limited. There are a number of manufacturers in the U. S. who have the plant facilities and the engineering talent to provide the Rig on receipt of a set of assembly plans and manufacturing drawings. None of the sub-assemblies comprising the makeup of the entire rig are seen to be in a 'high technology' classification or anticipated to require special handling to comply with environmental and ecological restraints.

2.1 MINING RIG HOUSING: (ASSEMBLY 1.4)

The Rig Housing is designed to facilitate semi-automatic handling of the mining hardware; the loading and placement of the heavy components referred to as the 'Drive Stem' units and the Mine Anchor and Support Collars.

The design plan shown on Assembly 1.4 proposes an I-Beam structure, with provisions to bolt connect its basic components after its arrival at a proposed mining site. The basic components are identified in this section of the manual entitled, "Nomenclature", and are listed as sub-assemblies with identifying numbers 1.4.1 through 1.4.11 (See 2 sheets of drawings: detached packet).

Assembly 1.5, referred to as a Service Rail, is a component assembly comprising part of the Mining Rig's main housing framework, and is a part of Assembly 1.4, requirement on manufacturing and assembly procedure.

Particular attention is directed to Beam H of the Rig and the 720 inch radius for which a 'hard way roll' is required. After the 'roll' is made, the beam must receive multiple strands of sprocket chain. (Rex Chain and Chabelco attachments suggested.) The Chabelco attachments should be spaced at a minimum of 10 feet and welded to the flange of Beam H.

Assembly Plan 1.0.4 identifies all the pertinent sub-assemblies to be housed and/or supported by the Rig Housing to make it functional. The identifying numbers listed on the nomenclature sheet for Assembly 1.4 are noted on Assembly Plan 1.0.4 wherever a specific functional requirement in the operation of the Mining Rig exists.

The component sub-assemblies of Assembly 1.4 are intended to show the Mining Rig's general configuration and component hardware units necessary to the operational requirements and capabilities it must have. Dimensions and data shown are guideline information required in the preparation of drawings providing for the manufacture of the Rig.

2.2 KELLY AND KFLLY DRIVE ASSEMBLY

Most of the drilling rigs currently used by the industry have Kelly assemblies on rigs which are primarily designed to drill vertical or near vertical holes or shafts.

By contrast, the Kelly and drive assembly required by the Remote Controlled Mining System has to function with a rig designed to drill large diameter holes deviating from the horizontal. Discussions elsewhere in this manual reference the technique by which the heavy drive stem members driven by the Kelly, and the mine support collar units, are handled by the Mining Rig.

The Drive Stem members, particularly when mining, become an extended part of the Kelly. The rotational drive to the Drive Stem units originates with the Kelly Assembly. A division of this manual section, entitled "Kelly Rail", discusses the technique by which the Kelly is held in control. It stabilizes the Kelly Assembly torque-wise when delivering rotational drive to the Drive Stem units and also provides the means for moving the entire string, Kelly and Drive Stem units, forward as the mine heading advances.

The drawing of Assembly 1.2 (3 sheets) offers an illustration of the mechanical makeup of the Kelly and drive assembly, and the means through which operational control is achieved. Observation of these drawings and the data thereon disclose a network of thrust and radial bearings which support and stabilize the rotary drive delivered through a bull and pinion gear assembly. A 3.6 reduction in the bull and pinion gear assembly, powered by hydraulic motors, delivers the rotational drive to the Kelly 'Drive Stem' member, which in turn is connected and drives the string of Drive Stem units extending to and providing the rotary drive to the Mining Head.

The Kelly Crowd Housing, referred to as Assembly 1.2.2, contains the gear drive and other stabilizing hardware required to move the Kelly back and forth on the Kelly Rail Assembly (1.1).

The Kelly 'Drive Stem' member, as illustrated in the drawings of Assembly 1.2, provides the means to separation of the coal and gas recovered from the mine bore. The flighting shown as part of the Kelly Drive Stem, during rotation, brings the mined coal to the upward or rearward extension of the Kelly Stem, which is equipped with elongated slots, permitting the discharge of the coal. This end of the Drive Stem unit is enclosed with a cowling identified as item 5.1.2. Assembly drawing 5.1 illustrates particularly the technique through which the cowling handles the separated coal and gas discharged by the Kelly Drive Stem. The Cowling Assembly (5.1) is bolt connected to the Kelly Drive Assembly, and becomes an integral part of the assembly.

Coal in the discharge process from the Drive Stem enters the cowling and, through a duct at the lower end of the cowling, is directed in a flow line extending to a conveyor haulage system. The arrangement can be noted in assembly drawing 1.0.4.

The cowling (5.1.2) is also equipped with a duct at its upper side, which is connected to a flow line assembly having the express purpose of drawing off the gases emitted in the mine bore. The gas flow line assembly can also be observed on assembly drawing 1.0.4. The plan further provides that, wherever necessary, the velocity, confinement and direction of flow to the gases can be instrumented through the assistance of impeller type pumps, providing a slight negative pressure in the flow line hardware assembly.

The hardware comprising the Kelly, its 'drive mechanization' and housing arrangement are discussed below and illustrated in Assembly Drawings 1.2; detached. (See Sub-assemblies 1.2.1 thru 1.2.8.)

All of the gear and bearing units required in the Kelly Assembly are conventional industrial type items currently commercially available.

2.3 KELLY RAIL ASSEMBLY

The Kelly Rail is assembled to the Rig Base, pivotally mounted at its front end, on a housing shaft. It is hydraulically powered to raise and lower itself through a range of approximately 40° from its horizontal attitude.

The main function of the Kelly Rail is to provide a support base for:

1. the Kelly.
2. the Crowd Ring Assembly.
3. the means to guidance of the Kelly's powered movement necessary to advancing the Drive Stem units into the mine bore or retrieving them from a mined-out bore.
4. the means to handling and positioning the Mine Support Collars: freeing this requirement of assistance from 'outside' or standby equipment. The Kelly Rail's function in providing the handling means to the Mine Support Collars semi-automates the procedure of 'adding on' or 'taking off' of Support Collars as the mine bore advances or the mining hardware is withdrawn from it. This benefits, in good measure, the available time that the Rig can be productive in mining.

It is anticipated that the Kelly Rail's self-contained mobility features in providing handling means to the Mine Support Collars and the Drive Stem units will allow the equipment's availability to mining approximately 75% of the total operational mining time allotted to a given mine site.

Assembly Plan 1.0.4 illustrates, in phantom outline, a Mine Support Collar with an internally held Drive Stem brought into an attitude whereby its position can be maneuvered to permit connecting it and the Drive Stem to the 'string' assembly of each of these units extending into the mine bore. Conversely, the illustration also demonstrates the technique wherein the Kelly Rail, through its mobility on a vertical plane, provides the means to remove units of the support collars and the Drive Stem from their respective assemblies extending from the mine bore, and lower them for loading on a Service Rail Dolly (1.6) for removal from the Rig.

The design plan shown on the referenced assembly, and on drawings No. 1.1 through 1.1.8, proposes a special beam configuration type structure as the main housing.

Assembly Plan 1.0.4 shows the manner by which the Kelly Rail is pivotally mounted to the Rig Housing.

The pivotal action of the Kelly Rail is necessary to the handling requirements of the mining hardware, namely, the Drive Stem units and Mine Anchor and Support Collar units. The pivotal action is the means to position the Kelly Rail at the particular angle from the horizontal at which a mine bore is to be developed and, further, to raise and lower it in the process of handling and positioning the mining hardware components referenced above.

The mechanics to raise and lower the Kelly Rail propose the use of a hydraulic motor (Hagglund) which provides drive power to a complement of sprocket gears.

(See sub-assemblies 1.1.3 through 1.1.8.) During maneuvers, when the Kelly Rail is raised or lowered, the sprocket gears referred to engage with a double strand arrangement of sprocket chains which are part of and securely fastened to the Rig Housing. (See Beam H of Assembly Drawing 1.4.)

The design plan provides that the Kelly Rail houses gear racks (Sub-assembly 1.1.1.4) which provide the means for control and drive direction to the hydraulically driven Kelly Assembly and to stabilize it torque-wise when delivering rotational drive to the Drive Stem String driving the Mining Head.

After the Kelly Rail Assembly has been assembled to the Rig Housing, Assembly 1.8, referred to as the Kelly Rail Torsion Lock, requires mounting jointly to the Rig Housing and to the Kelly Rail. This is shown on Sheet No. 1 of Assembly Drawing 1.4. Sub-assemblies of Assembly 1.8 will require welding and/or bolt connections to the Kelly Rail Assembly. The illustration pertinent to the mounting of these is shown on the drawings of the Kelly Rail Assembly. The sub-assemblies are identified by numbers 1.8.2 thru 1.8.7.

Sub-assembly 1.1.1.3, referred to as the Crowd Cylinder Mount, is part of the Kelly Rail unit. It is discussed in paragraphs following since it is the main housing provision to an assembly on the Mining Rig referred to as the Crowd System.

2.4 DRIVE STEM UNITS CONFIGURATION AND MECHANICS

As stated earlier (Section I), the Drive Stem has a dual function in the Remote Controlled Mining System's operational plan. These are:

1. Remove the mined consist from the mine heading; and
2. Deliver rotational drive power to the Mining Head.

The design evaluation process selected random Drive Stem diameters which, under a mandatory 25% of maximum capacity loading, could remove the mined consist from a mine bore heading at a rate of approximately 135% of the consist production rate. This is required since the 'swell' of the mined consist will influence an increase in volume by approximately 35%. A mine consist production rate of 78 tons per hour (TPH), when mining is in progress, is considered. The 78 TPH factor is derived from the advance rate of 27 feet per hour (FPH) by a 9 ft. diameter Mining Head.

The evaluation process eliminated Drive Stem diameters smaller than 45 inches. These were determined as inadequate in the capacity as the 'cuttings' removal system for a mining production rate of 78 TPH.

Known required pertinent mechanical functions which governed the evaluations are:

1. The RPM of the Mining Head to be at approximately 7, to secure maximum service life and efficiency from the mining tools (Disc Cutters) on the Mining Head.
2. An RPM ratio of 1 to .736; Drive Stem over Mining Head. (Planetary gearing ratio through which the Drive Stem delivers rotary drive to the Mining Head.)

3. 7 RPM of Mining Head = 420 Rev./hr.
4. From above, a 27 FPH Mining Head advance rate requires;

$$\frac{27 \times 12}{420} = .771 \text{ inches of advance by Mining Head per Revolution;}$$

therefore, Mining Head advance rate = .771"/Rev.
5. Consider 45" diameter drive stem (U.D.) with a shell thickness of .312"; therefore, I.D. = 44-3/8"
 and area = 1546.6 in.²
6. Consider 25% of total drive stem area as 'available' and the average requirement to the conveyance of the mined consist; therefore, conveyance area = 386.65 in.²
7. Consider Drive Stem unit length 20 ft.
8. Conveyance Volume therefore per unit stem = $\frac{386.65 \times 20 \times 12}{1728} = 53.7 \text{ ft.}^3$
9. Consider Sp. gr. of coal at average of 1.5; therefore 91. lbs./ft.³
10. Ton loading per unit 'stem' = $\frac{53.7 \times 91}{2000} = 2.44$
11. To move 78 TPH each unit 'stem' must transfer

$$\frac{78}{2.44} = 32 \text{ times its 'available capacity' per hour;}$$

or once every 1.875/min.

12. Consider flighting pitch at $18\frac{1}{2}''$
 and revolutions required to unload 'stem' =

$$\frac{20' \times 12''}{18\frac{1}{2}''} = 13$$
13. From items 2 & 3, above, the Drive Stem RPM will = 9.5
 therefore, time required to unload the unit = $\frac{13}{9.5} = 1.36$ min.
14. Efficiency of Drive Stem conveyance over Mining Head

$$\text{Production} = \frac{\text{Mining Hd. Production}}{\text{D. S. Conveyance}} = \frac{1.875}{1.36} = 138\%$$

Mathematical calculations investigating feasibility and limitations on the Drive Stem as a unit, and as an assembled 'string', were made. These identified:

1. Haulage capacity versus the angle from the horizontal at which the 'string' and the internal flighting can function efficiently; particularly when the diameter alone of the individual units was considered.
2. Deflection characteristics were analyzed. These extended the data necessary to ascertain the minimum radius at which the 'string' assembly could be made to deflect; identifying thereby the minimum radius at which a mine bore could be made to extend in a coal deposit having either a geometric syncline or anti-cline structure.
3. The compressive and torsional load on the Drive Stem.
4. Load calculations on compression and tension values of the Drive Stem and Mining Head at static conditions. They considered the mass weight of the 'string', and its loading will have as a burden on the Kelly Assembly and/or the Mining Head as the angle from the horizontal deflects downward to i.e. 30^0 .

The calculations on these functions are included in Section III of this manual and are entitled, "Drive Stem -- Structural Limitations -- Drive Stem Casing"

In the interest of providing a means for connecting individual Drive Stem units at a minimum loss to mining production time, the mechanics and technique illustrated in Assembly Drawing 3.1 is proposed. The technique provides that alignment and rotational drive power be transmitted through dowel pins which are made to extend from the flange section of one Drive Stem unit through the flange section of the adjoining stem. The individual Drive Stems are held together in their end to end relationship by means of an 'interlocking' channel which engages and provides a shroud type cover over the entire circumferential distance of the joining Drive Stem flanges. The shrouding channel, in its closed and stem joining attitude, requires the placement of a single pin to lock the joints and the shroud together as an integrated assembly.

The hardware and assembly technique require an assembly time between any two Drive Stem units ranging to approximately 2 minutes. By contrast, a bolted connection would require approximately 12 minutes.

Calculations indicate that deflection value of a 45" O.D., 5/16" wall casing, considering a 20 foot long unit, are negligible (.004 inch). It is an objective of the mining system to follow and mine from a coal seam structure declining from the horizontal at an occasional or consistent downward curvature. Since deflection as a physical property of the individual Drive Stem units, when connected as a string assembly, will not allow an appreciable radial extension to a desired curvature, a supplementary provision is required to permit mining a declining curved seam.

The design plan for a string assembly of Drive Stem Units provides that a neoprene, or other durable and compressible material, in the 40 to 50 durometer hardness range be positioned as grommets between the flanges of joining Drive Stem Units.

As stated above, the Drive Stem Units are joined for rotational drive via dowel pins, and for end to end connection via a shrouding type channel encircling and confining the flanges on the stem ends. The shrouding channel permits the use of a grommet, placed between the flanged ends, to respond cyclically to compressive loading; a condition that will prevail when the 'string' assembly is made to rotate on a curved axis. The placement of a one-half inch thick grommet will permit the Drive Stem to perform, with a nominal loss of energy in transmission, on a curvature extended on an approximate 3600 foot radius.

The drawings (detached) of Assembly 3.1; Sub-assemblies 3.1.1 thru 3.1.7; provide illustration of the 'joint connecting system' and the required hardware. The planned use of the grommet, and the manner it is retained, is illustrated in that assembly drawing.

The individual Drive Stem Units are housed and made functional while mining, or when in transport to and from the Mining Rig, through their relationship with hardware on the Support and Anchor Collars. The manner and mechanics involved are discussed in this section of the manual under the caption, "Support/Anchor Collars -- Means to Housing and Stabilizing Drive Stem Units". The technique is illustrated in Assembly Drawing 2.1, sheet No. 3 (detached).

2.5 MINING HEAD -- CONFIGURATION AND MECHANICS

The cutting structure planned for the Mining Head is a 'rolling' Disc Cutter. Cutters of this type are only mildly sensitive to impact or shock loading, which oftentimes damages the conventional type cutter bit used on other mining equipment. The Disc Cutter, having a high resistance to breakdown, will enable the Mining Head to negotiate much greater distances, to the extension of the mine heading, than could be expected from the 'pick' type cutter bit. This allows planning longer mine bores; and more continuous and consistent mine production rates with less down time for cutter maintenance.

It is a known fact that the Disc Cutter requires a greater drilling thrust (normal loading) than the conventional cutter bits to achieve a planned production rate. On the other hand, rotational power requirements are less than common to Mining Heads equipped with the conventional type cutter bits. Coal, being a very soft material, is expected to require a drilling thrust on each of the Disc Cutters ranging from 2,000 to 4,000 pounds.

The Mining Head design plan for the RCMS and the 9 foot diameter mine bore (pilot study) proposed considers the use of 19 Disc Cutters and a center ploy. (The ploy is a device made to house two Point Bits which serve to mine the center portion of the heading confining the Pilot Hole.) It is anticipated that a normal loading from 2,000 to 4,000 per cutter will effect a production rate of approximately 3 tons per hour average per Disc Cutter. Pick type cutter bits are planned to act as sweepers directing the flow of material, through portals on the face plate housing the cutters, into the flighted section of the Mining Head Assembly.

A remote Controlled Mining System does not propose to have operating personnel anywhere near the heading vicinity. In the absence of personnel, the Mining Head's performance ability depends at all times that the following mining requirements and conditions prevail:

1. It receives drilling thrust in a continuous manner and in a measure adequate to achieve a planned advance rate of the heading.
2. The consist mined must be fairly uniform in its sized dimensions to assure that the conveying system will move the mined material free of any interference due to bulky or overly large parcels.
3. The mined consist is allowed to enter the conveyance compartment of the Mining Head in a controlled manner. Failure to do this could subject the conveyance system, extending to the portal, to malfunction in that it could become overloaded and subsequently plug the system.
4. The mining cutters and their service life must exceed the planned depth of the mine bore, and are never threatened in this behalf because of intrusive materials embedded with the coal.

Assembly drawing entitled "Mining Head", and designated as Assembly 4.1, presents a design configuration and the mechanical technique through which the primary requisites stated above are achieved. Design Plan 1.0.5 illustrates the assembly arrangements and the connection between the Mining Head, the Drive Stem units, and the Mine Bore Support System. Careful observation shows a flighting arrangement extending from the leading edge of the Mining Head and continuing in each of the Drive Stem members extending to the portal. The Plan further illustrates that the connection between the Drive Stem units and the Mining Head provides the means to the control of drilling thrust and rotational drive to the Mining Head.

With reference to the plan and the pertinent details, it should be noted that the assembly arrangement, when mining, never allows a separation between the Mining Head and the immediate trailing Anchor Collar. The Drive Stem connection with the Mining Head, providing its means to rotation, thrust bearings, along with sealing devices and their housing arrangement, assure the Mining Head to achieving

rotation without interference from the Anchor Collar immediately behind it to which it is telescopically mated.

As noted above, the Mining Head receives its rotary drive and the drilling thrust required by the Disc Cutters through its connection with the Drive Stem assembly. Stability to these functions delivered by the Drive Stem assembly is achieved through units referred to as 'Stabilizers' which are housed in the Mine Bore Support Collar units.

The spacing of the Disc Cutters on the Mining Head is planned to produce grooves and a subsequent breakdown of the mineral on the heading in a particle size ranging to 4 inches. The cutter spacing is such that in rotation the grooves' cuts are spaced 4 inches radially from each other. The mechanics of the mining plan require that the mined consist is directed to pass through portals on the face plate of the Mining Head to an inner compartment which is equipped with flighting providing the transport means to the connecting Drive Stem units.

The spacing of the cutter bits and the entry size of the openings (portals) to the inner flighted compartment of the Mining Head prevent any particle too large in size from entering that compartment. Particles released by the heading larger than the portals will be subjected to further breakdown in size by either impact from the Disc Cutters or from a sub-assembly referred to as "Cuttings Sizer and Scoop" (shown as Sub-assembly 4.1.16 on Assembly Drawing 4.1).

The design plan of the Mining Head provides a two-compartment arrangement of the Mining Head. This is important since none of the mined consist can be permitted to enter into the compartment housing the hardware associated to the rotary drive mechanics of the Mining Head. This, and other pertinent details important to the function of the Mining Head, are illustrated and identified on Assembly Drawing 4.1, detached, and included in the packet of drawings accompanying the manual.

2.6 MINE BORE SUPPORT COLLARS

The purpose of the Support Collar is to prevent the mine bore from collapsing, and thereby permit the mine heading to advance. The manner in which they accomplish this is discussed in Section I. (See Mine Bore Support System.)

The Support Collars' mechanical specifications must provide:

1. Structural design, shell thickness and ribbing re-enforcement adequate to withstand overburden pressures that exist and prevail at the mine site where the mining system is scheduled to work. An example of these and comparative data has been developed for various types of geological structures. It is submitted in the Appendix, under the caption "Overburden Impact On Mine Bore Support Systems".
2. An assembly whose longitudinal center line coincides with the longitudinal center line of the Mining Head when resting on the mine bore floor (invert), and at the same time have diametric clearance on the sides and the crown of the mine bore.
3. A rapid means to connect or disconnect the collars from one another as they are placed either into or withdrawn from a mine bore.
4. An assembly order and connection means to a mine bore support unit referred to as "Mine Bore Anchor Collars". The Anchor Collars are the key units through which groups of the Mine Bore Support Collars are thrust forward in or retracted from a mine bore.

Assembly Drawing 2.1, detached and included in the packet of drawings (3 sheets), provides a design plan for a Support Collar to serve a 9 foot diameter mine bore in a medium rock strength type overburden. The drawing is complete in detail on design requirements and includes procedural plans for its manufacture.

Primarily, the plans call for a true round cylinder, rolled from plate stock steel and welded at the joining seam. Internal units of continuous circular ribbing, formed by a 'hard way' roll of plate stock and welded to the cylinder, is planned as the re-enforcement to maintain collar roundness and structural soundness capable of withstanding burden pressures that may develop when the collar is placed into a mine bore.

2.6.1 SUPPORT/ANCHOR COLLAR -- MEANS TO HOUSING AND STABILIZING DRIVE STEM UNITS

Although the Support/Anchor Collars and the Drive Stem units each have specific and independent functions, it is an added function of the Support/Anchor Collars to provide housing means and the hardware to stabilize the Drive Stem (string assembly) when it is put to rotation while mining. The handling technique at the mine site, haulage, moving the 2 units either onto the Mining Rig for entry into a mine bore or removing them, requires that the Drive Stem units be placed inside each of the Support and Anchor Collars before they are placed on the Mining Rig for mining service.

Assembly Drawing 2.1, sheet No. 3, illustrates the position and use of Stabilizing Rollers to assist the rotational function of the Drive Stem units; and the provisional hardware with which to hold the units firmly in place while they are in transport.

The referenced drawing is self-explanatory in all details except that the Stabilizer Rollers and their housing are designed to permit the rollers a pivotal action. This permits the Drive Stem units and/or string assembly to move some distance, backward or forward, independent of the movement of the Support or Anchor Collars.

2.7 MINE BORE ANCHOR COLLARS

The purpose of the unit and its mode of operation is discussed in Section I of this report, and its placement in the mining system's hardware assembly is shown in Assembly Plan 1.0.6.

The collar is designed to permit anchoring with the wall of the mine bore, and through the anchor develop either a forward or reverse movement to the string of mine Support Collars extending from either, or both ends, of the Anchor Collar.

Sheet 1 of Drawing No. 2.2 offers an assembled view of the unit. Section A-A of the assembly view gives illustration to the hydraulic cylinders which provide the anchor means with the mine bore wall. The cylinders are substantially supported near the center area of the main housing assembly

2.2.1. It can be noted that the cylinder positions within this housing are diametrically opposed and connect with units referred to as Anchor Shoes.

Outward thrust from the cylinders moves the Anchor Shoes into engagement with the bore wall. They are hydraulically activated to provide an anchor thrust approximately one-third greater in value than the thrust the Anchor Collar develops on and through its longitudinal axis. The illustration referenced also shows in its plan view hydraulic cylinders mounted onto the main housing shell of the collar in an opposing attitude; 180° to each other.

These are hydraulically activated to provide either a forward or a retracting movement to a sub-assembly on the Anchor Collar referred to as a 'Tang Housing'; unit 2.2.3.2. This unit, in turn, connects with the first collar of an 'in line' string of mine bore Support Collars. Forward thrust to all the mine Support Collars in a given group is delivered through this connection.

The design characteristics of Assembly 2.2.3.2 are very important to the efficient function of the Anchor Collar. Particular consideration has to be given to the probability that as the Anchor Collar progresses through a mine bore, a small amount of material is certain to slough off. This material has to be allowed an escape passage in and through the area where the 2.2.3.2 assembly engages with the rest of the Anchor Collar; the 2.2.1 assembly. The design plan allows that any material sloughing off of the mine bore will be allowed entry into the inside of the main anchor shell (2.2.1). The plan view of the illustration shows the installation of a wiper element which is made to engage firmly with an inner ring assembly of the Tang Housing (2.2.3.2). The leading edge of the main Anchor Collar Housing is designed to permit entry of the sloughed off material as the Tank Housing is thrust forward, allowing a gap to develop between it and the leading edge of the main Anchor Collar Housing. The mechanics of the inch-worming system, explained earlier, necessitate that the Tang Housing be retractable. In the process of retraction, the loose material gathering between the two referenced units will be allowed to pass by the wiper element, thereby entering the inside area of the Anchor Collar's main housing. Passage of the loose material will prevent an accumulation which could become a hard compacted mass if not allowed a means of dispersment.

It is not expected that a great amount of material will be given to sloughing, because of the mining action at the mine bore heading; therefore limiting the amount of material that the Anchor Collar has to cope with and provide for disposal. (It should be noted that if disposal of the material is not allowed, and compaction occurs, it could pose restrictions to the free movement of both the Anchor Collar itself and the regular mine bore Support Collars.)

It is anticipated that some coal seam structures, imbedded either on a near horizontal plane or in syncline, will require some leeway in mechanics in the mining system to permit extending the mine bore in a curved or deflected line of advance. In other words, a turn radius will have to be negotiated. This, in essence, requires that a linear assembly of mine Support Collars, and the intermediate placed Anchor Collars, are 'flexible' in their mode of operation to permit this. It is expected that this will nearly always require the mine support system to be deflected, either upward or downward from a given line of advance (deviation on grade). The mine support system is designed to permit all units to engage with the floor of the mine bore in a manner so as not to interfere with the projected line of advance that the Mining Head must follow. In other words, the longitudinal axis, through the Support Collars and the Anchor Collars, coincides with the longitudinal axis through the Mining Head. To accomplish this, the Support Collars have 'shoe' elements which are radially distanced from the longitudinal axis of the mine bore to coincide with the radius of the rotating Mining Head. The Anchor Shoes, in a fully retracted position, provide an attitude to the Anchor Collar wherein its sides and the top Anchor Shoe are totally disengaged with the mine bore wall, leaving the lower Anchor Shoe engaged with the invert of the bore. This arrangement is seen as necessary to hold to a minimum the amount of attrition the hardware will cause as it advances or is withdrawn from a mine bore. The mechanical design of the Anchor Shoes, and their mounted arrangement as shown in drawing number 2.2, identify the clearance 'function' established between the bore wall and the hardware.

