Design and Recommended Specifications
for a Safe Methane Gas Piping System

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

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FOREWORD

This report was prepared by Energy Applications, Inc., Grand Rapids,
Michigan under USBM Contract Number JO155145. The contract was
initiated under the Coal Mine Health and Safety Program. It was administered
under the technical direction of the Pittsburgh Mining and Safety Research
Center with Mr. Herbert H. Fields acting as the Technical Project Officer.
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16. Abstract
This report describes the engineering work leading to the design of an under-
ground coal mine piping system to transport approximately 2,000,000 cubic
feet per day of methane gas to the surface from degasification holes drilled
horizontally into the coalbed in existing coal mines. Safety instrumentation
for detection of gas leaks and provisions for automatic emergency shutdown
are included in the design. It also includes specifications for a safe system
of handling gas, water, and drill cuttings during drilling of the horizontal
holes and recommendations for compressor and metering facilities at the
surface.
The main pipeline is recommended to be constructed of polyethylene plastic
pipe joined by a butt fusion method while lateral lines and separator and
meter piping at the horizontal holes are recommended to be screwed steel
piping. The materials used are to be resistant to the forces of impact exerted
by falling rock. The pipelines are to be suspended from the ceiling with pipe
hangers. All steel components are protected from chemical corrosion by
applying protective coatings and the vertical casing to the surface is protected
from electrolytic corrosion by a rectifier station. Methane gas detectors
monitor the mine atmosphere to detect the presence of gas leaks and a
pneumatic plastic tubing line provides for control of the safety shutdown
system.
Both the recommended design and the required construction procedures are
in compliance with the applicable Federal codes for coal mine safety.

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Drawings

Selection of the Pipe Material

The objective of this phase of the project was to select the material most suitable
for use in the mine piping system. Based upon information given in the contract
specifications and data gathered during a trip to the Federal #2 Mine in Bula,
West Virginia, a list of design criteria was developed. Different metallic and
non-metallic materials were then evaluated for their ability to meet these require-
ments. The investigation resulted in the selection of a polyethylene material for
the header pipeline and carbon steel for the small diameter lateral lines.

A. Selection Criteria

The following list of requirements provided the basis for the pipe material
selection.

1. The pipe must be resistant to both internal and external corrosion which
   may be caused by chemicals in the gas, chemicals in the mine atmosphere,
   oxidation, or electrolysis.

   Discussion: Internal corrosion of the pipeline can be caused by corrosive
   chemicals in the coalbed gas and water which is released from the coal
   seam through the horizontal boreholes. Analysis of samples of this gas and
   water taken from the Multipurpose Borehole of the Federal #2 Mine has re-
   vealed that no excessively corrosive chemicals were present. Based upon
   these results, it was concluded that corrosion on the interior of the pipeline
   would not be a problem. An analysis of each individual mine's fluids is
   recommended.

   External corrosion can be caused by chemicals in the mine environment or
   by moisture condensation causing the formation of oxides on the pipe sur-
   faces. Samples of ground water taken from two locations within the Federal
   #2 Mine were analyzed and found to be free of corrosive agents. However,
   high concentrations of moisture in the mine atmosphere during the summer
   months create a corrosive situation for ferrous metals.

   External corrosion due to electrolysis can occur when a metal pipe carries
   an anodic potential with respect to another substance with which it is in
   electrolytic contact. The pipe metal will sacrifice itself as positively
   charged current flows from it to the other substance. This type of corrosion
   can be caused by electrolytic contact between dissimilar metals in the
   presence of an electrolyte with the metal of highest anodic potential
   experiencing the corrosion. It can also be caused if the pipeline picks
   up stray currents from large electrical equipment or from electric railway
   traction systems. In this case, the pipe gains in anodic potential with
   respect to the soil.

2. The pipe must be able to withstand impact forces similar to those which might be exerted by roof falls in the mines. It must also be able to resist bending and tensile stresses which may be caused by floor heaving.

   Discussion: Because of the possibility of rock falls, floor heavings, and pillar bursts in the mine, it was required that the selected material be highly resistant to impact forces and bending and tensile stresses. A pipeline break caused by such an accident, or by some other mishap in the mine, could result in a catastrophe.

3. The pipe material must not contribute to the chances of starting a mine fire. The pipe must resist fire or heat for a reasonable length of time, that is, it must not fail from heat before the safety instrumentation system has had time to react to the damage.

   Discussion: Fire prevention is an important consideration in any gas piping system and any pipe material which may increase the chances of starting a mine fire will not be considered for use in the mine pipe system. Furthermore, it is imperative that safety instrumentation respond to shut the pipeline down before the pipe fails as a result of damage from heat or fire. How readily a material fails from heat or fire will therefore be an important criteria in selecting the pipe material.

4. The pipe must be capable of withstanding pressures ranging from 10 inches of mercury vacuum to 10 inches of mercury positive.

   Discussion: This criterion was given in the contract specifications, but it was later suggested that gas pressures could possibly reach as high as 275 psig. This new requirement became a piping system design problem rather than a material selection criterion. The final selections resulted in materials which could easily withstand the design pressures.

5. The pipe should be relatively lightweight, and it should be compatible with a reliable joining method which can be utilized in the mine.

   Discussion: The use of heavy cumbersome materials for the pipeline would cause the construction project to be time-consuming and expensive. It would also contribute to safety problems which might be avoided if lighter materials were used. A method of joining the pipeline that results in reliable connections must be chosen in order to minimize the probability of leaks. The method must be feasible with respect to mine regulations.

6. In making the pipe material selection, consideration should be given to the cost and availibility of the material.

   Discussion: The cost of the material itself, and of the labor to install it

is an important criteria for the selection of the pipe material. However, low cost materials will not be selected at the expense of safety. Utilization of commercially available pipe materials is desirable. Their use will permit the degasification program to proceed without lengthy delays.

Pipe Material Evaluation

With respect to the selection criteria listed above, several piping materials were investigated, both metallic and non-metallic. Aluminum alloys, copper alloys, carbon steel and stainless steel were the metals which were evaluated. Non-metallic materials included fiberglass, polyethylene, polybutylene, and polyvinyl chloride. The chart on page 30 of this report summarizes the results of this investigation.

1. Aluminum and Aluminum Alloys - Since aluminum naturally forms a self-healing oxide coating on its surface, it would be free from corrosive attack by chemicals in the mine environment. Aluminum is very susceptible to electrolytic corrosion, however, both stray current and galvanic. If used, it would be important to protect it from stray currents, and to insulate it from contact with other metals.

   Aluminum has a relatively high impact resistance and is fairly resistant to heat or fire. (Melting point is 1220°F.) A problem with aluminum, however, is that it can give off high energy sparks when violent contact is made with a rusted steel surface. Although not especially prone to this type of frictional sparking, it must be recognized that an aluminum pipeline could increase the chances of starting a mine fire.

   Aluminum is a lightweight material and in this respect, its use would greatly reduce construction labor costs. Joining an aluminum line would be a problem however. It would have to be done mechanically, since welding is not allowed in the mine return airways. Even if welding could be accomplished by temporarily rerouting intake and return airways, the result would be a pipeline that was expensive to build and difficult to disconnect or repair. Several types of mechanical couplings were considered during the investigation of aluminum piping systems. Among these, Victaulic and Dresser couplings were the most promising. Victaulic couplings can withstand high pressure from liquids, and form an excellent seal when used in water or petroleum applications. The manufacturer does not recommend them for use with natural gas or air lines, however, so they were ruled out on that basis. The Dresser coupling was found to be a relatively good method of connecting an aluminum pipeline, although it would be necessary to insulate the steel coupling from the aluminum pipe to prevent galvanic corrosion. The only situation under which a Dresser coupling is likely to fail is a deflection at the joint of ten degrees or greater. This represents a problem for an underground pipeline which may be deflected by bottom heaving. A pipeline

supported from the floor or suspended from the ceiling could also be caused to deflect by a roof fall.

Aluminum alloy pipe is not unreasonable in cost and is readily available in a variety of different sizes and wall thicknesses.

2. Copper and Copper Alloys - Although copper and its alloys are fairly resistan to corrosion, they exhibit poor resistance to impact. Copper is also heavy when compared to other materials and it is difficult to connect in a manner that is reversible. For these reasons, and also because of the high cost of copper, we eliminated copper and its alloys as possibilities for use in the mine piping system.

3. Carbon Steel - Carbon steel tends to corrode in the presence of oxygen which not only reacts with iron but also acts as a depolarizer. A carbon steel pipeline in the mine would require an external protective coating. A buried carbon steel line would have to be protected from stray currents, a cause of electrolytic corrosion.

Carbon steel is highly resistant to impact forces, and it has greater resistanc to heat or fire than the other materials under consideration. (Melting point is 2800°F.)

Steel pipe can be easily and safety connected by the use of screwed couplings. Dresser couplings would not be recommended because of the possibility of joint deflections.

The greatest disadvantage in using carbon steel for the mine piping system is the weight of the larger diameter pipe sizes. The installation of 8" carbon steel pipe in the Federal #2 Mine was a time-consuming and expensive project. The use of carbon steel for pipelines greater than 4" diameter shoul be avoided if possible.

Carbon steel is the standard material in the piping industry and it is readily available in many different sizes at reasonable cost.

4. Stainless Steel - Like carbon steel, stainless steel is highly resistant to impact forces and to heat. It has an advantage over regular carbon steel in that it is resistant to corrosion and it could be used in the mine piping system without a protective coating. The extremely high cost of stainless steel as compared to the other materials is the major drawback to its use.

5. Fiberglass - Fiberglass is highly resistant to all types of corrosion that might be expected in the mine piping system. It will not react chemically with any of the materials present in the coalbed gas; and as a non-conductor, it is not subject to electrolytic corrosion.

Fiberglass has a very poor resistance to impact and it easily cracks when subjected to external forces. For this reason, it cannot be recommended for use in a pipeline which is exposed to rock falls.

Fiberglass is a flammable material and since it is generally available only in thinner wall thicknesses, the possibility exists that it could fail from heat rather quickly if exposed.

Although fiberglass is very lightweight and easy to handle, it is not so easy to connect safety. It is joined by the use of an epoxy adhesive. Great care must be taken in preparing the joints and applying the adhesive in order to obtain leakproof connections. There is a considerable chance for error in this procedure.

Fiberglass pipe is relatively inexpensive, but it is available only in a limited variety of sizes and wall thicknesses.

5. Polyethylene - Polyethylene is excellent in its ability to resist corrosion from chemicals and as a non-conductor, would not be subject to electrolytic corrosion.

Polyethylene pipe has a relatively high impact resistance, (see page 31 of this report) but it is not highly resistant to heat or fire. It is available in large wall thicknesses, however, which increases the length of time until failure occurs when exposed to heat or fire. As a non-sparking material, there is no chance of polyethylene starting a mine fire as a result of severe frictional contact with other materials.

Polyethylene is a lightweight material and if used in the mine piping system, it would greatly reduce construction labor costs as compared to a heavy steel pipeline. Polyethylene pipe can be easily and safely joined by a butt-fusion method which provides a very positive connection. It can also be easily disconnected to make repairs or replacements by cutting with a hand saw or sabre saw.

Polyethylene pipe is less expensive than most other kinds of pipe materials and it is readily available in the sizes and wall thicknesses which are required for the mine piping system.

6. Polybutylene - Polybutylene, like the other plastics, is highly resistant to corrosive agents. It rates poor in its ability to withstand impact forces, however, because it cracks fairly easily when subjected to large loads. It is slightly more resistant to fire than the other plastics as it melts and ignites at slightly higher temperatures.

Polybutylene is more expensive than polyethylene and at this time is not

available in pipe sizes greater than 6" diameter.

7. Polyvinyl Chloride - Like the other plastics, PVC is highly resistant to corrosive agents. It is not as resistant to impact forces as polyethylene, however.

   PVC pipe is joined by solvent cementing. This type of connection is not as reliable as the butt-fusion method. For this reason, PVC pipe is more often used for water lines than it is for natural gas. Polyvinyl Chloride is a heavy plastic, but it is still much lighter than steel. It is inexpensive and commercially available in many different sizes and wall thicknesses.

C. Conclusions

1. Polyethylene pipe can best meet the design criteria for the main pipeline.

   a. It is not vulnerable to corrosion in the mine. (Ground water and coalbed water should be tested to verify this for each individual mine.)

   b. It is very resistant to impact forces. DuPont Aldyl "A" polyethylene pipe proved to be as resistant as steel in impact testing of the diameters tested. Other brands exhibited impact vulnerability in diameters of 3" or less.

   c. It is lightweight and easy to join. None of the other materials can compare with polyethylene's ease of installation in the type of environment encountered in coal mines.

   d. From a fire protection standpoint, it is safe in that it cannot spark, but it is not as resistant to heat as are the metals.

   e. The polyethylene pipe specified can withstand the maximum and minimum design pressures.

   f. Polyethylene pipe is inexpensive, and installation costs are much less than those for metal pipelines.

   g. Several manufacturers can readily supply the size of pipe that is needed for this project. DuPont Aldyl "A" pipe is recommended.

2. Carbon steel pipe is a better selection for the pipeline laterals and relief line

   a. Steel pipe in smaller diameters is generally more resistant to impact forces than is small diameter polytheylene pipe.

   b. The lateral components such as valves, meters and separators are more

readily available in steel and therefore are more compatible in a steel pipeline than in a line constructed with polyethylene.

    c. The weight problem is not significant when dealing with small diameter steel pipe. Installation costs are low.

    d. Steel pipe in small diameters is more resistant to the effects of mine fires than polyethylene pipe of small diameters.

    e. Steel pipe, being more rigid in smaller diameters, can be supported from the mine ceiling with less effort.

3. The design problems which will develop in a plastic or steel piping system can be solved.

    a. The problem of a plastic pipeline becoming a fire hazard can be solved with a good safety instrumentation system.

    b. Corrosion problems in a steel piping system can be solved by applying protective coatings.

Pipe Sizes

A. The Flow Equation

The first step in the solution of the pipe sizing problem was to select a flow equation. Unfortunately, there is no single general equation that can be applied to any flow problem. Many gas flow equations are currently used by the gas industry. They are based upon the results of gas flow experiments. Each flow equation is applicable to only a limited range of flow and pipe surface conditions. Since we are dealing with medium pressures and relatively smooth pipe, we can expect partially turbulent flow in the piping system. For these conditions the IGT Distribution formula is well suited.

$$Q_b = C(T_b/P_b) \left(\frac{P_1^2 - P_2^2}{T_f L}\right).5555 \left(\frac{D^{2.667}}{G^{.4444} \mu^{.1111}}\right)$$

$$
\begin{aligned}
C &= \text{a constant whose value depends on the units of the other terms} \\
Q_b &= \text{flow} \\
T_b &= \text{base temperature} \\
P_b &= \text{base pressure} \\
P_1 &= \text{upstream pressure} \\
P_2 &= \text{downstream pressure} \\
T_f &= \text{flowing temperature} \\
L &= \text{length} \\
D &= \text{pipe inside diameter} \\
G &= \text{specific gravity} \\
\mu &= \text{viscosity}
\end{aligned}
$$

In order to solve the flow equation for pipe size it is necessary to place a value on the other variables. Some of this information was available as part of the design criteria for this project. Part of the information had to be assumed in order to make the calculations.

B. The Network Problem

A simplified layout of the piping system is shown on page 32 of this report. In order to solve this piping network problem for optimum pipe diameters, it would first be necessary to make certain assumptions regarding the flow conditions.

1. The gas flow in each lateral is 200,000 cfd. (From contract specifications)

2. The mine temperature is 60°F. (estimate)

3. The flowing temperature of the gas is 55°F. (estimate)

4. The specific gravity of the gas is .66. (From gas analysis at Federal #2 Mi

5. The lateral length is 95 feet. (Estimate for distance from side of one return airway to the center of another)

6. The initial gas flowing pressure is 4.5 psig. (Less than 10 inches of mercury; a small pressure drop will occur in the separator and meter piping)

7. The vertical portion of the pipeline will be 24" steel pipe. (Necessary to provide escapeway to the surface similar to Federal #2 Mine)

A sample calculation given on page 33 will demonstrate the use of the IGT Distribution equation to solve for the line pressure drop.

Using the IGT Distribution equation, the network problem was solved for different combinations of lateral and mainline pipe diameters. Based upon these calculations, the selected sizes were 8.625" O.D. (7.055" I.D.) for the polyethylene mainline and 2.375" O.D. (2.067" I.D.) for the steel lateral lines. The solution to the network problem for these sizes is presented in a table on page 34 of this report. The section numbers refer to points on the simplified layout on page 32.

The problem was resolved after the entire piping system was designed in order to more accurately include the pressure drops of the horizontal hole piping. The calculations were made for borehole pressures of 15 psig and 5 psig and the results appear in the table on drawing USBM-1.

It should be noted here that a 10" mainline instead of an 8" would greatly improve the gas delivery pressure at the surface for this particular set of flow conditions. The advantage of this pressure gain, however, is offset by the greater expense of a 10" line. The 10" pipe weighs 13 lbs./ft. as compared to the 8 lbs./ft. for 8", making construction labor costs much higher. It currently costs approximately $8.00/ft. as compared to $5.25 for the 8" pipe.

