INTERPRETATION OF 30 CFR 75.1100-1 AND 75.1100-2 REGARDING WATER DELIVERY CAPABILITY OF COAL MINE WATERLINES WHEN FIGHTING A FIRE WITH A FIREHOSE AND NOZZLE

Firehose Friction Loss and Elevation Pressure Calculation Methodologies

Fire Hose Friction Loss

The standard formula for calculating pressure friction losses in firehose is:

$$FL = cq^2l$$

Where
- FL = friction pressure loss in pounds per square inch
- c = constant of proportionality that changes for different hose diameters and types
- q = water flow rate through the hose in gallons per minute divided by 100
- l = hose length in feet divided by 100

Typical values of c for commonly used rubber-lined hoses are as follows:

Hose diameter	*c* value
1	150
1-1/4	80
1-1/2	24
1-3/4	15.5
2	8

The above equation, along with values of c for various hoses, can be found in the Fire Protection Handbook published by the National Fire Protection Association (NFPA). Note that the two smallest hose sizes listed above are not normally associated with firehose.

Example Calculation
Calculate the friction loss in 500 feet of 1-1/2 inch hose flowing 50 gpm.

From the chart above, c = 24 for 1-1/2 inch hose.
q = 50gpm÷100 = 0.5
l = 500feet÷100 = 5
$FL = cq^2l = (24)(0.5)^2(5) = (24)(0.25)(5) = 30$ psi

The total required pressure at the hose outlet then becomes:

30psi + 50psig = 80 psig.

As indicated under the Background heading of this PPL, the 1-inch and 1-1/4-inch hoses above are not normally available firehose sizes. These hose sizes would typically be represented by the rubber-lined pressure hoses used to supply a continuous miner with dust suppression water. These small hose sizes typically create excessive friction loss and reduce the likelihood of compliance with the 50/50 rule. Also note that the full length of the miner hose must be accounted for in the friction loss calculation, especially since it is not unusual for these hoses to exceed 500 feet in length.

The *c* values for other firehose sizes can be found in the referenced NFPA Fire Protection Handbook. However, as an alternative source for this data, the mine operator can contact the hose manufacturer directly.

Using the NFPA methodology and *c* values, the needed pressures at the hose outlet for various hose sizes and lengths, with 50 gpm flowing, are:

Table of hose friction losses and pressure requirements

hose diameter (inches)	hose length (feet)	friction loss in hose (psi)	total pressure required at hose outlet [1] (psig)
1	500	188	238
1	700	263	313
1.25	500	100	150
1.25	700	140	190
1.5	500	30	80
1.5	700	42	92
1.75	500	19	69
1.75	700	27	77
2	500	10	60
2	700	14	64

[1] Friction loss plus 50 psi nozzle pressure

Note that 700 feet represents the length of a typical continuous miner hose. If a mine is using a different length miner hose, the methods provided in this appendix can be used to determine the friction pressure loss and the pressure required at the hose outlet.
It is also very important to note that the presence of water pumps in the water system, including underground water pumps, adds additional issues of complexity in evaluating both the capacity and reliability of the water supply for firefighting. MSHA Technical Support should be contacted where concerns exist for these issues.

Changes in Elevation

Most coal mines are relatively level. However, some mines can have a noticeable change in elevation within the length of a lay of fire hose or miner hose. Generally, changes in elevation over this distance exceeding about ten (10) feet should be included in the analysis. Since uphill directions from the VFO represent the worst case situation, only uphill changes in elevation should be included in the analysis.

For each vertical change in elevation of one foot, an additional pressure of 0.434 psi must be added to the pressure requirement at the VFO. This works out to approximately 5 psi for each twelve feet of elevation increase.

Revised Example Calculation

Using the previous example, assume that the belt entry is on a ten percent slope. For a 500 foot hose lay, this would represent an elevation change of approximately 50 feet from the VFO to the nozzle. The elevation pressure can be found by multiplying the elevation change by 0.434, or by dividing the elevation change by 12 and then multiplying by 5.

