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CRYOGENICS IN COAL MINING

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UNITED STATES STEEL CORPORATION
PITTSBURGH, PENNSYLVANIA
CRYOGENICS IN COAL MINING

If this talk were to have a sub-title I would choose, "Enthusiasm Begets Temerity".

It is somewhat rash for one who is neither a scientist nor a researcher to speak at this Eighth Space Congress. On the other hand pride in modern coal mining and my admiration for coal miners easily overcame any inclination to reject this opportunity.

I hesitate to plunge into examples of noting today's cryogenic technology in coal mining without depicting the coal miner as I know him and touching upon several of the industry's gravest problems.

The following is extracted from testimony which I gave in behalf of the American Mining Congress before appropriate sub-committees of both House and Senate in 1969.

"At the outset I must assert that I am for the coal miner. My admiration and fondness for him began with first acquaintance in 1937, and continues unabated. My regard extends to him in whatever capacity, be it face worker or foreman, coal executive or labor leader, state or federal inspector.

"Tools, equipment and working conditions in 32 years have changed drastically for the better. The coal miner has adapted to each change, yet basically he remains the rugged individual who has so long appealed to me.

"He is strong, energetic, competitive, resourceful and courageous. He
is truly 'A workman that needeth not to be ashamed'.

"I could not think of him nor refer to him as a fatalist. He does not pass the buck, nor does he pre-judge. He may, in times of stress, say things that one may not understand unless he, himself, is a member of the mining fraternity.

"On the contrary, his dominant characteristic, a very American one, is that he is an optimist. When this is excessive or not affirmatively channeled it can lead to his undoing. Military commanders recognize that this positive American virtue presents problems of its own.

"The typical coal miner is so highly motivated that he can become impatient, impulsive, and at times even imprudent. His very resourcefulness can be hurtful, especially when it leads him to make do or improvise excessively.

"If in truth 'The best mirror is an old friend,' you may now have a somewhat different reflection of my friend.

"Summarizing these comments, our problem is not one of overcoming fatalism, a discouraging prospect indeed.

"The coal miner readily absorbs and responds to training when designed to sharpen his skill, improve his awareness and condition his reflexes. But such educational and training programs must be thoroughly prepared, well presented and mindful of his time."
"Gentlemen, you wish to see mine disasters eliminated, mine accidents greatly reduced and mine work performed without jeopardizing anyone's health.

"So do the mine workers, so do state and federal enforcement officials. And so - beyond anyone else - do the operators, for it is they who carry the ultimate responsibility for leadership and direction, it is they who bear the criticism, the onus of failures.

"Coal mining, with its attractive wages and other benefits, must become a good career choice in all respects. The industry's continued success, its very existence, its ability to serve the nation's energy needs hinge upon how it attracts and retains thousands of new miners and hundreds of technical graduates."

The American public has some comprehension of the amazing productivity rise in bituminous coal mining from 6 tons per man-shift in 1946 to 19 in 1970. This is generally attributed to the purely mechanical aspects of mechanization. You may be certain that modernization with its vastly improved work environment both as to health and safety played an important part.

Let us identify a few of such influences, without elaboration.

Year round ambient temperatures in working sections of 63° to 68° F.

Frequency of air changes that would not even be attempted in air conditioning surface buildings.
Means of operating modern machinery without exposure of the miner beyond supported roof, and with positive protection for the operator.

A trend toward designing operator comfort into machines. This is also being accomplished in field modifications and at overhauls.

We now have the means of abating the very fine coal dust which has been in some cases a propagating fuel for methane gas explosions.

Decided advancement of technology of abating the respirable portion of flat coal dust which will eliminate coal miners' pneumoconiosis.

The initial thrust to apply cryogenics in coal mining sprang entirely from safety and health considerations.

At this time applications are:
1. Liquid oxygen self-containing breathing apparatus for mine rescue teams. Wherein adopted this replaces a rebreather type which employs compressed oxygen.
2. An extrapolation of the breathing apparatus in simplified form to supply clean air. Liquid air is employed in this application.
3. Liquid oxygen at mine shops, for cutting and burning.

**MINE RESCUE APPARATUS**

Oxygen breathing apparatus has been worn by mine rescue men in this country as far back as 1905. The early imported equipment was quite hazardous, negative pressure being a grave defect. The slightest leak while in hostile atmosphere immediately imperiled the wearer.
The U. S. Bureau of Mines, formed in 1910, early sponsored improvements in the Draeger and Fleuss apparatus then employed. Subsequently the Gibbs apparatus was approved in 1920 and the McCaa in 1925. Both of these domestic apparatuses employed positive pressure, and have been standbys of the industry.

Upgrading equipment design and care, intensified training, personal physical condition checks and refinement of procedures have combined to effect the following improvement: From 1908 to 1921 - 26 fatalities occurred in apparatus accidents; from 1922 to 1940 - 8 fatalities and from 1940 to the present - 1 fatality.