C. The selection of the 8" mainline and 2" laterals is based upon the flow conditions stated above. If the actual conditions for a certain mine differ greatly from the assumed conditions, it will be necessary to re-evaluate the network problem.

. Connecting the Pipe

A. Polyethylene Pipe

The most reliable method of joining larger diameter polyethylene pipes is by heat fusion. This method provides connections that are just as strong as the pipe itself.

The procedure for joining pipe by the heat fusion method is relatively simple. The ends of each pipe section are squared with a facing tool and then brought into proper alignment. An electrically heated joining tool with a heating face temperature of 350°-400° is inserted between the aligned ends. While maintaining pressure against the hot plate, the pipe ends are allowed to melt back a fraction of an inch. The pipe ends are then moved away from the plate, the plate is removed, and the pipe ends are brought together with a moderate pressure to make the connection. The machine lineup clamps can be removed as soon as the joint has cooled.

The butt-fusion machine contains all the necessary tools to perform the joining operation including facing tool, alignment clamps and hot plate. The machine is electrically powered but cannot meet requirements for permissibility as intrinsically safe. During its use, it will be necessary to reroute fresh air flows to the construction site. It may also be possible to modify the machine electrically to make it permissible for use in the return airway of coal mines in some states.

B. Steel Pipe

Steel pipe shall be joined by means of threaded couplings and fittings. This method results in connections which are stronger than those from other types of mechanical couplings. Although welding provides a better connection, it is not desirable because of the limitation of its use in mine environments and the difficulty of making repairs. Screwed piping, with unions, allows for easy disassembly of the line when required. (See detail #17, drawing USBM-7)

C. Transition from Polyethylene to Steel Pipe

A plastic to steel transition fitting called the "Ripple Grip" transition fitting
will be used to make the connections at those locations where polyethylene
pipe ties in to steel pipe. These fittings are manufactured by swaging a
length of steel pipe at one end and machining closed grooves or ripples on
the inside diameter of the swaged end. A length of plastic pipe is then insert
into the swaged end and a steel insert is rammed into the assembly. Tests by
manufacturers indicate that pull-out will not occur before the plastic pipe
yields. Tests also indicate that the joint is stronger than the plastic pipe in
shear, burst strength, and torsion.

Connections of the steel laterals to the mainline can be made with a fused
connection on the plastic end of the transition fitting and a screwed connectio
on the other. To install the 8" steel isolation valves, it will be necessary
to weld a flange on the steel end of the transition fitting. (See sections B-B
and C-C, drawing USBM-2.) By following the manufacturer's recommendation
this weld can easily be made without damaging the plastic part of the fitting
by overheating. All welding should be performed on the surface, or in permis-
sible areas of the mine.

IV. Corrosion Protection

All steel components of the piping system including pipe, valves, fittings, pipe
hangers, bolts, etc. must be protected externally from corrosion. This requireme
is the result of an investigation of the various corrosion causing mechanisms in
the Federal #2 Mine. The results of a chemical analysis of water taken from hori
zontal holes into the coal seam at the multipurpose borehole and an analysis of
the coalbed gas indicate that substantial internal corrosion of the steel pipelines
will not occur. (This test should be made for each individual mine.) External
corrosion can be expected however, because oxidation will occur on the steel
pipe surfaces in the presence of moisture. This moisture can be expected during
the summer months in the coal mine when highly humid, warm air is introduced
by the ventilation system and moisture condenses on the cooler pipe surfaces.

Electrolytic corrosion will be an important factor only for the vertical casing, as
it will be the only section in direct contact with the soil.

A. 2" Steel Pipelines

Although the polyethylene pipe will require no protection from corrosion, the
steel piping must be externally coated to prevent corrosion. Because ceiling
supports are recommended, no real corrosion problems will be presented as
a result of contact with adjacent soils. The main concern will be protection

from surface corrosion resulting from moisture condensation on the pipe.
A good surface coating is required to prevent or inhibit the formation of rust.
We have studied various types of coatings commonly used to coat pipe in
the petroleum industry. The coatings were classified on their performance with
respect to eighteen different parameters. A chart which appears on page 35
lists these parameters and the ratings of the different coatings. As a result
of this study we recommend a thermo-set epoxy manufactured by Minnesota
Mining and Manufacturing Company, called Scotch-Kote 202. A generic
type of this coating called Scotch-Kote 212 is more resilient and generally
a little thicker than the 202. Either type is suitable for application to the
exterior of the pipeline. The 2" steel pipe can be coated with this material
at a coating mill, and then shipped to the jobsite.

After the installation of the pipe, it will be necessary to patch coat those
areas of the pipe where damage has occurred to the mill applied coating. This
can be accomplished with a cold applied primer and tape, such as Tapecoat Ct.
This same material can be used to coat the connection in the steel piping
system.

B. Miscellaneous Steel

Irregularly shaped items such as valves, pipe hangers, etc., can not easily
be protected with a tape material. For this reason, a paintlike material,
Tapecoat TC Enviroshield, which can either be brushed or sprayed on, may
be used.

C. Vertical Casing

Unlike the ceiling suspended pipelines in the mine, the vertical casing is
in direct contact with the earth, and is susceptible to electrolytic corrosion.
Electrolytic corrosion may be caused by either stray currents, or by galvanic
action.

Stray current corrosion always is a result of currents which are introduced
into the ground from neighboring sources of DC current such as electric railways,
DC machinery, or foreign cathodic protection systems. Detection of stray
currents is usually easy because these currents are rarely constant and variations
in the potential of underground structures indicate the presence of stray currents.
Three reasons account for the fact that stray currents will have a minimal effect
on any vertical casing. 1) The methane gas gathering system is fabricated
utilizing plastic non-conductive pipe and 2) any metallic piping connections
are electrically isolated from the casing with effective electrical flange insulator
kits, and 3) the vertical casing is generally located at some distance remote
from and ahead of the active mine face. When the vertical casing is located
close to the mining operations, stray current effect is not expected to be
detrimental due to electrical isolation via flange insulation.

Corrosion from galvanic action will be the main cause of corrosive attack on a vertical casing. A metallic structure in the ground can be shown to be analogous to a group of electrically interconnected galvanic cells, such as the ordinary dry cell. The negative electrode in the dry cell, or anode is the zinc and the positive electrode or cathode is the carbon. The zinc or anode is the electrode which is attacked by corrosion. Similarly, on an underground structure which is attacked by galvanic action, the more negative locations are those at which damage will occur.

When vertical casings are installed in soils of different resistivities, the pipe in lower resistivity soils becomes anodic with respect to the portion of pipe in the high soil resistivity and corrosion will occur at the anodic portion.

The practicalities of construction and installation of the casing do however somewhat minimize this corrosion situation. The cement grout that is pumped into the annular space between the borehole wall and the outside of the casing to hold the casing in place, acts as a coating on the pipe. This minimizes the concentrated corrosion effect of the steel casing passing through various resistivity soils.

It cannot be certain, however, that every square inch of casing surface is coated with cement and not touching any soil. It is at these cement coating imperfections that corrosion can be anticipated. (See the sketch on page 36) The discharge of DC current at the cement voids can be stopped by smothering it with an impressed DC current of greater voltage and magnitude and opposite charge. This then will stop the possible concentrated corrosion attack and shift the voltage of the casing into the range that is universally accepted as the area of structure to soil voltage where corrosion is almost impossible to occur.

A protective current requirement test was performed on the vertical casing at the Federal #2 Mine. Various amounts of DC current were impressed into the earth using aluminum foil as well as galvanized steel fence posts for the groun bed. It was determined that one ampere of DC current was the minimum amount of current necessary to overcome existing corrosion areas on the casing wall.

Conservative design would dictate that more than one ampere be available at this location due to the fact that as the cement grout ages it will take on the soil resistivity characteristics of the soil around it. More current would then be necessary to protect the casing. A rectifier and ground bed that will deliver 5 amperes of DC current with an output voltage of 72 volts DC could be installed for about 120% of what a 1 ampere installation could be installed. The 5 amp design will not only provide the anticipated larger current requiremer at this location but will in 9 times out of 10 take care of installations in other parts of the United States.

Protection of the Pipeline from External Forces

The pipeline installation must either be resistant to or protected from two different types of external forces - impact forces caused by roof falls, and bending or tensile forces caused by floor heaving. This section of the report evaluates different methods of supporting the pipeline with respect to these dangers.

. Roof Falls

It is difficult to place a quantitative value on the forces that might be generated by a roof fall. A three hundred pound rock which hits flat upon the pipeline may do less damage than a one hundred pound rock that strikes at an angle. Because of this difficulty, we devised a practical test which exerted impact forces in excess of those likely to be exerted by a mine roof fall. The test involved dropping an 1800 pound weight onto a sample of pipe. The weight, a 1' x 1$\frac{1}{4}$' x 3' block of steel, exerted an impact force over a one foot length along the pipe when dropped on end as shown below.

In addition to the vertical load force, tremendous shear forces are exerted on the pipe at the edges of the steel block. Pipe protection methods which can withstand the impact forces of this test can be used in the mine piping system. The test results are shown on page 31.

. Floor Heaving

It is also difficult to exactly describe the magnitude of the bending and tensile forces which can be exerted on a pipeline as a result of floor heaving. Observations of areas where floor heaving occurred in the Federal #2 Mine indicated

that a considerable quantity of soil could be displaced upward into the center of the mine corridor. In some areas the height of this displacement was 12" - 16" in the center of the corridor. This type of movement could exert extremely large bending forces on a buried pipeline and could also effect a floor supported pipeline. It is also possible for a floor heaving problem to become so severe that a complete collapse of the mine corridor occurs. Corridors should be investigated for structural soundness before a pipeline route is selected.

C. Consideration of Pipe Protection Methods

The following methods of protecting the pipeline from external forces have been evaluated for effectiveness and practicability:

1. Laying the pipeline along the sidewall and protecting it with an inclined chain link fence.

   This method prevents falling rocks from exerting direct impact forces on the pipeline. The location near the sidewall minimizes the possibility of floor heaving displacements as this phenomenon has its greatest effect at the corridor center. The chain link fence could be fabricated in 3' x 12' sections and installed with relative ease.

2. Laying the pipeline near the sidewall and protecting it with a wooden box.

   This method has the same advantages as the previous method and would also be relatively easy to install. Further protection against impact forces could be provided by covering the pipe with sand before enclosing it, but the cost of this operation would be considerable.

3. Direct burial of the pipeline.

   This method eliminates the effects of falling rock, but it renders the pipeline vulnerable to bending and tensile forces caused by floor heaving. The cost of providing the trench would be very high.

4. Placing the pipe in a notch in the side wall.

   This method provides complete protection from rock falls and floor heaving but it has several disadvantages. It requires expensive cutting in the side wall and creates an undesirable weakness in the wall as well as the roof. It also requires a change of support method at each intersecting corridor.

5. Suspending the pipe from the ceiling with pipe hangers.

   A pipeline supported in this manner would be exposed to impact from

falling rock, but would be located at the source of most rock falls, and
therefore sustain less severe impact forces. The effects of bottom
heaving can be neglected. Also, the cost of installing pipe hangers
is not excessive.

6. Anchoring the pipe directly to the floor.

   This method results in the greatest exposure to falling rock. The pipeline
   is also subjected to bending forces that might be exerted if bottom heaving
   causes the line to displace. This effect can be minimized, however, by
   placing the line nearer the sidewall where floor heaving displacement is
   minimized. This installation method is the least expensive.

). Results of Impact Tests

1. The results of the previously described impact test are shown on page 31
   of this report. Several different pipe materials were also tested in order
   to verify some of the conclusions made in the pipe materials selection
   phase of the project. The results of the impact test performed on large
   diameter plastic pipes and small diameter steel pipes indicate that a severe
   roof fall can occur without failure of the pipeline. The test shows that 2"
   steel laterals and an 8" polyethylene main installed on the floor can be
   utilized without dangerous exposure to falling rock. Although not tested,
   a ceiling supported pipeline would yield similar results if no additional
   forces were encountered at the supports. The use of pipe hangers which
   release when a roof fall occurs can solve this problem. On this basis,
   it was concluded that the pipelines could be installed without a special
   roof fall protection system.

2. In order to more closely simulate an actual mine roof fall, one further
   impact test was performed on a sample of 8" polyethylene pipe. A four
   ton loader lifted a bucketfull of 18"-30" diameter rocks to a height of
   approximately 10 feet and dropped them on the pipe. The pipe remained
   virtually undamaged, exhibiting several minor scratches and abrasions
   only.

). Protection of Piping at the Horizontal Holes

The separator and metering facilities near the horizontal boreholes will require
special roof fall protection for shielding of the various components. Three
different methods of providing this protection were evaluated: 1)crib installation
2)rigid arch installation 3)steel mesh anchored in place by conventional roof
bolting. They are shown in the sketch on page 37 of this report.

The criteria for selecting the best protection for this particular application were
reliability, permanance and cost. Although the initial cost of the rigid arch
method is greater than the other two approaches, it was concluded that this
method would be much more reliable in preventing damage to the piping

components. The rigid arch method will also be more permanent that the other two methods, reducing maintenance costs and downtime. (See drawing USBM-10)

Drawing USBM-2 shows the piping at the horizontal holes supported from the floor with wooden skids. This type of support could be easily replaced with a pipe hanger attached to the ceiling or to the rigid arch support. Ceiling supports may be desired if the piping is in a mine corridor where bottom heaving is likely to occur.

VI. Support of the Piping System

A. The Selected Method of Support (See drawing USBM-4)

The chart on page 38 of this report shows the desirable and undesirable features of the different support methods. Hanging the pipe from the ceiling or anchoring it directly to the floor are the methods which are most advantageous with respect to ease of installation and ease of maintenance. The ceiling supported method has been selected for the following reasons:

1. The pipe will not be subjected to the effect of floor heaving.

2. The line will be more accessible for maintenance and inspection.

3. The instrument lines can be attached immediately adjacent to the pipeline.

4. No contact with the soil, eliminating chances of electrolytic corrosion.

5. No floor space is taken up.

6. The line is less vulnerable to accidental collision from mine equipment and manpower moving down the passageways.

In certain cases, because of ceiling irregularities, it may not be practical to suspend the pipe from the ceiling. In these situations, the option of anchoring the pipe to the floor should be left open. If this option is taken, consideration must be given to floor heaving effects and to corrosion from contact with the soil.

With respect to floor heaving, the polyethylene pipeline would not be greatly effected by a gradual displacement. It is a highly ductile material and its butt fusion connections are just as strong as the pipe itself. The 2" steel line could be effected by such a displacement, however. It is not highly ductile and the screwed connections could be caused to fail if deflected. If the floor anchored option is elected, it is recommended that the steel line be placed near the sidewall where deflections due to floor heaving are minimized. The

steel line should also be carefully watched to make sure that no breaks in the coating occur. Imperfections in the coating would provide locations for DC current to enter and leave, resulting in pipe corrosion.

B. Spacing the Pipe Hangers

The spacing of the pipe hangers has been calculated for both the 8" plastic main and the 2" steel laterals.

8" Plastic Pipe		2" Steel Pipe	
Span	Deflection	Span	Deflection
13.8'	.5"	18.1'	.5"
15.3'	.75"	20.0'	.75"
16.5'	1.00"	21.5'	1.00"
18.2'	1.50"	23.8'	1.50"
19.6'	2.00"	25.6'	2.00"
21.7'	3.00"	28.3'	3.00"
23.3'	4.00"	30.4'	4.00"
25.8'	6.00"	33.7'	6.00"

All of the spans considered in the table are less than the span for maximum stress. A span of 20' for the 8" supports and 28' for the 2" supports is recommended. This corresponds to a 3" vertical deflection of the pipeline.

C. The Pipe Hanger

The major cause for concern in the proposed ceiling supported pipe system has been the possibility of damage to the pipe by partial roof falls. If a load fell on the pipe and forced it to the floor, shear stresses would develop at the pipe hangers, and tensile stresses throughout the pipe adjacent to the load. The pipe hangers have been designed to release before excessive shear and tensile forces could cause the pipe to fail. The pipe would then deflect to the ground and be subjected only to impact forces, which the pipe is capable of withstanding. The pipe hangers are attached to roof bolt plates, which should be installed by conventional methods. The hanger design includes a rod coupling-shear pin device which will fail when the load on the hanger exceeds a certain value. Although a pipe hanger such as this is not commercially available at this time, Fee and Mason Manufacturing Company, Manasquan, New Jersey, has indicated that they can manufacture and sell the assembly at a price of approximately $6.00. The shear pin itself cannot be specified until different materials and sizes have been tested. The material which exhibits a satisfactory failure range can be utilized for the pin. The desired failure ranges are 340-990 pounds for the 8" mainline and 140-180 pounds for the 2" steel laterals. The minimum value is great enough to prevent all the hangers from breaking in domino fashion if one is released by a rock fall.