First method
elevation pressure = 0.434 ×50 = 22 psi

Second method

$$\text{elevation pressure} = \frac{50}{12} \times 5 = 21\,\text{psi}$$

Either value can be rounded down to 20 psi since pressure gages are generally read to the nearest 5 psi value.
The total required pressure is now the sum or the nozzle pressure, friction loss, and elevation pressure or:

50psi + 30psi + 20psi = 100 psig.
Hence, the FVO must be capable flowing 50 gpm at a pressure of 100 psi.

Technical Issues Involving Mine Water Supplies Used for Fire Fighting and Compliance Assistance Examples

GENERIC ISSUES ON PERFORMANCE CAPABILITY

In order to fight a fire using a hose line and nozzle, an adequate rate of water flow, along with sufficient pressure, must be available at the nozzle. Sufficient flow rate must be available to effectively cool and quench the heat generated by the burning material. This material can typically include coal, conveyor belting, hydraulic fluids and greases, paper and cardboard packaging for mining supplies, and wood cribbing.

Sufficient pressure must be available to ensure that the water flow pattern from the nozzle has the proper shape and reach. Effective nozzle pattern shape helps ensure efficient use of the water being applied to burning surfaces. Effective reach helps ensure that those fighting the fire can maintain a safe distance from the effects of the fire during firefighting operations. Fires in underground coal mines not only produce deadly smoke and heat, they can also cause dangerous roof conditions in close proximity to the fire. Therefore, being able to fight the fire from a distance is a crucial safety issue.

HOSE DIAMETER ISSUES

The most common firehose used for manual firefighting has a diameter of one-and-one-half inches (a.k.a. 1-1/2 or 1.5). This size of hose is reasonably easy to handle while still delivering flow rates capable of suppressing many fires. Larger diameter firehoses are also available and have the benefit of yielding lower friction losses or higher water flow rates, which ever is deemed more beneficial by the mine operator. However, larger firehoses also have the disadvantages of being heavier, thus requiring greater manpower, effort, and time to layout during a fire or clean and return to service after a fire. These hoses also have a higher initial cost and can require additional training.

The only official firehose smaller than 1.5 inch is one-inch diameter hose. It is intended only for wild land firefighting and is often referred to as "forestry hose." It is <u>not</u> suitable for fighting fires in mines or structures since it generally cannot deliver the flow and nozzle pressure needed to meet the performance standard.

CONTINUOUS MINER HOSE ISSUES

For dealing with fires at the working section and face, many mines have made plans for using the rubber hose supplying water to the continuous miner as the hose for fighting a working section fire. For modern continuous miners, this hose is typically 1-1/4 inches in diameter, although some mines may still be using older one-inch diameter hose. Although MSHA currently accepts this practice, there are several issues that mine operators must address when considering this option.

1. The smaller diameter of the continuous miner hose may cause substantial friction losses for which the water system may not be able to compensate for, thus preventing compliance. The mine operator must be acutely aware of this potential problem. For continuous miners using one-inch diameter hose, compliance is extremely unlikely.
2. The booster pump often provided on the section for supplying the miner hose may not be capable of providing either the pressure <u>or</u> the flow required for firefighting. The pump must be capable of providing at least 50 gpm at the required hose outlet pressure.
3. A means must be available to quickly disconnect the miner hose from the continuous miner and permit the attachment of a firefighting nozzle.
4. The miner hose can get tangled up with the miner trailing cable or hydraulic hoses during normal operations, thus preventing or impeding the ability to quickly advance this hose to other parts of the working section should a fire occur away from the continuous miner.

COMPLIANCE ASSISTANCE EXAMPLES

Example 1
The XYZ Coal Company's No. 1 mine stores 1-3/4 inch firehose along the belt flights. A water flow test at the farthest hose outlet not located on the section indicates that at 50 gpm, 75 psig is available. Does this comply with the standard?

From the table in Appendix A, the friction loss in 500 feet of 1-3/4 inch firehose is 19 psi, for a minimum required available pressure of 69 psig. Since the available pressure (75 psig) is greater than the required pressure (69 psig), the mine is in compliance with the standard for all other areas of the mine.

Example 2
At this same mine above, the continuous miner hose is planned for use as the fire fighting hose on the section. The miner hose is 700 feet of 1-1/4 inch rubber hose. The hose is fed by a booster pump at the section mouth. The discharge from the pump is tested and found to produce a pressure of 175 psig at 50 gpm. Does this comply with the standard?