The 5 sheets of drawings illustrating the Anchor Collar and its mechanics provide data and information necessary to a suggested manufacture and assembly plan. The drawings are detached and contained in a separate packet.

2.8 MEANS OF CONNECTING THE SUPPORT AND/OR ANCHOR COLLARS

The conventional manner through which a number of tunnel bore support rings are connected to each other is generally accomplished with bolts and nuts. This technique is time-consuming and poses a lost time burden to mining production hardware. To gain the maximum potential in mine production, a support collar 'joint connection system' capable of reducing the 'lost' time element associated to bolts and nuts is planned and designed into the mine support system.

It should be noted that the mine support system, necessary to the RCMS, when propelled either into or out of a mine bore is in a work movement wherein the individual joints at their connection terminals never encounter forces that will tend to pull them apart. The anchor collars (which anchor to the mine bore wall) provide a push force to the entire mine support system regardless of the direction of movement.

The 'joint connection means' provides a network of dowel pins which in one attitude phase provide an interlocking connection between any two support collars; and, in a second attitude phase, permit the support collars to separate from each other. The dowel pins are spring bar loaded and normally retain the interlocking attitude referred to above. To achieve the second phase attitude, hydraulically activated plungers, housed in an auxiliary piece of equipment, force the dowel pins to recede from the interlocking attitude to a position which will permit the individual collar joints to be separated. The mechanics of the 'connection system' will permit assembling or disassembling an individual support collar from a 'string' in approximately 2 to 3 minutes of time, whereas a bolt and nut connecting system could require from 10 to 12 minutes.

The mechanics of the system are illustrated in Sub-assemblies 2.1 and 2.2, and in Sub-assembly 1.3, Drawings 1.3.1 through 1.3.2.3.2.

2.9 OPERATIONAL MECHANICS -- STRING ASSEMBLY OF SUPPORT COLLARS AND INTER-DISPERSED ANCHOR COLLARS (JACKING TECHNIQUE)

Assembly Plan 1.0.6 illustrates a typical mine support arrangement, wherein a group of Anchor Collars alternately grip the mine bore wall while a second group is 'relaxed' from the bore wall, and through that anchor provide a linear harmonious thrust function extending from either end of each of the Anchor Collars in the group. For purposes of discussion, only 2 groups will be considered. One group, starting with Anchor Collars No. 1 and No. 1A as the lead members, would further consist of Anchor Collars 3, 5, 7, 9, etc.

The second group, starting with Anchor Collar No. 2 as the lead member, would further consist of Anchor Collars 4, 6, 8, 10, etc.

Assembly Plan 1.0.6 illustrates Anchor Collars No. 1, No. 1A and 3 of, for example, Group A; and identifies Anchor Collar No. 2 of Group B. Notations on the Drawing accompany the Anchor Collars and their individual placement positions within the string of the regular mine Support Collars.

The illustration further depicts an arbitrary arrangement, wherein each Anchor Collar function is responsible to provide thrust to the movement of 10, 20 foot long mine Support Collars. An exception to this provision exists with the performance of Anchor Collars No. 1 and No. 1A. The exception to the function of Anchor Collars 1, and 1A, is discussed below.

The thrust of Anchor Collars No.1, 1A, and 3 (phase 2 of their cyclic operation) comprises the first phase of the cyclic operations (forward movement) to Anchor Collars 2 and 4 and their adjacent Support Collars; accordingly:

- : Anchor Collars No. 1 and 1A, WHEN ADVANCING -- provide drilling thrust to the Mining Head only.

- : Anchor Collars No. 1, and 1A, WHEN WITHDRAWING FROM A MINE BORE -- provide thrust to Mine Support Collars 2 thru 10 and Anchor Collar No. 2.
- : Anchor Collar No. 3 -- WHEN ADVANCING IN THE MINE BORE, in synchronization with Anchor Collars 1 and 1A, 5, 7, 9, etc., -- provides forward thrust to the Mine Support Collars 20 down thru 11 and to Anchor Collar No. 2.
- : Anchor Collar No. 3 -- WHEN WITHDRAWING FROM A MINE BORE, in synchronization with Anchor Collars 1 and 1A, 5, 7, 9, etc., -- provides thrust to Mine Support Collars 21 thru 30 and Anchor Collar No. 4. (Only Support Collar 21 is shown.)

The thrust of Anchor Collars 2, 4, 6, 8, etc. (phase 2 of their cyclic operation) comprises the first phase of the cyclic operations (forward movement) to Anchor Collars 1 and 1A, 3, 5, 7, 9, etc.;

Accordingly:

- : Anchor Collar No. 2 -- WHEN ADVANCING IN THE MINE BORE, in synchronization with Anchor Collars 4, 6, 8, 10, etc., -- provides forward thrust to Mine Support Collars 10 down thru 2 and to Anchor Collars No. 1 and 1A.
- : Anchor Collar No. 2 -- WHEN WITHDRAWING FROM A MINE BORE, in synchronization with Anchor Collars 4, 6, 8, 10, etc., -- provides thrust to Mine Support Collars 11 thru 20 and to Anchor Collar No. 3.
- : Anchor Collar No. 2 (not shown) -- WHEN ADVANCING IN THE MINE BORE, in synchronization with Anchor Collars 2, 6, 8, 10, etc., -- provides forward thrust to Mine Support Collars 30 down thru 21 (only 21 is shown) and to Anchor Collar No. 3.

: Anchor Collar No. 4 -- WHEN WITHDRAWING FROM A MINE BORE, in synchronization with Anchor Collars 2, 6, 8, 10, etc., -- provides thrust to Mine Support Collars 31 thru 40 and to Anchor Collar No. 5 (not shown).

The jacking plan outlined above presents a 2-phase, cyclic operational, plan to the movement of the mine support system into and out of a mine bore. The plan can be modified to operate as a 3 or 4-cycle system. In that framework, for example, a 4-cycle system would provide alternating movement cycles to 4 groups of Support Collars, and the Anchor Collar for each group.

The synchronization of the advance rate of the Mining Head to the advance rate of each of the cyclic movements of the groups of Support Collars is easily achieved. The advance rate anticipated at the mine heading will range from 20 to 30 feet per hour, whereas the hydraulics providing energy to the Mine Support Collar's jacking requirement can be expected to accomplish approximately 40 feet per hour, should it be necessary.

The function of Anchor Collars 1 and 1A are slightly different than the functions of all the other Anchor Collars. A 2500 ft. long mine bore will have 12 Anchor Collar 'stations' involving Anchor Collars 2 thru 12. These will be required to provide either a forward or retreat movement to the Mine Support Collars positioned between them. Anchor Collars 1 and 1A will provide a continuous advance movement to the Mining Head. The milli-second delay connected to the switching of valve positions on the hydraulic circuitry can be adjusted in a compensation manner so that one of the Anchor Collars will always be applying forward thrust to the Mining Head, regardless of the ground conditions at the Mine Heading Vicinity.

As the last jacking station when retreating (removing the mine support system) from a mine bore, the 2 Anchor Collars set adjacent to each other provide the

required cyclic movement and jacking power to move the string of Mine Support Collars (1 thru 10) ahead of them toward the mine adit. There, function in this behalf is especially important, in the retreat process, after Anchor Collar No. 2 has been removed from the string after passing through the adit. The energy required to pull the last 10 Mine Support Collars, an Anchor Collar and the Mining Head out of a mined-out bore, declining, for example, at 20° from the horizontal, could be beyond the thrust capacity of the Crowd Ring Cylinders (Assembly 1.3.2 on the Mining Rig). This circumstance could develop if the soil conditions in the vicinity of the adit area are unstable, causing an abnormal amount of overburden pressure on the Mine Support Collars.

The assembly of Anchor Collar No. 1A, immediately next to Anchor Collar No. 1, provides a cyclic thrust means to the string of Mine Support Collars until each has been withdrawn from the Mine Bore. The 'pull' energy required of the Crowd Ring, Assembly 1.3.2 on the Mining Rig, would be in a measure sufficient to move Anchor Collars 1 and 1A, and the Mining Head from the mine bore.

2.10 CROWD SYSTEM

FUNCTION AND MECHANICS

The Mine Support Collars, extending from the Mining Rig to the Anchor Collar nearest the adit of the mine bore, depend on the Crowd System and its hydraulic energy source as the thrust means through which they are moved forward or backward in the mine bore; following, of course, a prior 'cyclic' forward or backward movement of that Anchor Collar. The principal device in the system is a unit referred to as the "Crowd Ring".

The Crowd Ring can engage with either end of a Mine Support or Anchor Collar. It has an overall movement range, in line with the plane of the Kelly Rail, of no less than 270 inches (22.5 ft.). Its mobility is hydraulically energized

and controlled. Its specific function during all phases of the mining system's technical procedures, when either advancing a mine bore or retreating from it, is discussed in detail in this section of the manual under sub-headings of the caption, "Handling Procedures of the Mining Accessories By The Mining Rig". (Please note the sub-headings listed as items 1 thru 6 in that discussion.)

MECHANICS:

The 'Crowd Ring' unit of the Crowd System is designed slightly larger in diameter than the Anchor and Support Collars. This permits positioning it at either end of those units, pending the desired direction of movement.

It engages with either an Anchor or a Mine Support Collar by means of hydraulically controlled plungers. These are dowel pins, 2 inches in diameter, which, when activated hydraulically in one manner, engage dowel pin holes of equal diameter on the collars (located on each end), thereby locking the Crowd Ring to the Collar.

In a second manner of operation, the plungers, when activated, engage and dislodge special sets of dowel pins housed by each individual collar in such an attitude that they interlock with an adjacent collar in tandem at any time they are made to engage each other; their ends in a telescopic manner.

The Mine Support and Anchor Collars are proposed as 240 inch (20 ft.) long units. Thus, to enable the movement of any of the collars a distance equal to its length, the Crowd System has to be mobile and capable of delivering hydraulic force over an equal distance, plus some leeway to counter incidental requirements in handling the Mine Support and Anchor Collars. Design provisions, therefore, consider a 270 inch movement range to the Crowd System.

Housing and mounting arrangements for the hydraulic cylinders providing mobility and the thrust capacity of the Crowd System can be observed in the drawing Assembly 1.1; Drawing No. 1.1.1.3.

2.11 COAL AND GAS GATHERING AND TRANSFER SYSTEM

Discussions and illustrations in other portions of this manual illustrate the manner in which mined coal is transferred via an internally flighted drive stem member from the heading to the surface or adit. It is expected that gases, particularly methane, released at the heading and, through the formation pressure existing at the heading area, will be instrumented to flow toward the portal of the bore. They will be confined within the mine support system and within the drive stem members transferring the mined coal. This assumption is based on methane having physical properties of .554 in specific gravity and .0424 as the average density after its release from the coal formations in an approximate 70°F temperature environment.

Preliminary design plan 1.0.4 offers an illustration of the mine support system extending from the mine bore and the equipment assembly plan existing between the mine support system, the drive stem members, and the Kelly Assembly (1.2). The Kelly Assembly, as noted elsewhere, is the mechanical assembly of the mining technique which transmits rotary drive to the drive stem member.

All of the mined coal and the released mine gases are directed through the Kelly Assembly and discharged from it through mechanics identified in preliminary design plan 1.0.4 and illustrated in detail in drawing No. 5.1.

The manner in which the separation of coal and gas is accomplished is illustrated in that drawing.

The basic plan provides that while mining is in progress at the heading, a unit referred to as "Support Collar Shroud" (5.1.1) is hydraulically activated to engage with and provide a cover over the last mine support collar extending from the bore. The cover is held in engagement with that support collar via

hydraulic cylinder pressure sufficient to contain the gas pressure existing within the support collar. The entire coal and gas gathering and transfer system is assembled to the Kelly Assembly (1.2). This provides the means for constant contact between the support collar shroud and the last support collar extending from the mine bore since it and the Kelly Assembly advance with the advance of the mine bore heading.

Gases confined within the mine support collars are free to be exhausted through flexible pipelines referred to as "Shroud Exhaust Pipe" (5.1.1.1) extending from the shroud envelope covering the end of the mine support collar to a unit referred to as the "Kelly Stem Cowling" (5.1.2), which is positioned at the back or upper side of the Kelly Assembly. The Kelly Stem Cowling is a chamber-like unit which totally encloses the back side, or uppermost extension, of the Kelly Assembly's Kelly Stem (1.2.1).

Gas entering the Kelly Stem Cowling through the flexible pipe members is free to exhaust through a "Gas Venting Pipe" (5.1.2.2) at the upper end of the Kelly Stem Cowling. Preliminary design plan 1.0.4 shows provisions for a turbine type pump which can, if necessary, develop a negative pressure within the Kelly Stem Cowling. The pump can further direct the flow of the gas to downstream processing hardware necessary to its preparation as a commercially useful item.

The rotary drive member of the Kelly Assembly identified as the Kelly Stem (1.2.1), through its internal flighting, directs the coal to the upper section of the unit. The upper end contains a series of elongated slots which permit the coal to discharge from the rotating Kelly Stem at its bottom side. The discharge occurring within the Kelly Stem Cowling provides transfer means from the cowling through a duct positioned at the bottom side. It is referred to as the "Coal Discharge

Duct" (5.1.2.1). The duct extends and discharges the coal onto a belt conveyor system per the illustration and preliminary design plan 1.0.4.

2.12 HANDLING PROCEDURES OF THE MINING ACCESSORIES BY THE MINING RIG

The mining technique requires, in the interest of maximum mine production, that the Mining Rig be made available to mining approximately 75% of its 'on site' time. The net 'on site' mine production time can be scheduled to accomplish this, due to provisions in the design of the Mining Rig which semi-automates the handling requirements of the principal hardware components of the Mining System.

Aside from the Mining Rig's performance capacity, it is also important to assure stable adit conditions, so that once a mine bore is started, it will be void of interruptions due to unstable ground at the adit. The safeguard desired requires the placement of an adit casing before the mining operation starts, and retrieving it after the mining equipment has been withdrawn from a mine bore.

In pages following, the operational technique implemented by and through the Mining Rig are detailed. Provided are specific suggestions for the handling of:

1. The Adit Casing; under the caption, "Placement of the Adit Casing and Its Removal".

2. The Mining Head; when starting a bore, under the caption, "Placement and Handling of the Mining Head and Anchor Collars No. 1 and 1A When Starting A Mine Bore".
3. The Mine Support and Anchor Collars, and the Drive Stem units; when advancing in a mine bore, under the caption, "Handling of the Mining Hardware When Advancing the Mine Bore".
4. The Mine Support and Anchor Collars, and the Drive Stem units; when withdrawing from a mine bore, under the caption, "Handling of the Mining Hardware When Withdrawing From A Mine Bore:."
5. The Mine Support Collars adjacent to Anchor Collars 1 and 1A; under the caption, "Withdrawal Handling of the Mining Head, Anchor Collars 1 and 1A and the Adjacent Support Collars".
6. Anchor Collars 1 and 1A and the Mining Head from the adit; under the caption; "Withdrawal of Anchor Collars 1 and 1A, and the Mining Head".

The function of Anchor Collars 1 and 1A are crucial to the withdrawal of all the mining hardware ahead of Anchor Collar No. 2 (heading direction). Discussion on operational procedure is therefore included, as noted above, in separate detail to help isolate and identify proper concern.

2.12.1 PLACEMENT OF ADIT CASING AND ITS REMOVAL

OPERATIONAL PROCEDURE

Following the development of the pilot hole through the center of the coal seam and the placement of the small diameter casing which provides the guidance means to the Mining Head, the mine bore adits specifically require the following attention:

1. Provisions to stabilize the mine bore adits against caving; and
2. A procedure for positioning the Mining Head to align with the longitudinal axis of the planned bore.

Prior to the start-up of mining from a planned bore, an adit casing will shelter the adit entry against caving. Caving, should it occur, could interfere with the movement of the mine Support Collars into and out of the mine bore. It is therefore suggested that a steel casing be positioned at the adit entry. The unit can be drilled into place with the Mining Rig. The hardware assembly required to do this is illustrated in Fig. 10. The casing I.D. and its internal flighting should be 1 inch larger than the Mining Head and should be drilled into the adit soil or mineral from 8 to 12 feet, pending the strength of the adit soil or mineral formation, and the height of the bench wall.

The leading edge of the Casing should be serrated (cutting Teeth formed) with hard facing applied to the tips of the serrations so that they will sustain against rapid breakdown from wear.

An adit Casing is planned and intended as a temporary installation. Pending unforeseen circumstances, its withdrawal from the adit should be planned, and its re-use scheduled.

Following below is a suggested procedure for the placement of the adit casing.

1. Disconnect the guidance hole drill pipe at the adit entry.
(Remove the first 20 ft. long joint below the Kelly of the Pilot Hole Drilling Rig.)
2. Remove the Pilot Hole Drilling Rig.
3. Excavate (Jack Hammers) an entry port area to receive the leading end (Approximately 1 ft.) of the casing (see serrated edge). Assure that the adit entry has proper clearance; center of Guidance Hole to floor horizon, and the diameter of the excavation is adequate to receive the adit casing.
 - 3.1 Proceed with the excavation producing a hole diameter of approximately $8\frac{1}{2}$ ft., and extend it the depth at which the Adit Casing will be set.
4. Move up the Mining Rig; extend the leveling pads and level the Rig across the sides and corners.
5. Lower the Kelly Rail (1.1.1) to horizontal attitude and release the Collar Support Carriage (1.1.2), setting it into the Collar Loading Carriage (1.6.1).
6. Raise the Kelly Rail to approximately 15° from the horizontal.
7. Extend the Crowd Ring (1.3.2) to its maximum height or distance.
8. Withdraw the Collar Loading Carriage to the end of the Collar Loading Track.
9. Install the Caisson Stabilizer Rollers into the Support Collar Guide Housing. (See Drawing 1.7.1.1; sheet No. 2.)

ADIT CASING AND HARDWARE ASSEMBLY REQUIRED TO DRIVE --
 "DRILL" IT INTO BENCH FACE; AND TO REMOVE THE ADIT CASING AFTER
 A BORE IS "MINED" OUT.

PLACEMENT OF ADIT CASING

FIG. 10

10. Bolt connect the Caisson (flange) to the Caisson Sub (1.7.2). (This can be done either away from the Mining Rig, or with the two members positioned on the Collar Loading Carriage.)
11. Position the Caisson and bolt connected Caisson Sub on the Collar Loading Carriage; centering it on the Collar Support Carriage (1.1.2).
 - 11.1 Move the Carriage in and under the Kelly Rail, at the approximate area where the Collar Support Grapples will be when the Kelly Rail is lowered.
12. Lower the Kelly Rail and engage the plungers (1.3.2.3.1) on the Crowd Ring with the dowel pin holes on the Caisson Sub. Use the Collar Support Carriage Hydraulic Cylinders to provide the alignment so that the Crowd Ring can slip over the end of the Caisson Sub.
13. Raise the Kelly Rail to the angle from the horizontal at which the mine bore will be developed.
14. Under Crowd Ring Control, move the Caisson Assembly (Adit Casing and Caisson Sub) toward the adit area. Keep a close surveillance on the entry area where the Caisson engages the Caisson Stabilizer Rollers in the Guide Housing (1.7.1.1). Proceed with the movement until the Adit Casing engages the adit heading.
15. Lift the Caisson Drive Sub (with the hoist line), and align it to the Caisson Sub. Bolt connect it.
 - 15.1 Connect the overhead hoist line, with the chain length (3.1.5) attached, and connect the chain ends to the Lock Ring on the Kelly Sub.

- 15.2 Close the Lock Ring with force from the hoist line, and insert the pin (3.1.3.3) and the keeper (3.1.3.3.1) as shown on the drawing of assembly 3.1.
16. Bring the Kelly Assembly (1.2) down and firmly engage the Kelly Drive Stem Sub with the Caisson Drive Sub. (Note: The dowel pin holes on the Caisson Drive Sub must align.)
17. Start rotation to the Adit Casing (2 to 3 RPM), applying light thrust by the Kelly Assembly until the casing's cutting teeth have developed a relatively smooth and uniform cutting action around the entire peripheral area of the bore's gauge.
 - 17.1 Should boulders be encountered, withdraw the casing from the bore, position a temporary roof shelter, and break down the boulder or remove it through the use of a Jack Hammer. (The Adit Casing, during the process of placing it, should not be allowed to become deformed from true round.)
 - 17.2 If the area is free of drilling problems, proceed and drive the Adit Casing to the total planned depth.
18. After the Casing is set in place, unbolt the Caisson Sub from the Adit Casing and, with the Kelly Assembly, move the Caisson Sub back up the Kelly Rail and engage it with the extended Crowd Ring.
19. Remove the Caisson Drive Sub from its engagement with the Kelly Drive Stem Sub, and lower it to the ground with the Hoist.
20. Engage the Collar Support Carriage with the Caisson Sub.

21. Lower the Kelly Rail and set the Collar Support Carriage and Caisson on the Collar Loading Carriage.
22. Release the Crowd Ring from the Caisson Sub.
23. Raise the Kelly Rail to approximately 15° from the horizontal.
24. Withdraw the Collar Loading Carriage to the end of the track (1.5.1) and remove the Caisson Sub.

The discussion above treats a suggested procedure for placing a casing into the adit as a support element. Its withdrawal, after a mine bore has been completed, can also be accomplished with the Mining Rig. The recovery procedure requires implementation in reverse order of most of the procedural steps outlined above. The primary concern being, to re-connect the adaptor caisson and the Caisson Sub. This provides the means to providing the simultaneous action of 'pull' and rotation to the casing, and to ultimately place it on the Collar Loading Carriage (1.6.1) for removal from the mined-out bore site.

2.12.2 PLACEMENT AND HANDLING OF THE MINING HEAD AND ANCHOR COLLAR
UNITS NO. 1 AND NO. 1A WHEN STARTING A MINE BORE

OPERATIONAL PROCEDURE

The mechanics of the Remote Controlled Mining System require a Mining Head fairly simple in its configuration in contrast to those units assembled to current tunneling machines or underground mining machines. This is due to the absence of a driving power plant as part of its assembly in the immediate Mine Heading Vicinity. This, in turn, permits the construction of a Mining Head fairly compact in design configuration, and in a weight measure only slightly higher than that common to the Mine Bore Anchor and/or the Mine Bore Support Collars. Its weight and size compactness permit its handling and -- setup to start mining -- requirements as a function accomplished by the Mining (Drilling) Rig.

The suggested procedure to place the Mining Head onto the Mining Rig, and from there into the Mine Bore, is as follows:

1. Check the Assembly of the Mining Head (Assembly 4.1). Make sure the Disc Cutters are bolted down securely; the Cutter Bits are secure in the holders; the Guidance Bushing rotates freely; the Planetary Gear compartment of the Mining Head is loaded with grease; and that the Load Cell has been calibrated to coincide with readings on the operator's control panel.
2. Move the Service Rail Dolly (1.6 Collar Loading Carriage), via the winch line system, into position under the Kelly Rail, as illustrated in Assembly Plan 1.0.4.
3. Lower the Kelly Rail (1.1.1) to a horizontal attitude (down position).

- 3.1 Release the Collar Support Carriage (1.1.2) from its hydraulic lift cylinders (1.1.2.1), and assure it seating properly in the Service Rail Dolly (1.6).
4. Raise the Kelly Rail (1.1.1) to an elevated position (approximately 15° from the horizontal), and move the Crowd Ring (1.3.2) to the top side of the Kelly Rail and next to the Kelly Assembly (1.2).
5. Move the Service Rail Dolly (1.6), with the Support Carriage (1.1.2) attached, to the end of the Service Rail (1.5.1).
6. With a minimum 25-ton Mobile Crane, position Anchor Collar No. 1 (2.2) with its Adaptor Sub -A- (2.2.8) end facing toward the front of the Mining Rig, and the Anchor Shoe, Sub-Assembly 2.2.2, is facing upward at true vertical.
7. Pick up the Mining Head with the Mobile Crane, and lower it into a position ahead of the Anchor Collar, and aligned so that it can be telescopically mated to Sub-Assembly 2.2.8 of the Anchor Collar.
8. Move the Anchor Collar, via the Dolly Winch (1.5.2), forward to engage with the Mining Head.
 - 8.1 Position and bolt connect the Load Cell Housing (3.1.7) to the Mining Head Drive Housing (4.1.5) and to the Drive Stem Flange (See Assembly Drawing 1.0.9).
 - 8.2 Bolt connect the Limit Switch Assemblies, 9.1.2 and 9.1.2.1 to their mounting panel (9.1.1); then bolt connect panel 9.1.1 to Anchor Collar No. 1, as shown in Assembly Plan 1.0.5.

- 8.3 Provide a temporary chain connection, tying the Mining Head to the Anchor Collar so that they will not separate during the movement procedures 9 and 10, noted below.
9. Move the Service Rail Dolly with the Mining Head Assembly, via the Winch (1.5.2), into position under the Kelly Rail, as illustrated in Assembly Plan 1.0.4.
 10. Lower the Kelly Rail. It will straddle the Mining Head Assembly on the Dolly. Before lowering the Kelly Rail, be sure the Crowd Ring (1.3.2) is fully extended by the Hydraulic Cylinders (1.3.2.1).
 11. Connect the Support Carriage (1.1.2) to its Kelly Rail hookup.
 12. Position the Anchor Collar (on the Support Carriage) with the Hydraulic Cylinders (1.1.2.1) and the Support Grapples (1.1.2.2) so that the Adaptor Sub -B- (2.2.9) will align to receive the Crowd Ring (1.3.2).
 13. Engage the Crowd Ring with Adaptor Sub -B-, via the Hydraulic Cylinders (1.3.2.2) and Aligning Shoes (1.3.2.2.1).
 14. Place the grommet (shown as item 3.1.4 on drawing of assembly 3.1, Sec. D-D) over the end of the Drive Stem Flange, aligning the holes in the grommet with the dowel pins on the Drive Stem Flange.
 - 14.1 Engage the Kelly Sub (1.2.5) of the Kelly Assembly (1.2) with the Drive Stem. Make sure the dowel pins and dowel pin holes align properly before applying pressure to the engaging Kelly Sub, via the Kelly Assembly Drive.