The maximum value is small enough to prevent the pipe from yielding in tension as it is deflected. It should be noted that these upper limits are based upon yield strength rather than ultimate strength. Also, the tensile stresses in the pipe are far greater than the shear stresses, so the maximum load for breakaway of the hangers is based upon yield in tension. (See drawing USBM-5)

D. Miscellaneous Supports

1. The piping at the horizontal holes can be supported by placing wooden skids at strategic locations. If a particular location is prone to floor heaving, this piping can be suspended from the ceiling with pipe hangers. (See drawing USBM-2)

2. The 8" shutoff valves will be suspended directly from the ceiling rather than be supported by the pipeline. This will prevent excessive torsional or shearing forces from developing in the plastic pipeline. (See drawing USBM-5)

. Components of the Piping System

A. Water Separation

1. Design Criteria

a. The liquid separation system must be capable of handling a maximum of 139 SCFM of gas at 5 psig, and 7 gpm of liquid.

Discussion: The gas flow rate and pressure is based upon information given in the contract specifications. The water flow rate is based upon the maximum average discharge from the horizontal holes at the Federal #2 Mine's Multipurpose Borehole. Other mines may of course have different water flow rates.

b. The liquid separation system must remove entrained liquids as well as slugs of liquid.

Discussion: Entrained liquids, if not removed, may fall out of suspension and accumulate at points in the piping system downstream of the separator. Large accumulations may partially obstruct the flow of gas and also increase the amount of corrosion in the piping system.

c. Methane gas must not escape into the mine atmosphere when the liquid is drained from the separator or water trap.

2. Selection of Separation System Components

    a. A water trap with a float valve can effectively remove large slugs of liquid from the gas stream without allowing gas to escape during draining, but it cannot remove a large percentage of the entrained liquids.

       Gas/liquid separators are commercially available which can remove virtually all entrained liquids 10 microns in size or larger, but they usually cannot handle heavy liquid loads. It is possible to purchase a large enough separator to handle both heavy slugs of liquid and entrained liquids, but these are unusually large and expensive. Also, they require an automatic dump valve to drain the liquids which tend to let gas escape during the draining operation. Furthermore, we can expect the water flows from the horizontal holes to reduce considerably after the piping system has been in operation for a short time. It is not reasonable to install an expensive separator with automatic dump valves at each horizontal hole when it is really only needed for a few months.

    b. We have designed a relatively inexpensive liquid separation system which can meet the design requirements. As shown on drawing USBM-2, a water trap, a small gas/liquid separator, and a small drip tank are utilized. The bulk of the liquid will fall out in the drip tank, and be drained to the trap. Any liquid which passes the drip tank, as well as the entrained liquids, will be removed by the separator and drained to the water trap. The trap, which is equipped with a float valve, will dump the liquid without allowing any gas to escape into the mine atmosphere. The Anderson Model 82 float trap is capable of handling 8 gpm of water. It is recommended that this be replaced with a Model 81X which has a 2 gpm capacity as soon as water flows drop off. It is important that the traps be inspected periodically to insure that the float valves are functioning properly.

B. Metering

The objective as we understand it for the measurement of gas flows from the individual boreholes is to provide flow data to the operator of the methane removal system to assist him in evaluating the effectiveness of each borehole and provide a means of checking for malfunctions or line blockages.

Measurement of gas for sale purposes or for compilation of data on the effectiveness of the entire system, will be done at the surface.

The following are our criteria for the two measurement situations:

Surface Measurement	Borehole Measurement
Accurate (within $1/2$%)	Accuracy not critical (within 2-3%)
Cost not critical	Low cost essential
Readout of gas measured	No permanent recording necessary
Low turndown permitted	Low turndown permitted
Will require periodic surveillance	No regular surveillance required

After a thorough comparison of conventional gas measurement instrumentation, we selected a 2" Aeroquip Barco Venturi meter for the borehole measurement situation. These meters are inexpensive and require no maintenance. Their rangeability (turndown) is within the limits we expect for borehole flowrates. Static pressures will be evidenced by permanent pressure gauges upstream of each meter. Flowrates will be calculated from differential pressure readings made with a portable master meter carried from one borehole measurement station to another. The total cost per meter should not exceed $100. Accuracy although advertised at $1/2$% will more probably be in the range of $\pm$ 2%. (See drawing USBM-2)

For the surface measurement situation we narrowed our selection down to these types of commercially available meters:

    1) Orifice Meters
    2) Turbine Meters
    3) Vortex Meters

The turbine meters and vortex meters have very large turndown capabilities and require less space for installation but cost 2-3 times more than the comparably-sized orifice meter. Because we do not require a large rangeability we believe that conventional orifice metering will provide the most economical and practical selection. Natural gas utilities rely on orifice measurement for most of their large volume flow metering applications. A basic installation including instrumentation will cost approximately $1200. Extra sophistication in instrumentation including direct readout might add another $500 to the total. (See drawing USBM-13)

If the surface meter is to be used as a sales meter for sale to a pipeline or gas utility, the buyer may wish to provide the metering facility or have specific recommendations for their measurement needs.

C. Flow Control

The installation of a globe valve on each 2" lateral line will allow mine operato to control the flow from the boreholes if necessary. The specified valve also

provides for tight shut-off, which is required if repairs have to be made on
the lateral lines. It was sized at 3" instead of 2" because the pressure drop
across the 2" valve for these flow conditions is excessive. (See drawing
USBM-2)

D. Automatic Shutoff Valves

1. Each borehole will be equipped with a Rockwell 2" Model DPS-H security
   valve which will be controlled by the instrument system. (See Section VIII)
   The security valve will have to be manually reset before production can
   begin at each borehole following a shutdown. The Rockwell valve has
   several advantages when compared to other types of spring controlled shut-off
   valves. (See drawing USBM-2)

   a. It is full opening and therefore has a very low pressure drop. Most
      other types are globe valves with large pressure drops.

   b. It is less expensive that the others.

   c. It is simpler in design and easily maintained.

2. Automatic shut-off valves have also been included in the design of the 8"
   mainline pipeline. They will serve to divide the pipeline into four separate
   sections, each of which will be isolated from the others in the event of
   a pipeline break. (See drawing USBM-1 & 2)

   Discussion: The addition of five 8" Maxitrol-Century Automatic Shut-off
   Valves to the pipeline provides another safety feature to the design. In
   the event of a rock fall, the loss of pressure in an instrument line will
   cause these valves to shut, thereby isolating the section where the fall
   occurred from the rest of the pipeline. If the damage was severe enough
   to rupture the pipe, only the gas in the damaged section could escape
   into the mine atmosphere.

   The Maxitrol Security Valve is designed to close automatically in the event
   of an underpressure condition in the pneumatic control line. When this
   occurs, the valve disc moves to the closed position aided by a spring
   and the line pressure. The valve provides shut-off in only one direction
   and must be manually reset to the open position after normal pressure
   has been restored.

   The sketch on page 39 of this report shows the location and orientation
   of these valves in the mainline pipeline. The arrows indicate flow direction
   required for positive shut-off. If a line break occurred in Section III,
   valve number 5 would prevent the compressor from pulling air into the
   vertical borehole. Valve combinations 1-2 and 3-4 simply allow for isolation

of Sections I, II and III. If the line pressure is 5 psig, approximately 1300 SCF of gas will escape into the mine atmosphere if a failure in one of these sections occurs.

Valve combinations 1-2 and 3-4 could each be replaced with a single automatic control-type shut-off valve which provides tight shut-off in both directions. A valve of this type, however, would have to be sized extremely large to duplicate the pressure drop characteristics of the specified 8" security valves, say 12". The cost of such a valve with its attendant controls would be prohibitive.

E. Pressure Relief Line

During a shutdown of one of the laterals, it is possible that fairly substantial pressures will build up in the shut-in holes. This could lead to an excessive leaking of methane through the coal adjacent to the 20 feet of 4" borehole casing. A pressure relief system has been designed which will relieve excessive gas pressures in the casing during a shutdown period.

A 2" line will tie in to each 2" lateral upstream of the safety shut-off valve. A Fisher Model 1805 relief valve set at 30 psig will be installed at this location. The relief line will vent to the vertical borehole. It will be installed in a different return airway than the 8" mainline in order to minimize the chances of both lines being damaged at the same time. (See drawing USBM-1 & 2)

The sample calculations shown on page 40 of this report show that the 2" relief line, when operated at 30 psig, can vent more than 200,000 cfd from the most remote horizontal hole. Those horizontal holes which are located nearer the vertical borehole can be relieved more easily because shorter sections of the line offer less total resistance to flow. If 200,000 cfd flows from each horizontal hole, the relief line is capable of venting one or two holes completely depending upon their location. The relief line is not designed to provide total relief in the event the entire 8" mainline is shutdown. During a mainline shutdown, the relief valves will activate at each hole where pressures build up to 30 psig. The relief pipeline will then provide either partial or total relief of these pressures depending upon the flow from these holes and the number and location of the activated holes.

The 2" steel relief line will be installed in the same manner as the 2" laterals. It will be a threaded and coupled line, suspended from the ceiling, and covered with a protective coating of Scotchkote 212.

. Safety Instrumentation

An instrumentation system is included in the design of the mine piping system which will effect a pipeline shutdown in an emergency situation. Protection against the following dangers is provided for: 1) Excessive methane buildup in the area adjacen

to the pipeline leak, 2) rock fall on the pipeline, 3) fire near the pipeline, 4) excessive pressure in the horizontal hole piping.

A. The Shut-down Mechanism

The key to the successful operation of the instrument system is a series of automatic shut-off valves connected with a pneumatic tubing system. A 2" shut-off valve is located at each horizontal hole to shut down the flow of methane when activated. Five 8" shut-off valves are located at strategic locations along the mainline to divide the pipeline into four isolated sections when activated. The valves will normally be maintained in the open position by a supply of nitrogen at 30 psig transmitted through the instrument tubing line. A drop in pressure of the instrument nitrogen supply will cause an immediate closing of the security valves. (See drawing USBM-6)

1. The methane detection system will send an alarm signal to a 3-way switching valve in the instrument line when it has detected excessive concentrations of methane in the area of the pipeline. The vent port of the 3-way valve will then open and the resulting loss of pressure in the tubing will shut down the security valve. The methane detection system is described in Section IX.

2. Rock fall detection is provided simply by a break in the instrument tubing. The pressure loss will cause the 2" and 8" shut-off valves to shut the pipeline down. It should be noted that any mechanical breaking of the tubing will cause the pipeline to shut down. A man could easily puncture the line if he detected an emergency situation. Also, three manual relief valves have been installed at locations along the instrument line for manual venting of the tubing.

3. A fire in the area of the pipeline will quickly melt the thin wall polyethylene tubing. The resulting failure will cause the security valves to close.

4. Overpressure protection is provided at each borehole and on the 8" main pipeline by means of a pneumatic relay which will when activated, cause a loss of pressure in the tubing from the relay to the security valve. It allows a particular borehole to be shut down without affecting the remainder of the piping system.

B. The Instrument Nitrogen Supply

The instrument line pressure is supplied by a 300 cubic foot nitrogen cylinder regulated to 30 psig. An extra bottle of nitrogen is available which will automatically provide the needed pressure when the first bottle is empty. Relief valves on the instrument line are set at 50 psig to protect against overpressure of the line due to a faulty regulator. (See drawing USBM-8)

C. The Instrument Tubing Line

The instrument line shall be $\frac{1}{2}$" x .062 wall polyethylene tubing. This tubing is available from several manufacturers. Samual Moore Type "P" is recommended.

Discussion: The criteria for the selection of the instrument tubing is as follows

1) The tubing must be capable of withstanding 50 psig internal pressure.

2) Fittings must be available to provide for a leak-proof installation.

3) In the event of a fire, it must fail before the plastic pipeline fails.

4) It must be easy to break, either by falling rock or by human hands.

An evaluation of several types of instrument tubing was performed. The results of that evaluation are shown in the table below.

	Nylon	PVC	Polyethylene	Butyrate	Acrylic	Glass
1. 50 psig internal pressure	+	+	+	+	+	+
2. easily connected	+	+	+	-	-	-
3. melts or burns easily	+	+	+	+	+	-
4. shatters easily	-	-	-	+	+	+
5. cuts easily	+	+	+	-	-	-

+ indicates desirable feature
- indicates undesirable feature

Those types of tubing which shatter easily are not desirable from the standpoint of ease of installation. They are manufactured in 6 foot lengths and are not easily connected in a leakproof manner. This would greatly reduce the reliabilit of the instrument system.

The flexible types can be purchased in 250 foot coils which provide for easy installation. There are several types of connectors available to join flexible tubing. The overall reliability of such a system is excellent.

We recommend the polyethylene material because it is easier to break than both the nylon and the PVC. It can be ruptured easily with a sharp object or severed with a pen knife.

The instrument line shall be connected by means of brass compression fittings which are manufactured for use with the polyethylene tubing. Finger tightening of the fittings holds pressure far exceeding the burst pressure of the tubing. (See drawing USBM-7)

Methane Detection System

A. Selection of the Methane Detection Equipment

After investigating several kinds of commercially-available flammable gas detection equipment, the Mine Safety Appliance Company's equipment was selected. Although more expensive than gas detection equipment manufactured by competitors, the MSA system was best able to meet the safety requirements for the mine environment. (See drawing USBM-9)

B. Spacing and Location of Components

1. Sensors have been located in those areas where the highest probability of piping leaks will occur--at the horizontal boreholes where numerous piping connections have been made. Sensors are also located at 1000 foot intervals along the 8" mainline in order to detect a methane buildup from a pipeline break.

2. Sensor power supplies must be located in an intake airway where intrinsically safe electrical wiring is not required.

3. Analog Output Assembly has been located underground in the intake airway near the instrument nitrogen supply. The annunciator panel is a part of the analog output modules.

C. Warning Mechanism

A signal from a sensor indicating a high level of methane in a particular location will be transmitted to an analog output module which provides a display of the methane concentration on a meter. The annunciator panel will then provide the necessary signals to shut the pipeline down and notify mine operators of the emergency situation.

Separation of Methane Gas During Drilling

The objective of this phase of the project was to design a safe system for handling methane gas, water, and drill cuttings during the drilling of the horizontal holes.

Methane must be separated from the water and drill cuttings and piped to the surface. During the separation process, it is important that methane not escape into the mine atmosphere, and that air not be introduced into the methane exhaust line. (See drawing USBM-11)

A. Procedures Considered

Before selecting an approach similar to the stuffing box already in use by the U.S. Bureau of Mines, two other ideas were considered.

1. Centrifugal Separator - A mechanically-driven centrifugal separator is utilized to separate the solid and liquid particles from the methane gas. While water and drill cuttings are drawn off the periphery of the separator, the methane is free to leave the center of the separator at a positive pressure. This idea was rejected because a constant flow of water into the separator cannot be guaranteed by the drilling operator. Interruptions in flow would break the natural seal between gas and liquid in the separator

2. Drilling Mud - Instead of water, drilling mud is pumped to the drill bit to seal the methane in the formation and carry the drill cuttings away. Drilling mud can be recycled after the cuttings are allowed to settle out in a tank. This method is similar to the procedure used in drilling oil and gas wells.

   This idea was rejected because prior experience by USBM personnel indicate that drilling mud will plug the coal to such a degree that methane production is greatly reduced after the hole has been drilled.

B. Conclusion

One workable solution to the separator problem is simply to remove methane with a negative pressure and allow water and drill cuttings to fall out naturally. The major objective with this approach is to prevent air from entering the stuffing box during the dumping of the water and cuttings. The recommended design of the stuffing box includes several provisions for minimizing this problem, as well as safety instrumentation to alarm the operators before a dangerous situation develops. (See drawing USBM-11)

1. The stuffing box is constructed of welded pipe fittings and valves to eliminate the possibility of leaks at places other than the opening. If desired, the openings could be sealed with pipe fittings for hydrostatic testing prior to use.

2. A mechanical seal is utilized at that location where the drill rod enters the box. This seal will cut down considerably on the amount of air entering at that point. How well this seal works depends upon the closeness of the

drill rod tolerances and the amount of drill rod vibration.

3. A butterfly valve with good shut off capabilities is used to seal the methane from the water and drill cuttings during dumping. The seal in this valve can be replaced if damaged during operation.

4. A water drain including screen is included to reduce the number of dumpings required. Only water and those cuttings smaller than $3/32$" will be able to pass through the screen to drain.

5. A water head in the drain line will prevent air from entering the stuffing box. In order for this to operate properly, the pressure in the stuffing box must always remain between 8 inches of water negative and 8 inches of water positive. A Rockwell Security valve set at 6 inches of water positive provides overpressure protection to prevent methane from escaping into the mine atmosphere.

6. A Ranarex Gravitometer will continuously measure the specific gravity of the gas being vented. The Ranarex will signal an alarm if the specific gravity of the gas reaches a certain level. The coal bed gas at the Federal #2 Mine has an upper explosive limit of approximately 15% methane in air and a specific gravity of approximately .65. To sound an alarm at 30% methane, the Ranarex signal should be set at .90. At this reading, the instrument has an uncertainty of $\pm$ .01 specific gravity.