The next significant two-hour mine rescue apparatus date saw approval of the Aro Corporation's liquid oxygen apparatus in 1965. This unit, designed and manufactured by its Firewell Company, Inc. subsidiary, is the standard apparatus at U. S. Steel's Frick district, Pennsylvania (22 units) and its Gary, West Virginia newest mine (7 units). (Mine Safety Appliance Company's liquid oxygen apparatus was approved in 1967, but is not yet offered commercially.)

Veteran mine rescue team members approve the liquid oxygen unit's greater reserve supply, its comfort to the wearer, its 70°F oxygen as breathed, and its helpful weight reduction as used. A former awkward problem of face piece fogging is virtually eliminated.

Expanded adoption of cryogenic apparatus for mine rescue and recovery is anticipated.

SUPPLIED CLEAN (LIQUID) AIR

Upon request by James Burgess, General Manager, of West Virginia Ventilation Systems, Inc., Firewell produced a prototype clean air supply apparatus.
U. S. Steel had recognized a need for some sort of clean air supply for use in unusual situations. Application of known technology was not in every mining condition sufficient to abate concentrations of (float) coal dust to acceptable levels in the respirable size range, 5 microns by 0.

In December of 1965 the prototype was given a two day feasibility test on a continuous mining machine. In 1966 an extended field test was made of an improved model.

It was found that use of the clean air system only during the periods of dust make by the machine, (approximately 200 minutes per operating shift) assured the operator an exposure well below the rigorous standards later established in the Federal Coal Mine Health and Safety Act of 1969.

After a period of urging development and trying various clean air systems Gary district No. 2 Mine was equipped with liquid (clean) air apparatus on each continuous miner. Essex Manufacturing Company supplied the unit and accessories.

Slides, which follow, depict all three cryogenic applications.
In this simulated emergency a mine rescue team changes to mine clothing.

Concurrently the rescue station technician prepared to charge the apparatus. This takes 5 minutes.

And in 5 more minutes 6 units are charged with 7.5 liters each.

As the team gets into apparatus; tests and checks are all important.

Apparatus with back cover removed, featuring the Dewar and heat exchanger coils.

A close-up featuring the face piece, harness, speaker, gauge and valve.

The team enters the man cage ready to be lowered. In 1961 I titled a paper devoted to mine rescue teams "The Selfless Ones". Perhaps you understand why.

The portable 10 liter Dewar, or liquid air converter, is a complete clean air unit in itself. It consists of a storage tank and heat exchanger mounted on a metal plate, 15.5 inches square and 7.5 inches high. The unit has an automatic pressure relief valve and discharge valve.

The unit is taken from the storage rack and transported on the mantrip by the machine operator.

It is placed into the holder on the mining machine and then connected to the respirator equipment.
SLIDE XI The system permits the high pressure air from the Dewar to be reduced to a breathable pressure by means of a demand type regulator which supplies air at a slight pressure on inhalation demand and automatically stops on exhalation. The low pressure hose is routed from the regulator to a slip fitting on the oranasal type face piece. The slip coupling permits quick release as required. Eye protection is worn.

SLIDE XII The Norelco cryogenerator operates from a 440 volt, AC, 3 phase, 60 cycle source and uses 4 gallons of cooling water per minute to produce approximately 8 liters of liquid per hour. A helium refrigerant reduces the output temperature of the liquid air to about 320° F.

SLIDE XIII The attendant spends about four hours daily to satisfy the liquid air requirements for eighteen mining machine shifts per day. This includes making routine checks on the cryogenerator, together with handling, cleaning, inspecting, purging, and filling of the Dewars. Purging removes the moisture from the container. Filling time for six units is about 30 minutes.

SLIDE XIV After filling, the container is weighed to assure a full capacity of 10 liters or 20 pounds of liquid. The total weight of the unit and contents is 38 pounds. A Beckman oxygen analyzer is used to check for an acceptable oxygen range of 21 to 28%.

SLIDE XV A 50,000 cu. ft. liquid oxygen supply storage for a large shop is serviced weekly by the supplier.
We have dealt with today's three applications of cryogenics in coal mining, all of which have a growth potential. It goes without saying that manufacturers and suppliers must really apply their best efforts at further improvements in reliability and costs.

It is interesting to do some blue sky conjecturing concerning tomorrow's technology. One might envision liquid gas to fuel natural gas engines for certain types of underground mining equipment. Another potential might be combining on-site refrigeration with underground pressurized methane drainage. The liquid methane, approximately 95% pure, might be shipped out in this safe form or perhaps furnish the fuel for the engines using natural gas.

Feasibility, economics and well being of coal miners will determine the shape of future progress.
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