- 14.2 After the joint is firm, lower the overhead hoist line, with the chain length (3.1.5) attached, and connect the chain ends to the Lock Ring on the Kelly Sub.
- 14.3 Close the Lock Ring, with force from the hoist line, and insert the Pin (3.1.3.3) and the Keeper (3.1.3.3.1) as shown on the Drawing of Assembly 3.1.
- 14.4 Disconnect the chain (3.1.3) and retract the hoist line.
15. Bolt connect the Support Beam (1.7.1.1.1) for the Mining Head to the Support Collar Guide (1.7.1.1). (See Assembly Plan 1.0.4.)
16. Raise the Kelly Rail (1.1.1) to mining (drilling) attitude.
 - 16.1 Through coordinated movement of the Kelly Assembly and the Crowd Ring, move the assembly until the Mining Head engages and rests on the Support Beam (1.7.1.1.1) of the Support Collar Guide (1.7.1.1). (The Anchor Collar will be supported by Rig Base Collar Support 1.4.2.)
17. After the mining attitude (Drilling Angle) is attained, simultaneously move the Anchor Collar (now held by the Crowd Ring) and the Mining Head, with the attached Drive Stem (now connected with the Kelly Drive Assembly), downward on the Kelly Rail.
18. Undo the temporary chain connection tying the Mining Head to the Anchor Collar (See procedure item 8.2).
19. Undo the Lock Ring on the Kelly Sub (1.2.1.1) and free it from its Drive Stem Connection.

20. Drive the Kelly Drive Assembly upward on the Kelly Rail to maximum extension.
21. Extend the Crowd Ring (1.3.2) upward to close proximity of the Kelly Drive Assembly.
22. Draw up the Collar Support Carriage (1.1.2) to its maximum 'up' position.
23. Lower the Kelly Rail (1.1.1) to a horizontal attitude.
24. With the completion of procedure No. 23, Anchor Collar No. 1A, and the Drive Stem it contains internally, must be brought up, positioned, and connected; Anchor Collar No. 1 to Anchor Collar No. 1A, and the Drive Stem to its counterpart extending through and from Anchor Collar No. 1. The procedure to the handling and the connection of these components to each other involves repeating procedural steps 3.1, 4, 5, 6, 9 thru 14.4, and 16; allowing, of course, that in steps 6 and 10, the hardware involved is Anchor Collar No. 1A.
25. After procedure 16, proceed as follows:
26. Extend the Stops (1.4.2.1) housed on the Mining Rig.
27. Through coordinated movement of the Kelly Assembly and the Crowd Ring, move Anchor Collar No. 1A down the Kelly Rail, allowing the Drive Stem it contains internally to advance slightly ahead of the Anchor Collar since the Drive Stem must be connected to its counterpart in Anchor Collar No. 1 before the two Anchor Collars are connected. The Anchor Collar will engage the Stops 1.4.2.1.

28. After the Collar has engaged the 'Stop', turn the power switch to the solenoid in control of the Crowd Ring's hydraulic circuitry to the 'off' position.
29. Extend the extendible floor of the Drive Stem Service Platform (1.4.8.1), housed on the Mining Rig, inward to its maximum extension.
30. Assure that the dowel pins and the dowel pin holes on the Drive Stem Units align to each other.
 - 30.1 Engage the Drive Stem in Anchor Collar No. 1A with the Drive Stem in Anchor Collar No. 1.
 - 30.2 After the joint is firm, lower the overhead hoist line with the chain length (3.1.5) attached, and connect the chain ends to the Lock Ring connected to the Flange of the Drive Stem in Anchor Collar No. 1A.
 - 30.3 Close the Lock Ring with force from the hoist line, and insert the Pin (3.1.3.3) and the Keeper (3.1.3.3.1).
 - 30.4 Disconnect the chain (3.1.5) and retract the hoist line.
31. Connect the hydraulic lines; the lines extending from Anchor Collar No. 1 to Anchor Collar No. 1A; and from Anchor Collar No. 1A to the main Mine Support System circuitry. Open the valves on the line in Anchor Collars No. 1 and 1A.
 - 31.1 Connect the electrical lines, extending from the Limit Switches mounted on Anchor Collar No. 1, with the circuit lines extending to the microprocessor controlling the Servo Unit on the Support System's hydraulic drive.

- 31.2 Connect the Load Cell Lines between Anchor Collars No. 1 and 1A, and then connect with the line extending to the Drilling Thrust Monitoring Gauge on the Computer Control System.
32. Withdraw the extendible floor of the Drive Stem Service Platform (1.4.8.1).
33. Turn the power switch referred to in procedure step 28 to the 'On' position.
34. Move Anchor Collar No. 1A upward slightly with the Crowd Ring so as to free the Anchor Collar from the 'Stop' (1.4.2.1) on the Rig.
 - 34.1 Recline the stops into their 'recess'. (Manual Operation)
35. Under Crowd Ring Hydraulic Control, move Anchor Collar No. 1A downward to engage slightly its leading edge with Adaptor Sub -B- (2.2.9) of Anchor Collar No. 1.
 - 35.1 Assure that the spring loaded locking dowel pins and the dowel pin holes on the mating ends of the collar units are in alignment (longitudinally), and that when the ends are telescopically mated, each of the dowel pins will engage with their counterpart dowel pin hole.
 - 35.2 With pressure from the hydraulically operated Crowd Ring, telescope the end of the 'new' Mine Support Collar over the end of the collar extending from the mine bore.
 - 35.3 Make sure the spring loaded dowel pins of Sub -A- on Anchor Collar No. 1 have engaged and locked with the dowel pin holes of Sub -B- on Anchor Collar No. 1A.

36. With Crowd Ring Hydraulic Control, move the entire Assembly, Mining Head and the 2 Anchor Collars upward slightly, so as to free the Mining Head from the Support Beam (1.7.1.1.1) on the Support Collar Guide.

36.1 Unbolt and remove the Support Beam (1.7.1.1.1).

37. Set the Computer Program Control on 'Adit Advance'. (This allows manual control, by the operator, on the forward movement of the Kelly Assembly, and rotational drive power from it to the Mining Head through the Drive Stem Units.)

38. Synchronize the Crowd Ring's forward movement rate so that the Anchor Collars, with which it is connected, will move forward with the Mining Head at the same rate that the adit is to be drilled.

39. Start rotation of the mining, and proceed with drilling on the adit until Anchor Collar No. 1 is totally within the adit casing and the Crowd Ring has been retracted to its minimum extension.

After Anchor Collar No. 1 has been 'drilled' in, mining from the projected bore can proceed on a scheduled basis. The procedure program providing for the placement of Mine Bore Support Collars and Anchor Collars required as the mine bore extends is discussed under captions, in pages following, treating the handling of the hardware units.

The next requirement following procedure 39 is to place a Mine Support Collar into the Drilling Assembly. The discussion under the caption "Handling of the Mining Hardware When Advancing The Mine Bore" treats the suggested procedure.

The suggested procedure to the withdrawal of the Mining Head from a Mined-out Bore is discussed under the caption following entitled, "Withdrawal Handling of the Mining Head".

OPERATIONAL PROCEDURE

The design plan of the Mining Rig (Drilling Rig) provides a semi-automatic self-contained means for positioning the Mine Support Collar units and the Drive Stem units on the Rig and then into the attitude they must have to permit connecting each of these units to the string of each entering the mine bore.

Assembly Plan 1.0.6 illustrates the hardware comprising the mine bore support system. It identifies the cyclic manner by which the Anchor Collars provide movement, forward or backward, to the mine support system. The discussion "Anchor Collar -- Operational Mechanics" provides support data to the drawing.

Part of the problem, relating to handling, was resolved with specifications that the Mine Support Collars, the Anchor Collars, and the Drive Stem Units, be of equal length, and that each of these units be added onto their respective 'strings', extending into the mine bore, as a single operational procedure.

Both of the hardware systems, having each of their component units identical in length, permit placing one inside the other (the Drive Stem units inside of the Mine Support Collar and or Anchor Collar units) before they are brought onto the Mining Rig for placement to the mine bore. Preliminary Assembly Dwg. 2.1, Dwg. No. 2.1.2 offers an illustration of the composite assembly referred to above, and the mechanics by which the Drive Stem Units are stabilized and held in a desired attitude, while in transfer to and on the Rig or when mining is in progress so that they share a common longitudinal center line.

Following below is an outline of a step by step procedure suggested to the handling (positioning onto the Mining Rig) of the composite assembly and the procedure to connecting each of the individual units to their respective string assemblies extending into the mine bore.

Please refer to Assembly Plan 1.0.4; and assume the Kelly Rail (1.1.1) to be at a horizontal attitude (down position); and the Rig ready to receive either an Anchor Collar or a regular mine bore Support Collar, and that a Drive Stem unit is contained inside of it. The suggested procedure below should then follow:

1. Release the Collar Support Carriage (1.1.2) from its hydraulic lift cylinders (1.1.2.1) and assure it seating properly in the Service Rail Dolly (1.6).
2. Raise the Kelly Rail (1.1.1) to an elevated position. (View shown in the illustration.) Make sure the Crowd Ring (1.3.2) is positioned to the top side of the Kelly Rail and next to the Kelly (Assembly 1.2).
3. Move the Collar Loading Carriage (1.6), with the Support Carriage (1.1.2) attached, to the collar loading area at the rear end of the Rig.
4. With a minimum 25 ton mobile crane, deliver and position a Mine Anchor or Support Collar and its internally contained Drive Stem unit on the loading carriage. (See Assembly Plan 1.0.4 and the collar position in phantom outline.) (Caution is necessary to prevent the Drive Stem from becoming dislodged inside the collar.)
5. Move the carriage and collar, via the winch line system, into position under the Kelly Rail, as illustrated in Assembly Plan 1.0.4.
6. Lower the Kelly Rail. It will straddle the Mine Support Collar.
7. Connect the Support Carriage (1.1.2) to its Kelly Rail hook-up.
8. Position the Support Collar into alignment with the Crowd Ring via the hydraulic cylinders (1.1.2.1) and the support grapple (1.1.2.2).

9. Engage the Crowd Ring (1.3.2) with the collar via the hydraulic cylinders (1.3.2.2) and aligning shoes (1.3.2.2.1).
10. Remove the hold down chain from around the leading end of the Drive Stem (Lock Ring end).
 - 10.1 Assure that the Drive Stem is properly situated on the stabilizer rollers (housed by the Mine Support and/or Anchor Collars).
11. Place the grommet (shown as item 3.1.4 on drawing of assembly 3.1, Sec. D-D) over the end of the Drive Stem flange, aligning the holes in the grommet with the dowel pins on the Drive Stem Flange.
 - 11.1 Engage the Kelly Sub (1.2.1.1) of the Kelly Assembly (1.2) with the Drive Stem; make sure the dowel pins and dowel pin holes align properly before applying pressure to the engaging Kelly Sub via the Kelly Assembly drive.
 - 11.2 After the joint is firm, lower the overhead hoist line, with the chain length (3.1.5) attached, and connect the chain ends to the Lock Ring on the Kelly Sub.
 - 11.3 Close the Lock Ring, with force from the hoist line, and insert the Pin (3.1.3.3) and the Keeper (3.1.3.3.1) as shown on the Drawing of Assembly 3.1.
 - 11.4 Disconnect the chain (3.1.5) and retract the hoist line.
12. Raise the Kelly Rail (1.1.1) to mining (drilling) attitude.
13. After the mining attitude (drilling angle) is attained, simultaneously move the Mine Support, or Anchor Collar, (now held by the Crowd Ring) and the Drive Stem (now connected with the Kelly Drive Assembly)

downward on the Kelly Rail. Use the Crowd Ring (cylinder pressure) to move the Mine Support or Anchor Collar.

- 13.1 Move the Mine Support or Anchor Collar until it engages the stops (1.4.2.1) housed on the Mining Rig.
- 13.2 After the Collar has engaged the 'stop', turn the power switch to the solenoid in control of the Crowd Ring's hydraulic circuitry to the 'off' position.
- 13.3 Extend the extendible floor of the Drive Stem Service Platform (1.4.8.1) housed on the Mining Rig inward to its maximum extension. (The crew member tending to the connection of the hydraulic electrical and Drive Stem units will need this to stand on while procedure items 13.4, 13.5, 14.2 and 14.3 are implemented.)
- 13.4 Continue movement to the Drive Stem until it reaches the vicinity of its counterpart extending from the mine bore.
- 13.5 Make sure the grommet on the flange of the Drive Stem, extending from the mine bore, is in good condition (no tears or breaks), and that the dowel pins on it are aligned to mate with the dowel pin holes of the 'new' Drive Stem being lowered for connection.

14. Engage the 'new' Drive Stem firmly with the unit extending from the mine bore.

- 14.1 After the joint is firm, lower the overhead hoist line with the chain length 3.1.5 attached, and connect the chain ends to the Lock Ring connected to the flange of the 'new' Drive Stem.
- 14.2 Close the Lock Ring, with force from the hoist line, and insert the Pin (3.1.3.3) and the Keeper (3.1.3.3.1).
- 14.3 Disconnect the chain (3.1.5) and retract the hoist line.

- 14.4 Connect the hydraulic and electrical lines, and open the valves on the Support Collar jacking system and on the Load Cell line.
15. Withdraw the extendible floor of the drive stem Service Platform.
16. Turn the power switch, referred to in procedure step 13.2 to the 'On' position.
17. Move the Mine Support or Anchor Collar upward slightly with the crowd ring, so as to free the collar from the 'stop' (1.4.2.1) on the Rig Base.
 - 17.1 Recline the stops into their 'recess'. (Manual operation)
18. Under Crowd Ring Hydraulic Control, allow the Mine Support Collar to move downward to engage slightly its leading edge with the Support and/or Anchor Collar extending from the mine bore.
 - 18.1 Assure that the spring loaded locking dowel pins and the dowel pin holes on the mating ends of the collar units are in alignment (longitudinally), and that when the ends are telescopically mated, each of the dowel pins will engage with their counterpart dowel pin hole.
 - 18.2 With pressure from the hydraulically operated Crowd Ring, telescope the end of the 'new' Mine Support Collar over the end of the collar extending from the mine bore.
 - 18.3 Make sure that the spring loaded dowel pins have engaged and interlocked with the 'new' Mine Support Collar.
19. See Assembly Drawing 5.1 and item 5.1.1; the Mine Support Collar Shroud.
 - 19.1 Move the collar shroud into position over the upper and open end of the Mine Support Unit, and apply a firm holding pressure to it via the hydraulic cylinders 5.1.1.4. (See discussion in Section I of this manual entitled "Gas Monitoring and Retention".)

20. Check the Gas Monitoring Instruments for percentage of Gas versus air being drawn from the mine bore.

20.1 If the gas volume in the bore and the flow lines does not have commercial or on site value, set the valves (6.1.2) on the flow control system for discharge to air (6.1.3).

20.2 If the gas volume is significant and of commercial or on site value, set the valves on the flow control system for discharge into the processing line (6.1.5).

21. Start the conveyor slaving the Kelly Coal Discharge Duct (7.1.1).

22. Lower the Kelly Rail Collar Carriage 1.1.2 to maximum extension of Cylinders 1.1.2.1.

23. Start mining Procedure.

23.1 Build up the pressure in the Crowd Ring Cylinders 1.3.2.1 until it equals the pressure indicated by the Load Cell on the Mining Head. The Load Cell pressure, responsive to the advance of the Mining Head, provides the intelligence to the Servo Unit ministering to and regulating the hydraulic pressure providing the thrust necessary to the movement of the Mine Support Collars. The hydraulic pressure on the Crowd Ring should always be just slightly higher than that indicated as being used by the hydraulic network advancing the Mine Anchor and Support Collars. (For further details on the hydraulic system and its functions, please note the discussion entitled "Hydraulic Control Plan" in this section of the manual.)

23.2 Assure that the Servo Unit equals the hydraulic pressure in the system driving the Kelly Assembly to the calculated required pressure for the rotary drive of the Kelly and to the calculated required pressure providing the drilling thrust to the Mining Head. The Kelly Assembly and its geared drive on the Kelly Rail (1.1.1) provides thrust to the Drive Stem assembly. The calculated pressure required by both of these functions will be a computer evaluation, considering the angle from the horizontal at which the Drive Stem is disposed, its internal loading of mined mineral, and the rate of rotation desired.

NOTE: The geared drive to the Kelly Assembly on the Kelly Rail will oftentimes require a "holding force" to prevent the Drive Stem assembly and the reactionary forces working on it from providing excessive thrust to the Mining Head. Computer control on the planned Mining Advance Rate will determine the value the "holding force" should be and will, through the microprocessor control of the servo unit, deliver this to the Kelly assembly. Rotation of the Drive Stem and the Mining Head should not start until the computer demanded "holding force" is active and the signal is given to proceed with rotation. Failure to comply with this requirement could result in a demand for rotational power beyond the capacity of the power plant, and/or should rotation be achieved, the Mining Head would be forced to produce a crushing action and an excessive volume of fines at the heading since the ports on the face of the Mining Head will only permit a fixed volume of material to pass through them.

In the event rotation of the Drive Stem and the Mining Head is required without gaining advance of the mine bore heading, the "holding force" indicated by the computer will have to be increased slightly. This can be done through takeover and manual control of the valve regulating the hydraulic pressure to the Kelly Assembly's drive on the Kelly Rail. This procedure is required primarily every time a mine bore has reached its planned depth of development. Before withdrawal of the mining hardware from the mine bore can start, the Drive Stem string has to be emptied of cuttings through and by means of rotation.

23.3 Start mining and advance. Advance mine bore heading 20 feet.

(Length of Mine Anchor or Support Collar.)

24. Procedure prior to adding on a 'new' joint of Drive Stem and Mine Anchor or Support Collar after a 20 ft. length of these assemblies has completed a mining cycle.

24.1 Stop rotation to the Drive Stem and the Mining Head. Keep the Exhaust Turbine going until the gas flow from the mine bore is less than 4% of the total mix. (air and gas)

25. Retract the Mine Support Collar Shroud (5.1.1). (Remove it from the end of the collar.)

26. Extend the extendible floor (1.4.8.1) of the Drive Stem Service Platform.

27. Undo the Lock Ring on the Kelly Sub (1.2.1.1) and free it from its Drive Stem connection.

27.1 Close the hydraulic valve on the mine's support system jacking circuitry, and disconnect the coupling to the main.

28. Drive the Kelly Drive Assembly upward on the Kelly Rail to maximum extension.
29. Extend the Crowd Ring (1.3.2) upward to close proximity of the Kelly Drive Assembly.
30. Draw up the Collar Support Carriage (1.1.2) to its maximum 'up' position.
31. Lower the Kelly Rail (1.1.1) to a horizontal attitude.
32. Repeat steps 1 through 22 and resume advance of the mine bore heading.

2.12.4 HANDLING OF THE MINING HARDWARE WHEN WITHDRAWING FROM A MINE BORE

OPERATIONAL PROCEDURE

Assembly Plan 1.0.6 illustrates the hardware comprising the mine bore support system. It identifies the cyclic manner by which the Anchor Collars provide movement, forward or backward, to the mine support system. The discussion "Anchor Collar -- Operational Mechanics" Division 2.9 provides support data etc.

The procedure for withdrawing the mining hardware after a mine bore has reached its planned depth is outlined below. It should be a microprocessor servient, computer controlled procedure with manual takeover on emergency or maintenance repair requirements only. The procedural steps noted below provide the technique for removal of all hardware except the Mining Head, Anchor Collars 1 and 1A, and the first 10 Support Collars behind Anchor Collars 1 and 1A. The technique for withdrawing these units is discussed under the caption entitled, "Withdrawal Handling of the Mining Head, Anchor Collars 1 and 1A and the Adjacent Collars".

The most important requirement after the mine bore depth has been reached is to keep rotation on the Drive Stem until all of the mined mineral contained in it has been discharged through the Kelly Stem Cowling. (Assembly 5.1.2)

Under the caption entitled, "Power Requirements -- To Transport Mineral with Drive Stem Flighting", in this section of the manual, a rotational speed of $9\frac{1}{2}$ RPM of the Drive Stem String is suggested when mining is in progress. This is conditioned to attain a Mining Head rotation speed of 7 RPM; which in turn provides an ideal rotational speed to the disc cutters on the Mining Head.

When preparing to withdraw from the mine bore, the disc cutters will not be under-loading. It is therefore appropriate to rotate the Drive Stem at speeds up to 25 or 30 RPM. At 30 RPM a 2500 foot long Drive Stem String will empty itself of internally contained mined mineral in approximately 1 hour of rotation time. Accordingly, the mine withdrawal procedure can then follow, and is as follows:

1. Rotate and clear the Drive Stem String of all cuttings contained by its flighting.
2. Set the computer on "Mine Support Retreat". It must process the signals received from the Limit Switches 4.1.13 and 4.1.13.1 positioned on the Mining Head; and, through the microprocessors, provide control to the hydraulic valves by supplying hydraulic pressure to the drive of the Kelly Assembly (1.2) and to the Mine Support System in the cyclic manner they require as the retreat from the mine heading progresses. The cyclic nature of the retreat process is in reverse order to that when the mine heading is advancing. When the mine heading is advancing, the signals from the Limit Switches are processed so that the movement of the Mine Support System always follows the forward movement of the Mining Head. In the retreat process from a mine bore, the Mine Support System leads the movement and the Mining Head must follow.
3. Set the Servo Unit ministering the hydraulic thrust on the Mine Support System, the Anchor Collars to provide retreat or backward thrust.
4. Release the Crowd Ring (1.3.2) from its engagement with the top side of the Mine Support Collar to be removed from the string.

- 4.1 Hold the Crowd Ring at its down side position. Do not allow it to move with the Support Collar when it starts moving upward.

NOTE: The Crowd Ring does not provide thrust to the movement of the Mine Support Collars in retreat from a mine bore. The Anchor Collars provide this. The Crowd Ring provides thrust to the Mine Support Collars only when they are being advanced into the mine bore. In that phase, it is responsible for providing forward movement to all of the Support Collars, behind the first Anchor Collar in the mine bore, and extending from there to the Drilling Rig.

5. Please refer to Preliminary Design Plan 1.0.6 and note the incremental groups of Mine Support Collars. They are identified in groups of 10 per increment. Each increment of collars has an Anchor Collar in front of it and behind it. The Anchor Collars alternate in gripping the mine bore wall. When anchored to the mine bore wall, they apply thrust to the increment group of Mine Support Collars either in front of them or behind them, pending the desired direction of movement in the mine bore. The cyclic nature of the movement of each increment is controlled and regulated by a microprocessor governing the hydraulic circuitry.

Before starting the retreat movement of the Mine Support System, be sure that the Anchor Collars, which were engaged and gripped the mine bore wall during the last cycle of advance of the mine bore, are still in firm grip with the mine bore wall. This series of Anchor Collars must also provide the initial movement; be the first of the two cycle system, to start the retreat movement of the string of Collars from the mine bore.

The Anchor Collar adjacent to the Mining Head will have had to go through one cycle of retreat movement before retreat pressure can be applied to the Drive Stem and the Mining Head connected to it. The Limit Switch 4.1.13.1 on the Mining Head will signal this to the Computer, where it will be shown and indicated.

6. Set the computer 'control rate on the retreat movement' of the mining hardware from the mine bore to coincide with the Mining Head advance rate. (This is required only if 2 mining rigs are working adjacent to each other. This permits placing the mining hardware being recovered from the 'mined out' bore into the bore in the process of being mined.)

7. Draw up the Collar Support Carriage (1.1.2) to its uppermost position, engaging the Support Collar in transit.
8. Start the retreat movement from the mine bore. (Pipe Jacking)
9. After the first Mine Support Collar in the string has been completely recovered from the mine bore, it and the Kelly Assembly will be near the top side of the Kelly Rail. The collar will be resting on the carriage (1.1.2).
 - 9.1 Stop the movement of the mine bore support system. Reduce the jacking pressure on the Support Collars to zero, but maintain anchor pressure on all the Anchor Collars.
 - 9.2 Check the Gas Monitoring System for gas pressure and volume (if any) that is being exhausted by the turbine (6.1.1). Should gas be exhausting from the mine bore, keep the exhaust system running until the volume inflow is less than 4% of the total mix (air and gas).
 - 9.3 Engage the plungers of the Crowd Ring (1.3.2) with the dowel pin assembly joining the first two Support Collars in the string. Depress the dowel pins joining the two collars. This frees their engagement with each other, but leaves the plunger pins of the Crowd Ring engaged with the dowel pin holes of the first or topside Support Collar.
 - 9.4 After assurance that gas volume and flow is not of a critical nature, apply thrust with the Crowd Ring Cylinders to move the freed Support Collar upward until the lower end of it reaches the area of the Stops 1.4.2.1 housed on the Mining Rig.

- 9.5 Extend the Stops and allow the Support Collar to engage them.
- 9.6 Retract the Support Collar Shroud (5.1.1). (Remove it from the upper end of the collar.)
10. Extend the extendible floor (1.4.8.1) of the Drive Stem Service Platform.
11. Undo the Lock Ring connecting the two Drive Stem members together.
 - 11.1 Uncouple the hydraulic and electrical lines from their respective extensions.
12. Move the freed Drive Stem upward with the Kelly Drive Assembly (1.2) until its lower flange has entered and is inside the Mine Support Collar approximately 15 inches.
13. Retract the extendible floor (1.4.8.1) to its full 'out' position on the Drive Stem Service Platform.
14. With thrust from the Crowd Ring, free the Support Collar from its engagement with the Stops (1.4.2.1).
15. If the Collar Loading Carriage (1.6.1) is not positioned under the Kelly Rail to receive the Support Collar in transit, it should be brought to that position by the Dolly Winch (1.5.2).
16. Lower the Kelly Rail (1.1.1) to the horizontal attitude. Make sure that the Collar Loading Carriage (1.6.1) is properly located to receive the Collar Support Carriage (1.1.2) containing the Mine Support Collar.
17. Undo the Lock Ring on the Kelly Sub (1.2.1.1) and free it from the Drive Stem lockup. Make sure the Lock Ring channel units are in the full open position.

18. Retract the Crowd Ring Plungers (1.3.2.3.1) on the Crowd Ring, and remove the Crowd Ring from its hold on the Support Collar.
19. The Mine Support Collar, and its internally contained Drive Stem, should now be free of any connections with the Kelly Rail hardware.
 - 19.1 Lower the Support Carriage (1.1.2) with the Support Collar to engage with and rest on the Collar Loading Carriage (1.6.1). Cylinders (1.1.2.1) will lower the Support Grapples (1.1.2.2), freeing them from the Support Carriage (1.1.2).
20. Raise the Kelly Rail approximately 15° from the horizontal.
21. Chain Connect and tie down securely the Lock Ring end of the Drive Stem to the Support Collar.
22. Withdraw the Collar Loading Carriage (1.6.1) to the rear end of the Rig Base with the Winch Line (1.5.5).
23. Remove the Support Collar from the Collar Loading Carriage. (Place it either on an adjacent Mining Rig advancing a mine bore, or in the field storage area.)
24. Draw the Collar Loading Carriage back into the Rig and under the Support Carriage (1.1.2) area of the Kelly Rail.
25. Lower the Kelly Rail and with the Support Grapples (1.1.2.2) pick up the Collar Support Carriage (1.1.2).
26. Raise the Kelly Rail to its mining attitude.
27. Bring the Kelly Assembly down the Kelly Rail and engage the Kelly Drive Stem Sub with the Drive Stem extending from the mine bore.
28. Repeat procedures 7, 8, 9.2, and all others through 27.