Surface Facilities

Drawings USBM-12, 13 and 14 illustrate facilities that might be expected to be installed on the surface for the disposition of the collected methane:

A. Compressors

Drawing USBM-12 represents a typical reciprocating compressor station facility of the type that would normally be installed for recompression of gas to expected pipeline pressure levels (500-1000 psig). These units are usually sold as packages for installation on concrete foundations. They are combination units with a natural gas-fired engine as prime mover for the compressor.

Our drawing illustrates the typical piping connections to be made and the type of building that might be employed for weather protection.

Generally a compressor of this type would consume approximately 5% of its inlet natural gas for fuel for the engine.

These units run unattended, once started but require daily maintainance.

The compressor facility on drawing USBM-12 is not meant for use for a specific compression application but rather as a generalized illustration of the type of equipment that may be required.

B. Metering Facility

Drawing USBM-13 is indicative of the type of metering facility normally employed for natural gas measurement at locations of field pipeline injections. A dual meter run is utilized for two reasons. First, it is possible to make repairs to one side without losing metering capabilities. Secondly, two small meters provide much better rangeability than a single larger meter. This is especially true for conditions of low flow. Orifice meters are recommended for the surface facilities because they are less expensive and somewhat more practical than turbine or vortex meters. (See discussion of meters on pp. 18 & 19.) Included in the design of these facilities is a 2" bypass line. This line provides a means by which piping revisions or repairs can be made on the meter runs without a complete pipeline shutdown.

As stated elsewhere, the purchasing pipeline generally furnishes the metering arrangement or has very specific requirements for producer-installed facilities. The metering facility on drawing USBM-13 is not meant for use for a specific metering application but rather as a guide for developing a specific design tailored to the requirements of the application.

C. Flaring Equipment

Drawing USBM-14 illustrates a design for a surface-installed flare stack. This flare stack employs an electric ignition and is equipped with a gate valve control for throttling. It also has a flame arrestor protective device for prevention of a "burn-back" or explosion if the gas becomes too enriched with air leaking in at an upstream location.

This flare is designed for a flow rate of 85,000 SCFH of methane. It is unlikely that State hydrocarbon conservation agencies would permit the release of that quantity of gas in a flaring operation. Also, this quantity is a commercial quantity and would justify pipeline connections of up to 20 miles. Flaring is increasingly being discouraged in the U.S. If, however, temporary flaring was approved, this design would permit a clean and safe manner of disposing of this methane to the atmosphere.

We have recommended a distance of 100 feet for separation of flare stack from the vertical borehole hardware, simply to permit manpower to have access to the vertical borehole piping connections and safety instrumentation without undue exposure to heat and radiation from a flame of that magnitude.

D. Safety Instrumentation

To prevent an accidental discharge of methane contaminated with air at the surface facility, where gas is either directly injected or compressed and injected into a utility pipeline, two devices act as safeguards:

1. An 8" Security Shutoff Valve located adjacent to the 24" vertical borehole in the mine.

   This valve will close when the mine pneumatic safety system has reacted to a hazardous situation, shutting off all flow of methane to the surface facility except any release of methane in the 2" relief header system. Refer to drawing USBM-6.

2. Ranarex Specific Gravity monitering device coupled with an electric safety shutdown valve on the compressor suction line at the surface. Refer to drawing USBM-12.

   The specific gravity instrument was selected for monitoring the produced gas because of its capability for quick reaction. Almost all of the electronic oxygen or hydrocarbon detection equipment presently being marketed have reaction times from 30 seconds to two minutes. At the production rate specified, this amount of time would permit a considerable quantity of contaminating gases to be injected into a pipeline. Using the gravity instrument specified, the accuracy of contamination detection can be varied to permit even very slight changes in produced gas compositions.

   This detection is instrumented to cause a closure of a safety shutdown valve that would always be located so that it would simultaneously close the gas production line and the fuel line to the compressor.

   If an electric motor-driven compressor is utilized, a shutting down of its control circuit could also be accomplished.

   This instrumentation shall be employed whether the methane is recompressed or delivered directly into a pipeline.

Drawings and Specifications

This report describes the general approach to the design of the mine piping system. Detailed information on design, materials and construction are included on the drawings and specifications which accompany this report.
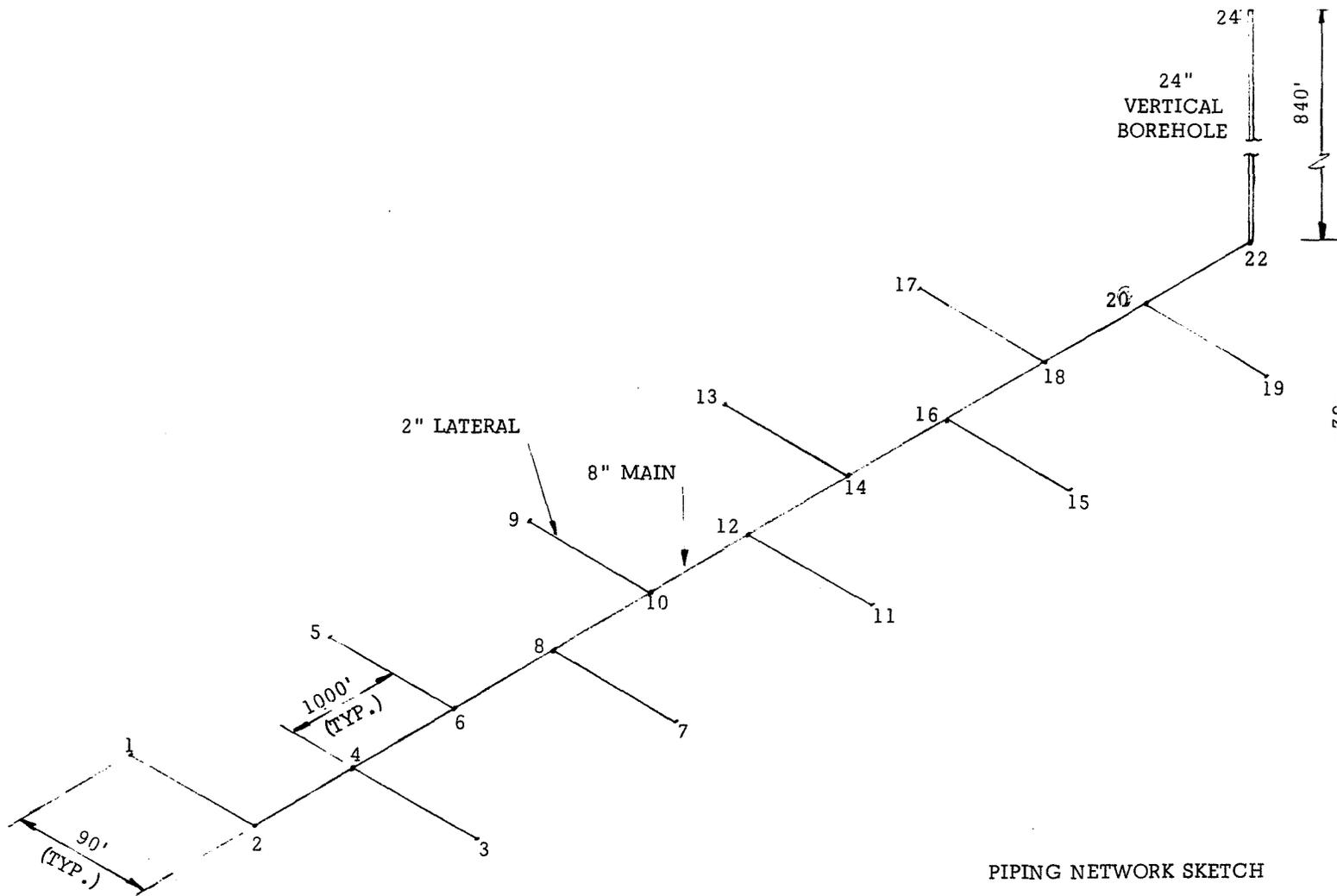
Pipe Materials Comparison Chart

	Aluminum	Copper	Carbon Steel	Stainless Steel	Fiber-glass	Polyethy-lene	Polybuty-lene	Poly-vinyl Chloride
1.a)Resistance to Internal Corrosion caused by Coalbed Gas & Liquids	Good	Good	Good	Good	Good	Good	Good	Good
b)Resistance to External Corrosion caused by Mine Environment	Good	Fair	Poor	Good	Good	Good	Good	Good
c)Resistance to External Corrosion caused by Electrolysis	Poor	Fair	Fair	Good	Good	Good	Good	Good
2.a)Resistance to Impact Forces	Good	Fair	Good	Good	Poor	Good	Poor	Fair
b)Resistance to Failure as a Result of Bending or Tensile Stresses**	Poor	Poor	Fair	Fair	Poor	Fair	Poor	Poor
3.Fire Resistance:a)Safety with respect to Causing a Fire	Poor	Good	Fair	Fair	Good	Good	Good	Good
b)Ability to Resist Heat or Fire	Fair	Fair	Good	Good	Poor	Fair	Fair	Fair
4.Ability to Withstand Design Pressures	Good	Good	Good	Good	Good	Good	Good	Good
5.a)Weight (Per 21' Joint of 8.625" O.D. Pipe)*	205 lbs	665 lbs	470 lbs	470 lbs	75 lbs	168 lbs	166 lbs	247 lbs
b)Ability to be Easily and Safely Connected	Poor	Poor	Fair	Fair	Poor	Good	Good	Fair
6.a)Approximate Cost per Ft.of Pipe (8.625" O.D. Pipe)*	$9.00	$60.00	$6.00	$40.00	$5.00	$5.25	$7.00	$5.00
b)Availability of Pipe in Various Diameters and Wall Thicknesses	Good	Poor	Good	Fair	Fair	Good	Fair	Good

*The comparisons shown are based upon the wall thicknesses of 8" pipe that would most likely be used if that particular material were selected. Copper-.3125; Fiberglass-.162; Aluminum-.322; Carbon Steel-.250; Stainless Steel-.250; Polyethylene-.750; Polybutylene-.750; Polyvinyl Chloride-.750

**Includes consideration of the joining method

Steel Block Impact Test

Test Sample	Manufacturer	Test Results
8.625" O.D. x .411" wall Polyethylene pipe	Dupont	flattened, several indentations but no complete penetrations
8.625" O.D. x .411" wall Polyethylene pipe with one fusion connection	Dupont	flattened, several indentations but no complete penetrations
6.625" O.D. x .576" wall Polyethylene pipe	Dupont	flattened, several indentations but no complete penetrations
6.625" O.D. x .581" wall Polyethylene pipe	Plexco	flattened, several indentations but no complete penetrations
6.625" O.D. x .581" wall Polyethylene pipe with 3 1/2" sand pad	Plexco	no damage
6.625" O.D. x .280" wall Steel pipe	Unknown	flattened, several indentations but no complete penetrations
4.500" O.D. x .395" wall Polyethylene pipe	Plexco	flattened, several indentations but no complete penetrations
4.500" O.D. x .265" wall Polyethylene pipe	Nipak	flattened, several indentations but no complete penetrations
4.500" O.D. x .295" wall Polybutylene pipe	Witco Chemical	cracked
4.500" O.D. x .110" wall Fiberglass pipe	A.O. Smith	cracked
3.500" O.D. x .307" wall Polyethylene pipe	Plexco	cracked
3.500" O.D. x .307" wall Polyethylene pipe with 2" sand pad	Plexco	cracked
2.375" O.D. x .154" wall Steel pipe	Unkown	flattened, several indentations but no complete penetrations
2.375" O.D. x .256" wall Polyethylene pipe	Dupont	flattened, several indentations but no complete penetrations
2.375" O.D. x .216" wall Polyethylene pipe	Dupont	flattened, several indentations but no complete penetrations

24"

24"
VERTICAL
BOREHOLE

840'

22

17

20

18

19

13

16

2" LATERAL

14

15

8" MAIN

9

12

11

10

5

8

1000'
(TYP.)

6

7

1

4

90'
(TYP.)

2

3

-32-

PIPING NETWORK SKETCH

Sample Calculations - Line Pressure Drops

Sample Problem: Determine the pressure at point 6 on the piping network
(ref: sketch on page 32)

First solve the flow equation for P_2, the downstream pressure.

$$P_2 = (P_1^2 - \frac{G^{.8}\mu^{.2}T_f L P_b^{1.8}Q^{1.8}}{D^{4.8}C^{1.8}T_b^{1.8}})^{.5}$$

This equation cannot be directly evaluated for P_2 (which in this case is the
pressure at point 6) because there are two separate contributions to its value;
a contribution from the lateral line section 5-6, and from the mainline section
4-6. These two sections are therefore evaluated separately and the results
averaged.

Section 5-6 ($P_1 = 4.5$ psig $= 18.9$ psia, $C = .6643$, $T_b = 60°F = 520°R$,
$P_b = 14.4$ psia, $T_5 = 515°R$, $L = 95$ ft., $D = 2.067$ in., $G = .66$, $u = 7 \times 10^{-6}$,
$Q = 200,000$ cfd. $= 8.333$ Mcfh.)

$$P_2 = \left[(18.9)^2 - \frac{(.66)^{.8}(7 \times 10^{-6})^{.2}(515)(95)(14.4)^{1.8}(8.33)^{1.8}}{(2.067)^{4.8}(.6643)^{1.8}(520)^{1.8}}\right]^{.5} = 18.501 \text{ psia}$$

$$= 4.101 \text{ psig}$$

Section 4-6 ($P_1 = 4.095 = 18.495$ psia, $L = 1000$ ft., $D = 7.055$,
$Q = 200,000 \times 2 = 400,000$ cfd. $= 16.667$ Mcfh)

$$P_2 = \left[(18.495)^2 - \frac{(.66)^{.8}(7 \times 10^{-6})^{.2}(515)(1000)(14.4)^{1.8}(16.67)^{1.8}}{(7.055)^{4.8}(.6643)^{1.8}(520)^{1.8}}\right]^{.5}$$

$$= 18.454 \text{ psia}$$

$$= 4.054 \text{ psig}$$

$$P_2 \text{ AVE} = \frac{4.101 + 2(4.054)}{3} = 4.070 \text{ psig}$$

NOTE: This procedure for determining node pressures was based on theoretical
borehole production rates of 200,000 SCFD of natural gas at flowing
rock pressures of 5 psig. For precise pressure drop determinations,
actual experienced production rates and rock pressures may be substituted
for theoretical values and the equations solved approximately. Accurate
predictions of production rates would require the development of special
resevoir equations with dependence on coalbed static and flowing pressures
and temperatures, the dimensions of the coal seam, and the porosity and
permeability of the producing coal formation.

IGT Distribution Formula

Solution to Network Problem – 8" Mainline and 2" Laterals

Section	D (in.)	Q_b (cfd)	L (ft.)	P_1 (psig)		P_2 (psig)
1-2	2.067	200,000	95	4.5		4.101
2-4	7.055	200,000	1000	4.101	4.089	
						4.095
3-4	2.067	200,000	95	4.5	4.101	
4-6	7.055	400,000	1000	4.095	4.054	
						4.070
5-6	2.067	200,000	95	4.5	4.101	
6-8	7.055	600,000	1000	4.070	3.985	
						4.014
7-8	2.067	200,000	95	4.5	4.101	
8-10	7.055	800,000	1000	4.014	3.871	
						3.917
9-10	2.067	200,000	95	4.5	4.101	
10-12	7.055	1,000,000	1000	3.917	3.701	
						3.768
11-12	2.067	200,000	95	4.5	4.101	
12-14	7.055	1,200,000	1000	3.768	3.405	
						3.556
13-14	2.067	200,000	95	4.5	4.101	
14-16	7.055	1,400,000	1000	3.556	3.015	
						3.151
15-16	2.067	200,000	95	4.5	4.101	
16-18	7.055	1,600,000	1000	3.151	2.622	
						2.786
17-18	2.067	200,000	95	4.5	4.101	
18-20	7.055	1,800,000	1000	2.786	2.115	
						2.313
19-20	2.067	200,000	95	4.5	4.101	
20-22	7.055	2,000,000	1000	2.313		1.474
22-24*	23.250	2,000,000	840	1.474		1.144

*Pressure drop in this section includes loss from gravity.

