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PROGRAM INFORMATION BULLETIN NO. P08-08

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SUBJECT: Precautions for the Use of the Analysis of Retreat Mining Pillar  
Stability (ARMPS) Computer Program

### **Scope**

Coal mine operators, miners and miners' representatives, and Mine Safety and Health Administration (MSHA) enforcement personnel should receive this bulletin.

### **Purpose**

The purpose of this program information bulletin (PIB) is to alert the mining community to precautions that should be taken when the Analysis of Retreat Mining Pillar Stability (ARMPS) computer program is used (especially older versions). This PIB also provides notice that an updated program is available that incorporates warning messages that correspond to several of these issues. The latest version of ARMPS is available at the National Institute for Occupational Safety and Health (NIOSH) web site: <http://www.cdc.gov/niosh/mining/prodcuts/product6.htm>. MSHA strongly encourages mine operators to use the updated program.

### **Background**

The ARMPS program was developed by NIOSH (and the former US Bureau of Mines) to assist the mining industry in evaluating ground stability during pillar recovery operations. Based on panel geometry and several additional user inputs, the program calculates stability factors that can be compared to a relatively large database of

successful and unsuccessful case histories. The program was first introduced in 1995 and then modified substantially in 2002 when additional case studies (under deeper overburden than the original data set) were included and corresponding design criteria were introduced. ARMPS was updated again in February 2008 (version 5.1.22 (2-11-2008)).

### **Information**

ARMPS program users should be alert to the following issues:

- **Unit Weight Input.**

Older versions of ARMPS provide no warning if an inappropriate overburden unit weight value is input to the program. Typical unit weights for coal measure rocks range from about 150 to 170 pounds per cubic foot. An unreasonably low value (e.g. entering coal density rather than rock density or a typographical error) could result in an underestimate of applied load and, consequently, inappropriately high stability factors.

The current version of ARMPS will display the following warning if the user selects an overburden unit weight other than 162 pounds per cubic foot:

*The ARMPS case history database was analyzed with an overburden unit weight of 162 pounds per cubic foot. Stability factors obtained with a different overburden unit weight may not be comparable to the suggested stability factor values obtained from NIOSH's analysis of the database.*

- **Coal Strength Input.**

NIOSH recommends that 900 psi be used for coal strength in the ARMPS program if comparisons are to be made with the ARMPS database and the recommended stability factors. Older versions of the program provide no warning when other coal strengths are used.

The current version of ARMPS will display the following warning if the user selects a coal strength value other than 900 psi:

*The ARMPS case history data base was analyzed with an in situ coal strength of 900 psi. Stability factors obtained with a different in situ coal strength may not be comparable to the suggested stability factor values obtained from NIOSH's analysis of the data base. Also, NIOSH research has shown that the reliability of the ARMPS design method decreases substantially when laboratory coal strengths were used in place of the default value. For more information, see Help/Resources/In situ strength of coal [available in the ARMPS Help file].*

Stability factors determined using a consistent strength value other than 900 psi could be compared to one another to assess relative stability (e.g., to compare successful and failed cases at a given mine site). However, these stability factors should not be compared directly with stability factors in the ARMPS case history database. Coal strengths other than 900 psi will result in stability factors that are inconsistent with those analyzed in the ARMPS database.

- **Abutment Angle (Beta) Input.**

Users should be aware that stability factors determined using an abutment angle (Beta) other than 21° are inconsistent with those in the ARMPS database.

Stability factors determined using a consistent abutment angle other than 21° could be compared to one another to assess relative stability but they should not be compared directly with those in the ARMPS case history database. Older versions of ARMPS provide no warning if an abutment angle other than 21° is input to the program.

The current version of ARMPS will display the following warning if the user selects an abutment angle other than 21°:

*The ARMPS case history data base was analyzed with abutment angles of 21°. Stability factors obtained with different abutment angles may not be comparable to the suggested stability factor values obtained from NIOSH's analysis of the data base. For more information, see Help/Project Input Parameters [available in the ARMPS Help file].*

Although the abutment angle and method of determining abutment loading used in ARMPS is intuitively consistent with caving gob (or cantilevered strata over it), it is not related to cave geometry. Although in some cases it may be appropriate to modify abutment angles to reflect greater loading due to cantilevered ground, it is not appropriate to use physical measurements (caving angles or subsidence data) to establish an abutment angle.

- **Breadth of Active Mining Zone (AMZ) Input.**

Users should be aware that stability factors determined using Breadth of Active Mining Zone (AMZ) values other than the ARMPS default (i.e., five times the square root of the overburden) are inconsistent with those in the ARMPS database. Stability factors determined using a consistent AMZ value other than the default could be compared to one another to assess relative stability but they should not be compared directly with those in the ARMPS case history database. Older versions of ARMPS provide no warning if a Breadth of AMZ value other than five times the square root of the overburden is input to the program.

The current version of ARMPS will display the following warning if the user elects to manually input a Breadth of AMZ distance:

The ARMPS case history data base was analyzed with the breadth of the Active Mining Zone (AMZ) calculated automatically ( $AMZ = 5 \text{ times the square root of the depth of cover}$ ). Stability factors obtained with a different AMZ may not be comparable to the suggested stability factor values obtained from NIOSH's analysis of the data base. For more information, see Help/Project Input Parameters [available in the ARMPS Help file].

- **Entry Height Input.**

ARMPS users should note that the value entered for Entry Height is the mined height of the pillars, which is not necessarily equal to the seam thickness.