NOTE: Should gas detection occur in a mix ratio with air approaching 4% in the vicinity of the open ended Support Collar, position the Support Collar Shroud (5.1.1) over the Support Collar being readied for transit and proceed with procedure 9.1 before starting procedure 9.2.

After completing procedure No. 16, the movement of the Mine Support Collar string (Procedure No. 8) can be started again, making sure, however, that the cyclic advance of the Anchor Collars is not changed from the cyclic order to which it was programmed when the movement of the Mine Support Collar string started. (The jacking process on the Mine Support System can be active while procedure steps 17 through 27 are going on.)

2.12.5 WITHDRAWAL HANDLING OF THE MINING HEAD,
ANCHOR COLLARS 1 AND 1A, AND THE ADJACENT SUPPORT COLLARS

OPERATING PROCEDURE

Removal of the Mining Head, Anchor Collars 1 and 1A, and the adjacent 10 Mine Support Collars requires a slight modification to the procedural steps suggested under the caption entitled, "Handling of the Mining Hardware When Withdrawing From A Mine Bore". This is due to the alternating and/or cyclic jacking pressure required from Anchor Collars No. 1 and 1A, of the Mine Support System, to remove the last 10 Mine Support Collars, positioned adjacent to those Anchor Collars, before they and the Mining Head can be removed from the mine bore.

Please refer to Assembly Plan 1.0.6 (drawing) and note the arrangement of an Anchor Collar (Assembly 2.2) positioned between each group of 10 Mine Support Collars (2.1 Assemblies). It can be surmised that as the Mining Head, in a withdrawal movement, approaches the adit area, it will not have the 'pull' energy assistance of Anchor Collar No. 2.

Anchor Collar No. 2, after clearing the adit, will be void of anchor means. Thus, the Anchor Collars 1 and 1A, adjacent to the Mining Head, will have to provide the thrust means to the movement of the 10 Mine Support Collars positioned between Anchor Collar No. 2 and the Mining Head.

Please refer to the last 3 paragraphs under the caption entitled, "Anchor Collar -- Operational Mechanics". The discussion there treats the function and requirement for Anchor Collars 1 and 1A to support the Mining Head in both its advancement in and its retreat movement from a mine bore; and as the means to provide jacking energy to the last 10 Mine Support Collars preceding the withdrawal of the Mining Head.

It can be noted in the procedural requirements, entitled, "Handling of the Mining Hardware When Withdrawing From A Mine Bore", that procedure item '2' required the Computer to be set on "MINE SUPPORT RETREAT". This control setting provided an alternating jacking pressure to the two groups of Anchor Collars; namely 1, 1A, 3, 5, 7, 9, etc., and to 2, 4, 6, 8, 10, etc. After Anchor Collar No. 2 is removed, the microprocessor control on the jacking procedure has to be directed by the computer to provide alternating jacking pressure to Anchor Collars No. 1 and 1A only. This provides the last 10 remaining Mine Support Collars with drive control means to their removal from the mine bore and onto the Mining Rig for removal handling from the string.

Thus, the only modification to the handling procedure, outlined under the caption "Handling of the Mining Hardware When Withdrawing From a Mine Bore", for the last 10 Mine Support Collars, is to change control procedure No. 2 from "Mine Support Retreat" to "Mining Head Retreat". All other procedural steps, where required or applicable, remain as stated.

WITHDRAWAL OF ANCHOR COLLARS 1 AND 1A; AND THE MINING HEAD

Following the withdrawal of the last Mine Support Collar (2.2.1 Assembly) from the mine bore, Anchor Collars 1A and 1, and the Mining Head, can be withdrawn and positioned on the Mining Rig for removal. This is accomplished with the Crowd Ring (1.3.2) housed on the Mining Rig. The suggested procedure is noted below.

Removal of Anchor Collar No. 1A.

1. Before the removal procedure starts, Anchor Collar No. 1 should be anchored to the mine bore wall (adit casing).

2. Raise the Kelly Rail to coincide with the angle of the mine bore.
(If other than horizontal.)
3. Bring the Kelly Assembly down the Kelly Rail and engage the Kelly Drive Stem Sub with the Drive Stem extending from the mine bore. Make sure the dowel pins on the Drive Stem and the dowel pin holes on the Drive Stem Sub are aligned.
 - 3.1 After the joint is firm, lower the overhead hoist line, with the chain length (3.1.5) attached, and connect the chain ends to the Lock Ring on the Kelly Sub.
 - 3.2 Close the Lock Ring, with force from the hoist line, and insert the Pin (3.1.3.3) and the Keeper (3.1.3.3.1) as shown on the Drawing of Assembly 3.1.
 - 3.3 Disconnect the chain (3.1.3) and retract the hoist line.
4. Engage the Crowd Ring (1.3.2) with Sub -B- of Anchor Collar No. 1A.
5. Release the Anchor hold, of Anchor Collar No. 1, on the mine bore wall (the adit casing).
6. Simultaneously, move the Crowd Ring, and the Kelly Assembly, upward on the Kelly Rail, until the Mining Head has cleared the inner edge of the Support Collar Guide (1.7.1.1) by approximately 18 inches.
7. Position and bolt connect the Support Beam (1.7.1.1.1) to the Support Collar Guide. (See Assembly Plan 1.0.4.)

8. Allow the Mining Head to move downward on the Kelly Rail, via the Crowd Ring and Kelly Assembly Control, until the Mining Head engages and rests on the Support Beam (1.7.1.1.1).
9. Release the Crowd Ring Hold on Sub -B- of Anchor Collar No. 1A, and lower it to engage the dowel pins connecting Sub -A- of Anchor Collar 1A to Sub -B- of Anchor Collar No. 1.
10. Draw up the Collar Support Carriage (1.1.2). It must support Anchor Collar 1A after it is disconnected from Anchor Collar No. 1.
11. Depress the Crowd Ring's Plunger Pins. This frees the collars from their engagement with each other, and leaves the plunger pins of the Crowd Ring engaged with the dowel pin holes of Sub A on Anchor Collar No. 1A.
12. Move Anchor Collar No. 1A upward on the Kelly Rail, with the Crowd Ring, until it can engage with Stops 1.4.2.1, housed on the Mining Rig after they are extended.
13. Extend the Stops, 1.4.2.1.
 - 13.1 Allow the Anchor Collar to rest against them.
 - 13.2 After the collar has engaged the 'stops', turn the power switch to the solenoid in control of the Crowd Ring's hydraulic circuitry to the 'off' position.
14. Extend the extendible floor of the Drive Stem Service Platform (1.4.8.1) to its maximum extension. (The crew member tending to the hydraulic and electrical lines will need this to stand on while tending to procedure of items under 15 below.)

15. Uncouple the Mine Support System's Hydraulic Line extending into Anchor Collar No. 1, and uncouple the Hydraulic Line extending to the Load Cell Assembly housed by the Drive Stem.
 - 15.1 Disconnect the electrical lines extending to the limit Switches housed in Sub -A- of Anchor Collar No. 1.
 - 15.2 Disconnect the Drive Stem extending from Anchor Collar No. 1A from the Drive Stem housed in Anchor Collar No. 1.
16. Withdraw the extendible floor of the Drive Stem Service Platform (1.4.8.1).
17. Turn the power switch referred to in procedure step 13.2 to the 'On' position.
18. Move Anchor Collar No. 1A upward slightly with the Crowd Ring so as to free the collar from the 'Stop' (1.4.2.1) on the Rig.
 - 18.1 Recline the stops into their 'recess'. (Manual operation)
19. Lower the Kelly Rail (1.1.1) to the horizontal attitude. Make sure that the Collar Loading Carriage (1.6.1) is properly located to receive the Collar Support Carriage (1.1.2) containing Anchor Collar 1A.
20. Undo the Lock Ring on the Kelly Sub (1.2.1.1) and free it from the Drive Stem lockup. Make sure the Lock Ring channel units are in the full open position.
21. Retract the Crowd Ring Plungers (1.3.2.3.1) on the Crowd Ring, and remove the Crowd Ring from its hold on the Support Collar.

22. The Anchor Collar, and its internally contained Drive Stem, should now be free of any connections with the Kelly Rail hardware.
 - 22.1 Lower the Support Carriage (1.1.2) with the Anchor Collar to engage with and rest on the Collar Loading Carriage (1.6.1). Cylinders (1.1.2.1) will lower the Support Grapples (1.1.2.2), freeing them from the Support Carriage (1.1.2).
23. Raise the Kelly Rail approximately 15° from the horizontal.
24. Chain Connect and tie down securely the Lock Ring end of the Drive Stem to the Support Collar.
25. Withdraw the Collar Loading Carriage (1.6.1) to the rear end of the Rig Base with the Winch Line (1.5.5).
26. Remove the Anchor Collar from the Collar Loading Carriage. (Place it either on an adjacent Mining Rig advancing a mine bore, or in the field storage area.)
27. Draw the Collar Loading Carriage back into the Rig and under the Support Carriage (1.1.2) area of the Kelly Rail.
28. Lower the Kelly Rail and with the Support Grapples (1.1.2.2) pick up the Collar Support Carriage (1.1.2).
29. Raise the Kelly Rail to its mining attitude.
30. Retract the Crowd Ring Cylinders. (Bring the Crowd Ring to the maximum down position.)
31. Bring the Kelly Assembly down the Kelly Rail and engage the Kelly Drive Stem Sub, via its Lock Ring, with the Drive Stem extending from Anchor Collar No. 1.

32. Chain Connect the Mining Head to Anchor Collar No. 1. (Taut connection)
33. Raise the Support Carriage (1.1.2) to where it will be in a position to receive Anchor Collar No. 1.
34. With the Kelly Assembly's (1.2) drive power, move the Mining Head and Anchor Collar No. 1 upward on the Kelly Rail to a point several inches past the Rig Base Collar Support (1.4.2).
35. Assure that the Collar Loading Carriage (1.6.1) is positioned under the Kelly Rail and aligned to receive the Support Carriage (1.1.2) with the Mining Head.
36. Lower the Kelly Rail to the horizontal attitude.
37. Disconnect the Kelly Drive Stem Sub (1.2.5) from the Drive Stem extending from Anchor Collar No. 1. This should free the Mining Head and the Anchor Collar from all connections with the Mining Rig except the Support Carriage (1.1.2).
 - 37.1 Lower the Support Carriage with Cylinders (1.1.2.1) until it rests on the Collar Loading Carriage (1.6.1).
38. Raise the Kelly Rail to approximately 15° from the horizontal.
39. Withdraw the Collar Loading Carriage with the Dolly Winch (1.5.2) to the end of the Collar Loading Track (1.5.1).

Before the Mining Rig is moved to an adjacent planned bore site, the Adit Casing, pending the mine site plans, can be withdrawn from the mine bore for re-use. The suggested procedure to do this follows and is discussed under the caption, "Removal of the Adit Casing".

3.0 SITE PREPARATION -- ALTERNATE MINING PLANS -- AUXILIARY EQUIPMENT

GENERAL

The basic plan of the mining technique is to provide a Remote Controlled Mining System to an underground deposit of a mineral, such as coal, from its near surface or hillside outcrop.

Site preparation necessary to permit the installation and employment of the RCMS' hardware must provide a bench or a plateau having a side wall or 'face' exposing the coal seam.

3.1 BENCH AND FACE CONFIGURATION

The bench face must be of sufficient height to allow the installation of an adit casing, and the width of the bench must provide adequate room for the setup of the Mining Rig, and the auxiliary equipment necessary to the handling of the mined coal and the gas processing equipment.

The face configuration will depend on the mining plan's approach to mining a given coal seam structure.

3.2 MINING PLAN -- DRILLING ANGLE: X OR Z AXIS

Fig. 11, a reduction of Plan 1.0.2, illustrates alternate approaches to the development of mine bores and the 'face' configuration each will have. Shown, in one view, is a 'face' developed when mine bores are planned on the X axis of the seam. They are perpendicular to the face of the coal deposit. Shown in the adjacent view is an alternate plan which will require a 'face' developed so that the mine bores will approach the coal deposit on a 'Z' axis. Development of a

mine bore layout plan will most often favor mining on the 'Z' axis of a coal seam declining at an angle greater than 15° . The reason for this is discussed below.

Data in Section III, following, identifies that as the angle from the horizontal increases, the mining costs (cost per ton mined) increases. This is due to the need for a greater Drive Stem diameter and also a greater power demand to convey the mined consist to the portal while mining. It is an efficiency related analysis taking into consideration the flighting pitch of the internally flighted Drive Stem. Compensation, offsetting the decrease in efficiency, for a given diameter stem requires an increase in the RPM in order that the conveyance capacity (TPH) remains in effect, and always in excess of the mining rate of the Mining Head.

Fig.*11 illustrates a hypothetical case of a coal seam dipping at 60° from the horizontal. Its geometry is identified on an X and Y axis basis; the X axis dominating the approach a mining plan would have to reckon with since a plane through the seam established on the Y axis intersects it at an angle of 60° . Mining a seam with the Drive Stem conveyance disposed at a 60° angle would pose an inefficient plan, whereas consideration of mining on the Z axis, as illustrated, would, for example, extend the bore on an angle of 20° from the horizontal. This would retain the expected efficiency of a Drive Stem's conveyance capacity as related to its diameter.

A similar approach, mining on the Z axis, would have an advantage in a seam structure declining, for example, on a 20° angle, but with a 'pinch' in the

*See Assembly Plan 1.0.2.

VIEW OF BENCH FACE
BORES PLANNED ON
Z-AXIS.

SEC. B-B

MINE BORE PLAN ON Z-AXIS
ON PLANE OF X-AXIS

FIG. 11

structure at a relatively short distance from the outcrop, limiting thereby the length to which the mine bore can be developed if mining were planned on the Y axis. Mining on the Z axis would decrease the angle from the horizontal and permit lengthening the mine bores, thus increasing the mining equipment's productive on site mining time.

3.3 AUXILIARY EQUIPMENT

Assembly Plan 1.0.4 offers illustration in plan view of a typical arrangement for the placement of the auxiliary equipment. It is required to dispose of the mined coal and mine gas that may be emitted; to move the mining rigs from one location to another, and provide the rigs with mining accessory hardware at certain times. Specifically, it consists of:

1. A conveyor setup for the transport of the mined coal to a haulage terminal, from where it is truck loaded or rail car loaded for a market destination. The haulage terminal can be one of several plans; i.e., a stockpile or a hopper setup which would load trucks or rail cars passing thru underneath it.
2. A gas processor station, which would house pumps and flow line valves, providing for regulated dispersement of the mine gases, if any, for commercial use.
3. A mobile crane in the 25 to 30 ton range.
4. A Crawler; needed to tow the rigs (Pilot Hole Rig & Mining Rig), storage racks for the mine bore support hardware, and other standby mining accessories.
5. A rack for the storage of mine bore Support Collars that may require temporary storage and service attention.

4.0 PROBE HOLE/PILOT HOLE DRILLING HARDWARE

The proposed Remote Controlled Mining System requires small diameter holes drilled into the coal seam. The purpose of these is twofold, and as follows:

1. To explore and identify the seam's boundaries.
2. To provide the means for laying a pipe line to serve as the guidance system to a large diameter Mining Head.

With reference to item 1; it is important that a coal seam's exact geometry is identified, particularly the deposit's configuration in its thickness range on the axis on which its mining is planned. Drilling the Probe Holes is an extension of the exploratory drilling achieved by the vertical core holes. They will provide necessary data to the development of the most efficient mining approach plan for pitching seams of coal.

The mining approach plan, for economic and 'mine production' reasons, should determine the smallest angle from the horizontal at which a pitching seam can be mined. As a convenience to discussions following, that angle is referred to as the 'Z' Axis. An illustration of its meaning is offered in Preliminary Design Plan 1.0.2 and discussed further in Division 3.2 of this section of the manual. The 'Z' Axis, in essence, comprises the longitudinal axis of a mine bore into a coal seam which will permit driving the straightest possible bore at the lowest angular deviation from the horizontal. Reduced mining costs will result since all drilling/mining functions can be accomplished at a faster rate when the projected bores are in a straight line plan rather than on a curved trajectory, or dipping at angles greater than 15° to 20° from the horizontal.

The exploratory holes necessary to the planning of the 'Z' Axis on which the mine bores are to be extended are referred to as 'Probe Holes' in the discussion following and on Drawings of the Drilling Hardware.

Drilling the Probe Holes will require more time than that required to drilling a straight hole. The Probe Holes will most often have to be on a trajectory of some order to be able to identify the floor and roof line of a deposit at several points on its linear extension from the exposed or the planned mining face. Frequent 'down-hole' surveys will be required. After the data on the seam's upper and lower boundaries is at hand, the 'Z' Axis can be planned.

With reference to item 2, the Pilot Holes, which will retain a pipe line as the guiding influence on a rotating Mining Head; these will be drilled after a plan on the 'Z' Axis of the mine bores has been established. These can be driven at much faster rates than the Probe Holes, and will require a great deal less surveying time.

Since the purpose of the small diameter holes differs as does the time required in their drilling, the hardware required by each differs also. This is discussed below and illustrations of hardware most ideally suited to each of the hole drilling requirements are included and referenced.

4.1 PROBE HOLE DRILLING TECHNIQUE-OIL FIELD TECHNOLOGY

At the present time, the directional hole drilling art has a recognized measure of success as used by the Oil Well Drilling industry. The art not only provides technology in the directional control of a drilled hole, but also identifies the technique and the hardware required to produce a correction to the direction, if required, to a hole in the drilling process. The technology, in its current state of development, provides one approach and field level expertise to drill the required probe holes.

Figures 3 and 4 in Section I of this manual illustrate typical current manners of application, and the tools important to the directional hole drilling technique. Fig. 12, following, illustrates one of several currently used hole surveying techniques, and instrumentation used to identify the direction, in which a hole in the drilling process, is developing.

The current oil field art requires that, before a correction effort can be applied to a hole in the drilling process, the drill string has to be withdrawn from the hole. The tools which are effective in providing a change to the hole's direction are then placed into the drill string assembly, after which the drill string is placed back into the hole. Placing the 'correctional tools' requires, of course, knowledge on the exact position they should have, considering the distance from the drill bit, so that the course of 'new' hole to follow will be in accord with its planned projection. Success with the technique also depends on the effective and correct use of the hole surveying instruments illustrated in Fig. 12 and, as stated earlier, some prior information on the geometry of the coal seam structure to be mined. An initial probe hole drilling plan should include a study of the drilling logs developed in the core hole drilling program. This will assist in establishing the axis which initial probe hole drilling should pursue in order to establish the center plane through a coal seam's deposit and the angle at which it declines from the horizontal, if any.

4.2 ALTERNATE TECHNIQUE AND HARDWARE SPECIFICALLY DESIGNED FOR DRILLING PROBE HOLES IN COAL SEAMS

The directional hole drilling assembly shown on Assembly Drawing 12.0 (see detached packet of drawings) is a modified technique over that used by the oil industry. The hardware plan illustrated takes advantage of the fact that

Mechanical Orienting Sub

It is not necessary to make a number of shots to check that the tool is facing in the right direction.

The orientation sub (fig. 38) can be used with a whipstock and it can be installed in the drilling string just below the whipstock collar. The sub also uses a ball to locate the low side of the hole. Instead of an orienting stem, it has a piston and a restricting nozzle. Before the sub is run in, the orienting notch is positioned in the proper relationship to the tool face and to the low side of the hole. When the ball and notch are not properly aligned, mud circulation is restricted, causing a higher than normal pressure reading at the surface. When the tools are oriented correctly, the ball is aligned under the notch and allows circulating mud to move a piston downward, opening a bypass around the restricting nozzle. The resulting drop in mud pressure at the surface indicates that the tool is oriented.

The Direct Method. One way in which the direct method of orientation differs from the indirect method is that prior knowledge of the direction of the hole is not required in the direct method. The directional data are taken simultaneously with the other data.

FIG. 12

PROBE/PILOT HOLE SURVEYING INSTRUMENTS

'Down-Hole Motors' do not require the drill string to rotate while drilling is in progress. The illustration also shows the drill string housing the Down-Hole Motor, contained within an outer casing of nearly the same diameter as the hole being drilled. Other details are as follows:

- (1.) The proposal provides that the drill string, at a point approximately 220 inches rearward from the drilling bit, has in its structure a network of lobes.
- (2.) These, at all times, have contact with a cam structure housed by the outer string of pipe.
- (3.) Both the drill string and the outer string of pipe extend to the Drill Rig.
- (4.) By rotating the drill string, i.e., a $\frac{1}{4}$ of a revolution, the drill bit, through the lobe's position change on the cams of the outer pipe, will be made to drill at an angle offset from the hole's longitudinal center line developed prior to the $\frac{1}{4}$ revolution induced on the drill string. This and other details important to the mechanics of the system are shown on sheets 1 and 2 of the referenced drawing.

The hardware plan and mechanics propose a directional hole drilling technique which would permit changing a bore hole's direction without the need of 'tripping' out of and into the hole for the sole purpose of placing onto or removing hardware from the drill string in order to control the hole's direction. This, in turn, could, in some coal deposits, reduce the probe hole drilling time by 50% when drilling rates of 50 feet per hour, or better, are possible, or when mine bores extending up to 2500 feet in length are planned. The hole surveying technique would be as per the oil field technology referenced in Division 4.1 above.

4.3 PILOT HOLE DRILLING HARDWARE

As stated above, drilling the pilot holes which will provide the means for guidance to the Mining Head is a task which can be pursued only after a mining plan has been established from data developed from the probe holes.

The Mining Head is dependent on the pipe line that drills the Pilot Holes for guidance. Drilling resistance across the face of the mine bore is certain to be unbalanced in some mineral structures, due to the variation in the strength of the minerals across the diameter of the bore. This, in turn, will produce lateral forces which will have to be countered by the pipe line serving as the guide. The drill pipe proposed for use in the RCMS pilot hole drilling function is re-enforced as per the plan shown on Assembly Drawing 10.0. The re-enforcement ribs will not interfere with the fluid circulation while drilling the pilot holes, and will serve to counter lateral forces that may develop across the Mining Head as it reams the pilot hole out to the full mine bore diameter.

In the event a coal seam has a curved configuration, the pilot holes will, accordingly, require drilling in a corresponding trajectory. Limitations to the degree of curvature that can be negotiated by the mining hardware exist. These are discussed in Division 4.4 following, and in Division 1.4 and 1.5 of Section III.

The drawings referenced above identify the hardware requirements specifically required for drilling the Probe Holes and the Pilot Holes. A Drilling Rig design specifically suited and proposed is illustrated in Assembly Plan 1.0.3 (included in the detached packet of drawings) and discussed in Division 4.5 following.

4.4 PILOT HOLE DEFLECTION AND LIMITATIONS AS DETERMINED BY DRIVE STEM MECHANICS

In another section of this report a member referred to as a drive stem, equipped with internal flighting as the cuttings' conveyance system, is discussed. This unit is a very rigid structure, due to its tubular configuration and diameter. It has an internal rib structure which also provides a small measure of resistance to deflection.

The limits to deflection by the drive stem from a straight line in any direction determine the maximum amount of pilot hole deflection that the pilot hole drilling hardware must develop. This is shown by calculations in Division 1.5 of Section III.

It is planned that neoprene gaskets will be placed between joining drive stem units. These will permit an approximate 3600 foot minimum radius to the pilot hole's deviation from a straight line bore.

The limitations for the mining hardware to follow a curved pilot hole bore also pertain, to a limited extent, to the support collars which are used in the mining system to prevent the full mining bore from collapsing while mining is in progress. These, however, are not critical, and will at all times conform below the limitations associated to the drive stem assembly.

4.5 PROBE/PILOT HOLE DRILLING RIG (ASSEMBLY PLAN 1.0.3)

Several types and makes of Drilling Rigs are currently available for drilling holes deviating from true vertical. These, in some areas of use, are referred to as 'Slant Hole Drilling Rigs'. Their identity, as such, also identifies their limitations. They are not suited to the drilling of horizontal holes or holes which may have to deviate from the horizontal, as may at times be required by the Remote Controlled Mining System (RCMS). Most of the mechanical features are similar on light conventional type drill rigs, whose major assemblies are a rotary table and a Kelly. The circulating media, necessary to keep the bit cool and remove the cuttings from a hole in the drilling process, is introduced through the Kelly, and rotary drive to the drill bit, in the absence of a Down-Hole Motor, is delivered by the rotary table.

The Drilling Rig required to produce the Pilot Holes for the RCMS is modified to negate the influence of gravity on the Kelly and the handling of the drill pipe. The manner in which this is accomplished is illustrated in the Design Plan Drawing 1.0.3 and discussed below.

Preliminary Design Plan Drawing No. 1.0.3 (see detached packet of drawings) identifies the basic mechanical features of a rig ideally suited to the drilling of the Pilot Holes required by the mining technique. Its design plan provides a ready adjustable means to drill holes ranging from the horizontal to 40° downward from the horizontal. In addition, it includes a semi-automated means to handling the drill pipe necessary to the drilling operation.

The Drilling Rig and the major necessary support equipment noted on the Preliminary Design Plan Drawing are as follows:

1. The Drill Rig,
2. A drill pipe handling facility referred to as 'Drill Pipe Magazine',
3. High pressure water/mud circulation system, and
4. Water/mud settling tanks.

The design plan of the rig provides a means to housing the Kelly and provide it with directional control when drilling holes deviating substantially from the vertical. This is accomplished through a sub-assembly of the rig referred to as 'Kelly Rail'. It is pivotally mounted on its front end. Its back or upper end is equipped with sprocket gearing and means to drive it. The aft section of the rig has a superstructure which is curved on a radius compatible with the radius at which the Kelly Rail functions through its front end journaled connection. The mechanical arrangement provides the directional control the Kelly must have while extending a bore since it must travel forward as the bore extends and at the same time provide the access means for the circulation media that is required to remove the cuttings from the bottom of the hole.

The Kelly Rail is equipped with gear racks, and the Kelly Housing is equipped with gearing and a hydraulic motor drive to them. The arrangement provides a self-powered means to the Kelly Assembly's required movement back and forth on the Kelly Rail as the drilling process continues.

Since the Pilot Hole Drilling Rig is near conventional to light oil field type rig and water well drilling rigs, no particular discussion is included in this manual on its operational procedure. The 'Drill Pipe Magazine' is discussed in further detail in Division 4.6, and the circulation system in Division 4.5.1, both of which follow below.

4.5.1 CIRCULATION SYSTEM

When drilling small diameter holes, a circulation media is required to remove the cuttings from the bottom of the hole. This can be either water, a prepared mud, air or a combination of air and water/mud.