COMPARISON OF VARIOUS TYPES OF PIPELINE COATINGS

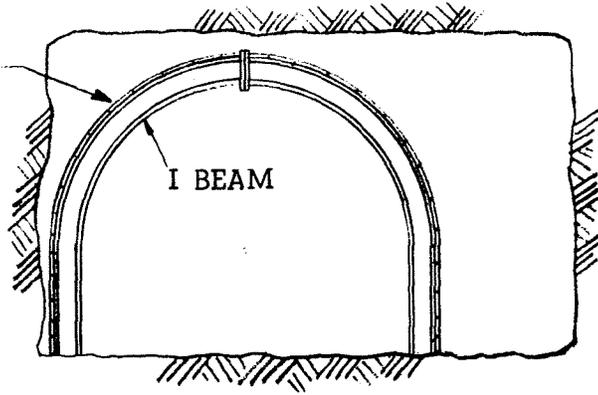**** Excellent   ** Fair
*** Good   * Poor

	Candidate Coating Systems				
	Scotchkote 202 & 212	Coal Tar	Asphalt	X-Tru Coat	Poly-ethylene
Coating uniformity	****	***	***	***	****
Continuous film	****	****	****	****	****
Freedom from voids	****	***	***	***	****
Continuing adhesion	****	****	***	***	****
Dimensional stability	****	****	***	**	**
High dielectric strength	***	****	****	****	**
Long period, low cost cathodic protection	****	****	****	****	****
Resistance to microbial digestion	****	****	****	***	****
Low moisture vapor transmission rate	****	****	***	***	**
Acids, alkalies, salts, petro. prod. in soil	****	****	**	***	****
Compatability with applied joint compound	****	****	***	***	****
Soil stress resistance	****	****	****	****	****
Impact resistance	***	***	***	***	***
Abrasion resistance	****	***	***	****	***
Broad temperature performance (-20°F to +250°F)	****	***	***	**	**
Flexibility	***	***	***	***	**
Negligible shrinkage	****	****	****	***	****
In-service performance history	****	****	****	***	***

FEDERAL #2 24" CASING

SURFACE FLANGES
& FIXTURES OR
EQUIPMENT

GROUND LEVEL

SHADED AREA INDICATES
CEMENT GROUT

POSSIBLE CONCENTRATED
CORROSION ATTACK

POSSIBLE CASING TO
SOIL CONTACT POINTS

POSSIBLE DC CURRENT
LEAVING CASING AT VOID
IN CEMENT AND GOING
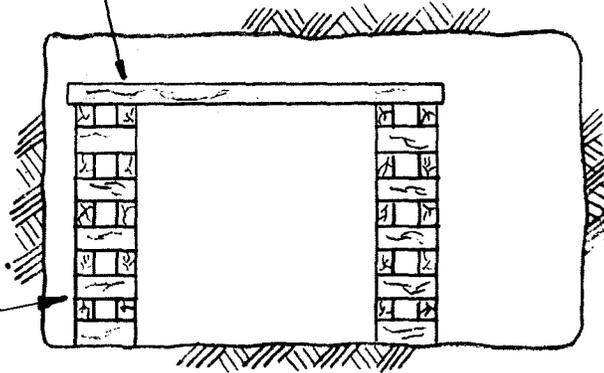TO ANOTHER VOID IN CEMENT

MINE SHAFT CEILING

WOODEN
LAGGING

I BEAM
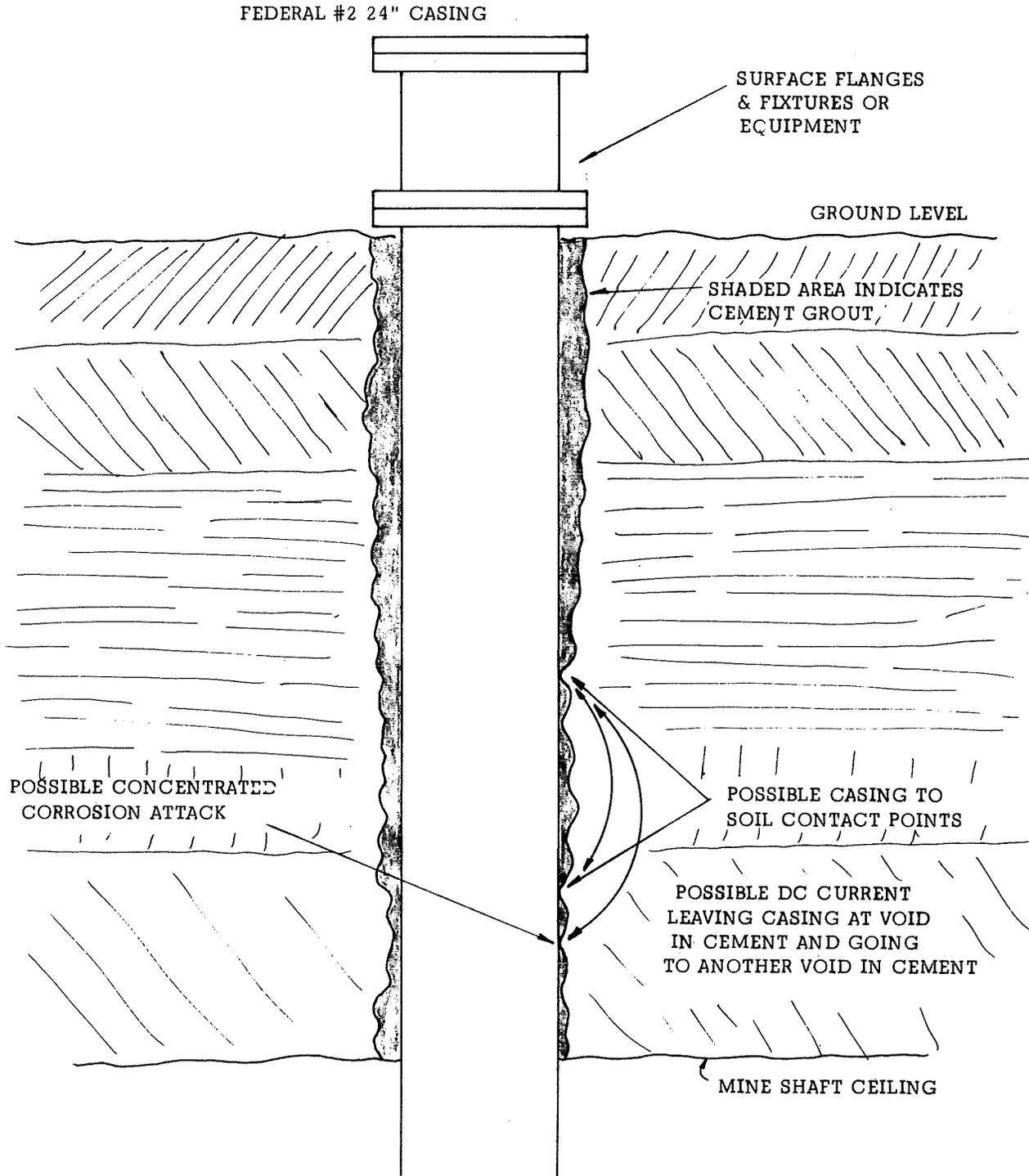
RIGID ARCH SUPPORT

TIMBER ROOF

TIMBER
SUPPORTS

CRIBBING INSTALLATION

ROOF BOLTS

WIRE MESH
ROOF BOLT PLATE
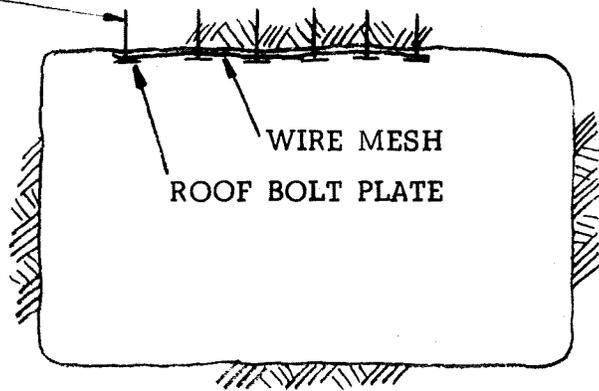
WIRE MESH INSTALLATION

Roof Fall Protection - Comparison of Methods of Supporting Pipeline

DESCRIPTION	A. CHAIN LINK FENCE- PIPE ON FLOOR	B. WOODEN BOX- PIPE ON FLOOR	C. PIPE BURIED UNDER FLOOR	D. PIPE IN NOTCH IN THE WALL	E. PIPE HUNG FROM CEILING	F. PIPE ANCHORED TO FLOOR
1. Effected by Bottom Heaving	Yes	Yes	Yes	No	No	Yes
2. Impact resistance of pipe important	Some	Some	No	Yes	Yes	Yes
3. Hangers required	No	No	No	No	Yes	No
4. Expensive to Install	Yes	Yes	Yes	Yes	No	No
5. Heavy Equipment for Installation	No	No	Yes	Yes	No	No
6. Restricted Location	Some	No	No	Yes	No	No
7. Pipe Inaccessible for Maintenance and Repair	No	Yes	Yes	No	No	No
8. Excavation required	No	No	Yes	Yes	No	No
9. Floor Space reduced	Yes	Yes	No	No	No	Yes
10. Headroom reduced	No	No	No	Some	Yes	No

'NO' ANSWERS INDICATE DESIRABLE FEATURES

IV   III   II   I

VERTICAL
BOREHOLE

#5   #4   #3   #2   #1

3400'   3400'
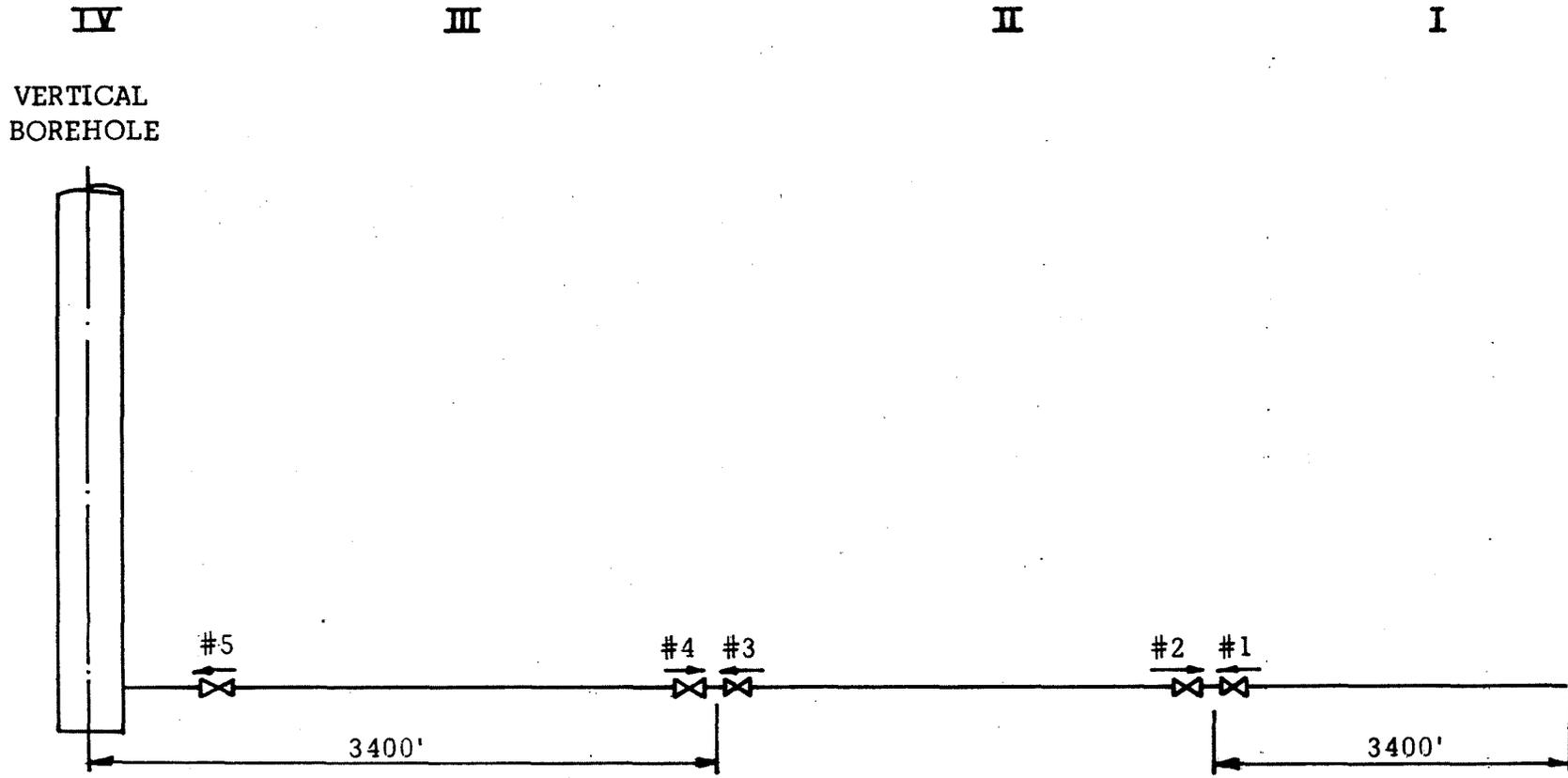
Sample Calculations - Relief Piping

If 200,000 cfd flows from each of the 10 horizontal holes, determine the size line required to vent the most remote borehole. For this size line determine the maximum number of horizontal holes which can be relieved. Operating pressure is 30 psig = 44.4 psia.

Most Remote Borehole

The flow equation is solved for D:

$$D = \left(\frac{Q_b P_b}{C T_b}\right)^{.375} \left(\frac{T_f L}{P_1^2 - P_2^2}\right)^{.2083} G^{.1667} \mu^{.0417}$$

$$= \left(\frac{8.33 \cdot 14.4}{.6643 \cdot 520}\right)^{.375} \left(\frac{515 \cdot 10500}{44.4^2 - 14.4^2}\right)^{.2083} (.66)^{.1667} (7 \times 10^{-6})^{.0417} = 2.038$$

A 2" nominal diameter pipe (2.067" Inside Diameter) is adequate.

Maximum Number of Holes Relieved

Since the horizontal holes nearer the vertical borehole can be vented most easily, the maximum will involve these holes.

The flow equation is solved for P_2:

$$P_2 = \left[P_1^2 - \frac{G^{.8} u^{.2} T_f L}{D^{4.8}} \left(\frac{P_b Q_b}{C T_b}\right)^{1.8} \right]^{.5}$$

$$P_{21} = \left[(14.4)^2 - \frac{(.66)^{.8}(7 \times 10^{-6})^{.2}(515 \cdot 1050)}{(2.067)^{4.8}} \left(\frac{14.4 \cdot 8.33}{.6643 \cdot 520}\right)^{1.8} \right]^{.5} = 42.50$$

$$P_{22} = \left[(42.50)^2 - \frac{(.66)^{.8}(7 \times 10^{-6})^{.2}}{(2.067)^{4.8}} (515 \cdot 1050) \left(\frac{14.4 \cdot 16.67}{.6643 \cdot 520}\right)^{1.8} \right]^{.5} = 35.1$$

$$P_{23} = \left[(35.1)^2 - 1106.55 \left(\frac{14.4 \cdot 25}{.6643 \cdot 520}\right)^{1.8} \right]^{.5} = 8.9$$

The maximum is two, since the final pressure must be atmospheric. (8.9 < 14.4 psia)

Manufacturers of Recommended Materials

\,eroquip Corporation
\,00 S. East Ave.
ackson, Michigan   49203

Venturi Flow Meter

\nderson I.B.E.C.
\19699 Progress Drive
\}trongsville, Ohio   44136

separator and float trap

\,.G. Co.
?.O. Box 1097
\}ellaire, Texas   77401

needle valves and manifold valve

Barton ITT
\}80 Monterey Pass Rd.
Monterey Park, California   91754

flow recorder and temperature
recorder

Burndy Corporation
\}5 Richard Ave.
Norwalk, Conneticutt   06856

copper compression crimpits

Cinch Connectors
1501 Morse Ave.
Elk Grove Village, Illinois   60007

terminal blocks

Conoflow Division of I.T.T.
175 Post Rd.
Warwick, Rhode Island   02888

regulator

Daniel Industries, Inc.
P.O. Box 19097
Houston, Texas   77024

orifice flanges and leveling saddles

Donogan Electrical Manufacturing Co.
2997 Franklin St.
Detroit, Michigan   48207

transformer

E. I. DuPont DeNemours & Company
Talley Building & Concord Plaza
Wilmington, Delaware   19898

plastic pipe

Durable Manufacturing Co.
176 West Adams St.
Chicago, Illinois   60603

gaskets

Duriron Company, Inc.
Dayton, Ohio

anodes

Eclipse Fuel Engineering Company
Rockford, Illinois

ignition plug and ignition switch

Fisher Controls
Marshalltown, Iowa   50158

relief valves, pneumatic relay,
excess flow valve, 3-way switching
valve, regulator, pop relief valve

Fee & Mason Manufacturing Company
2201 Atlantic Ave.
Manasquan, New Jersey   08736

pipe hangers

F.W.I., Inc.
P.O. Box 3249
Tulsa, Oklahoma   74101

check valves

Flexaust Company
Division of Callahan Mining Company
275 Park Ave.
New York, New York   10017

flexible pipe

Gits Bros. Manufacturing Co.
6385 W. 74th St.
Bedford Park, Illinois   60638

sight glass

Goodall Electric, Inc.
201 S. Spruce St.
Ogallala, Nebraska   69153

rectifier

Jefferson Electric Company
910 25th Ave.
Bellwood, Illinois   60104

transformer

John Crane Company
6400 Oakton St.
Morton Grove, Illinois   60053

shaft seal for stuffing box

C. M. Kemp Company
Glen Burnie, Maryland   21061

flame arrestor

Kerotest Manufacturing Corp.
2525 Liberty Ave.
Pittsburgh, Pennsylvania   15222

natural gas valve

unkle Valve, Inc.
1222 Bluffton Rd.
3ox 1740
'ort Wayne, Indiana 46809

safety relief valve

.unkenheimer Company
Waverly & Beakman Streets
Cincinnati, Ohio 45214

gate valves and check valves

?. H. Maloney Company
?.O. Box 287
Houston, Texas

flange insulating kits

Maxitrol Company
23555 Telegraph Road
Southfield, Michigan 48075

security shut down valves

Maxon Corporation
Muncie, Indiana 47302

reset shut-off valve

OPW Division
Dover Corporation
2735 Colerain Ave.
Cincinnati, Ohio 45225

sight flow indicator

Orbit Valve Company
P.O. Box 9070
Little Rock, Arkansas 72209

gate valves

Permacel Tape Corp.
300 Ellsworth Ave. SW
Grand Rapids, Michigan 49502

tape

Phillips Drill Co. ITT
Michigan City, Indiana 46360

anchors

Prestolite Company
Division of Eltra Corp.
511 Hamilton St.
Toledo, Ohio 43602

ignition cable

Rajah Company
35 Verona Ave.
Newark, New Jersey 07104

ignition plug fitting

Ranarex Division
Permutit Co., Inc.   process gas analyzer
E. 49 Midland Ave.
Paramus, New Jersey   07652

Rego Division
Bastian-Blessing Company   ball valves and gas regulator
4201 West Peterson Ave.   for nitrogen
Chicago, Illinois   60646

Rexare
P.O. Box 47   in line check valve
West Alexandria, Ohio   45381

Rockwell Manufacturing Company
400 N. Lexington Ave.   shutdown valves and Roto-seal meter
Pittsburgh, Pennsylvania   15208

Samuel Moore & Company
Mantua, Ohio   44255   polyethylene tubing and tube fittings

"Square D"
Executive Plaza   terminal blocks
Park Ridge, Illinois   60068

Tube Turns Division
Chemtron Corporation   hinged closure
P.O. Box 987
Louisville, Kentucky   40201

Winston Manufacturing Corp.
P.O. Box 640   instrument housing and core strainer
Bellaire, Texas   77401

Worcestor Controls
125 Hartwell St.   ball valve
West Boylon, Massachusetts   01583

Tapecoat Company, Inc.
1527 Lyons Street   protective coatings
Evanston, Illinois   60204

SPECIFICATIONS AND OPERATING INSTRUCTION

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ımonwealth of Pennsylvania, Dept. of Mines and Mineral Industries, Oil and Gas
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Kaltwasser.