- **Design Criteria.**

NIOSH recommends a minimum pillar stability factor equal to or greater than 1.5 at overburden depths up to 650 ft. At depths greater than 650 ft, NIOSH's recommendations vary as indicated in the table below (where "H" is the depth of overburden).

	Weak and Intermediate Roof Strength	Strong Roof
<b>ARMPS SF</b>		
$650 \text{ ft} \leq H \leq 1,250 \text{ ft}$	$1.5 - [H-650] / 1000$	$1.4 - [H-650] / 1000$
$1,250 \text{ ft} \leq H \leq 2,000 \text{ ft}$	0.9	0.8
<b>Barrier Pillar SF</b>		
$H > 1,000 \text{ ft}$	$\geq 2.0$	$\geq 1.5$ *
		$\geq 2.0$ **
		* Nonbump prone ground
		** Bump prone ground

It is important to note that when depth is greater than 1000 ft, NIOSH recommends that barrier pillar stability factors be considered in conjunction with pillar stability factors. Minimum recommended barrier pillar stability factors are 1.5 for mines with strong roof and nonbump prone ground, 2.0 for mines with weak or intermediate strength roof, and 2.0 for mines with strong roof and bump (or bounce) prone conditions. The latest version of the ARMPS software provides pillar stability factors and barrier pillar stability factors in the same output screen; a warning is provided if the barrier pillar stability factor does not meet the NIOSH recommended criteria.

In one of the resource files<sup>1</sup> provided in the ARMPS Help file, NIOSH provides the following guidance for developing site-specific criteria:

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<sup>1</sup> Chase, F. and C. Mark, "Analysis of Retreat Mining Pillar Stability (ARMPS)," Proceedings: New Technology for Ground Control in Retreat Mining, eds. C. Mark and R. Tuchman, NIOSH IC 9446, March 1997, p. 17-34.

*“ARMPS appears to provide good first approximations of the pillar sizes required to prevent pillar failure during retreat mining. In an operating mine, past experience can be incorporated directly into ARMPS. ARMPS stability factors can be back-calculated for both successful and unsuccessful areas. Once a minimum ARMPS stability factor has been shown to provide adequate ground conditions, that minimum should be maintained in subsequent areas as changes occur in the depth of cover, coal thickness, or pillar layout. In this manner, ARMPS can be calibrated using site-specific experience.”*

Site-specific criteria used in lieu of NIOSH’s recommendations should be developed cautiously using multiple case histories with known conditions at a given mine. Back analysis is most appropriate for mines that have a proven track record of retreat mining. In these cases, proper examination of individual mine data may demonstrate that stability factors above or below NIOSH’s recommended values are warranted. Proper examination would entail an analysis of the broad experience at a mine site rather than a focus on isolated case(s) that represent the extreme. Also, it is imperative that back analyses consider barrier pillar stability factors as well as pillar stability factors (especially at depths greater than 1000 ft.).

ARMPS criteria should be reevaluated if difficult ground conditions are experienced or if changes in mining conditions (e.g., geology or roof support type or density) are anticipated. Back-calculated stability criteria should be used only in conditions that are consistent with the mine-specific case histories. For example, an ARMPS stability factor developed from retreat mining experience in routinely developed panels of pillars may be inappropriate for recovery in older workings (e.g. mains or submains). Often these older workings contain irregularly shaped pillars that complicate the recovery process and may not be modeled effectively in ARMPS. Furthermore, the pillars, floor, roof, and roof supports may have suffered deterioration over time that makes older workings unsuitable for pillar recovery. Site-specific stability factors that are less than the NIOSH recommendations should not be used unless they are appropriate for the area to be mined.

- **Mining Between Gobs.**

Although the ARMPS program allows users to evaluate the recovery of panels between two gobs (ARMPS Loading Condition #4), this situation should be avoided if possible. This mining scenario can be particularly difficult under deep cover as demonstrated by the fact that only 2 of the 9 NIOSH deep cover case studies were successful; some of these cases were problematic even with substantial barrier pillar stability factors.

The current version of ARMPS will display the following warning if the user elects to evaluate an Active Retreat Section and Two Side Gobs scenario:

*In the ARMPS data base, of the nine case histories of Active Retreat and Two Side Gobs under deep cover, only 2 were successful. This extraction sequence should be avoided if possible.*

- **Complicated Panel Geometries.**

The ARMPS program was developed to accommodate geometries commonly used in room and pillar retreat mining operations. However, complicated geometries cannot be modeled directly. The latest version of ARMPS (version 5.1.22 (2-11-2008)) can account for a row of pillars left to establish a bleeder system but older versions of the software cannot. Users should exercise caution, make conservative assumptions, and use prudent engineering judgment in applying ARMPS to geometries that are not standard in the program.

The ARMPS program is not ideally suited for situations where unusual stress conditions are likely to be encountered (e.g., multiple seam settings). In these instances, it is advisable to use other models or analysis methods in lieu of or in conjunction with ARMPS.

#### **Authority**

The Federal Mine Safety and Health Act of 1977, as amended, 30 U.S.C. §801 et seq.; 30 C.F.R. §75.203.

#### **Internet Availability**

This PIB may be viewed on the Internet by accessing the MSHA home page at <http://www.msha.gov> "Compliance Info" and "Program Information Bulletins."

An updated version of the ARMPS can be downloaded free of charge from the National Institute for Occupational Safety and Health (NIOSH) at

<http://www.cdc.gov/niosh/mining/products/product6.htm>

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#### **Distribution**

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Underground Coal Mine Operators  
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