Most small bore rigs provide a 'stand pipe' and flexible hose connection to a Kelly swivel. This assembly provides the means by which high pressure circulation media is moved from water/mud pits via pumps through the rig's kelly and the drill string to the Down-Hole Motor, and from there on through the drill bit. After passage through the drill bit, the circulation media 'picks up' the cuttings from the hole bottom and carries them up the annulus to the surface. The surface portion of a drilled hole will require a surface casing, when water or drilling mud is used, so that the return flow of it from the bore can be directed to empty into settling tanks, and from there be recirculated through the hole being drilled.

Assembly Plan 1.0.3 illustrates a typical arrangement of the surface equipment necessary to a pilot hole drilling program. The drawing, included in the detached packet of drawings, is self-explanatory on details of the circulation system and hardware requirements to make it functional. It should be noted, specifically, that the surface casing is equipped with a flow control meter and valve intended to provide data on the velocity of the flow. (See item 14.8.2.) Normally, the pressure drop in the circulating fluid across the

drill bit will be to zero pounds. In the event gas is present in the coal deposit, its pressure will affect the velocity of the fluid passage in the annulus. The flow meter will indicate this. The valve is necessary when drilling horizontal holes. The entire drilling assembly, drill pipe and return flow hardware, should not be allowed to empty itself when drilling is stopped in order to permit adding on a new joint of drill pipe to the drill string. Preventing that occurrence eliminates the need for pumping the circulation fluid an interval of time before drilling can be resumed. It is also a necessary precaution to prevent a 'plug' from developing in the annulus due to the variation in fluid velocity when the system is made to 'start up again'.

4.6 DRILL PIPE MAGAZINE

MECHANICS

The handling of drill pipe, even though it is small in diameter, is of greater concern for horizontal or near horizontal hole drilling projects than it is for vertical holes. The influence of gravity, when drilling vertical holes, helps the task, whereas in horizontal hole drilling projects, it requires added attention and time on 'alignment' before connection with the drill rig's Kelly can be made.

Assembly Plan 1.0.3 (included in the detached packet of drawings) illustrates the design plan for a Pilot Hole Drilling Rig and the hardware (sub-assemblies) which are proposed for the semi-automated handling of the drill pipe, and thereby reduce, by approximately 30%, the manpower requirement normally assigned to the operation of a vertical hole drilling rig.

Illustrated in Assembly Drawing 15.1, also included in the detached packet of drawings, is the specific mechanism and the mechanical means designed to facilitate the handling of the Pilot Hole's drill pipe assembly. It is referred to as the "Drill Pipe Magazine". It is self-powered, with the capacity, and the means, to handle the drill pipe units which make up the drill string necessary to the drilling of the Pilot Holes.

The purpose and function of the Drill Pipe Magazine is as follows:

1. It stores all of the drill pipe required to drill a Pilot Hole of a predetermined length.
2. When extending a hole, it indexes the pipe and brings it into a position (aligns it) so that each joint, as it is required by the drill rig, is ready for its threaded connection to the Kelly of the rig.

3. When withdrawing from a drilled hole, it provides indexed control of compartments, in the 'magazine' section of the unit, to receive each joint of pipe as it is 'broken' from the string of pipe extending into the hole.
4. Power driven Tongs, mounted on the Kelly Rail of the drill rig, provide the means to making up the required threaded connections (drill pipe to Kelly) or disassembling them.

The design plan of the magazine provides an inner unit, circular in configuration, axially supported, with chutes to retain the pipe. It is the unit identified as Sub-assembly 15.1.1 on the drawing. The chutes, containing the pipe as illustrated on sheet No. 1 of the assembly drawing, can be positioned, via rotational drive means and with the support function of a component unit referred to as the Magazine Container (Sub-assembly 15.1.2), to either 'discharge' the pipe they contain or to receive pipe. Operationally, the pipe handling procedure plan through the magazine's mechanics are as follows:

1. The magazine and its housing structure (15.1.5) are wheel supported, as shown by drawing 15.1.4 of the Assembly. It is housed, and made mobile on the Drilling Rig, via a rail system shown as Sub-assembly 14.4.1.1 on Assembly Plan 1.0.3. The rail allows moving the magazine in under the Kelly Rail of the Drilling Rig and/or withdrawing it from that position, pending the particular requirement of a Pilot Hole's drilling program.
2. Any of the chutes housing the pipe can be brought to a true vertical attitude and the component assemblies supporting the magazine's function after that, in either the 'discharge' of pipe or receiving it, are as follows:

2.1 Note the unit referred to as "The Magazine Container" (Sub-assembly 15.1.5). Pipe can only be removed or placed into any one of the magazine chutes when it and the Container Ring, which is also rotatable, are aligned so that the elongated opening (slot) on the Container Ring aligns with a given chute on the Magazine. The Container Ring can be rotated so that the slot is either at the top or the bottom side of the Magazine and/or its housing. View B-B of Assembly Drawing 15.1 shows it at the top side, and View D-D shows it at the bottom side.

2.2 Note the unit referred to as "The Loading Shoe" (Sub-assembly 15.1.3). This sub-assembly 'holds' and directs (controls) the movement of a joint of pipe which is intended to be 'discharged' from or to be placed into the Magazine. It is also rotatable. If, for example, a joint of pipe is to be placed into the Magazine, the Loading Shoe would maintain an attitude, as shown in View C-C of assembly drawing 15.1, until the Magazine Container (15.1.2) has been rotated, and the slot in it has aligned with one of the Magazine's chutes. After the alignment, slot to chute, has been made, the pipe is free to drop into the chute. A similar procedure permits the unloading, or discharge, of a joint of pipe from the Magazine chutes when the two sub-assemblies, referenced above, are made to align on the bottom side of the Magazine.

View D-D on the referenced assembly drawing shows the Loading Ring with part of its assembly preventing a joint of pipe from leaving a chute's confinement. The joint will be allowed to leave the chute and enter the outer area between the Magazine Container and

the Magazine's framework after the Loading Shoe is made to rotate, and allows the joint to drop into the area of the assembly referred to above. View D-D illustrates a joint of pipe (phantom outline) which had previously been allowed by the Loading Shoe to drop from its confinement in one of the chutes and then, through the rotating action of the Loading Shoe, brought into the position noted in the phantom outline. The view of the joint of pipe identified in phantom outline is in a position for adaptation to the Kelly of the Drilling Rig. The exact procedure on this is discussed further below.

View B-B of the drawing illustrates a condition where the Loading Shoe and attached roller elements (15.1.3.1) have, through the rotation of the Shoe, been removed 180° from the position it previously held, and as shown in View D-D. The alignment shown in B-B permits a joint of pipe, as per the phantom outline, to drop into one of the chutes.

Other details important to the purpose and function of the Drill Pipe Magazine become apparent with a review of sheets 1 and 2 of Assembly Drawing 15.1.

4.6.1 OPERATIONAL PROCEDURE

As stated above, the Drill Pipe Magazine is housed and made mobile on the Drilling Rig via a rail assembly shown as Sub-assembly 14.4.1.1 on Assembly Plan 1.0.3. Following below is a typical suggested procedure on its use in the handling of the drill pipe as required by the rig when drilling the pilot holes required by the mining system.

1. Elevate the Kelly Rail to an attitude approximately 10^0 from the horizontal.
2. Via the winch and line system, pull and position the Drill Pipe Magazine under the Kelly Rail, as shown in preliminary design plan 1.0.3.
3. Lower the Kelly Rail to a horizontal attitude. This will align the Kelly of the Drilling Rig to align with a joint of pipe positioned in a 'discharge' attitude on the Drill Pipe Magazine. The alignment will allow the kelly to engage with the threads in the joint of drill pipe. Engage the hydraulically operated tongs, No's. 1 and 2, mounted on the Rig's Kelly Rail with the drill pipe and torque up the threaded connection.
4. Release the Tong hold of Tong No. 1.
5. Raise the Kelly Rail to the drilling attitude (angle from the horizontal) required by the pilot hole's planned direction.
6. Free the grip of Tong Set No. 2, to permit the joint to slide through it.
7. Move the kelly and joint of pipe downward on the Kelly Rail so that the lower end of the joint can engage with the joint of pipe extending from the hole and under control means by Tong Set No. 3.
 - 7.1 Assure that the gripping shoes of Tong Set No. 3 are set to hold the pipe, extending from the hole, for makeup of the threaded connection to the 'new' joint of pipe.
 - 7.2 After the pin and box of the joints have engaged, release entirely the tong hold by Tong Set No. 2.

- 7.3 Through rotational drive from the Kelly, firm up the threaded connection to the recommended torque specifications.
- 7.4 Release the tong hold of Tong Set No. 3.
8. Open the valves on the Stand Pipe. Resume and continue drilling until the newly added joint has been fully extended into the bore hole.
9. After the joint has been drilled down, engage its upper end (next to the Kelly) with Tong Set No. 2.
 - 9.1 Close the valves on the Stand Pipe.
 - 9.2 Apply reverse rotation to the Kelly and disengage the Kelly from the joint.
10. Retract the Kelly Assembly back up the Kelly Rail to its starting position.

On completion of the above procedure, the Kelly of the Drill Rig is ready to pick up another joint of pipe. During the time interval that the previous joint was 'drilled in', the Drill Pipe Magazine is made to bring another joint of pipe into 'discharge' alignment as shown in View B-B of Assembly Plan 1.0.3. The Kelly Rail is free to be lowered, and the Kelly to engage with the 'new' joint, and the pipe connection process can proceed as per the steps outlined above.

The procedure in removing drill pipe after a pilot hole is drilled is a similar procedure with the exception, however, that the Tong Set No. 1 and 2 must work in reverse order. Its gripping shoes must be set to hold the kelly's break-out torque. The Kelly connection to the joint of pipe coming out of the hole should not be broken at its upper end until Tong Sets No. 2 and 3 have broken the threaded connection, freeing the emerging joint from the string extending in the mine bore.

The function of the Drill Pipe Magazine for receiving pipe is of a modified sequence to that when pipe is brought into position for 'discharge'. The difference in its operational procedure is as follows: (Please note Assembly Drawing No. 15.1.)

1. The Magazine Retainer Ring (Sub-assembly 15.1.2) is brought to the attitude shown in View D-D.
2. After the Kelly is disconnected from the joint, rotate the Loading Shoe, (Assembly 15.1.3) so that its roller elements (15.1.3.1) are in the up position as shown in View C-C.
3. Rotate the magazine, if necessary, to align 'the designated' chute into position where it can receive joints of pipe. (Please note View B-B.)
4. After the selected magazine chute is in place, rotate the Magazine Container (Sub-assembly 15.1.2) until its slotted side is in the up position as shown in View B-B.
5. In the event the 'Drill Pipe Magazine' is empty, at the start of loading pipe into it, it is suggested that loading the chutes be made in a manner so that diametrical opposites are each loaded in sequence, and that that sequence be followed until all the chutes are filled. This will require less power to the control of the Magazine than will be required if it is subjected to unbalanced loading.

The 'conventional' means of handling drill pipe requires a minimum of 3 men and, oftentimes, standby hoisting equipment. The proposed magazine requires only 2, and is further expected to reduce considerably the time required to either add on 'new' drill pipe as drilling advances, or to remove it from the string when retrieving the pipe after a mine bore is completed.

5.0 NOMENCLATURE AND DEFINITIONS

The data following is a listing of all the illustrations prepared to identify the mining concept and the hardware assembly required to make it functional. The list is prepared in 2 divisions. The first division (5.1) lists the Concept and Preliminary Design Plans. The second division (5.2) lists Assembly Drawings of pertinent hardware related to the mechanics of the mining technique.

5.1 MINING/ASSEMBLY/EQUIPMENT PLANS

<u>PLAN</u>	<u>DESCRIPTION</u>
1.0.1	MINING TECHNIQUE (See discussion in Section I)
1.0.2	MINING PLAN; -Z- AXIS (See discussion in Section II, Item 3.2)
1.0.3	PILOT (PROBE) HOLE DRILLING RIG
1.0.4	FULL BORE MINING RIG & SUPPORT EQUIPMENT (See discussion in Section II)
1.0.5	MINING HEAD AND MINE HEADING SUPPORT EQUIPMENT ASSEMBLY (Hydraulics and operational detail pertinent to the function and coordination of the advance movement of the Mining Head, the Drive Stem String and the Mine Bore Support Collars)
1.0.6	MINE BORE SUPPORT SYSTEM (See discussion in Section II)
1.0.7	INSTRUMENTATION AND CONTROL SYSTEM OPERATIONAL CONTROL PLAN; Instrumentation plan layout on computer and Manual Controls necessary to the Mining System's Hardware and to the service requirements of the Mining Rig.

5.2 ASSEMBLY DRAWINGS -- NOMENCLATURE

MINE BORE MINING RIG (DESIGN PLAN 1.0.4)
(See Assemblies 1.1 Through 1.6)

1.1 KELLY RAIL ASSEMBLY

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.1.1			Kelly Rail		
1.1.1.1			Kelly Rail Pivot Shaft		
1.1.1.2			Kelly Rail Bearing - Dodge SCM Piloted Flange Bearing For 3½" Dia. Shaft		
1.1.1.3			Crowd Cylinder Mount (5,816 lbs.)		
1.1.1.4			44½ Fl. Boston Gear Racks 20° Pressure Angle (4 Places)		
1.1.2			Collar Support		
1.1.2.1			Collar Support Cylinders		
1.1.2.2			Support Grapple		
1.1.2.3			Collar Support Wheels		
1.1.3			Kelly Rail Elevator System		
1.1.3.1			Rail Elevator Drive (Hydraulic Motor)		
1.1.3.2			Sprocket Gear Assembly		
1.1.3.2.1			52 Tooth x ½" Pitch Double Width Sprocket		
1.1.3.2.2			30 Tooth x ½" Pitch Double Width Sprocket		
1.1.3.2.3			Dodge Type E Pillow Blocks For 4-7/16" Dia. Shaft		
1.1.4			Housing Beam		
1.1.5			Kelly Rail Drive Shaft		
1.1.6			Chain Tensioner		
1.1.7			Tensioner Housing Channel		
1.1.8			Kelly Rail Guide Roller		
					48,816

NOMENCLATURE
ASSEMBLY 1.2
KELLY ASSEMBLY

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.2.1			Kelly Drive Stem		
1.2.1.1			Upper Brg. Retainer		
1.2.1.2			Lower Brg. Retainer		
1.2.2			Kelly Crowd Drive Housing		
1.2.2.1			Kelly Crowd Drive Housing Roller		
1.2.2.1.1			Dodge Type E Pillow Blocks For 2" Dia. Shaft		
1.2.2.1.2			2" Dia. Shaft		
1.2.2.2			$\frac{3}{4}$ " Pitch x 22 Tooth x 4 Strand Width Sprockets		
1.2.2.2.1			2" Dia. Shaft		
1.2.2.2.2			Dodge SCM Piloted Flange Bearings For 2" Dia. Shaft		
1.2.2.3			$\frac{3}{4}$ " Pitch x 66 Tooth x 4 Strand Width Sprockets		
1.2.2.4			$\frac{3}{4}$ " Pitch x 4 Width Chain		
1.2.2.5			14.62" Dia. x 6" Width Pinion Gear		
1.2.2.6			Hagglund Hyd. Motor #40.630		
1.2.3			Kelly Drive Assembly		
1.2.3.1			Drive Stem Drive Housing		
1.2.3.2			52-7/8" P.D. x 9" Width Bull Gear		
1.2.3.3			10-1/8" P.D. x 9" Width Pinion Gear		
1.2.3.4			Dodge Type E Pillow Blocks For 2" Dia. Shaft		
1.2.3.5			2" Dia. Shaft		
1.2.3.6			Hagglund Hyd. Motor #40.630		
			See Next Sheet For Total Weight		

NOMENCLATURE
ASSEMBLY 1.2 - Continued
KELLY ASSEMBLY

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.2.4			Upper Brg. Cover Plate		
1.2.4.1			Lower Brg. Cover Plate		
1.2.5			Kelly Drive Stem Sub		
1.2.6			Timken Double Cup Single Cone Brg. No. LM288900		
1.2.7			Timken Two Row Double Cup Single Cone Brg. No. LL889000		
1.2.8			Timken Thrust Brg. No. T48000		
					43,478

NOMENCLATURE
ASSEMBLY 1.3
CROWD SYSTEM (Support Collars)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.3.1			Thrust Base -- See Sub-assembly 1.1.1.3		
1.3.2			Crowd Ring	1	
1.3.2.1			Crowd Cylinders (Est Wt. 850 #'s each)	4	
1.3.2.1.1			Plunger Guide Gusset	8	
1.3.2.1.2			Plunger Guide	4	
1.3.2.2			Aligning Cylinders - Sheffer MH Series, 4" Bore x 5" Stroke Front Flange Mount Cylinder	2	
1.3.2.2.1			Aligning Shoe	2	
1.3.2.3			Unlocking Cylinders - Sheffer MH Series, 1-1/8" Bore x 2" Stroke Front Trunnion Mount Cylinder	4	
1.3.2.3.1			Plunger	4	
1.3.2.3.2			Unlocking Cylinder Mount	2	
1.3.3			Crowd Chuck Cylinder Housing		
1.3.3.1			Crowd Cylinder Valve		
1.3.4			Wheel Assembly Housing	2	
1.3.4.1			Wheel Shaft	2	
1.3.4.2			Crowd Housing Wheel	2	
					9,400#

NOMENCLATURE
ASSEMBLY 1.4
RIG HOUSING

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.4.1			Rig Base		
1.4.1.1			Kelly Rail Mount		
1.4.1.2			Hoist Beam		
1.4.1.2.1			Hoist		
1.4.2			Rig Base Collar Support		
1.4.2.1			Collar - Lock Support		
1.4.2.2			Wheel Housing Support Base		
1.4.2.2.1			1½" Dia. Shaft		
1.4.2.3			Wheel Support Housing		
1.4.2.3.1			Wheel Attitude Brace		
1.4.2.3.2			1½" Dia. Shaft		
1.4.2.3.3			Bronze Bearing Plate	8,506#	
1.4.2.3.4			Pivot Pin		
1.4.2.4			Wheel Housing		
1.4.2.4.1			1½" Dia. Shaft		
1.4.2.4.2			Rig Base Collar Support Wheel 10" Dia. x 3" Width		
1.4.2.4.3			Timken Brg. #33800, Cup #33821D		
1.4.3			Collar Support - Fore Leg		
1.4.4			Collar Support - Aft Leg		
1.4.4.1			Aft Leg Diagonal		
1.4.5			Collar Support - Leg Mount		
See next sheet for total wt.					

NOMENCLATURE

ASSEMBLY 1.4

RIG HOUSING

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.4.6.			Leveling Jack		
1.4.7.			Collar Support Rollers		
1.4.8			Drive Stem Service Platform		
1.4.8.1			Extendible Floor		
1.4.9			Operator's Platform		
1.4.10			Service Lifeline		
1.4.11			Beam H Sprocket Chain		
1.4.12			Transport Wheels		
					93,506
1.5.1			Collar Loading Track		
1.5.1.1			Track Support Bracket		
1.5.1.2			Adaptor		
1.5.2			Dolly Winch		
1.5.3			Winch Line Sheave		
1.5.5			Winch Line		
					22,596
			ASSEMBLY 1.6		
			COLLAR CARRIAGE		
1.6.1			Collar Loading Carriage (See Sub-assembly 1.1.2)		
					16,325

NOMENCLATURE

ASSEMBLY 1.7

ADIT COLLAR

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
1.7.1			Surface Caisson		
1.7.1.1			Collar Support Guide		
1.7.1.1.1			Support Beam -- Mining Head		
1.7.1.2			Anchor Pin		
1.7.1.3			Collar Mounting Bar		
1.7.1.3.1			Collar Mounting Bar		
1.7.1.3.2			Support Guide Stabilizer Bar		
1.7.2			Caisson Sub		
1.7.2.1			Caisson Drive Sub		
ASSEMBLY 1.8					
KELLY RAIL TORSION LOCK					
1.8.1			Torsion Bar	2	
1.8.2			Torsion Cam Housing Plate	4	
1.8.3			Torsion Cams	4	
1.8.4			Lock Springs	4	
1.8.5			Torsion Lock Cylinders	4	
1.8.6			Kelly Rail Torsion Lock Hydraulic Hardware (1 Assembly)		
1.8.7			Kelly Rail Attitude Limit Switch	1	
ASSEMBLY 1.9					
GUSSET					
1.9.1			Beams E & L Connector Gusset		

NOMENCLATURE

ASSEMBLY 2.1

SUPPORT COLLARS (Consider 2560 Ft. Long Bore)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. IN TONS
2.1.1			Mine Support Collar	113	
2.1.1.1			Dowel Pin Assembly		
2.1.1.2			Collar Sleeve		
2.1.2			Drive Stem Stabilizer; Unit; and Assembly To Support Collar		
2.1.2.1			Mounting Base		
2.1.2.2			Roller Housing		
2.1.2.3			Wheel Assembly		
2.1.2.3.1			Wheel Shaft		
2.1.2.4			SKF Levellor Roller (See product K2701)		
2.1.2.5			Assembly Bolt and Jam Nuts		
2.1.3			Drive Stem Hold Down Bar		
2.1.3.1			Hold Down Bar Lock		
2.1.3.2			Hold Down Bar & Lock Springs		
2.1.4			Drive Stem Tie Down Chain		
2.1.5			Lebus Load Binder		
2.1.6			Support Bar (Hyd. & Electric Lines)		
2.1.7			Anchor Pin		
Total Wt. = 2,479,365 Lbs.				or -	1239.7

NOMENCLATURE
ASSEMBLY 2.2
ANCHOR COLLARS

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. IN TONS
2.2.1			Main Housing Shell		
2.2.2			Anchor Shoe Shell (Bore Wall Thrust - Top Side)		
2.2.2.1			Anchor Shoe Shell (Bore Wall Thrust - Bottom Side)		
2.2.3			Tang Housing	12	
2.2.4			Thrust Sleeve Wiper		
2.2.5			Thrust Cylinder (Advance Movement)		
2.2.5.1			Thrust Cylinder (Retreat Movement)		
2.2.6			Anchor Shoe Cylinder		
2.2.7			Dowel Pin Assembly		
2.2.8			Adaptor Sub -A-		
2.2.9			Adaptor Sub -B-		
Total Wt. = 492,750 Lbs.				or -	246.4 Tons
NOTE: Assemblies 2.1.3 through 2.1.5 (see Support Collar hardware units) must be provided for and mounted to the Anchor Collars.					

NOMENCLATURE

ASSEMBLY 3.1

DRIVE STEM

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
3.1.1			Drive Stem -- Outer Shell		
3.1.1.1			Chain Lug		
3.1.2			Dowel Pin Flange		
3.1.2.1			Dowel Pin		
3.1.3			Lock Ring Flange		
3.1.3.1			Lock Channel		
3.1.3.2			Lock Channel Pin		
3.1.3.3			Lock Pin		
3.1.3.3.1			Lock Pin Keeper		
3.1.4			Grommet		
3.1.5			Locking Chain		
3.1.6			Drive Stem Flighting		
3.1.7			Load Cell Housing Assembly	1	
3.1.7.1			Load Cells	4	
3.1.7.2			Retainer Bars	4	
3.1.8			Drive Stem Adaptor and Load Cell Mounting Base	1	
					4833 lb.

NOMENCLATURE

ASSEMBLY 4.1

MINING HEAD

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
4.1.1			Mining Head Face		
4.1.1.1			Guidance Bushing	1	
4.1.2			Mining Head Housing	1	
4.1.3			Mining Head Flighting Housing	1	
4.1.4			Mining Head Flighting		
4.1.5			Housing Enclosure Plate	1	
4.1.6			Lateral Thrust Bearing Housing	1	
4.1.7			Mining Head Housing Rear Closure Plate	1	
4.1.8			Outer Planetary Ring Gear	1	
4.1.8.1			Inner Planetary Ring Gear	1	
4.1.8.1.1			Inner Planetary Ring Gear Housing	1	
4.1.8.2			Planetary Drive Pinion Gear	4	
4.1.8.3			Pinion Gear Shaft	4	
4.1.8.4			Pinion Gear Bearing	4	
4.1.8.5			Pinion Gear Housing	1	
4.1.8.5.1			Pinion Gear Housing Cam Follow On (Torrington CR-36)	16	
4.1.9			Drilling Thrust Bearing - (Timken--T48000)	1	
4.1.10			Lateral Thrust Bearing (Torrington--1180SD39)	1	
4.1.11			Drilling Thrust Bearing Plate	1	
4.1.12			Closure Plate Seals	1	
See next sheet for total wt.					

NOMENCLATURE
ASSEMBLY 4.1
MINING HEAD

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
4.1.14			Anchor Collar Cleaning Element		
4.1.15			Cutters (Disc Gauge)		
4.1.15.1			Cutters (Disc Intermediate)		
4.1.16			Cuttings Sizer -- Scoop		
4.1.17			Point Bits		
4.1.18			Hardened Steel Balls: 1½" Dia., 128 Units		
4.1.18.1			Ball Retainer Plug		
					51,500#

NOMENCLATURE

ASSEMBLY 5.1

COAL and GAS GATHERING & TRANSFER SYSTEM

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
5.1.1		ONE SHEET	Support Collar Shroud		
5.1.1.1			Shroud Exhaust Pipe		
5.1.1.2			Kelly Sub Packer Housing		
5.1.1.2.1			Packer Sealing Shoe		
5.1.1.2.2			Sealing Shoe Pressure Tube		
5.1.1.3			Packer Housing Retainer		
5.1.1.4			Shroud Activator Cylinders		
5.1.2			Kelly Stem Cowling		
5.1.2.1			Coal Discharge Duct		
5.1.2.2			Gas Venting Line (to turbine)		
ASSEMBLY 6.1 GAS TRANSPORT SYSTEM					3,565#
6.1.1			Exhaust Turbine		
6.1.2			Valves and Flow Control Systems		
6.1.3			Air Exhaust Line		650#
6.1.4			Gas Monitoring Instrument		
6.1.5			Pipe Line to Processing		

NOMENCLATURE
ASSEMBLY 7.1
COAL CONVEYOR SYSTEM

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
7.1.1			Conveyor Duct to Belt Conveyor		
7.1.2			Belt Conveyor		
7.1.2.1			Duct Guide to Conveyor		
7.1.3			Conveyor to Car/Truck Loading Hopper		
7.1.4			Loading Hopper		
<div style="border: 1px solid black; width: 100px; height: 100px; position: relative; margin: 10px auto;"> <div style="position: absolute; top: 0; right: 0; width: 50px; height: 50px; border: 1px solid black;"></div> </div>				NO WT. EST. PREPARED	

NOMENCLATURE
ASSEMBLY 8.1
HYDRAULIC HARDWARE
(See Preliminary Design Plan 1.0.5)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
8.1.1			Load Cell Pressure Sensing Bar		
8.1.1.1			Sensor Connecting Lever		
8.1.1.2			Sensor Mechanism Housing		
8.1.1.3			Mounting Plate for Valve 8.1.2		
8.1.2			Valve - Servo-Unit Controlled to Drive Stem Advance System and to Adaptor Sub 2.2.9 of Anchor Collar No. 1		
8.1.3			Valve - Solenoid Controlled to cyclic advance movement in mine bore of Anchor Collar groups. (Group 1A, 3, 5, 7, 9, 11, etc., and Group 1, 2, 4, 6, 8, 10, 12, etc.)		
8.1.4			Valve - Solenoid Controlled to cyclic retreat movement of Anchor Collar groups from mine bore. (Group 1A, 3, 5, 7, 9, 11, etc., and 1, 2, 4, 6, 8, 10, 12, etc.)		
8.1.5			Valve - Solenoid Controlled from operator's panel, providing access to either Valve 8.1.3 or 8.1.4		
8.1.7			Hydraulic Line; Pump to 8.1.5 Valve		
8.1.7.1			Hydraulic Line; Connecting Valves 8.1.5 & 8.1.4 (cycle movement of Mine Support System). See Anchor Collars 1A, 3, 5, 7, 9, 11, etc.		
8.1.7.2			Hydraulic Line: Connecting Valves 8.1.5 & 8.1.3 (cycle movement of Mine Support System). See Anchor Collars 2, 4, 6, 8, 10, 12, etc.		
8.1.7.3			Hydraulic Line: Valve (8.1.2) to Adaptor Sub 2.2.9 Cylinders (2.2.5) of Anchor Collar No. 1 Only.		
8.1.7.4			Hydraulic Lines: Valve (8.1.3) to Thrust Cylinders 2.2.5 and to 2.2.5.1, and to Anchor Cyls. 2.2.6.		
8.1.7.5			Hydraulic Lines: Valve (8.1.4) to Thrust Cylinders 2.2.5.1, and to Anchor Cyls. 2.2.6.		
8.1.7.6			Hyd. Reservoir Line		
			See next sheet for total est. wt.		