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1961 by D.O. Sprowls and M.E. Carlislo, Jr.

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Area, United Fuel Gas Company, 1965 by William Lempert.

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Ventilation Air, USBM-RI8009, 1975 by M.C. Irani, P.W. Jeran and D.H. Lawhead.

Reference Publications cont.:

ASTM D2513-68 Standard Specifications for Thermoplastic Gas Pressure Pipe, Tubing and Fittings.

Experiment on the Danger of Ignition by Aluminum Spark, Gluekauf Ref. 92, pp.778-7 1956 by D. Herbert Shultze .

Frictional Sparking of Aluminum, The Institute of Mining Engineers, 1959 by J.C. Bailey.

Institute of Gas Technology, IGT Home Study Course Gas Distribution, Chapters V & VI, 1963.

Gas Flow Formulas, American Gas Association, 1975 by Hymen, Stoner and Karnitz.

Industrial Water Conditioning, Chapter 31, Cooling Water Treatment: Once Through Scale Control.

ASTM E162-67 Standard Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source.

Earthload Design Consideration for Polyethylene Gas Distribution Systems, DuPont Company, 1974 by William B. Allman.

A.G.A. Plastic Pipe Manual for Gas Service, 1968 by Plastic Pipe Committee of the American Gas Association.

Engineering Data Book, Natural Gas Processors Suppliers Association, 1972.

Control of Pipeline Corrosion, by A. W. Peabody, National Association of Corrosion Engineers, 1967, 2400 West Loop South, Houston, Texas 77027.

Stray Current Mitigation Bonds and Reverse Current Switches, by R. M. Keller, pp. 501-514: "Proceedings of the Seventh Annual Appalachian Underground Corrosi Short Course", 1962, West Virginia University, Morgantown, W. Virginia.

Testing and Evaluation of Current Requirements for Gas Storage Well Casings in Oakf Storage", by R. M. Niedbala, pp. 515 - 521: "Proceedings of the Seventh Annual Appalachian Underground Corrosion Short Course", 1962, West Virginia Universit Morgantown, W. Virginia.

Influence of Water Quality on the Corrosion and Electrochemical Behaviour of Mile Steel in Synthetic Acid Mine Waters, by Subrahmany, D. V. and Hoey, G. R. Corrosion-Nace, Vol. 31, No. 6, June 1975, pp. 202-207.

SECTION 100

GENERAL

101 APPLICATION

These specifications apply to the construction of a methane gas gathering system for an existing "gassy" coal mine.

102 SCOPE OF WORK

The company shall provide the materials for and install the following facilities:

a. Mainline Pipeline - approximately 10,000 LF of 8.625" diameter polyethylene pipe in the mine return airways.

b. Lateral Gathering Lines - 10 lines approximately 100 LF each in length of 2.375" diameter steel pipe in the mine return airways.

c. Relief Line - approximately 10,000 LF of 2.375" diameter steel pipe in the mine return airways.

d. Vertical Borehole - approximately 800 LF of 24.000" diameter steel pipe from the mine to the surface.

e. Water Separation Facilities - 10 in the mine return airways.

f. Methane Detection System - 21 sensors at various locations along the pipeline in the mine return airways.

g. Emergency Shutdown System - 10-2" and 6-8" safety shutdown valves with associated instrument tubing in the mine return airways.

h. Surface Compressor Facilities - 1-160 HP Natural Gas Compressor on a concrete foundation, within a metal building.

i. Surface Metering Facilities - 2 orifice meter runs on a concrete foundation, within a metal building.

103 CODES AND SPECIFICATIONS

The construction of all facilities shall be completed in accordance with the codes and standards listed below. In case of a conflict between two or more of the codes, the more stringent shall apply.

a. Code of Federal Regulations, Title 30 - Mineral Resources, Chapter 1 - Mining Enforcement, Safety Administration

b. Department of the Interior, Schedule 2 G, Electric Motor-Driven Mine Equipment and Accessories

c. Code of Federal Regulations, Title 49 - Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Safety Standards

d. Applicable State and Local Codes

e. API Standard 1104, 13th Edition, Standard for Field Welding of Pipe Lines

SECTION 200

MATERIALS

201 GENERAL

Materials shall be as specified on the drawings. Substitutions will be allowed if the properties of the substituted item meet or exceed the qualifications of the specified item and are approved by the United States Bureau of Mines.

202 HANDLING AND STORAGE

a. Polyethylene Pipe – Care must be taken to avoid pushing or pulling the polyethylene pipe over or around sharp projections. A scratched piece of pipe must be removed from the piping system if the scratch depth is greater than 10% of the minimum pipe wall thickness. Kinking or buckling should be avoided and any section of pipe which has been damaged in this manner should be cut out and replaced.

When unloading or loading the polyethylene pipe, operators must be cautioned against damaging the pipe with the forks or cables of the lift machine. Allowance should be made for some bending in the middle of the lift, but fork lift blades or spreaders should be positioned as far apart as possible to reduce the amount of bending. The pipe must not be dropped to the ground. Extra care should be taken in unloading pipe at temperatures of 40°F or below.

Occasionally, when long strings of pipe are joined together, it is necessary to drag the pipe to where it will be installed. When this occurs, precautions must be taken to protect the pipe from abrasion. Sand bags, used tires, or short logs may be used to support the pipe and prevent contact with sharp rocks.

The pipe should be stored in a manner to minimize damage from crushing, piercing, or cutting. It should not be subjected to outdoor exposure for periods in excess of 5 years. In areas experiencing high concentrations of direct sunlight, the outdoor exposure should be limited to one year.

b. Steel Pipe – Steel pipe shall be handled by the Company in a careful manner to prevent gouging, flattening, denting, scoring or other injury. Precautions shall be taken with coated and wrapped steel pipe to prevent damage to the coating. The same precautions taken in unloading or dragging sections of polyethylene pipe apply to coated steel pipe. During storage, coated and wrapped steel pipe shall be supported by wooden skids placed under the un-coated ends or by suitable pads positioned to distribute the weight of the pipe. Coated and wrapped pipe shall not be laid directly on the ground, sidewalk, or pavement.

SECTION 300

PIPING

301 GENERAL

a. The company shall fabricate all piping and install all valves and fittings as called for on the drawings. Such piping shall be installed true and level or plumb or where a slope is required, such slope shall be maintained without sags in the piping run.

b. The company shall insure that piping assemblies are under no strain prior to final bolting or welding. Misalignment will not be permitted.

c. The company shall insure that all piping assemblies are thoroughly swabbed clean of all dust, refuse, welding spatter, etc., prior to tie-in or final bolting.

302 THREADED CONNECTIONS

a. The company will furnish suitable pipe cutting and threading equipment to make required threaded lengths. Damaged threads shall be cut off and the pipe rethreaded.

b. The company shall properly align all threaded joints. Pipe entering unions shall be true to centerline so that the union does not have to be forced for make-up. Threaded pipe shall not project through fittings to cause interference with valves or other operating mechanisms.

c. Threaded connections shall be made up tight and a pipe thread compound satisfactory for use with methane shall be used.

d. Pipe wrenches shall not excessively scar the pipe.

303 FLANGED CONNECTIONS

a. The company shall insure that all flange faces are parallel and correctly centered prior to final bolting. Force will not be permitted in attaining alignment and a gasket of the proper size shall be installed in each joint.

b. Bolts shall be tightened in diagonal sequence and shall be centered with equal threads visible on both sides. Bolts shall be uniformly tightened to produce a leak-proof joint but shall not be tightened excessively so as to cause yield or permanent set.

304 WELDED CONNECTIONS

a. All welding shall be performed and all welders shall be qualified in accordance with API Standard 1104, 13th Edition, Standard for Field Welding of Pipe Lines, which is hereby made a part of these specifications.

b. Alignment between adjoining sections of pipe or fittings shall be so performed that the axial centerlines coincide.

305 BUTT FUSION OF PLASTIC PIPE

The company shall follow the polyethylene pipe manufacturer's butt fusion procedure to insure successful joining of the polyethylene pipe. Care must be taken to insure that the following operations are properly executed:

a. The heating tool temperature is within the specified range.

b. The pipe is properly aligned and securely clamped.

c. The pipe ends are properly faced.

d. During melting the pipe ends are in firm contact with the heating tool, the proper force is applied, and the correct amount of material is melted on the pipe ends.

e. The heating tool is properly removed.

f. During joining, the appropriate force is applied to the pipe ends and the force is maintained for the proper length of time.

g. The joint is not subjected to external stresses until it has cooled the proper amount of time in the ambient air.

306 DISCONNECTING PLASTIC AND STEEL PIPE

a. The company shall exercise caution when disconnecting the plastic pipelines to prevent sparking as a result of static charge buildup. The static charge can be dissipated by encircling the pipe with wet rags on both sides of the separation area. Encirclements should be two to three feet apart.

   This electric charge is sometimes generated as a result of high velocity flows of dry natural gas carrying any type of dirt, filings or dust. Laboratory testing has shown that the greater static charge buildup occurs around fittings and elbows rather than in continuous runs. Although the wet gas produced from coal seams is less likely to cause static charge buildup, it is still important to follow these safety procedures.

b. The company shall exercise caution when disconnecting the steel pipelines
to prevent sparking as a result of stray currents. A bond wire should always
be placed across the area where the separation is to be made.

SECTION 400   Instrumentation - Installation and Operating Instructions

401 Pneumatic Safety Shutdown System

As described, the pneumatic safety shutdown system relies on a rapid release of gas pressure at one or many release mechanisms which then causes the closure of certain safety shutdown devices for purposes of segregating the piping system into various segments, predetermined as safe increments.

1. The Pneumatic Supply

Pneumatic pressure supply shall be nitrogen furnished in commercial 300 cubic foot cylinders (containing 300 standard cubic feet of nitrogen compressed to over 1200 psig). The cylinders shall be furnished with commercial fittings for nitrogen service and be installed at an appropriate location in either air intake or air return passageways in the mine. A recommended wall support for two cylinders is pictured in drawing USBM-8.

A two-cylinder manifold is essential to permit changeover from one cylinder to another without interruption of the pneumatic media. Each cylinder is to be equipped with a pressure gauge. The recommended manifold is a Rego#M2523HP580 Automatic Changeover Regulator Assembly for Nitrogen. The outlet pressure from the Rego regulator assembly is to be field adjusted for a 100 psig discharge pressure The Conoflow Model #H-24 regulator and gauge shown immediately downstream from the Rego regulator assembly is to be field adjusted for a downstream gas pressure of 30 psig.

Piping from the supply cylinders to the Fisher #169 electrical 3-way switching valve is to be constructed of Schedule 40, Grade B steel threaded pipe materials conforming to the A-53 or A106 designation of the latest edition of the ANSI B36-10 Code.

The nitrogen supply pressure as indicated on the cylinder gauges is to be routinely checked (not less than weekly). When cylinders have been depleted, they are to be replaced immediately. The specified automatic changeover regulator will switch the supply from the depleted to the full bottle automatically by means of a regulator-type control.

2. The Pneumatic Conduit Medium

The conduit medium for distribution of the nitrogen throughout the piping grid shall be Dekoron type "P" polyethylene 1/2" O.D. black tubing #1201-86203.

This material is susceptible to punctures and should be handled carefully throughout the installation. It is available in 250 foot length reels. An ordinary

pocket knife can be used for cutting into the required lengths. All ends shall be squared before joining into the specified fittings.

All tubing connections are to be made using Dekoron E-Z fittings. Refer to drawing USBM-7 for correct configurations and styles. Although the manufacturer suggests that these fittings can be assembled by hand without tools, it is recommended that tightening of the compression nut be performed using a small adjustable wrench, applying a very small amount of torque. Care should be taken to avoid too much torque.

All tubing should be fastened to the natural gas piping by means of a double wrapping of one-inch wide Permacel 162 High-Strength Stapling Tape at intervals not less than 24 inches. The tubing is to be positioned on the top one quarter of the natural gas piping wherever possible. The natural gas piping surface shall be cleaned with a dry cloth at each location of the application of the tape. Refer to drawing #USBM-6 for illustration of this taping procedure.

At the intervals and approximate locations shown on drawing #USBM-6, relief valves are to be installed on the tubing. Refer to detail #15 on drawing #USBM-7 for correct installation arrangement of these valves. Kunkle No. 48-4 brass safety valves are to be used at these locations. The relief pressure setting to be 50 psig on all of these units. These are to be installed at locations that will permit free access to the manual relief ring.

No coatings, paint or tape will be installed on brass tubing fittings.

3. Release Mechanisms

To provide the safety capability of shutdown of the natural gas boreholes and pipeline two types of pneumatic release mechanisms have been specified:

a. Pressure Activated

The pressure activated pneumatic release device shall be a Fisher Controls type 168H-3 Snap-Acting Three-way Pneumatic Switching Valve. There will be one of these installed at each borehole location and at a central location on the 8" gas main as illustrated on drawing #USBM-6. They are to be furnished with a 50-150 psi range spring. Care is to be taken to install these units exactly as illustrated on drawing #USBM-6, with port A connected to the sensing line to the Rockwell Security Valve, port B will be the vent and port C will be connected to the mine pneumatic tubing system.

The range adjustment nuts on the operating stem are to be field adjusted to trip the snap switch on increasing pressure at a valve of 120 psig and return this switch to its original position on decreasing pressure at 106 psig. These 168H pneumatic switching valves can be pre-adjusted by use of a Ralston Quick Test Air Pump available from Ralston Engineering Co. of Cleveland, Ohi

Using this device, the set pressures can be simulated to permit manual adjustment of the range adjustment nuts prior to installation.

b. Electric Activated

The electric activated pneumatic release device will be a Fisher Controls type 169 Electro-Pneumatic 3-Way Switching Valve. The correct orientation of this valve is illustrated on drawing #USBM-8. Port B is to be connected to the nitrogen source; Port A will be the origin of the mine pneumatic tubing system and Port C will be a vent. This unit to be furnished for operation on 20 mA at 12 volts D.C. using a Circuit Part No. of #1040897X01. It will be wired with a two-wire cable protected in conduit from the MSA electrical methane detector annunciator panel. Refer to drawing #USBM-9 for a schematic representation of this wiring.

4. Safety Shutdown Devices

For purposes of closing the natural gas pipeline at appropriate locations in the event of a loss of pneumatic pressure in the mine safety shutdown tubing system, a Rockwell Security Shutoff Valve is required.

At each borehole location, a 2" Rockwell Model DPS-H, screwed, Ductile Iron, 100 psig Security Shutoff Valve equipped with a #163-08-021-07 spring shall be installed as shown on drawings #USBM-2 and #USBM-6. Care should be taken to insure that this valve is orientated correctly (body arrow in direction of flow).