From the table in Appendix A, the friction loss in 700 feet of 1-1/4 inch hose is 140 psi, for a minimum required available pressure of 190 psig. Since the available pressure (175 psig) is less than the required pressure (190 psig), the mine is <u>not</u> in compliance with the standard for the working section of the mine.

One solution in this particular case would be to store 700 feet of 1-3/4 inch firehose on the section with the intent of using the firehose instead of the miner hose to fight a fire. In this case, the required pressure is found from the table to be 77 psig at 50 gpm, well within the capability of the given arrangement.

WATER SYSTEM IMPROVEMENTS

It should be noted with great caution that where compliance does not exist, the solution may not always be as simple as changing the size of the hose. An engineering evaluation of the water system may be necessary and may reveal a more extensive solution is necessary. The evaluation may also highlight the availability of more than one possible solution, or the potential use of a combination of solutions for the most economical and reliable fix.

When the mine cannot meet the performance standard, the water system must be modified or enhanced sufficiently to bring the mine water supply back into compliance. Improvement strategies can sometimes include changing waterlines to bigger pipes, adding parallel waterlines, relocating gravity fed sources to higher elevations, adding booster pumps, or adding additional water sources.

In planning mine water system improvements, mine operators must take into account the requirement for fire hose to have burst pressure ratings at least four times the maximum expected working pressure available at each VFO. Additionally, the maximum pressure available at the nozzle must not exceed 100 psig.

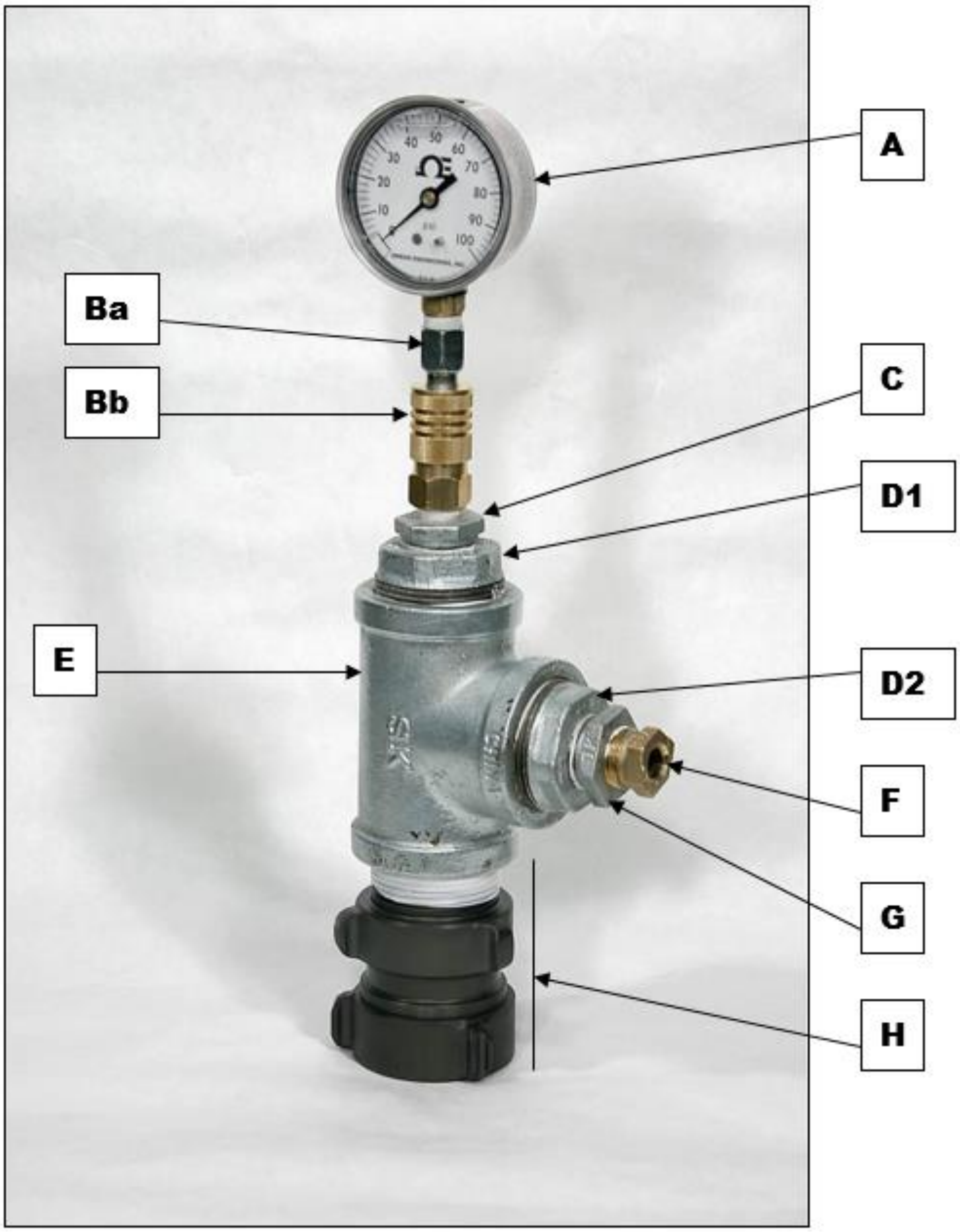
Where improvements are needed to the water system, MSHA Technical Support can be contacted for additional assistance.