NOMENCLATURE
 ASSEMBLY 8.1
 HYDRAULIC HARDWARE
 (See Preliminary Design Plan 1.0.5)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
8.1.8			Servo Unit; Control to Valve 8.1.2 (Mount on Mining Rig)		
8.1.8.1			Servo Unit; Control to 8.1.3 and 8.1.4 Valve (Mount on Mining Rig)		
8.1.8.2			Servo Unit; Control to 8.1.5 Valve (Mount on Operator's Control Panel)		
8.1.8.3			Servo Unit; Control to 1.4.1. Valve (Crowd Ring Cyl.)		
8.1.9			Microprocessor; controls Servo Units 8.1.8 & 8.1.8.1.		
8.1.9.1			Microprocessor; controls Drive Stem Functions		
8.1.10			Control Computer		
8.1.11			Manual Control to Valve 8.1.5. (Drive Stem Movement -- Advance or Retreat)		
8.1.12			Manual Control to Drive Stem Rotation		
8.1.13			Manual Control to 8.1.3 and 8.1.4 Valves on Mine Support System.		
8.1.14			Manual Control to Power Plant for operation of the Drive Stem String and to the operation of the Mine Support System.		
8.1.15			Manual Control to Power Plant for Mining Rig's Operation; the Kelly's movement and the Kelly Rail Attitude Control.		
8.1.16			Manual Control to Support Collar Shroud Cylinders (5.1.1.4)		
8.1.17			Manual Control to Gas Exhaust Turbine (6.1.1)		
8.1.18			Manual Control to Air Exhaust Line (6.1.3)		
					7,500#

NOMENCLATURE
ASSEMBLY 9.1
ELECTRONIC HARDWARE

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
9.1.1			Limit Switch Housing	1	
9.1.2			Limit Switch; Phone Control to Anchor Collars 1, 2, 4, 6, 8, 10, etc.	2	
9.1.2.1			Limit Switch; Advance Control to Anchor Collars 1A, 3, 5, 7, 9, 11, etc.	1	
9.1.3			Contact Bar		
9.1.4			Electric Line		
			See Assembly Plan 1.0.5 for Mounting & Functional Details.		
			Approximate Weight - All Units		50#

NOMENCLATURE

ASSEMBLY 10.0

PILOT HOLE DRILL STRING ACCESSORIES

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
10.1			Drill Pipe -- 2-7/8" API Drill Pipe With Internal Flush Tool Joints -- 1-5/8" T Ribbing - (16.4 lbs. per ft.)	81	39,852
10.2.1			Adapter Sub. to Drill Collars		
10.2.2			Stabilizer Sub.		
10.2.3			Adapter Sub. -- D.H. Motor to Drill Bit		500
10.3			Stabilizer		
10.3.1			Stabilizer Retaining Collar		
10.4			3 3/4" O.D. Non-magnetic Drill Collars	2	984
					41,336#

NOMENCLATURE

ASSEMBLY 11.0

PROBE HOLE DRILLING ACCESSORIES

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION.	NO. OF UNITS	TOTAL WT. ALL UNITS
11.1.1			Lead Casing Section -- Houses Down-Hole Motor		
11.1.2			Telescopic Member		
11.1.3			Retainer Sleeve		
11.1.4			"O" Ring		
11.1.5			Casing Held Offset Cam Unit (Houses Section of Drill Pipe With Deflection Lobes)		
11.1.6			Cam Housing Casing		
11.1.7			Deflection Sub Drill Pipe Unit Housing Directional Setting Lobes		
					550#
11.2			6" O.D.; Internal Upset Casing; 5.424 I.D. x 29' 14" Length: (Box to Box)		
11.3			6" O.D. Casing Coupling: (Pin to Pin)		
11.4			Drill Pipe -- 2-7/8" API With Internal Flush Tool Joints (10.4 lbs. per ft.)	84	26,000
			ASSEMBLY 12.0 DOWN-HOLE MOTOR		
12.1			Down-Hole Motor (Buy Out)		
			ASSEMBLY 13.0		
13.1			Rock Bit (Buy Out)		

NOMENCLATURE

ASSEMBLY 14.0

PROBE/PILOT HOLE DRILL RIG (DESIGN PLAN 1.0.3)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
14.0			PILOT HOLE DRILL RIG		
	14.1.1		Kelly Rail		
	14.1.1.1		Kelly Rail Gear Rack		
	14.1.1.2		Kelly Rail Pivot Shaft		
	14.1.1.3		Kelly Rail Bearing - Dodge SCM Piloted Flange Bearing For 3½" Dia. Shaft		
	14.1.1.4		Elevator System Drive Shaft (3" Dia.)		
	14.1.1.5		Hydraulic Motor		
	14.1.1.6		¾" Pitch x 6" Dia. Sprocket		
	14.1.1.7		¾" Pitch x 12" Dia. Sprocket		
	14.1.1.8		¾" Pitch Chain		
	14.1.1.9		Dodge Type E Pillow Blocks for 3" Dia. Shaft		
	14.1.1.10		3½" Pitch x 14 Tooth Sprockets For RX-238 Chain		
	14.1.2		Kelly Carriage		
	14.1.2.1		Kelly Carriage Drive (Hyd. Motor)		
	14.1.2.1.1		Kelly Carriage Drive Shaft		
	14.1.2.1.2		Kelly Carriage Gear Shaft		
	14.1.2.1.3		Kelly Carriage Roller		
	14.1.2.1.4		Kelly Carriage Roller Shaft (2" Dia.)		
	14.1.2.1.5		Dodge SCM Piloted Flange Drgs. For 2" Dia. Shaft		
	14.1.2.1.6		Dodge Type E Pillow Blocks For 2" Dia. Shaft		
	14.1.2.1.7		6" Dia. Pinion Gear		
	14.1.2.1.8		10" Dia. Sprocket Gear x ½" Pitch		
	14.1.2.1.9		20" Dia. Sprocket Gear x ½" Pitch		

NOMENCLATURE

ASSEMBLY 14.0

PROBE/PILOT HOLE DRILL RIG (DESIGN PLAN 1.0.3)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
	14.1.2.1.10		$\frac{1}{2}$ " Pitch Chain		
	14.1.3		Kelly		
	14.1.4		Kelly Swivel		
	14.1.5		Tongs		
	14.1.5.1		Tong Housing Cylinders		
See Reg. Total Wt. Est. on Page 2-126					

NOMENCLATURE

ASSEMBLY 14.0

PROBE/PILOT HOLE DRILL RIG (DESIGN PLAN 1.0.3)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
	14.2.1		Mud Pumps	1	20,000
	14.2.2		Power Plant		
	14.2.3		Power Plant Skid		
	14.3.1		Stand Pipe	15,000	15,000
	14.3.1.1		HI. Press. Line -- Fr. Pump		
	14.3.2		Flexible Hose (HI. Press.)		
	14.3.2.1		Flexible Hose Coupling		
	14.3.3		Mud Swivel		
	14.3.4		Mud Tank		
	14.4.1		Rig Base	70,000	70,000
	14.4.1.1		Rig Base - Aft Attachment		
	14.4.1.2		Rig Superstructure - Aft Section		
	14.4.1.3		Rig Superstructure - Fore Section		
	14.4.2		Rig Sub Base		
	14.4.3		Transport Carriage		
	14.4.4		Kelly Rail Elevator System		
	14.4.4.1		Rail Elevator Drive Motor - (Hagglund 42-1600)		
	14.4.5		Leveling Jack		
	14.4.6		Stabilizer Cable		
	14.4.7		#RX-238, 3½" Pitch Chain		
See Reg. Total Wt. Est. on Page 2-126					

NOMENCLATURE

ASSEMBLY 14.0

PROBE/PILOT HOLE DRILL RIG (DESIGN PLAN 1.0.3)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
	14.5.1		Kelly Carriage Tong Housing		
	14.5.1.2		Turnbuckles		
	14.5.2		Kelly Rail Tong Housing		
	14.5.2.1		Dodge Piloted Flange Bearing For 2" Dia. Shaft		
	14.5.2.2		½" Pitch x 6" Dia. Sprocket		
	14.5.2.3		2" Dia. Shaft		
	14.5.2.4		6" Dia. Pinion Gear		
	14.5.2.5		Lateral Thrust Roller		
	14.5.2.5.1		Wheel Bearing		
	14.5.2.6		½" Pitch Chain		
	14.5.2.7		Thrust Roller Shaft		
	14.5.2.8		Hydraulic Motor		
	14.5.2.9		½" Pitch x 3" Dia. Sprocket		
	14.5.2.10		½" Pitch x 5" Dia. Sprocket		
	14.5.2.11		½" Pitch x 15" Dia. Sprocket		
	14.5.2.12		Dodge Type E Pillow Blocks For 2" Dia. Shaft		
	14.5.2.13		2" Dia. Jack Shaft		
	14.5.3		Rig Base Tong Housing		
					2,500
					130,000

NOMENCLATURE

ASSEMBLY 14.0

PROBE/PILOT HOLE DRILL RIG (DESIGN PLAN 1.0.3)

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
	14.6		Drill Pipe x 10.25 lbs./ft. (Probe Hole)	83	25,896
	14.7		Drill Pipe x 16.4 lbs./ft. (Pilot Hole)	83	40,836
	14.8		Probe Hole Drilling Casing x 5,5 kbs./ft,	83	38,595
	14.8.1		Surface Casing	1	666
	14.8.2		Valve (Return Flow)	1	1,500
	14.8.3		Return Mud Line
	14.9.1		Hydraulic Pumps	1	2,500
	14.9.2		Hydraulic Reservoir

NOMENCLATURE
ASSEMBLY 15.0
DRILL PIPE MAGAZINE

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. PER UNIT
15.1.1		1	Magazine	1	25,000
15.1.1.1			Torrington Pillow Block #SAF 23056A10 W33		
15.1.1.2			24" Dia. Sprocket		
15.1.2			Magazine Container	1	14,500
15.1.2.1			Torrington Pillow Block #SDAF 23064A12 W33		
15.1.2.2			24" Dia. Sprocket		
15.1.2.3			Chain		
15.1.3			Loading Shoe	1	7,000
15.1.3.1			Torrington Pillow Block #SDAF 23076A14 W33		
15.1.3.2			Loading Shoe Drive Cylinders		
15.1.3.3			Torrington Cam Followers #CRS-56		
15.1.3.4			24" Dia. Sprocket		
15.1.3.5			Chain		
15.1.4			Magazine Framework	1	15,300
15.1.4.1			3" Dia. Drive Shaft		
15.1.4.2			8" Dia. Sprockets		
15.1.4.3			5 HP. Reduction Motor #TGF5260		
15.1.4.4			1 HP. Reduction Motor #TCR32100		
15.1.4.5			Chain		
15.1.4.6			Track Wheels		
15.1.4.7			Dodge Type C Pillow Blocks For 3" Dia. Shaft		
15.1.4.8			Chain Coupling		
TOTAL WEIGHT - ALL UNITS					61,800

NOMENCLATURE
ASSEMBLY 15.0
DRILL PIPE MAGAZINE

SUB ASSEMBLY	DETAIL DESIGN DWG. NO.	NO. OF SHTS.	DESCRIPTION	NO. OF UNITS	TOTAL WT. ALL UNITS
15.2			Magazine Towing Winch		
15.2.1			Magazine Line Sheave		
15.2.2			Winch Line		
15.3			Winch Motor (Hyd.)		
16.1			Surface Caisson		
16.1.1			Valve (Return Flow)		
16.1.2			Return Mud Line		
17.1			Hydraulic Pumps		
17.2			Hydraulic Reservoir		

SECTION III

EVALUATIONS & ANALYSIS

SECTION III

EVALUATIONS & ANALYSIS

1.0 CALCULATIONS

Following below are a series of calculations pertinent to the Design of the principal Mining Hardware, its functional limitations, and a limited analysis on the system's performance, cost-wise, to mine coal on a cost per ton basis.

The 'test vehicle', around which the evaluations were made, is a 9-foot diameter tunnel machine type miner. Specific functionaries of the unit, important to the overall efficiency, include the following:

- : The Drive Stem's efficiency as a haulage means, its structural and performance characteristics.
- : Power requirements to transport the mined mineral from the heading to the surface via the internally flighted Drive Stem.
- : Power requirements to rotate and advance the Mining Head.
- : Power requirements to Jack the Mine Support System.
- : Broad estimates on the cost of the mining hardware, its service life and the manpower (crew) required on its operation and maintenance.
- : Anticipated mine production costs, in terms of dollars per ton mined and delivered to a surface based stockpile.

The Mining Rig's function is to provide the means to handle and control the mining hardware. This is illustrated in Preliminary Design Plan 1.0.4. One of the prime functions, in the area of handling the drilling hardware, requires that one of its sub-assemblies, the Kelly Rail, be made to pivot about Anchor Shafts retained on one of its ends. The pivotal action provides the means to handling the heavy Mine Support Collars and the Drive Stem Units required in the mining process. The power requirements to do this are also analyzed in pages following.

1.1 STEM VOLUME ANALYSIS

THE CRITICAL CONDITION WILL OCCUR WHEN IT IS NECESSARY TO OPERATE THE SYSTEM AT ANGLES DIPPING FROM THE HORIZONTAL.

CONSIDER:

I.D. OF DRIVE STEM = 44.375"

OPENING THRU CTR. OF FLIGHTING = 8"

HORIZONTAL POSITION

AREA REQUIRED FOR TRANSMITTING MATERIAL = A_c

IF, I.E., $A_c = 338 \text{ in}^2$; THEN

$$A_c = A_{\text{sec.}} - A_{\text{TRI.}}$$

$$338 = \frac{1}{2} R^2 (\theta - \sin \theta)$$

$$\theta = 130^\circ$$

$$h_c = R - R \cos \frac{\theta}{2}$$

$$= 22.1875 (1 - \cos 65^\circ)$$

$$h_c = 12.31 \text{ in.}$$

NON-HORIZONTAL POSITION

FIG. 2 IS THE EXPECTED CONFIGURATION AT VARIOUS ANGLE θ . AS θ INCREASES, THE AVAILABLE VOLUME FOR TRANSMITTAL WILL DECREASE. THE LIMIT FOR THIS VOLUME WILL OCCUR WHEN SPILLAGE BEGINS THROUGH THE STEM HOLE IN THE TRAILING FLIGHTING.

FIG. 2

$$h = (R - 4) - 18 \tan \theta$$

$$h_{30^\circ} = (22.1875 - 4) - 18 \tan 30^\circ$$

$$h_{30^\circ} = 7.80 \text{ in.}$$

FIG. 3 TRAILING FLIGHTING

FIG. 4 LEADING FLIGHTING

FOR A 30° ANGLE FROM HORIZONTAL AND 45.00 O.D. CASING.

$$\cos \frac{\theta_1}{2} = \frac{d_1}{R} = \frac{4}{22.1875}$$

$$\theta_1 = 2.73 \text{ (radians)}$$

$$A_1 = \frac{1}{2} R^2 (\theta_1 - \sin \theta_1)$$

$$A_1 = 597.3 \text{ in}^2$$

$$\cos \frac{\theta_2}{2} = \frac{14.40}{22.1875} \quad d_2 = (R - h_{30^\circ})$$

$$\theta_2 = 1.73 \text{ (radians)}$$

$$A_2 = \frac{1}{2} R^2 (\theta_2 - \sin \theta_2)$$

$$A_2 = 183.0 \text{ in}^2$$

$$\text{AVAILABLE VOLUME (V)} = \left[\frac{597.3 + 183.0}{2} \right] 18 ; \quad V = 7023 \text{ in}^3$$

For a 20 ft. long Drive Stem, $V = 54.86 \text{ ft}^3$, which represents approx. 25% of a single stem's total area.

THE ABOVE PROCEDURE IS USED TO DETERMINE THE CASING SIZE REQUIREMENTS FOR ANGLES OTHER THAN 30 DEGREES. ONLY THOSE WORKABLE VALUES ARE SHOWN IN TABLE 1.

O.D.	HORIZ. & (DEGREE)	VOL. / FLIGHTING (IN ³)	M.S.
45	30°	7023	+0.026
48	40°	7047	+0.010
50	45°	7212	+0.033
55	50°	7662	+0.098

TABLE 1

* M.S. = MARGIN OF SAFETY

1.2 MINING RATE ANALYSIS

1. Specify gravity for coal.

- anthracite $sg_a = 1.4$ to 1.8 @ 97 lbs./Ft.^3
- bituminous $sg_b = 1.2$ to 1.5 @ 84 lbs./Ft.^3

Case A

2. From Division 1.1, above, 25.8% of the 'stem' can be filled with coal when working in a -30° angle mine bore. The volume of coal that can therefore be put to transport in a given 20' long, 44.375 I.D. Drive Stem will be:

$$V \text{ Coal} = \frac{TTR^2 \times (L \times 12 - \text{thickness of flighting})}{1728} \times 25.8\% = \text{ft.}^3$$

$$V \text{ Coal} = \frac{TTR^2 \times 237.16 \times 25.8\%}{1728} = \text{ft.}^3$$

$$= \frac{1546.6 \times 237.16 \times 25.8\%}{1728} = 54.86 \text{ ft.}^3$$

3. Consider the wt. of coal with a Specific Gravity from 1.4 to 1.5;

therefore - - - - - 91 lbs. ft.³

Volume by wt. in a 20' long drive stem = 4992 lbs.

4. Mine Production Rate considers the volume of mineral produced per hour, inclusive of time lost to the handling of the mining hardware. The term 'Equipment Availability' defines the net amount of time per hour or per shift during which the mining hardware is producing. The connection time required to 'add' additional units of Mine Support Collars and Drive Stems as the mine bore extends in length will have a limited influence on the mine production rate. It is anticipated that the time lost to the 'connection procedure' of all the pertinent hardware will not exceed 22% of the total scheduled on site mining time. Automated handling, by the Mining Rig of the Support Collars and the Drive Stem Units will assure this.

The analysis following considers a 9' dia. Mining Head, given a rotational speed of 7 RPM and subsequently a cutter (mining tool) speed of approximately 200 ft. per minute. Assume actual mining time (equipment availability) to be 78% or 46.8 minutes per hour of on site time.

5. Haulage capacity of the Drive Stem per item 2 (Case A) specifications is evaluated as follows:

- 5.1 Drive Stem RPM = 9.5
- 5.2 Flighting Pitch = 18.21 inches net
- 5.3 Drive Stem Length = 20 ft.
- 5.4 Haulage Speed = 14.25 ft./min.
- 5.5 Haulage Capacity = V_1

Where:

L = Drive Stem Length

MM = Actual mining time per hour of on site time = 46.8 min.

R = Haulage Speed

SG = Specific Gravity = 1.4 - 1.5 = 91 lbs. ft.³

t = 1 minute of mine production

t_1 = time to move material 1 Drive Stem length

$$t_1 = \frac{L}{R} = \frac{20}{14.25} = 1.403 \text{ minutes.}$$

V = Allowable Drive Stem unit Volume in ft.³ (From Stem Volume analysis, Division 1.1 above = 54.86 ft.³)

VS = Net Volume after 'Swell' of mined consist.

V_1 = Haulage Vol./min. of Drive Stem Rotation

$$V_1 = \frac{t}{t_1} \times V \times W$$

$$V_1 = \frac{1.00}{1.403} \times 54.86 \times 91 = 3558.3 \text{ lbs./min.}$$

W = 91 lbs. per ft.³

5.6 Assume Swell factor 32%; therefore net volume, by weight, of mined consist that stem can haul = 68% of 'in place mineral'.

$$5.7 \text{ Haulage Capacity of 1 Drive Stem Unit} = \frac{V_1 \times MM \times VS \times 60}{2000 \text{ MM}} \\ = \frac{3558.3 \times 46.8 \times .68 \times 60}{2000 \times 46.8} = 72.6 \text{ TPH}$$

6. Haulage Capacity Versus Mining Rate - 30° angle Mine Bore.

Permissible mining advance rate for the Mining Head is equal to the haulage capacity of the Drive Stem; and mine production rate translates to the advance rate of the Mining Head in terms of feet per hour.

From above item 5.7 and a Drive Stem specification as per item 2, the haulage capacity is determined to be 72.6 tons per hour of operating time; therefore:

$$HC = A \times MR \times \frac{W}{2000}$$

$$72.6 = 63.617 \text{ ft.} \times MR \times \left(\frac{91}{2000}\right) = 2.895 \text{ MR}$$

$$MR = 25.07 \text{ ft.}$$

25.07 = permissible mining advance rate in terms of feet per hour.

Where:

A = Area of 9 ft. dia. bore.

MR = Distance of Mining Head advance for a given period of time.

W = Weight per ft.³

TPH = Tons per hour

HC = Haulage Capacity = TPH

Case B. - 20° Angle Bore

Considering a - 20° angle mine bore, 30% of the total Drive Stem Volume would be available to haulage in the same Drive Stem. The material volume this allows = 63.68 ft.³. Considering the swell factor, and again the formula, items 5.5 and 5.7 above; wherein,

$$V_1 = \frac{1.00}{1.403} \times 63.68 \times 91 = 4130.3 \text{ lbs./min. and; Haulage Capacity of}$$

$$1 \text{ Drive Stem unit per hour of rotation time} = \frac{V_1 \times MM \times VS \times 60}{2000 \text{ MM}}$$

Accordingly: $\frac{4130.3 \times 46.8 \times .68 \times 60}{2000 \quad 46.8} = 84.26 \text{ TPH}$

Haulage Capacity Versus Mining Rate

Considering analysis and process of item 6 above; $HC = \frac{A \times MR \times W}{2000}$

Accordingly; $84.26 = 63.617 \text{ ft.} \times MR \times \left(\frac{91}{2000}\right) = 2.895 \text{ MR}$

$MR = 29.1 \text{ ft.}$

29.1 feet = permissible mining advance rate in terms of feet per hour.

Case C. Horizontal Bore (-0° Angle)

Considering a true horizontal mine bore, 38.6% of the total Drive Stem Volume would be available to haulage. The material volume this allows is 81.87 ft.³.

Considering the swell factor, and again, the formula, item 5.5 and 5.7 above; wherein:

$V_1 = \frac{1.00}{1.403} \times 81.87 \times 91 = 5310.2 \text{ lbs./min. and; Haulage Capacity of}$

1 Drive Stem unit per hour of rotation time = $\frac{V_1 \times MM \times VS \times 60}{2000 \quad MM}$

Accordingly: $HC = \frac{5310.2 \times 46.8 \times .68 \times 60}{2000 \quad 46.8} = 108.33 \text{ TPH}$

Haulage Capacity Versus Mining Rate

Considering analysis and process of item 6 above; $HC = \frac{A \times MR \times W}{2000}$

Accordingly: $108.33 = 63.617 \text{ ft.} \times MR \times \left(\frac{91}{2000}\right) = 2.895 \text{ MR}$

$MR = 37.42 \text{ ft.}$

37.42 Feet = permissible mining advance rate in terms of feet per hour.

Conclusion:

1. Mine production rates, or the rate at which a mine bore heading can advance, is limited to the Haulage Capacity of a given Drive Stem's inside diameter and the negative angle from the horizontal at which it is made to work.
2. With a given set of mining hardware specifications, mine production can be influenced positively, primarily by considering a higher RPM to the Drive Stem's function, or by decreasing the negative angle from the horizontal at which a mine bore will be developed.

1.3 STRUCTURAL CALCULATIONS: (DRIVE STEM CASING)

THE CASING STRUCTURE IS SUBJECTED TO SEVERAL LOADING CONDITIONS WHICH DEFINE THE LIMITS OF THE SYSTEM.

1. THE COMPRESSION LOAD REQUIRED TO PRODUCE THE CUTTING ACTION WITH THE MINING HEAD.

$$P_c = 40,000 \text{ lbs. (REF. DIV. 1.2, THIS SECTION; POWER REQ'D.)}$$

2. THE TORQUE REQUIRED TO MOVE MATERIAL UP THE FLIGHTING.

$$T = 4.323 \times 10^6 \text{ lb. in. (30° ANGLE) REF. COMBINED HEAD AND TRANSPORT CALC.}$$

CASING PROPERTIES AND SYMBOLS *

D_o = OUTER DIAMETER
 D_i = INNER DIAMETER
 E = MODULUS OF ELASTICITY
 I = MOMENT OF INERTIA
 J = POLAR MOMENT OF INERTIA
 L = LENGTH
 P = COMPRESSION LOAD
 T = TORQUE
 w = UNIFORM LOAD (lb/ft)

$$\begin{aligned} D_o &= 45.00 \text{ in.} \\ D_i &= 44.375 \text{ in.} \\ E &= 29 \times 10^6 \text{ PSI} \end{aligned}$$

$$I = \frac{\pi}{64} [D_o^4 - D_i^4] = 10.95 \times 10^3 \text{ in.}^4$$

$$J = 2I = 21.90 \times 10^3 \text{ in.}^4$$

w = CASING + FLIGHTING + MATERIAL.

$$w = \left[\frac{\pi (D_o^2 - D_i^2)}{4} \right] \frac{293}{1728} + \frac{53.7 \times 91}{20}$$

$$w = 107.8 + 21.7 + 242 = 381 \text{ lbs/ft.}$$

*THE PRESENCE OF THE FLIGHTING WILL HAVE A NEGLIGIBLE EFFECT ON SECTION PROPERTIES.