The spring adjustment on this device shall be made prior to installation by using the previously described Ralston Quick Test Air Pump connected to the external control tap. The pressure setting for closure of the valve shall be 25 psig or less.

Five 8" Maxitrol Century Model A216 GWCB steel, Security Shutoff Valves, each equipped with a spring set to close at 25 psig shall be installed at the locations indicated on drawing #USBM-6. Care should be taken to insure that these valves are orientated in accordance with the body arrow designations shown on drawing #USBM-6.

The spring adjustment on these valves shall be made prior to operation by using the previously described Ralston Quick Test Air Pump connected to the external control tap. The pressure setting for closure of the valve shall be 25 psig or less.

At initial start-up of the complete methane piping system facility and after the nitrogen pneumatic supply has been activated and all pneumatic tubing has been pressurized to 30 psig, each of the 8" Maxitrol Security Shutoff Valves,

starting at the 24" vertical borehole, shall be manually opened using a 12" adjustable wrench to rotate the external adjustment knob.

After all of the 8" security valves have been opened, the horizontal borehole security valves shall be opened in the same manner beginning with Borehole #10 and ending with Borehole #1.

After all security valves are opened and only then should the 4" shut-in horizontal hole block valves be opened to permit production of the natural gas.

Whenever a mine hazard has caused a shutoff of one or more of these security valves, it will be necessary to manually reset the valve to an open position when all conditions have reached a safe and normal operational level.

402 Gas Relief Piping System

Immediately downstream from each of the horizontal borehole 4" shutoff valves, a 2" Fisher Model 1805-3 relief valve with malleable iron body and equipped with a #1D6659-2702 spring, factory set to relieve at 30 psig is to be installed on a branch connection and the outlet tied into the 2" steel relief piping system. Refer to drawing #USBM-2.

The 2" relief piping is to be roof-supported and protected against corrosion in the same manner as the 2" steel lateral lines.

Refer to drawing #USBM-3 for details of the connection of this line to the 24" vertical borehole.

403 Surface Safety Instrumentation

To prevent an accidental discharge of methane contaminated with air at the surface facility, where gas is either directly injected or compressed and injected into a utility pipeline, two devices act as safeguards:

1. The 8" Maxitrol-Century Security Shutoff Valve located adjacent to the 24" vertical borehole and described under 401-4 (Safety Shutdown Devices).

    This valve will close when the mine pneumatic safety system has reacted to a hazardous situation, shutting off all flow of methane to the surface facility except any release of methane in the 2" relief header system. Refer to drawing #USBM-6.

2. Ranarex Specific Gravity monitering device coupled with an electric safety shutdown valve on the compressor suction line at the surface. Refer to drawing #USBM-12.

The latter safeguard includes a gas specific gravity instrument described as follows:

Ranarex Process Gas Analyzer, Bulletin 170 Wall Mounting, 0.5 to 1.0 Specific Gravity Range, Indicating and Recording, Spring Type, 24-hour Rotation, 7-day Wind, Single High Alarm DPDT, 5 ampere 115 VAC non-inductive contact, 115 volt, 60 Hz, Explosion-Proof Drive Motor, calibrated for Dry Ambient Reference Air and equipped with a Reference Air Drier and a Gas Sample Flowmeter.

This instrument is to be installed as indicated on the drawing at a convenient location on the outside wall of the compressor building. It shall be wired in accordance with Class I, Group D, Explosion-Proof wiring provisions of the latest edition of the National Electric Code. The high alarm DPDT contact is to be pre-adjusted to close on the specific gravity protection setting desired. The following table will assist in the selection of the proper set point for safeguard against the contamination of the methane by air resulting from a mine piping failure:

(Assuming 0.60 Specific Gravity Methane)

% Volume of Air	5	10	20	30	40	50	60	70	80	90
Specific Gravity of Gas	.62	.64	.68	.72	.76	.80	.84	.88	.92	.96

The Ranarex Instrument is to receive its gas sample through a $1/2$" dia. steel instrument line connected upstream of the electric shutdown valve as indicated on the drawing. The instrument is to be housed in a Winston Manufacturing Corp. Type 802SB weather-protecting cabinet.

The electric shutdown valve is a spring operated manual reset, 115 VAC 60 Hz valve which is manually opened and will remain open as long as it receives 115 VAC power. When power is interrupted, it will close. This valve can be wired in such a manner that a remote light or bell would activate when the valve is closed. It is to be installed horizontally, as shown on drawing #USBM-12. Its control electric circuit is to be wired through the Ranarex high gravity alarm contacts as shown on the simplified electrical schematic on drawing #USBM-12. Specifications for purchase of this valve are as follows:

> 6" Maxon Series 7000-S
> Manual Reset Automatic
> Shutoff Valve, Position AW
> Cast Steel Body, 150 #ANSI
> Flanged, 115 VAC, 60 Hz

This valve is rated for a maximum of 50 psig inlet pressure. If surface gas pressures in excess of 50 psig are anticipated, another valve must be considered.

404 Drilling Operations Safety Instrumentation

During the actual drilling of the horizontal boreholes, there is a need to alarm the operator if the effluent gases resulting from the boring operation would fall into

the category of explosive mixtures. This would occur if the released methane became contaminated with too high a proportion of air. To protect against that occurrance, a Ranarex specific gravity monitoring instrument is to be installed as illustrated on drawing #USBM-11. The instrument shall be as follows:

> Ranarex Process Gas Analyzer, Bulletin 170 Wall Mounting, 0.5 to 1.0 Specific Gravity Range, Indicating and Recording, Spring Type, 24-hour Rotation, 7-day Wind, Single High Alarm DPDT, 5 ampere 115 VAC non-inductive contact, 115 volt, 60 Hz, Explosion-Proof Drive Motor, calibrated for Dry Ambient Reference Air and equipped with a Reference Air Drier and a Gas Sample Flowmeter.

The high specific gravity alarm contact will activate an audible alarm to signal the drilling personnel if a dangerous gas mixture is encountered. The high specific gravity alarm is to be set to signal air concentrations in excess of 70% by volume. Refer to the table under C2 for setting information.

To prevent the possibility of natural gas escaping with the liquid effluent from the liquid/solid trap, a Rockwell 2" Model IPSL, screwed, cast iron, equipped with a #163-08-021-00 spring factory set to close at 6" W.C.

This valve shall have its external control port connected to the gas release piping as shown on drawing #USBM-11 with $1/2$" steel piping. This security valve is a manually opened valve and will therefore require a manual adjustment prior to start of drilling operation.

In addition, prior to start of drilling operation, the 2" pipe plug on top of the 180° return liquid piping leg on the liquid effluent line should be removed and this piping leg filled with water until water overflows each vertical riser. (Refer to drawing #USBM-11). This step is necessary to provide a water volumn seal at start of drilling to prevent any methane from being released down the liquid effluent piping.

405 Electronic Methane Detection Instrumentation

(Refer to drawing #USBM-9).

The instruments specified to comprise a mine atmosphere pipeline leak detection system will be the recently-developed MSA Multichannel Underground Gas Detection System.

This system will include the following components:

6 Sensor Power Supplies: To supply power to the sensor amplifier units, and to keep the nickel cadmium battery packs in the sensor amplifiers at full charge in event of a power failure. (Each sensor amplifier powered by its respective power supply.)

21 Sensor Amplifiers, (intrinsically safe), calibrated for a range of 0-100% LEL methane gas in air, (0-5% methane by volume).

6 Analog Output - Annunciator packages: Function is to receive signals from each sensor amplifier and display the readout on meters. Annunciator circuitry is to inform the operator of an increase of gas, and alarm when gas reaches a predetermined value. Hermetically sealed warning and alarm relays having 3 amp. contacts are an integral part of this package, one for each sensor. Flashing blue trouble indicator signals sensor burnout and/or power supply failure.

6 Power Supplies for Analog Output - Annunciator function is to supply power to above, including recorder, if used, in event of a power failure for (4) four hours.

1 Specially fabricated 20 mA source panel for operation of remote, intrinsically safe electro-pneumatic switching valve furnished by others.

Drawing #USBM-9 illustrates the correct wiring for installation of this system. This instrumentation provides alarm contacts but no design was included for local or remote audible or light alarms wiring circuits. The respective mine operator may alarm this equipment in accordance with his own specific requirements.

The sensors should be factory adjusted to provide a warning at 1% methane by volume in the mine atmosphere and alarm at 3% methane by volume in the mine atmosphere including the electrical activation of the electro-pneumatic safety valve.

Power supply is assumed to be available at the locations indicated on drawing #USBM-9.

406 Gas Metering

1. Borehole Measurement

At each horizontal borehole, an Aeroquip 2" Barco Venturi flow meter is to be installed at the location illustrated on drawing #USBM-2. These meters are available in three different beta ratio models, 393, 483 and 636. Selection of the correct beta ratio model depends on line pressure. For instance, at the design flowrate of 8500 SCFH of natural gas per borehole, a Model 483 would perform accurately at 5 psig line pressure and a Model 393 would perform accurately at 25 psig.

When ordering these meters, it will be necessary to provide correct information on approximate flow rates and pressures and have the manufacturer suggest the appropriate model. Also a factory-prepared, direct-reading calibration chart for readings in standard cubic feet per hour at different differential pressures and static pressures, should be furnished with each meter. This should be in the form of a permanently attached tag for each meter.

Venturi sizes and beta ratios shall be selected so that design flow rates shall read between 20% and 80% of the full scale range on a linear meter with permanent pressure loss of not more than 25% of indicated flow rate differential pressure.

Meter readings shall be routinely taken by use of an Aeroquip Barco Portable Master Meter complete with two 10' connecting hoses, blowdown valves and reinforced plastic carrying case.

2. Surface Measurement

At the surface, standard natural gas orifice measurement equipment has been specified. A typical surface metering facility is illustrated on drawing #USBM-13. A dual 2" orifice run installation is pictured here. This facility would be able to accomodate the metering of natural gas after being compressed to say 500 psig and before delivery to a customer's pipeline.

All surface orifice measurement equipment should meet the requirements of the American Gas Association Gas Measurement Committee Report No. 3.

The metering equipment pictured represents the least expensive means of performing this measurement task while preserving the utmost in accuracy. More sophisticated orifice metering accessories are available including electronic flow computers with digital totalized flow and rate-of-flow indicators.

In most cases, the purchaser of the gas will specify the type and design of metering facility required. It is also customary to maintain the measurement equipment in a locked, metal, weather-protecting building as pictured on drawing #USBM-13.

407 Borehole Flow Control

To provide the capability to manually control the production rate of individual horizontal boreholes, a 3" Rego Model A7517A, Ductile Iron Globe Valve shall be installed in the 2" steel lateral lines near the connection to the 8" plastic main. These shall be installed in the 2" pipeline using 3" x 2" forged steel bushings.

When the entire piping facility is initially brought on stream, these valves are to be in the fully opened position. If after production has begun it is necessary to throttle one or more of the boreholes to maintain the desired 8500 SCFH gas production per hole or throttling is necessary to provide a more even production pattern among all of the boreholes, the handwheel of the Rego Globe Valve is to be turned while checking production rates on the Barco Venturi Meter until the correct flowrate has been attained.

When throttling is necessary, mark the valve stem with tape to provide a record of the valve travel for future correlation purposes.

SECTION 500 COATING REQUIREMENTS

501   STEEL PIPE COATING

SCOTCHKOTE 212

APPLICATION, HANDLING AND INSTALLATION SPECIFICATIONS

MATERIAL

Scotchkote 212 is a commercially one part, heat curable thermosetting powdered epoxy coating designed to provide corrosion protection of small diameter pipe. This material is a product of the Electro-Products Division, 3M Company, 3M Center, Saint Paul, Minnesota, 55101. It is applied by various commercial applicators located in various parts of the United States.

SURFACES PROTECTED

Seamless, continuous weld, continuous stretch reduced and electric resistance weld steel pipe, casing, conduit and reinforcing rods.

SURFACE PREPARATION

The pipe surface must be prepared by the commercial applicator before application of Scotchkote 212 by:

1 – Removing oil, grease and loosely adhering deposits. Note: Whenever ordering pipe from a steel mill, affirm that it is free of all mill oil, grease and surface laquers.

2 – Abrasive blasting the pipe surface to NACE near white condition.

3 – Preheat the cleaned pipe to approximately 450°F (232°C).

4 – Electrostatically depositing the powder epoxy coating on the pipe surface to a coating thickness of 12 mils.

5 – Allowing the coating to cure from the residual heat in the pipe, and then water quenching it to about 200°F (93°C).

6 – Electrically inspect the pipe coating for imperfections at a minimum of 1000 volts D.C.

7 – Repair all imperfections found.

8 – Bundle pipe and pad for shipment to customers.

NDLING BY CUSTOMER

e cranes to lift bundles of pipe from rail cars and place on wooden skids so that 'face debris and stones will not damage newly coated pipe. Similar storage facilities st be provided when coated pipe is delivered by self-unloading trucks from the iting applicator.

STALLATION

re must be exercised when handling the joints of coated pipe during installation in i mine to minimize and/or eliminate coating damage. All coating damage sustained 'ing installation from impacts, wrench marks and welding must be repaired and :oated in accordance with Joint Coating Protection Specifications.

502 JOINT COATING PROTECTION

TAPECOAT CT

APPLICATION SPECIFICATIONS

MATERIAL

Tapecoat Ct is a cold applied fortified tape combined with a corrosion resistant coal tar fortified pressure sensitive bonding agent, manufactured by the Tapecoat Company, In 1521 Lyons Street, Evanston, Illinois, 60204, U.S.A.

SURFACES PROTECTED

Welded, screwed and mechanically coupled steel pipe joints, steel pipe, conduit, cable, tie rods, tanks and elevator casings, and portions of steel pipe coatings damaged during the installation of the pipe.

SURFACE PREPARATION

Prepare surface before application of TC Coldprime and Tapecoat CT by hand wire brushing to remove any loose rust and scale, dust or dirt. Oil and grease are to be removed with a suitable solvent.

PRIMING

Stir TC Coldprime before using. Brush on a thin coat and let dry to a tacky consistency. One gallon will cover approximately 400 square feet.

APPLICATION

Tapecoat Ct is applied either spirally with a minimum lap or with a single lap cigarette wrap method. Draw Tapecoat Ct tightly around pipe so that it evenly conforms to the surface being coated, being careful to remove all air pockets under the tape.

<u>503</u> <u>EXPOSED STEEL COATING</u>

(STEEL CEILING PIPE HANGERS)

<u>TC ENVIROSHIELD</u>

<u>MATERIAL AND APPLICATION SPECIFICATIONS</u>

<u>ATERIAL</u>

C Enviroshield brush or spray applied coating is a blend of chemically inert resins,
gments and fillers formulated by the Tapecoat Company, Inc., 1521 Lyons Street,
anston, Illinois, 60204, U.S.A.

<u>OLORS</u>

C Enviroshield is available in white, gray and orange.

<u>JRFACES PROTECTED</u>

door and outdoor above grade steel surfaces from industrial corrosive environments.

<u>JRFACE PREPARATION</u>

r optimum adhesion, commercial grade sandblasting is recommended. Surfaces to be
ated should be clean and dry of all mill oil, laquer and scale. Lifting or wrinkling
sts should be performed on previously coated surfaces prior to application of
C Enviroshield.

<u>PPLICATION</u>

C Enviroshield is one-coat brush applied to a recommended thickness of 7 mils wet,
mils dry. Brush coverage 240 sq. ft. per gallon. TC Enviroshield may be one-coat
ray applied to a recommended thickness of 8.5 mils wet, 2 mils dry when diluted
to 1 with ES thinner available from the Tapecoat Company, Inc. For best results apply
ove 50°F. Maximum in-service temperature is 120°F. TC Enviroshield will dry dust
e in one hour and may be handled after twenty-four hours.

PACKAGING

TC Enviroshield is available in one gallon containers packaged in two, four or six gallon cartons and five gallon pails. Stock should be stored in cool area and rotated within six months.

SPRAY EQUIPMENT REQUIREMENTS

Pump:	30 : 1 - Ratio Minimum
Hose:	1/4 Inch High Pressure, Solvent Resistant
Gun:	Twist Tip Nozzle Binks Model 50 or 50H; or Equivalent
Tip:	.026 P.S.I. Orifice Minimum
Pressure Input:	100 P.S.I. Minimum (46 CPM Minimum)

AIR TYPE*

Pump:	Heavy Duty (9 : 1 Ratio)
Hose:	3/4-1 Inch ID, High Pressure, Solvent Resistant
Gun:	Graco Heavy Material Hand or Pole Gun or Equivalent
Atomizing:	3/16 - 3/8" - Internal Mix is Recommended
Fluid Tip:	3/16 - 3/8"

*Suitable spray equipment is available from Binks Mfg. Co., Chicago, Illinois, Gray Company, Minneapolis, Minnesota and other equivalent manufacturers.

HEATERS

Cold weather application is greatly improved by using electric in-line heaters as recommended by Gray Company, Binks Mfg. Co., or equivalent.