NATIONALLY RECOGNIZED CONSESUS STANDARDS

Nothing in any of the regulatory standards prohibits the mine operator from having waterlines capable of delivering a greater flow or having more outlets than required. In fact, experience has shown that it is often necessary to provide adequate flow and pressure to three or more hose lines simultaneously in order to effectively fight an underground coal mine fire. This expectation of flowing at least three hose lines for a total of at least 150 gpm at nozzle pressures of at least 50 psig, is reflected in the national consensus standard on underground coal mine fire protection published by the National Fire Protection Association. [NFPA 120-2004: Standard for Fire Prevention and Control in Coal Mines.]

MSHA *highly recommends* that when mine operators are evaluating the needs of planned new mines, or re-evaluating the needs of existing mines, they should give serious consideration to meeting the recommendations of the NFPA 120 standard.

Waterline Compliance Test Device and Bill of Material



BILL OF MATERIAL

Item ID	Description	Notes
A	Liquid filled bourdon tube pressure gage	1
Ba	¼″ female NPT by ¼″ industrial male quick connect plug	2
Bb	¼″ male NPT by ¼″ universal female quick connect recepticle	2
C	¾″ by ¼″ hexnut reducer bushing	3
D1	1-1/2″ by ¾″ hexnut reducer bushing	3
D2	1-1/2″ by ¾″ hexnut reducer bushing	3
E	1-1/2″ threaded straight pipe tee	3
F	Calibrated orifice with ½″ NPT male threads	5
G	¾″ by ½″ hexnut reducer bushing	3
H	light-weight anodized aluminum hose/pipe adapter, Redhead Model 54RL, 1-1/2″ male NPT by 1-1/2″ female NPSH swivel with gasket (or equivalent)	4

NOTE 1: Pressure gage scale should be such that the required flow pressure should be approximately at half scale, or greater.

NOTE 2: The "air chuck quick connection" is optional. The pressure gage can alternatively be screwed directly into the hex reducer bushing (Item C). However, the quick connect allows the gage to be easily turned in any direction for better visibility during the test, and it allows for easy removal for storage.

NOTE 3: The fittings shown are galvanized, threaded Class 125 standard gray cast iron fittings. These fittings have a water pressure rating of 175 psig, which should be adequate for most flow test scenarios. If higher flow pressures are expected, then higher pressure rated fittings must be used.

NOTE 4: This adapter fitting is optional since the pipe tee (Item E) can be threaded directly onto a 1-1/2 inch NPT hose outlet. However, the adapter allows the test device to be easily turned in any direction for aiming the stream in the most appropriate location, and permits tightening/untightening by hand or with a small firehose spanner wrench rather than a pipe wrench.

NOTE 5: Contact MSHA Technical Support for specific information on calibrated orifices.