THE DRIVE STEM STABILIZERS AT THE END OF EACH 20 FT. SECTION WILL CAUSE EACH SECTION TO FUNCTION AS A SIMPLY SUPPORTED BEAM AND A GUIDED COLUME.

SIMPLY SUPPORTED BEAM

UNIFORM LOAD

$$w = 381 \text{ lbs/ft (REF. PG. 3)}$$

$$\text{MAXIMUM BENDING MOMENT} = \frac{wL^2}{8}$$

$$M = \frac{(381)(20 \times 12)^2}{8} = 2.743 \times 10^6 \text{ lb}\cdot\text{in.}$$

$$\text{BENDING STRESS } (f_b) = \frac{Mc}{I}$$

$$f_b = \frac{(2.743 \times 10^6)(22.1875)}{10.95 \times 10^3} = 5558 \text{ psi.}$$

BENDING STRESS IS AT MAXIMUM WHEN THE SYSTEM OPERATES IN A HORIZONTAL POSITION. AT ANY ANGLE, OTHER THAN ZERO, THE UNIFORM LOAD PERPENDICULAR IS REDUCED. (SEE PG. 3)

TORSION LOAD

$$T = 4.323 \times 10^6 \text{ lb}\cdot\text{in (SEE PG. 10)}$$

$$\text{SHEAR STRESS } (\tau) = \frac{TR}{J}$$

$$\tau = \frac{(4.323 \times 10^6)(22.5)}{21.90 \times 10^3}$$

$$\tau = 4440 \text{ psi.}$$

COLUME LOAD

THE COMPRESSION LOAD WILL BE OF CONSTANT MAGNITUDE. THE LOAD REQUIRED WILL NOT CHANGE, DUE TO A HORIZONTAL ANGLE.

$$P = 40 \times 10^3 \text{ lbs (SEE PG. 8)}$$

$$\text{CASING AREA} = \frac{\pi}{4} (D_o^2 - D_i^2) = \frac{\pi}{4} (45^2 - 44.375^2) = 43.85 \text{ in}^2$$

$$\text{COMPRESSION STRESS } (f_c) = \frac{P}{A} = \frac{40 \times 10^3}{43.85} = 912 \text{ psi.}$$

THE LOW STRESS LEVEL SUGGESTS THAT EACH 20 FT. SECTION WOULD ACT AS A COMPRESSION BLOCK, RATHER THAN A COLUME. HOWEVER, THE CRITICAL LOAD FOR A COLUME WILL BE DETERMINED.

$$P_{CR} = \frac{C\pi^2 EI}{L^2}$$

C = FIXITY COEFF. OF 4 FOR AN
END GUIDED COLUME.

$$P_{CR} = \frac{4\pi^2 EI}{L^2} = \frac{(4\pi^2)(29 \times 10^6)(10.95 \times 10^3)}{(20 \times 12)^2}$$

$$P_{CR} = 2.17 \times 10^8 \text{ lbs.}$$

THE MAGNITUDE OF P_{CR} INDICATES THAT THERE WILL BE NO COLUMING EFFECT.

COMBINED MARGIN OF SAFETY:

FOR NORMAL STRUCTURAL STEEL:

$$M.S. = \frac{1}{\sqrt{\left(\frac{I_b}{F_b}\right)^2 + \left(\frac{F_T}{F_r}\right)^2 + \left(\frac{F_c}{F_c}\right)^2}} - 1 = \frac{1}{\sqrt{\left(\frac{5558}{90,000}\right)^2 + \left(\frac{4440}{55,000}\right)^2 + \left(\frac{712}{90,000}\right)^2}} - 1$$

$$= +8.79 \text{ (WORKS IN A HORIZONTAL POSITION)}$$

THE M.S. VALUE OF 8.79 WILL ALLOW PLACING A LOAD IN ACCESS OF THE ANTICIPATED LOADING BY THAT VALUE.

THE PRECEDING ANALYSIS DID NOT CONSIDER TWO POSSIBLE CONDITIONS THAT MAY EXIST.

1. OPERATION OF THE SYSTEM AT VARIOUS HORIZONTAL ANGLES.
2. THE NECESSITY OF A CHANGE IN DIRECTION TO FOLLOW THE COAL SEAM.

LOADING AT ELEVATED ANGLES

W_N = UNIFORM LOAD PERPENDICULAR TO THE CASING.

W_T = UNIFORM LOAD PARALLEL TO THE CASING.

$$W_N = W \cos \theta$$

$$W_T = W \sin \theta$$

SINCE THE CASING IS CAPABLE OF CARRYING THE LOAD IN A HORIZONTAL POSITION, W_N IS NOT CRITICAL.

THE AXIAL LOAD CAUSED BY " W_T " IS OF SOME CONCERN.

$$W_T = W \sin \theta$$

THE TOTAL LOAD PRODUCED BY A 2500 FT. CASING IN A STRAIGHT CONDITION IS VERY LARGE

$$W = W_T (2500) = W \sin \theta (2500)$$

AS AN EXAMPLE:

$$\text{FOR } \theta = 30^\circ \quad W = 381 \sin 30^\circ (2500) = 476,200 \text{ lbs.}$$

THE MAGNITUDE OF THIS LOAD INDICATES THAT NOT ONLY WOULD THE CASING FAIL, BUT THE MINING HEAD WOULD PROBABLY STALL: IT HAS A VERY GREAT EFFECT ON THE REQUIRED TORQUE.

REMEDIES:

1. REDUCE THE MINING RATE; OR
2. REDUCE THE MINING ANGLE; OR
3. REDUCE THE LENGTH OF THE BORE.
4. INCREASE POWER PLANT CAPACITY.

1.3.1 BENDING RADIUS

TO DETERMINE THE POSSIBLE RADIUS OF CURVATURE FOR THE CASING, IT IS NECESSARY TO ANALYZE THE DEFLECTION CAPABILITY OF EACH SECTION.

FOR A UNIFORMLY LOADED BEAM;

$$\text{DEFLECTION } (\Delta) = \frac{5WL^4}{384EI}$$

$$\Delta = \frac{5 \left(\frac{381}{12} \right) (20 \times 12)^4}{(384)(29 \times 10^6)(0.95 \times 10^3)}$$

$$\Delta = .004 \text{ in.}$$

DUE TO THIS STIFFNESS, THE CASING WILL NOT DEFLECT SUFFICIENTLY TO NEGOTIATE A CURVE OF ANY REASONABLE RADIUS. IT WILL BE NECESSARY TO PROVIDE A FLEXIBLE JOINT BETWEEN SECTIONS OF THE CASING IF A RADIUS TO THE MINE HOLE IS CONTEMPLATED.

ASSUMING THAT THE MAXIMUM COMPRESSION OF A SOFT GROMMET WILL BE 0.125 IN., THE MINIMUM RADIUS OF CURVATURE CAN BE DETERMINED.

FIG. 5

$$S_0 = 20.00 \text{ ft} = 240.00 \text{ in.}$$

$$S_i = 240.00 - 2(.125)$$

$$S_i = 239.75 \text{ in.}$$

$$S - S_i \quad \theta \text{ IS CONSTANT}$$

$$R = \frac{3.75(240.00)}{.25} = 3600 \text{ ft.}$$

1.3.2 DIRECTIONAL CHANGE
LIMITATION

ARC LENGTH (S) = RADIUS (R) $\times$ INTERNAL ANGLE (θ).

$$\theta = \frac{S}{R}$$

$$L = R \sin \theta$$

$$d = L \tan\left(\frac{\theta}{2}\right)$$

MINIMUM RADIUS = 3600 ft. (pg. 2).

THEREFORE FOR A 100 FT ARC LENGTH;

$$\theta = \frac{100}{3600} = \frac{1}{36} \text{ rad.} = 1.592 \text{ degrees.}$$

$$L = 3600 \sin 1.592 = 99.995 \text{ ft.}$$

$$d = 99.995 \tan\left(\frac{1.592}{2}\right) = 1.389 \text{ ft.}$$

$$d = \frac{(1.389 \times 12)}{5} = 3.33 \text{ in. / 20 ft. SECTION}$$

DUE TO THE SMALL CHANGE IN THE MINE BORE'S DIRECTION THAT IS POSSIBLE WITHIN THE CASING, IT WILL BE NECESSARY TO APPROACH CURVED SEAM DEPOSITS OF COAL WITH A SHALLOWER ANGLE FROM THE HORIZONTAL AND AT ANGLE TO THE LINEAR PLANE OF THE SEAM. (THE PLANE OF THE SEAM EXTENDING FROM THE EXPOSED FACE.)

1.4 POWER REQUIREMENTS -- TO ROTATE AND TO TRANSPORT MINERAL WITH THE DRIVE STEM

Removal of the mined consist from the mine bore heading via the drive stem flighting requires an increase in power as the mine bore extends in length, or as the angle at which the mine bore dips from the horizontal increases.

The analysis following considers the maximum power demand for mine bores developed up to 2500 ft. in length, and in synclines dipping 20° and 30° from the horizontal in coal weighing 91 lbs. per ft.³.

From previous calculations: -30° Angle Bores

- : Mining Rate cannot exceed haulage rate; therefore = 72.6 TPH
(See item 5.7 Division 1.2 above)
- : Haulage Speed @ 9.5 Drive Stem RPM and $18\frac{1}{2}$ " flighting pitch = 14.25 FPM
- : Transport time = $\frac{2500 \text{ ft.}}{14.25 \text{ FPM}}$ = 175 min. or = 2.92 hrs.
- : Tonnage mined in 2.92 hrs. of mining time is equal to
weight of Coal contained in Drive Stem = 2.92×72.6 = 2127 Tons
- : Coefficient of friction, coal on steel = .33

Power requirements are expressed in the

formula: $HP = \frac{P \times S}{33000}$ and

where: $P = \frac{100}{S \times 3} (HFT + VTt)$

S = speed of conveyance in feet per min.

H = horizontal distance of transport (2500 ft.)

F = Sliding Friction (.33)

T = Tons per hour

V = Vertical distance mineral is in lift

t = time material is in transport (2.92 hrs.)

Haulage: - 30° Angle Bore

Calculations for a seam pitching at 30° from the horizontal:

$$\begin{aligned} P &= \frac{100}{5 \times 3} (2500 \times .33 \times 72.6) + (\sin 30^\circ \times 2500 \times 72.6 \times 2.92) \\ &= \frac{100}{42.75} (59,895) \times (264,990) \\ &= 2.33 \times 324,885 = 756,982 \end{aligned}$$

$$HP = \frac{756,982 \times 14.25}{33000} = 327$$

Haulage: - 20° Angle Bore

Calculations for a seam pitching at 20° from the horizontal:

$$\begin{aligned} P &= \frac{100}{5 \times 3} (2500 \times .33 \times 84.26) + (\sin 20^\circ \times 2500 \times 84.26 \times 2.92) \\ &= 2.33 \times 279,890 = 652,144 \end{aligned}$$

$$HP = \frac{675,444 \times 14.25}{33000} = 281$$

Haulage -0° Angle Bore

$$\begin{aligned} P &= \frac{100}{5 \times 3} (2500 \times .33 \times 108.33) + (108.33 \times 2.92) \\ &= 2.33 \times 89,688 = 208,974 \end{aligned}$$

$$HP = \frac{208,974 \times 14.25}{33000} = 91$$

1.4.1 POWER REQUIREMENTS FOR CURVED MINE BORE CONDITIONS

DUE TO THE POSSIBILITY THAT THE SYSTEM MAY BE REQUIRED TO OPERATE IN A CURVED CONFIGURATION, THERE WILL BE AN INCREASED POWER REQUIREMENT.

FIG. 6

FIG. 6 INDICATES THAT THE LOADS AT OUTPUT LOADS AT "B" WILL BE LESS THAN THE INPUT LOADS AT "A".

$$P_A = \frac{P_B}{\cos \theta} \quad , \quad T_A = \frac{T_B}{\cos \theta}$$

ASSUMING THAT THE LOADS AT "B" ARE THOSE NECESSARY TO OPERATE THE MINING HEAD; P_B AND T_B WILL BE 40,000 AND 180,000 LB. FT. RESPECTIVELY.

1.5 POWER REQUIREMENTS -- TO DRIVE MINING HEAD

The Mining Head will be equipped with disc cutters. These are rolling cutters with anti-friction bearings, and, as such, require less torque to the rotational drive of the Mining Head than is common with drag type cutter bits. The disc cutter will require a greater component of drilling force (normal loading) than the cutter bit. The mechanical nature of the mining system, however, is not critical to the transmission of the normal loading required by the cutting tools; therefore, no advantages are lost to the disc cutter selection.

The disc cutter effects a drilling action through compressive loading of the rock or mineral being mined. Fracture is produced through compressive failure. Failure of the drilling device through high impact or shock type encounter with high strength intrusive materials is practically non-existent.

It is anticipated that a normal load of approximately 1000 lbs. on a disc cutter will produce a good drilling action in coal; that is, cause fracture and fragmentation at a constant rate, providing the force is not allowed to deteriorate. Intrusive materials in a coal seam, such as pyrites, hard slates and shales will not void the drilling effort, but will cause a reduction in the mining rate.

A nine foot diameter Mining Head, as illustrated in Dwg. No. 4.1, will, as an average, contain 20 Disc Cutters. As noted above, the drilling force (normal load) required by each is not expected to exceed 1000 lbs. for the mining of pure coal. This loading should cause 3/4", or deeper, fragmentation with each rolling pass of the disc over the coal face.

To insure, however, that an expected mining rate can be achieved through coal deposits containing hard intrusive materials, the portion of the power plant serving the Mining Head should have a 100% reserve.

The calculations following therefore, for maximum values, consider:

- : 108" Dia. Mining Head; 9 ft.
- : Unit normal loading - - - - - 1000 to 2000 lbs./disc
- : Total normal loading required for 20 disc cutters (max.) = 40000 lbs.
- : From the formula $HP = \frac{T \cdot 2 \cdot \pi \cdot n}{550 \cdot 60}$

where:

$$T = \text{torque} = W.R = 40000 \times 4.5 = 180,000$$

$$n = \text{RPM} = 7$$

$$W = \text{normal load on Disc Cutter} = 40000$$

$$R = \text{Radius} = 4.5 \text{ ft.}$$

therefore:

$$HP = \frac{180000 \cdot 2 \cdot \pi \cdot 7}{550 \cdot 60} = 240$$

Assume friction losses thru the stabilizers supporting the rotating drive stem and through the planetary gear drive to the Mining Head to accrue to .25%:

therefore, net power plant output required = $1.25 \times 240 = 300 \text{ HP}$

Assume installation of a 300 BHP Diesel Engine.

1.6 POWER REQUIREMENTS -- TO JACK MINE SUPPORT SYSTEM

The mine support system is comprised of a series of round cylindrical collars connected to each other. In the connection plan, the collars are staged in groups of 10, the tenth collar being the unit from which jacking pressure is applied to the other 9 collars ahead of it. The jacking pressure is applied cyclically to alternate groups. It is a 2-cycle system, wherein jacking pressure is applied to one-half of the collars in the mine bore at any given instance.

Jacking the support system into a -30° angle bore is a smaller scale power function than jacking them out of it. Therefore, only the jacking force required to move them up a -30° angle bore will be considered, and this from a mine bore extending 2500 ft.

The mining system suggests that 2 Mining Rigs, set adjacent to each other, be operated at the same time; one of them extending a mine bore while the other is retrieving hardware from a completed bore. Hardware drawn from one bore is immediately transferred and placed into the production bore. This mandates that the retreat rate of hardware from a bore should equal the advance rate in a production bore. The procedure will reduce equipment handling costs to a minimum.

The evaluation following will use 2400 ft. of collars, to simplify the process.

Given:

1. Length of single collar = 20 ft.
2. Number of collars comprising a group = 10
3. Length of 1 group of collars = 200 ft.

4. Weight of 1 group, @ 22,000 lbs. ea. = 220,000 lbs.
5. Number of groups = $\frac{2400}{200}$ = 12
6. Number of Jacking Cycles = 2
7. Number of groups per Jacking Cycle = 6
8. Number of Anchor Collars -- (Jacking Stations) = 6
9. Weight of 6 groups of collars = 1,320,000 lbs.
10. The Support and Anchor Collars house the Drive Stem Assembly via stabilizer units. Calculations made in Division 1.3.1, above, indicate that the Drive Stem Assembly will allow only .004" deflection per unit. The Drive Stem string is supported on one end by the Mining Rig, and by the Mining Head on the other end, which in turn is supported by the guidance pipe. It is expected that, only after a mine bore reaches the maximum length, will the Drive Stem weight have an impact of value on the estimated Support Collar weights as used in this analysis. (Before jacking out of a mine bore starts, it will be emptied of the mineral contents.) A 2500 ft. long Drive Stem will weigh approximately 604,000 lbs. The analysis assumes that 30% of that weight will impact the total estimated Support Collar weight. Therefore, the total weight factor associated to 6 groups of collars is equal to $1,320,000 + \frac{(.30 \times 604,000)}{2}$ = 1,410,600 lbs.

11. Coefficient of friction: assume maximum to be 100%.
(coef. coal on steel at 33% plus weight from subsiding overburden) = 100%
12. Total mass load to jack per each cycle of the 2-cycle system = 2,821,000 lbs.
13. From previous analysis, advance rate of mine heading, -30° angle bore = 25.07 ft./hr.
14. Since 2-cycle system, advance rate per each group in the cyclic movement = 50.14 ft./hr.
and time allotted per cycle = 30 secs.
therefore; the jacking rate = 10.03 in./min.
15. Movement up a 30° angle bore; therefore lift =
Slope Length x Sin of 30° = 10.03 x .5 = 50.15 inches
16. HP required in lift = $\frac{5.015 \times 1.320.000}{12 \times \frac{33000}{2}}$ = 33.4
(The impact of the Drive Stem does not apply.)
17. Number of cylinders in 6 jacking stations
(Anchor Collars) = 24
18. Consider operating hydraulic press = 2250 psi
19. Cylinder bore required = $\frac{\text{LOAD}}{\text{PSI} \times \text{NO. OF CYL.} \times \text{Eff.}}$
$$= \frac{\frac{2,821,000}{45,900}}{.785d^2} = \frac{61.464}{.785d^2} \text{ and } d = 8.849 \text{ inches}$$

Use 9" diameter bore cylinders.

20. Hydraulic Horsepower Input required =

$$\frac{\text{Flow Rate Output (GPM x pressure (psi))}}{1714 \times \text{efficiency (85\%)}} \quad \text{or}$$

$$\text{HP in.} = \frac{\text{GPM} \times \text{PSI}}{1714 \times \text{Eff.}}$$

$$\text{GPM} = \frac{\text{Area of Cyl.} \times \text{length} \times \text{No. of Cyls.}}{231}$$

$$= \frac{63.617 \times 10.03 \times 24}{231} = 66.294$$

$$\text{HP in.} = \frac{66.294 \times 2250}{1714 \times 85} = \frac{149,161.5}{1456.9} = 103$$

21. There will be a slight time loss (milli-second delays) in the control and shifting of the valves ministering to the cyclic demands of the jacking operation. Assume this time loss to accrue to 10% of total; therefore, jacking time per cyclic movement of Collars; approximately = 9.00 min.

The movement of inertia will also penalize the system and will require an approximate 20% increase over the norm; therefore, power plant demand to provide movement = 123.6

Power required to provide upslope lift = 33.4 H.P.

Total Power Demand - Approx. = 157 H.P.

Since only the power required in the 'lift phase' will diminish as the negative angle of the mine bore decreases, and the power plant, on a continuous basis, should preferably operate at 75% of its maximum rated, a 200 H.P. Power Plant will be required to handle the Mine Support Collars.

1.7 POWER REQUIREMENTS TO RAISE THE KELLY RAIL OF THE MINING RIG.

THIS ANALYSIS WILL NOT CONSIDER THE DYNAMICS OF THE SYSTEM. IF THE MOST CONSERVATIVE CONDITION IS ANALYZED, THE SYSTEM WILL FUNCTION.

THE MOST CONSERVATIVE CONDITION WILL EXIST WHEN THE RAIL IS IN A HORIZONTAL CLEARANCE POSITION. THAT IS, WHEN A FORCE IS APPLIED, AT THE UNPINNED END, SUFFICIENT TO LIFT THE RAIL FROM ITS HORIZONTAL POSITION.

PLEASE REFER TO ASSEMBLY PLAN 1.0.4
AND TO THE KELLY RAIL ASSEMBLY DWG. 1.1

FIG. 1

CG. LOCATION IS AN APPROXIMATE VALUE. HOWEVER, AT NO TIME SHOULD ITS LOCATION EXCEED THE INDICATED VALUE.

A SUMMATION OF MOMENTS ABOUT PT. "O" WILL DETERMINE THE "F" LOAD.

$$74,811 (624) - F (832) = 0$$

$$F = 56,108 \text{ lbs.}$$

FROM AN ENERGY CONDITION THE FORCE "F" CAN BE SHOWN NOT TO EXCEED THE VALUE ABOVE. THE WORK $(U)_{1-2}$ OF EXTERNAL LOADS MUST BE ZERO

$$U_{1-2} \text{ OF THE } 74,811 \text{ lbs} = U_{1-2} \text{ OF } F$$

$$74,811 (624 \sin \theta) = F (832 \theta) \quad \text{"F" WILL ALWAYS BE TANGENTIAL TO THE ARC.}$$

$$F = \frac{74,811 (624 \sin \theta)}{832 \theta}$$

$$\text{SINCE } \frac{\sin \theta}{\theta} \leq 1 \quad F_{\text{MAX}} = 56,108 \text{ LBS}$$

THE RAIL IS EXPECTED TO TRAVEL ALONG THE ARC AT 60 FT. PER MIN.

60 FT./MIN. = 1 FT./SEC.

$$\text{HORSEPOWER} = \frac{(56,100)(1)}{550} = 102$$

1.8 TOTAL POWER REQUIREMENTS (-300'± BORES)

Power Plant
#1

1. Drive Stem drive to Mining Head; requires - - - - - 300 HP
(when at max. of 2500 ft. long bore)
2. Drive Stem Conveyance of Material; requires - - - - - 327 HP
(when at max. of 2500 ft. long bore and
maximum grade requirements at -30° from
the horizontal)

Total power plant requirement for Drive Stem Mechanics = 627 HP

Power Plant
#2

Jack Mine Support System - - - - - 200 HP

NOTE:

Power Plant No. 2's function on the control of the
Mine Support System cannot be interrupted; therefore,
Power Plant No. 1 will have to provide the means to
raising and lowering the Kelly Rail of the Mining Rig.

2.0 ESTIMATES

EQUIPMENT WEIGHTS & COST

Following below are a series of broad estimates on hardware weights and approximate cost in terms of '1983' dollars. The weights are presented to help explain the cost estimates compiled in sub-division 3 following, which approximate the mining system's potential mine production costs.

2.1 PROBE/PILOT HOLE

DOWN-HOLE MOTOR, DRILL BITS, AND

ANCILLARY EQUIPMENT REQUIRED FOR DRILLING

This class of hardware is not sold outright domestically; however, plans by at least 1 equipment manufacturer are currently under way to do so. The suppliers currently market to the Oilfield industry through lease arrangements.

The circulation system, necessary to drilling, generally determines the rate at which the probe and/or pilot holes can be drilled. Thus, the lease cost can be translated on a 'cost per foot of hole drilled' basis. Drilling rates ranging to 50 feet per hour, or better, are common in soft earth materials. Other factors which impact, especially the probe hole drilling costs, are as noted elsewhere in the manual;

- a. the amount of geological and geometric data made available from prior vertical hole core drilling programs; and,
- b. the volume of mineable reserve in a given seam deposit.

A hypothetical case, wherein 4,000,000 tons of coal can be mined from a single seam, via 9-foot diameter bores extending 2500 ft. in length, may expect probe and/or pilot hole drilling costs to impact the final mining cost in a range as shown in Table 2 following. It includes labor and Drill Rig costs.

2.2. SUMMARY: WEIGHTS & COSTS

The chart below is an assembly of data; approximate equipment weights and cost that may be considered feasible for a project site wherein 4,000,000 tons are mineable from a seam, permitting 9-foot diameter mine bores to extend 2500 feet in length.

ITEM NO.	TYPE OF EQUIPMENT	NO. OF UNITS	WT. IN LBS. PFR UNIT	EST. COST PFR UNIT	TOTAL WT. IN TONS	TOTAL COST
1	PROBE/PILOT HOLE DRILL RIG (WITH POWER PLANT)	1	112,200	\$ 280,000	56.1	\$ 280,000
2	DRILL PIPE MAGAZINE	2	61,800	101,400	61.8	247,200
3	DRILLING WATER/MUD TANKS	2	8,000	10,000	8.0	20,000
4	DRILL PIPE (PROBE HOLE)	83	312	(30 ft. Jt.) 360	12.9	30,000
5	DRILL PIPE (PILOT HOLE)	*100	492	(30 ft. Jt.) 720	24.6	72,000
6	CASING PROBE HOLE DRILLING	83	465	(30 ft. Jt.) 200	19.3	16,600
7	MINING RIG	2	239,000 (average)	500,000 (average)	229.0	1,000,000
8	POWER PLANTS MNG. RIG & SUPPORT SYS.	6	4,500	30,000	13.5	180,000
9	DRIVE STEM	125	4,833	12,000	302.0	1,500,000
10	MINING HEAD	2	51,500	200,000	51.4	400,000
11	MINE SUPPORT SYSTEM SUPPORT COLLARS	113	21,941	35,000	1,239.7	3,955,000
12	MINE SUPPORT SYSTEM ANCHOR COLLARS	13	41,062	38,000	267.15	494,000
13	**ANCILLARY EQUIP.	**6			60.0	580,000
TOTALS					2,345.45	\$ 8,774,800.

*INCLUDES 17 SPARE JOINTS

**INCLUDES: 25 TON MOBILE CRANE, 20 TON TRACTOR TRAILER, CONVEYER, GAS TURBINE, COMPRESSOR, GENERATOR & AUXILIARY PIPE RACKS

TABLE 1

-30° AND -0° ANGLE PILOT HOLES
OPERATION: 3 SHIFTS/24 HRS.

PROBE/PILOT HOLE DRILLING COSTS
5,800,000 MINEABLE RESERVE: ANTICIPATED RECOVERY 70%
(HYPOTHETICAL CASE)

Mine Bore Spacing = 13 ft.
Length of Bores = 2500 ft.
Length of Seam Outcrop = 5000 ft.
Seam Thickness, Average 10 ft.