SECTION 600   Rectifier Installation Specifications

(Refer to Drawing #USBM-3)

601 Pole Installation

1. Vertical pole hole should be 4' - 6" deep for a 20' pole; 6" deeper for each additional 5' of pole length.

2. Pole hole must be packed and tamped with rock, except DO NOT tamp rock against PE/PVC coated cables. BE CAREFUL NOT TO DAMAGE INSULATION ON ANY CABLES.

3. Mound dirt 6" ot 12" all around base of pole to allow for backfill settlement.

4. Tapered roof of pole should slope toward rectifier and be square with rectifier unit.

5. The rectifier mounting pole should be set immediately next to a fence to allow for fence wires to be stapled to the back of the pole

602 Meter Loop Installation

1. Cut conduit and fabricate meter loop so that weatherhead is in proper position at top and so that top of meter box is in line with the top of the rectifier case. Make all joints pipe tight.

2. Meter loop should be installed at 90° to and square to the rectifier case.

3. Attempt to place weatherhead approximately 12" from top of pole and not more than 6" higher or lower.

4. For 230 volt alternating current supply: Bring two black wires out of the top of the weatherhead and one white wire out of the bottom.

5. For 115 volt alternating current supply: Bring one white and one black wire out of the top of the weatherhead.

   (NOTE: Hot wires are usually black but can be any color. The neutral wire must always be white.)

6. Use three straps on the meter loop to support it to the pole spaced as follows: Under the weatherhead, just above the meter, and one equally spaced in between the other two.

7. Entrance wires to AC electric meter can be either no.6 or no.8, which ever local electrical codes dictate. These wires must be evenly cut and neatly formed and all wire connectors must be made up tight and firm.

8. Be careful in making up meter to breaker box snug, but not too tightly, the hubs can be broken off quite easily.

603 Breaker Box Installation

1. Attach the breaker box to pole with wood screws.

2. Two single pole breakers are needed for 230 volt alternating current service while only one single pole breaker is needed and should be used with 115 volt alternating current service.

3. The breaker box neutral plate must always be solidly grounded.

4. External conduit connection to the breaker box must be made fast with a lock nut and bushing inside the breaker box.

604 Grounding System

1. No. 6 bare copper ground wire (solid) must be used when grounding the breaker panel box and the rectifier unit. Form the ground wire neatly, staple to the pole with evenly spaced staples.

2. Connect the solid ground wire securely to the ground rod.

3. The 5/8" x 8' Copperweld Ground Rod must be driven to ground level next to the rectifier mounting pole.

605 Rectifier Installation on Pole

1. Mount rectifier on wood pole utilizing vertical mounting brackets supplied with the rectifier. Bore holes in wood pole and place bolts all the way through the pole and secure in place with washers and nuts. Make sure the case is plumb with the pole. Cut off excess length of bolts.

(NOTE: The bottom of the rectifier case should normally be 4' - 6" from ground level, and approximately 5' - 3" when installed in a cattle feeding pasture.)

2. When connecting the alternating current to the rectifier make sure that all twisted wires thread up into the Scotchlok wire connectors. Once again all conduit connections to the rectifier case must utilize a 3/4" bushing and lock nut on the inside of the unit. 3/4" Greenfield conduit with straight or 90° bend fittings on each end as best fits the situation can be used in the AC supply to the unit.

**606 Direct Current Conduction from and to the Structure and the
Ground Bed**

1. One inch rigid conduit connected internally to the rectifier case
   and formed for easy attachment to the pole must be terminated 12"
   below ground level.

2. The Direct Current supply wire to the ground bed #8 HMW PE
   from the rectifier must be run from the header cable of the ground
   bed under ground, then through a vertical 1" rigid conduit into
   the bottom of the rectifier unit and attached to the DC ground bed
   terminal.

3. The Direct Current return wire from the 24" casing, #8 HMW PE
   must be attached to the casing utilizing the thermite welding
   process, (no brazing or arc welding) run under ground, then
   through vertical one inch rigid conduit attached to the pole and
   into the bottom of the rectifier unit where it is connected to the
   structure or pipeline DC connection.

NOTE: a) Check all wiring before turning the rectifier on.

           b) Double check all wiring and Direct Current polarity before
              leaving the site of the completed installation.

           c) The unit should be checked monthly to assure its sustained
              proper operation.

           d) If problems should develop with the operation consult with
              a qualified Corrosion Control Engineer.

**607 Impressed Current Ground Bed Anode Back-Fill Metallurgical Grade
Coke Breeze**

Carbonaceous backfill material will often reduce the total resistance
of impressed current anodes buried in soil. Carbonaceous backfill
suitable for use around anodes can be coke breeze (crushed coke) or
flake graphite. The coke should originate from coal, or be recalcined
petroleum coke. Flake graphite is usually more explosive than coke
breeze that does an adequate job.

Coke breeze should have a maximum resistivity of 50 ohms-centimeters
with approximate physical and chemical analysis as follows:

Physical Analysis	Chemical Analysis
100% to pass $1/2$" screen	Moisture 9.5 to 14.7%
85% to pass $3/8$" screen	Volatile Matter 3.0 to 3.14%
	Fixed Carbon 78.22 to 78.40%
	Ash 18.6% Maximum
	Sulphur 1.2% Maximum

Presoaking of metallurgical coke breeze backfill with water is recommended to minimize the possibility of bridging. The water soaking allows for greater compaction of the particles of coke breeze. When pre-packaged anodes are used, presoaking with water is recommended to minimize absorption of mud.

SECTION 700   ELECTRICAL (CONSTRUCTION)

701 GENERAL

a. Contractor shall supply all labor, tools, equipment and materials necessary to install the electrical system as shown on their construction drawings and as set forth in this specification.

b. Contractor shall install all electrical equipment and equipment requiring electrical connections according to the best industrial practice. All equipment installations and workmanship shall conform to or exceed the requirements of the latest editions of the following rules and codes:

> National Electrical Code
> National Board of Fire Underwriters
> National Electrical Safety Code
> City, County and State Codes having Jurisdiction
> The AIEE Standards
> Applicable Mining Regulations and Codes

It shall be understood that all codes mentioned above shall be in force at the time the contract is signed. Should any code be changed during the construction period, the specifications may be changed by mutual agreement between Contractor and Engineer. Should any part of the design conflict with provisions of codes, laws, or regulations, Contractor shall so notify Engineer.

c. After completion of the work, Contractor shall furnish to Engineer a certificate of final inspection and approval from the inspection bureau having jurisdiction, if such is required.

702 CONDUIT AND FITTINGS

a. Joints in galvanized, rigid conduits and connections to conduits shall be made with red or white lead. Joints and wrench marks shall be painted over with rust-resisting paint. All joints in conduits shall be watertight.

b. Conduits shall be cut square, and all ends must be reamed to eliminate sharp edges. End bushings shall be used on all open ends. All temporary ends of conduits shall be plugged during construction to prevent moisture or rubbish from entering, and all unused holes in conduits or boxes shall be provided with galvanized pipe plugs.

c. Bends in steel conduits larger than one inch, shall be prefabricated elbows. The radius of curvature of field bent elbows shall not be less than six times the outside diameter. The entire conduit system shall be finished, and

cleaned immediately before pulling wires or cables. At controllers, push-buttons, switches, etc., conduit lines shall be sealed to prevent the possibility of a fire traveling in the conduit. Sealing shall consist of plugging all bottom and side conduit entrances with "Dux-Seal".

d. Underground conduits outside of buildings shall be buried to a minimum depth of 18 inches. Adjacent conduits shall have one (1) inch minimum separation. Where conduit crosses underground piping, a minimum clearance of one (1) foot shall be maintained between the pipe and the conduit. All underground conduits shall be grouped as much as practical.

e. Neither conduit nor conduit fittings shall be welded to any structure. All conduit systems shall be complete and shall be swabbed free of all foreign material before pulling wire or cables. Ends of conduit runs shall be protected immediately after installation by steel bushings and flat non-corroding metallic disc or other suitable means. Disc shall not be removed until necessary in order to pull wire. Contractor will be responsible for the entrance of foreign matter into the conduit system and if required by Engineer, shall make repairs or replacements at no expense to company.

703 WIRING

a. Wire and cable shall be pulled into their conduits with the application of suitable lubricants which have no injurious effects on the covering of the conductor. Care shall be used to protect insulations and prevent overstraining the conductors while pulling.

b. No joints or splices shall be permitted except at outlets or permanently accessible junction boxes or manholes, as specified on drawings. All splices, joints and free ends of conductors shall be covered with an insulation equivalent to that of the conductors.

c. Conductors entering cabinets for connections to terminate shall be formed in a neat workmanlike manner, and shall be properly and neatly grouped and laced or taped.

d. After each wire is meggered it shall be permanently identified at each end with a Brady wire label. Identification shall be the same as called for on the design drawings.

Section 800 Testing

All piping that will contain methane shall be subjected to a pressure test prior to being put into service.

801 Test Procedure

The test procedure shall be established by Contractor, subject to mine operator's approval, after due consideration of mine conditions. Testing operations shall be performed to the satisfaction of the mine operator. A piping system may be tested as a complete unit or in individual sections as the construction of the system progresses.

Contractor shall notify mine operator at least three days prior to any tests that such tests are being scheduled.

Contractor shall not test a piping system against a closed valve. All valves in the system under test shall be in a half-open position. Where valves are in the system to be tested, test pressure shall not exceed test pressure limits for the valve body set by the manufacturer.

Contractor shall furnish all necessary equipment and labor to perform the required tests, including compressors, pumps, gauges, caps, temporary piping and connections, testing medium, charts of suitable scale, etc.

Test results shall be verified by dead-weight testing gauges.

802 Test Duration, Medium and Pressure

All plastic and steel piping designed for transportation of methane shall be air tested to 215 psig for a period not less than 24 hours. This shall include the vertical borehole piping but not those portions of the horizontal boreholes that are within the coal.

The water separation equipment excluding the water trap shall be subjected to the test along with the piping. Nitrogen-carrying instrumentation tubing is not to be pressure-tested.

803 Test Results

All piping systems shall withstand the test pressure prescribed without showing any evidence of leakage or other distress. If signs of leakage or other distress appear, the affected portion of the system shall be uncovered or exposed and the defective parts of the system repaired or removed and replaced as directed by mine operator.

To determine if there are any leaks in the piping system during the test, all screwed or flanged piping joints shall be "soaped" for purposes of revealing connection imperfections. "Leak-Tec" soaping liquid should be used for this purpose.

804 Test Records

The Contractor will furnish mine operator with the original and two copies of a test report for high pressure gas piping system and Gas Vessel tests that will include temperature and pressure recording charts, dead weight pressure data and other information pertaining to the tests, properly certified by a professional engineer.

PRESSURE DROP TABLE

LOCATION	SECTION	PRESSURE DROP IN SECTION	ACCESSORY	DROP IN SECTION
X		5.000	.001	5.000
A	X-A	4.999	.032	5.000
B	A-B	4.992	.038	4.968
C	B-C	4.952	.464	4.930
D	C-D	4.906	.385	4.920
E	D-E	4.531	.145	14.911
F	E-F	3.753	.311	14.712
G	F-G	3.509	.036	13.914
H	G-H	3.712	.016	14.178
I	H-I	3.716	.018	14.153
J	I-J	3.637	.014	14.861
K	J-K	3.556	.012	10.958
L	K-L	3.54	.117	10.141
M	L-M	3.44	.117	16.991
N	M-N	2.91	.373	18.029
O	N-O	2.511	.160	13.043
P	O-P	2.048	.443	13.110
Q	P-Q	1.554	.114	12.443
R	Q-R	710	.184	11.419
S	R-S			560

NOTE 1: ALL PRESSURE VALUES ARE GIVEN IN PSIG.

NOTE 2: THE CALCULATIONS ARE BASED UPON TWO POSSIBLE
FLOWING PRESSURES, 5,000 CFH AND 10,000 CFH, IN EACH CASE.
GAS FLOWS ARE SPLOTED CFH FROM EACH BOREHOLE.

SECTION B-B

SECTION A-A

SECTION C-C

PLAN VIEW

DETAIL #4
1" PIPE HOLD DOWN
SCALE: 3"=1'-0"

(1) 3/4" HOLES

ROOF BOLT

ROOF BOLT PLATE
SEE DETAIL #5

FREE MASON ROD EXTENSION
FIN. #157 OR EQUAL

THIS END OF ROD
COUPLING TO BE
THREADED, THEN TACK

ROD
COUPLING
WELD THESE TWO ENDS
OF COUPLING FAST

THIS END OF ROD
COUPLING TO BE
DRILLED OUT

SOLID SHEAR PIN
AFTER ASSEMBLY

DETAIL #7
SCALE: 6"=1'-0"

3/4" STEEL ROD

NOTE: SHEAR PIN IS SIZED
FOR CORRECT PULLOUT LOAD
(SEE SPECIFICATIONS)

3/4" x 3 1/2" FREE MASON
PIN #157 OR EQUAL

DETAIL #6
SCALE: 6"=1'-0"

DETAIL #8
SCALE: 6"=1'-0"

3/4" HOLE

(TYP.)

DETAIL #3
8" PIPE HOLD DOWN
SCALE: 3"=1'-0"

(2) 3/4" HOLES

DETAIL #1
1" HANGER ASSY
SCALE: 3"=1'-0"

SEE DETAIL #7

3/4" ROD

SEE DETAIL #8

1" HAMMER ROD

1" PEE & MASON PIN #153
OR EQUAL

1" STEEL PIPE

AS REQUIRED

DETAIL #9
HANGER ASSY FOR SHUTDOWN VALVE
SCALE: 1"=1'-0"

SEE DETAIL #9

SEE DETAIL #8

3/4" ROD

8" 150° WELDING NECK FLG.

8" PLASTIC PIPE

8" PLASTIC TO STEEL
TRANSITION PIECE

1 1/2"
HEX

8" MANIFOLD SHUT DOWN VALVE

8" 90° M.J. ELL

8" STEEL PIPE

8" 150° M.J. FLG.

DETAIL #2
8" HANGER ASSY
SCALE: 3"=1'-0"

SEE DETAIL #7

3/4" ROD

SEE DETAIL #8

1" HAMMER ROD

8" PEE & MASON PIN #153
OR EQUAL

8" PLASTIC PIPE

AS REQUIRED

DETAIL #5
ROOF BOLT PLATE
SCALE: 3"=1'-0"

3/4" HOLE

DETAIL #1
ALL TUBING TEE
FULL SCALE

DETAIL #2
1" TUBING TO 2" PIPE
FULL SCALE

DETAIL #3
2" TUBING TO 1" PIPE
FULL SCALE

DETAIL #4
TUBING UNION
FULL SCALE

DETAIL #5
1" TUBING TO 1" PIPE
FULL SCALE

DETAIL #6
RELIEF VALVE CONNECTION
FULL SCALE

SECTION AA
SCALE: 1:10

DETAIL #10
DRIP TANK
SCALE: 1:10

DETAIL #12
TYP. STEEL PIPE TO PIPE CONNECTION
SCALE: 6:1:10

NOTE: PIPE JOINT COMPOUND
APPROVED FOR NATURAL GAS SERVICE
ON ALL THREADED JOINTS

PLAN VIEW
SCALE 1"=30'

ELECTRICAL DIAGRAM
NO SCALE

LEGEND:

POWER SUPPLY
JUNCTION BOX
METHANE DETECTOR
NITROGEN CYLINDERS

SECTION A-A
NO SCALE

SECTION DOES NOT SHOW SCRIM PIPING

PLAN VIEW
NO SCALE

ISOMETRIC VIEW
NO SCALE

A

A

SECTION AA
SCALE 1"=1'-0"

(22) BARTON MODEL 242 TEMPERATURE RECORDER OR EQUAL

(21) BARTON MODEL 199A FLOW RECORDER OR EQUAL

(20) "BIFF" MODEL 441 MANIFOLD VALVE OR EQUAL

(19) DANIEL LEVELING SADDLES OR EQUAL

(18) 3" DANIEL ORIFICE FLGE. OR EQUAL

CAPILLARY TUBING

FLOOR LEVEL

PLAN VIEW
SCALE 3/8"=1'-0"

OUTLINE OF METER BLDG.

3'-7" HOLLOW STEEL DOOR
(TYP. 2 PLACES)

2'6"x2'6" HORIZONTAL SLIDING WINDOW
(TYP. 4 PLACES)

TEMPERATURE RECORDER

FLOW RECORDER

2" BYPASS

2" TO PIPELINE

ELEVATION VIEW
SCALE 3/8"=1'-0"

TEMPERATURE RECORDER

FLOW RECORDER

METER BLDG. FOUNDATION

PIPE SUPPORTS

1" FROM COMPRESSOR

1" UNDERGROUND BYPASS

6" TO PIPELINE

NOTE: MATERIAL QUANTITIES ARE TO BE USED FOR REFERENCE ONLY. THEY ARE SPECIFIC FOR THIS TYPICAL COAL MINE CHAT

NOTE: QUANTITIES OF PIPE DO NOT INCLUDE UNDERGROUND PIPE FOR SURFACE FACILITIES

ENERGY APPLICATIONS INC.
GRAND RAPIDS, MICHIGAN

MATERIAL LIST