ITEM NO.	ITEM	*2 O E C	PILOT HOLE DRILLING DATA										OPERATIONAL COSTS				
			NO. OF HOLES	DRILLING RATE (MINIMUM)		TOTAL DRILLING HRS. PER HOLE (MAX.)		TOTAL HRS. TRIP-OUT/HOLE		TOTAL ON SITE TIME IN YEARS		MAINTENANCE AT 5% AVE. OF OEC PER YEAR IN \$		ALL RELATED COSTS ESTIMATED TOTAL IN \$		COST PER TON	
				-30° BORE	-0° BORE	-30° BORE	-0° BORE	-30° BORE	-0° BORE	-30° BORE	-0° BORE	-30° BORE	-0° BORE	-30° BORE	-0° BORE	-30° BORE	-0° BORE
1	Probe/Pilot Hole Drilling-Rig (1 unit) (Includes Items 1 thru 6 of Table 1, Division 2.0)	\$547,200	385	25.07	37.42	99.7 *3 34.1 133.8	66.82 *3 24.78 91.60	14.00	14.00	6.5	4.6	177,840	125,856	725,040	673,056	\$.181	\$.168
2	Labor: 3 Man Crew/Shift at \$60/hour	NA	385	NA	NA	NA	NA	NA	NA	6.5	4.6	NA	NA	*4 3,416,400	2,417,760	.854	.604
3	Drill Pipe: Probe Hole Drill Pipe Pilot Hole Drill Pipe Casing (Probe Hole)	118,600	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	38,545	27,278	157,145	145,878	.039	.036
4	Circulation System & Accessories	See Item 1 above															
5	Depreciation, Taxes, Interest at 15% Per Year On Items 1, 3, 4 & 7	NA	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	NA	NA	732,030	518,052	.183	.129
6	Expendable Hardware & Accessories: Drill Bits, Drilling Additives	15,000	385	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	15,000	15,000	.004	.004
7	Down-hole Motors & Surveying Equipment (See Item 13 of Table 1, Division 2.0)	85,000	385	25.07	37.42	NA	NA	NA	NA	6.5	4.6	27,625	19,550	112,625	104,550	.028	.026
8	*1 Power Costs (150 H.P. Diesel)	NA	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	NA	NA	*5 213,331	*6 226,459	.053	.057
															TOTAL COSTS	\$1,342	\$1.024

*1 Diesel Power: Fuel wt. = 7.34 lbs./Gall.
Consumption rate 1/3 lb. per BHP hr.

*2 Original Equipment Cost

*3 Surveying and directional control time
allowable per 2500 ft. long hole.

*4 6.5 x 365 x 24 x \$60

*5 Maximum Power Consumption est. at 50% of site time

Formula: 1/3 x BHP x Time x Cost/Gall.

Cost = $\frac{.33 \times 150 \times 24 \times 365 \times \text{years} \times .50 \times \$1.10/\text{Gall.}}{7.34}$

*6 Maximum Power Consumption est. at 75% of on site time

Cost = $\frac{.33 \times 150 \times 24 \times 365 \times \text{years} \times .75 \times \$1.10/\text{Gall.}}{7.34}$

NOTE: The Pilot Holes must be drilled at a minimum rate equal to or less than the time required to ream it to a 9 ft. dia. mine bore through the total length of 2500 ft. See Table 3 and note that the anticipated Mining Rates are 25.07 and 37.42 feet per hour respectively for -30° and -0° angle bores. Logistics pertinent to minimum Equipment and Labor costs require this.

TABLE 2

TABLE 2

9 FT. DIA. BORES
LENGTH OF BORES = 2500 FT.
MINE BORE SPACING = 13 FT.
OPERATION: 3 SHIFTS/24 HRS.

FULL BORE MINING COSTS
COST PER TON MINING ESTIMATES -0° and -30° ANGLE BORES

Seam Thickness = 10 ft.
Length of Seam Outcrop = 5000 ft.

LENGTH OF BORES = 2500 FT. MINE BORE SPACING = 13 FT. OPERATION: 3 SHIFTS/24 HRS.			MINE BORE DATA								OPERATIONAL COSTS				COST PER TON			
ITEM NO.	ITEM	*3 O E C	NO. OF BORES	ADVANCE RATE FT. PER HOUR		MINING TIME PER BORE IN HOURS		TOTAL HOURS PER BORE		TOTAL ON SITE TIME IN YEARS		MAINTENANCE AT 5% AVE. OF DEC PER YEAR IN \$		ALL RELATED COSTS ESTIMATED TOTAL IN \$				
				-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	-30° ✓ BORE	-0° ✓ BORE	
1	Mining Rigs (2) & Power Plants	\$1,180,000	385	25.07	37.42	*4 127.8	85.6	*5 147.8	105.6	*6 6.5	4.6	383,500	271,400	1,563,500	1,451,400	\$0.391	\$0.363	
2	Labor to operate 2 Rigs 6 Man Crew at \$120 per hour	NA	385	NA	NA	NA	NA	147.8	105.6	6.5	4.6	NA	NA	*7 6,832,800	4,835,520	1.708	1.209	
3	Drive Stem; (125 Units)	1,500,000	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	487,500	345,000	1,987,500	1,845,000	0.497	0.461	
4	Mine Support System: Support Collars (113 Units) Anchor Collars (12 Units)	3,955,000 494,000	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	6.5 6.5	4.6 4.6	1,285,374 160,550	909,650 113,620	5,240,375 654,550	4,864,650 607,620	1.31 0.164	1.216 0.152	
5	Ancillary Equipment: 25 Ton Mobile Crane, 20 Ton Tractor-Trailer, Gas Exhaust Turbine, Compressor, Generator, and Auxilliary Pipe Racks	480,000	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	1,560,000	110,400	636,000	590,400	0.159	0.148	
6	Mining Head	400,000	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	130,000	92,000	530,000	492,000	0.133	0.123	
7	Depreciation, Taxes and Interest 15% of OEC per year. Items 1, 3, 4, 5 and 6	.15 x 7,569,000 = 1,135,350	NA	NA	NA	NA	NA	NA	NA	6.5	4.6	NA	NA	7,379,775	5,222,610	1.845	1.306	
8	*1 Power Costs: Rotational Power Demand Peak (2500 ft. Long Bore = 627 HP Average Demand = 1250 ft. Long Bore Therefore = Approx. 350 H.P. (Diesel) 2 Bore Operation, therefore, Approx. 700 HP	NA	385	25.07	37.42	127.8	85.6	NA	NA	*8 5.69	*8 3.81	NA	NA	*9 1,690,909	*10 1,149,060	0.422	0.287	
9	*2 Power Cost for Mine Support Jacking System 157 HP. 2 Bore Operation, therefore 315 HP	NA	385	25.07	37.42	99.7	66.81	*11 99.7	*12 66.81	6.5	4.6			601,475	403,063	0.151	0.101	
															TOTALS		\$6.78	\$5.366

*1 Power Costs; -0° Versus -30° Anole Bore.

*3 OEC: Original Equipment Cost

*7 6.5 x 365x 24 x \$120

*1 Power Costs; -0° Versus -30° Angle Bore.
These are approximately the same. On a -0° Angle Bore the volume of material, due to the higher mining rate, requires proportionately more power; however, this is compensated by the absence of lift as associated to a -30° Angle Bore.

*2 From Analysis in Division 1.6, Section III, it can be assumed that the average demand will be 157 HP since the average bore length will be 1250 ft.

*3 OEC: Original Equipment Cost

*4 $25.07 \times \frac{46.8 \text{ min. of mining time/hr.}}{60} = 19.55 \text{ ft./hr.} \times \frac{2500}{19.55} = 127.8$

*5 147.8 hrs. includes 20 hours as 'move on and off time' per bore.

*6 $\frac{147.8 \times 3.85}{24 \times 365 \text{ (days)}} = 6.5 \text{ Years}$

*7 $6.5 \times 365 \times 24 \times \120

*8 Represents actual mining time considering 78% of advance rate. (in terms of ft./hr.)

*9 1,537,190 Gallons @ \$1.10/Gall (Sp. Gr. .88)

*10 1,044,600 Gallons @ \$1.10/Gall

*11 Based on move, rate of 25.07 ft./hr. into and out of bores ave. distance of 2500 ft.

*12 Based on move, rate of 37.42 ft./hr. into and out of bores

TABLE 3

Reserve Estimate 5,800,000 Tons
Plan 70% Recovery; therefore, production 4,000,000 Tons

TABLE 3

SUMMARY - TOTAL MINING COSTS

5,800,000 Mineable Reserve
 70% Recovery; therefore, 4,000,000 Tons
 Final Mine Bore Dia., 9 ft.

REFERENCE: TABLES 2 & 3.

I T E M	ON SITE TIME, EXPRESSED YEARS		C O S T P E R T O N	
	-30° BORE	-0° BORE	-30° BORE	-0° BORE
PILOT HOLE	6.5	4.6	1.342	1.024
FULL BORE DIA. MINING	6.5	4.6	6.780	5.366

Sub-Total	\$ 8.122	\$6.39
Contingency 25%	2.03	1.597
TOTAL COST	\$10.152	\$7.987

TABLE 4

OVERBURDEN VERSUS MINE SUPPORT REQUIREMENTS

The analyses on the pages following present typical data processing techniques in evaluating the strength of the support system required to maintain a tunnel against ultimate collapse. The evaluating process is addressed to bores that had been developed with explosives, and, therefore, is concerned with earth materials highly fractured, stressed, and rubbelized at the bore's periphery. It is not ideally suited to an evaluation process which seeks specifications for a support system to maintain the integrity of a machine driven tunnel-like bore. This is true, since machine driven bores leave the peripheral earth formations free of stress and induced fissures. In the absence of these, the subsidence time and the volume of earth material given to shifting, or movement, is of a comparatively limited nature and of different measures. The evaluating process on tunnel support systems, as currently used, considers the support system as a permanent deterrent to the tunnel's collapse. The Remote Controlled Mining System requires a support System primarily to deter caving. Subsidence, in most earth materials that are prone to it, will be of a very limited measure since the mining system will concern itself with each bore only a matter of days, whereas the full measure of overburden pressure, from materials other than mud, sand, loess and gravel, takes several months to accrue.

The evaluations following, therefore, are intended to identify their importance, but not necessarily as the kind, or the nature of, evaluations that will ultimately be used in the design of a mobile mine support system required in a remote controlled, tunnel oriented mining technique.

Overburden Impact on Mine Bore Support
To Ascertain Ring Section Strength Requirement

DIA. OF BORE	VERTICAL UNIT LOAD LB./Ft ²	HORIZONTAL UNIT LOAD LB./Ft ²	DENOTATION OF ROCK	UNIT WT. LB./cuFt	NO.
6'-0"	31.0	20.5	GRANITE & ALIKE, VERY RESISTIVE	155.0	I
9'-0"	46.5	30.7	SAND & LIMESTONES, QUARTZ.		
15'-0"	77.5	51.1	SOLID CONGLOMERATES		
6'-0"	50.0	33.0	NORMAL SANDSTONE	150.0	II
9'-0"	75.0	49.5			
15'-0"	125.0	82.5			
6'-0"	75.0	49.5	CLAY-SHALES, SAND & LIME-	150.0	III
9'-0"	112.0	74.0	STONES OF SMALLER RESISTANCE.		
15'-0"	175.0	115.5	LOOSE CONGLOMERATES		
6'-0"	135.0	89.1	LOOSE SHALE & VERY LOOSE LIME-	135.0	IV
9'-0"	202.5	133.65	STONE, GYPSUM, FROZEN GROUND,		
15'-0"	337.5	222.75	COMMON MARL, BLOCKY SANDSTONE,		
			CEMENTED GRAVEL & BOULDERS, STONEY GROUND.		
6'-0"	275.0	181.50	LOOSE LOAM, LOESS, GRAVEL	110.0	V
9'-0"	411.8	271.8			
15'-0"	687.5	453.75			

ROCK PRESSURE DUE TO LOOSENING

IN SOILS COMPOSED OF VARIOUS LAYERS OF ADEQUATE THICKNESS THE PHYSICAL PROPERTIES OF THE LAYER IMMEDIATELY ABOVE THE TUNNEL ONLY MUST BE TAKEN INTO CONSIDERATION, THE DEVELOPMENT OF THE STRESS-FREE BODY BEING NO LONGER AFFECTED BY SUBSEQUENT LAYERS.

ASSUMED CONDITIONS

ZONE OF ARCHING "h": IF

STRENGTH FACTORS: OVERBURDEN FORCE -- EARTH FORMATION

$f_1 = 10$	$\delta_1 = 155$ lbs./cuFt	HIGH STRENGTH GRADE OF ROCK
$f_2 = 6$	$\delta_2 = 150$ lbs./cuFt	MODERATELY " " " "
$f_3 = 4$	$\delta_3 = 150$ lbs./cuFt	MEDIUM " " " "
$f_4 = 2$	$\delta_4 = 135$ lbs./cuFt	MODERATELY LOOSE " " " "
$f_5 = 0.8$	$\delta_5 = 110$ lbs./cuFt	LOOSE " " " "

OVERBURDEN PRESSURE (P_v) DESIGNATION

- P_{v1} - GRANITES AND ALIKE; AND SOLID CONGLOMERATES.
- P_{v2} - SANDSTONES AND MODERATELY STRONG ROCK FORMATIONS.
- P_{v3} - DENSE CLAYS; SHALE; FIRM SAND; LIMESTONE.
- P_{v4} - LOOSE SHALE; MARL; AND STONEY GROUND.
- P_{v5} - LOOSE LOAM; LOESS AND GRAVEL.

ZONE OF ARCHING: (h)

$$\underline{D_2 = 9'-0'' \text{ DIA. OF BORE}}$$

$$h_1 = \frac{D_2}{2 f_1} = \frac{9}{2 \times 10} = 0.45 \text{ Ft}$$

$$h_2 = \frac{D_2}{2 f_2} = \frac{9}{2 \times 6} = 0.75 \text{ Ft}$$

$$h_3 = \frac{D_2}{2 f_3} = \frac{9}{2 \times 4} = 1.12 \text{ Ft}$$

$$h_4 = \frac{D_2}{2 f_4} = \frac{9}{2 \times 2} = 2.25 \text{ Ft}$$

$$h_5 = \frac{D_2}{2 f_5} = \frac{9}{2 \times 0.8} = 5.62 \text{ Ft}$$

AREA OF THE ARCHING ZONE: (F)

$$\underline{D_2 = 9'-0''}$$

$$F_1 = \frac{2}{3} \times D_2 \times h_1 = \frac{2}{3} \times 9 \times 0.45 = 2.7 \text{ Ft}^2$$

$$F_2 = \frac{2}{3} \times D_2 \times h_2 = \frac{2}{3} \times 9 \times 0.75 = 4.5 \text{ Ft}^2$$

$$F_3 = \frac{2}{3} \times D_2 \times h_3 = \frac{2}{3} \times 9 \times 1.12 = 6.72 \text{ Ft}^2$$

$$F_4 = \frac{2}{3} \times D_2 \times h_4 = \frac{2}{3} \times 9 \times 2.25 = 13.5 \text{ Ft}^2$$

$$F_5 = \frac{2}{3} \times D_2 \times h_5 = \frac{2}{3} \times 9 \times 5.62 = 33.7 \text{ Ft}^2$$

VERTICAL ROCK LOAD: (P_v) (PER LINEAR FT.)

$$\underline{D_2 = 9'-0''}$$

$$\underline{P_{v1}} = F_1 \times L \times \delta_1 = 2.7 \times 1 \times 155 = \underline{418} \text{ lbs.}$$

$$\underline{P_{v2}} = F_2 \times L \times \delta_2 = 4.5 \times 1 \times 150 = \underline{675} \text{ lbs.}$$

$$\underline{P_{v3}} = F_3 \times L \times \delta_3 = 6.72 \times 1 \times 150 = \underline{1,008} \text{ lbs.}$$

$$\underline{P_{v4}} = F_4 \times L \times \delta_4 = 13.5 \times 1 \times 135 = \underline{1,822} \text{ lbs.}$$

$$\underline{P_{v5}} = F_5 \times L \times \delta_5 = 33.7 \times 1 \times 110 = \underline{3,707} \text{ lbs.}$$

(See P_v designation - page 3)

CALCULATIONS OF RING SECTIONS

MOMENT AT RING SECTIONS:

1) IF: DENOTATION OF ROCK IS NO. 1 (SEE PAGE 2)

D = 9'-0" DIA. OF BORE

LOAD PER UNIT LENGTH: (UNIT LENGTH = 1 FT.)

$$P_1 = F_1 \times \gamma_1 = 2.7 \times 155 = \underline{418.5 \text{ lbs./Ft.}}$$

MAX. MOMENT: (Mmax)

Mmax WILL BE AT $\alpha = 90^\circ$ & $\alpha = 0^\circ$

$$\cos. 2\alpha = 1$$

$$M_{\max} = \frac{P_1 \times R^2}{1} \cos. 2\alpha$$

$$M_{\max} = \frac{418.5 \times 4.5^2}{1} = 8474.6 \text{ Ft. lbs.}$$

$$\underline{M_{\max} = 101,695 \text{ in. lbs.}}$$

SECTION MODULUS OF RING: (Z_1)

(STEEL)

ALLOWABLE STRESS: $S_B = 57,000 \text{ lbs./in}^2$

$$Z_1 = \frac{M_{\max}}{S_B} = \frac{101,695}{57,000} = 1.78 \text{ in}^3$$

$$\underline{Z_1 = 1.78 \text{ in}^3}$$

NEEDED RING THICKNESS: (b_1)

$$Z_1 = \frac{a \times b_1^2}{6}$$

$$b_1 = \sqrt{\frac{6 \times Z_1}{a}} = \sqrt{\frac{6 \times 1.78}{12}} = \sqrt{.892} = .944$$

$$\underline{b_1 = .944 \text{ in.}}$$

2) IF: DENOTATION OF ROCK IS NO. II (SEE PAGE 2)

D = 9'0" DIA. OF BORE

LOAD PER UNIT LENGTH: (UNIT LENGTH = 1 FT.)

$$P_2 = F_2 \times \delta_2 = 4.5 \times 150 = \underline{\underline{675 \text{ lbs./Ft.}}}$$

MAX. MOMENT: (Mmax)

Mmax WILL BE AT $\alpha = 90^\circ$ & $\alpha = 0^\circ$

$$\cos. 2\alpha = 1$$

$$M_{\max} = \frac{P_2 \times R^2}{1} \cos. 2\alpha$$

$$M_{\max} = \frac{675 \times 4.5^2}{1} = 13,668 \text{ Ft. lbs.}$$

$$\underline{\underline{M_{\max} = 164,025 \text{ in. lbs.}}}$$

SECTION MODULUS OF RING: (Z₂)

(STEEL)

ALLOWABLE STRESS: $S_B = 57,000 \text{ lbs./in}^2$

$$Z_2 = \frac{M_{\max}}{S_B} = \frac{164,025}{57,000} = 2.877 \text{ in}^3$$

$$\underline{\underline{Z_2 = 2.877 \text{ in}^3}}$$

NEEDED RING THICKNESS: (b₂)

$$Z_2 = \frac{a \times b_2^2}{6}$$

$$b_2 = \sqrt{\frac{6 \times Z_2}{a}}$$

$$b_2 = \sqrt{\frac{6 \times 2.877}{12}} = \sqrt{1.438} = 1.20$$

$$\underline{\underline{b_2 = 1.20 \text{ in.}}}$$

3) IF: DENOTATION OF ROCK IS NO. III (SEE PAGE 2)

D = 9'-0" DIA. OF BORE

LOAD PER UNIT LENGTH: (UNIT LENGTH - 1 FT.)

$$P_3 \times F_3 \times \gamma_3 = 6.72 \times 150 = \underline{\underline{1008 \text{ lbs./Ft.}}}$$

MAX. MOMENT: (Mmax)

Mmax WILL BE AT $\alpha = 90^\circ$ & $\alpha = 0^\circ$

$$\cos. 2\alpha = 1$$

$$M_{\max} = \frac{P_3 \times R^2}{1} \cos. 2\alpha$$

$$M_{\max} = \frac{1008 \times 4.5^2}{1} = 20,412 \text{ Ft. lbs.}$$

$$\underline{\underline{M_{\max} = 244,944 \text{ in. lbs.}}}$$

SECTION MODULUS OF RING: (Z₃)

(STEEL)

ALLOWABLE STRESS: $S_B = 57,000 \text{ lbs./in}^2$

$$Z_3 = \frac{M_{\max}}{S_B} = \frac{244,944}{57,000} = 4.297 \text{ in}^3$$

$$\underline{\underline{Z_3 = 4.297 \text{ in}^3}}$$

NEEDED RING THICKNESS: (b₃)

$$Z_3 = \frac{a \times b_3^2}{6}$$

$$b_3 = \sqrt{\frac{6 \times Z_3}{a}}$$

$$b_3 = \sqrt{\frac{6 \times 4.297}{12}} = \sqrt{2.148} = 1.465$$

$$\underline{\underline{b_3 = 1.465 \text{ in.}}}$$

4) IF: DENOTATION OF ROCK IS NO. IV (SEE PAGE 2)

$$D_2 = 9'-0'' \text{ DIA. OF BORE}$$

LOAD PER UNIT LENGTH: (UNIT LENGTH = 1 FT.)

$$P_4 \times F_4 \times \delta_4 = 13.5 \times 135 = \underline{1822 \text{ lbs./Ft.}}$$

MAX. MOMENT: ($M_{\max}$)

$$M_{\max} \text{ WILL BE AT } \alpha = 90^\circ \text{ \& \> } \alpha = 0^\circ$$

$$\cos. 2\alpha = 1$$

$$M_{\max} = \frac{P_4 \times R^2}{1} \cos. 2\alpha$$

$$M_{\max} = \frac{1822 \times 4.5^2}{1} = 36,895 \text{ Ft. lbs.}$$

$$\underline{M_{\max} = 442,746 \text{ in lbs.}}$$

SECTION MODULUS OF RING: (Z_4)

(STEEL

$$\text{ALLOWABLE STRESS: } S_B = 57,000 \text{ lbs./in.}^2$$

$$Z_4 = \frac{M_{\max}}{S_B} = \frac{442,746}{57,000} = 7.76 \text{ in.}^3$$

$$\underline{Z_4 = 7.76 \text{ in.}^3}$$

NEEDED RING THICKNESS: (b_4)

$$Z_4 = \frac{a \times b_4^2}{6}$$

$$b_4 = \sqrt{\frac{6 \times Z_4}{a}}$$

$$b_4 = \sqrt{\frac{6 \times 7.76}{12}} = \sqrt{3.883} = 1.97$$

$$\underline{b_4 = 1.97 \text{ in.}}$$

5) IF: DENOTATION OF ROCK IS NO. V (SEE PAGE 2)

D = 9'-0" DIA. OF BORE

LOAD PER UNIT LENGTH: (UNIT LENGTH = 1 FT.)

$$P_5 = F_5 \times \delta_5 = 33.7 \times 110 = \underline{\underline{3707 \text{ lbs./Ft.}}}$$

MAX. MOMENT: (Mmax)

Mmax WILL BE AT $\alpha = 90^\circ$ & $\alpha = 0^\circ$

$$\cos. 2\alpha = 1$$

$$M_{\max} = \frac{P_5 \times R^2}{1} \cos. 2$$

$$M_{\max} = \frac{3707 \times 4.5^2}{1} = 75,066 \text{ Ft. lbs.}$$

$$\underline{\underline{M_{\max} = 900,801 \text{ in. lbs.}}}$$

SECTION MODULUS OF RING: (Z₅)

(STEEL)

ALLOWABLE STRESS: $S_B = 57,000 \text{ lbs./in}^2$

$$Z_5 = \frac{M_{\max}}{S_B} = \frac{900,801}{57,000} = 15.80 \text{ in}^3$$

$$\underline{\underline{Z_5 = 15.80 \text{ in}^3}}$$

NEEDED RING THICKNESS: (b₅)

$$Z_5 = \frac{a \times b_5^2}{6}$$

$$b_5 = \sqrt{\frac{6 \times Z_5}{a}}$$

$$b_5 = \sqrt{\frac{6 \times 15.80}{12}} = \sqrt{7.90} = 2.81$$

$$\underline{\underline{b_5 = 2.81 \text{ in.}}}$$

VERTICAL UNIT LOAD: (P_v)

6' DIA. BORE

$$P_{v1} = \frac{P_{v1}}{D_1 \times L} = \frac{744}{6 \times 4} = 31 \text{ lbs/Ft}^2$$

$$P_{v2} = \frac{P_{v2}}{D_1 \times L} = \frac{1,200}{6 \times 4} = 50 \text{ lbs/Ft}^2$$

$$P_{v3} = \frac{P_{v3}}{D_1 \times L} = \frac{1,800}{6 \times 4} = 75 \text{ lbs/Ft}^2$$

$$P_{v4} = \frac{P_{v4}}{D_1 \times L} = \frac{3,240}{6 \times 4} = 135 \text{ lbs/Ft}^2$$

$$P_{v5} = \frac{P_{v5}}{D_1 \times L} = \frac{6,600}{6 \times 4} = 275 \text{ lbs/Ft}^2$$

15' DIA. BORE

$$P_{v1} = \frac{P_{v1}}{D_2 \times L} = \frac{4,650}{15 \times 4} = 77.5 \text{ lbs/Ft}^2$$

$$P_{v2} = \frac{P_{v2}}{D_2 \times L} = \frac{7,500}{15 \times 4} = 125 \text{ lbs/Ft}^2$$

$$P_{v3} = \frac{P_{v3}}{D_2 \times L} = \frac{10,500}{15 \times 4} = 175 \text{ lbs/Ft}^2$$

$$P_{v4} = \frac{P_{v4}}{D_2 \times L} = \frac{20,250}{15 \times 4} = 337.5 \text{ lbs/Ft}^2$$

$$P_{v5} = \frac{P_{v5}}{D_2 \times L} = \frac{41,250}{15 \times 4} = 687.5 \text{ lbs/Ft}^2$$

9' DIA. BORE

$$P_{v1} = \frac{P_{v1}}{D_2 \times L} = \frac{1,674}{9 \times 4} = 46.5 \text{ lbs/Ft}^2$$

$$P_{v2} = \frac{P_{v2}}{D_2 \times L} = \frac{2,700}{9 \times 4} = 75.0 \text{ lbs/Ft}^2$$

$$P_{v3} = \frac{P_{v3}}{D_2 \times L} = \frac{4,032}{9 \times 4} = 112.0 \text{ lbs/Ft}^2$$

$$P_{v4} = \frac{P_{v4}}{D_2 \times L} = \frac{7,290}{9 \times 4} = 202.5 \text{ lbs/Ft}^2$$

$$P_{v5} = \frac{P_{v5}}{D_2 \times L} = \frac{14,828}{9 \times 4} = 411.8 \text{ lbs/Ft}^2$$

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