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EMPIRICAL MODELS OF ZONES PROTECTING AGAINST COAL DUST EXPLOSION

MODELE EMPIRYCZNE STREF ZABEZPIECZAJĄCYCH PRZED WYBUCHEM PYŁU WĘGLOWEGO

The paper presents predicted use of research' results to specify relations between volume of dust deposition and changes of its concentration in air. These were used to shape zones protecting against coal dust explosion. Methodology of research was presented, including methods of measurement of dust concentration as well as deposition. Measurements were taken in the Brzeszcze Mine within framework of MEZAP, co-financed by *The National Centre for Research and Development (NCBR)* and performed by the Institute of Mining Technology KOMAG, the Central Mining Institute (GIG) and the Coal Company PLC. The project enables performing of research related to measurements of volume of dust deposition as well as its concentration in air in protective zones in a number of mine workings in the Brzeszcze Mine.

Developed model may be supportive tool in form of system located directly in protective zones or as operator tool warning about increasing hazard of coal dust explosion.

Keywords: explosive coal dust, mining, dust hazard, prevention, modelling

W artykule przedstawiono wykorzystanie wyników badań do określenia zależności intensywności osiadania pyłu od zmian jego stężenia w powietrzu kopalnianym. Posłużyły one do modelowania stref zabezpieczających przed wybuchem pyłu węglowego. Przedstawiono metodykę badań, w tym metodykę pomiaru stężenia pyłu i intensywności jego osiadania. Pomiary przeprowadzono w KWK Brzeszcze w ramach projektu badawczego MEZAP dofinansowanego przez *Narodowe Centrum Badań i Rozwoju* i realizowanego przez Instytut Techniki Górniczej KOMAG, Główny Instytut Górnictwa oraz Kompanię Węglową S.A. Realizacja projektu umożliwiła wykonanie badań związanych z pomiarami intensywności osiadania pyłu oraz jego stężenia w powietrzu w strefach zabezpieczających szeregu wyrobisk górniczych w KWK Brzeszcze.

Opracowany model może stanowić narzędzie wspomagające w formie systemu zabudowanego bezpośrednio w strefie zabezpieczającej, lub jako narzędzie dyspozytorskie ostrzegające o rosnącym zagrożeniu wybuchem pyłu węglowego.

Słowa kluczowe: wybuchowy pył węglowy, górnictwo, zagrożenie pyłowe, profilaktyka, modelowanie

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1. Introduction

In hard coal mines, in mine working classified as A or B of coal dust explosion hazard, there's duty to maintain protective zones against transfer explosion at length not less than 200 meters (Cybulski, 2004).

Pursuant to regulations (Journal of Laws 94 of 2002, item 841 as further amended), (Journal of Laws as of 2002 No. 139 item 1169 as further amended), those zones are maintained by washing or dusting with stone dust at contour of mine working (Amyotte, 2006). This operation protect against explosion, only if works in protective zones are made precisely (Cybulski & Malich, 2006). Frequency of constructing of protective zones depend on volume of dust collected in mine working (Echoff, 2003). Qualitive prevention is important element of effectiveness of protective zones (Cybulski, 2004). Changing excavation conditions (e.g. increased volume of operation), ventilation condition or volume of conveyed coal may affect effectiveness of protective zones against transfer of coal dust explosion (Branny & Filipek, 2008).

2. Fields tests

Measurements of volume of coal dust deposition and concentration were conducted in protective zones of eight different paths. Paths were located in the Brzeszcze Mine:

- Ventilation path of longwall I
- Conveying path of longwall I
- Ventilation path of longwall II
- Conveying path of longwall II
- The research path
- The pilot downcast
- Conveying path north
- Conveying path south

Measurements of volume of dust deposition were taken on measuring plates and dust concentration in air was measured with optical dust meter. Detailed description of measuring methods was presented in papers in said papers (Malich et al., 2013; Prostanski et al., 2014).

Measurements of volume of dust deposition were conducted each time on nine measuring plates located on contour of mine working (3 plates were located at floor and 3 plates at each sidewall) (Fig. 1). Measurements were conducted at length of 200 meters in selected 10 measuring points (Fig. 2). For purpose of analysis of relations between volume of dust deposition and dust concentration in air measuring plates located in top of path were selected at height near to optical dust meters. 2 or 3 optical dust meters were located in each path at length of zone protecting against coal dust explosion.

Both methods measurements were conducted concurrently all day long (Malich et al., 2013; Prostański et al., 2014).

Plates to measure of volume of dust deposition were located at the same distance from dusting source. Fig. 3 presents example results of volume of dust deposition in ventilation path of longwall II (Prostański, 2015). Measurements of dust concentration in air, in all protective zones were conducted where power supply was available for dust meters and recorder and transmitting device on the ground.

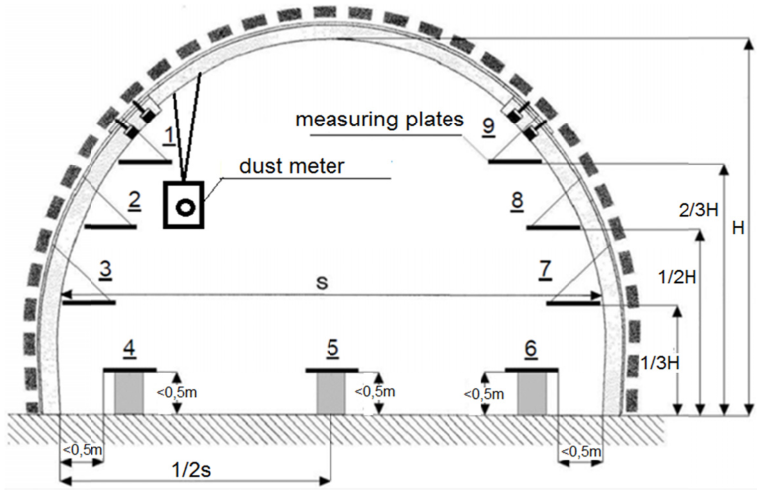


Fig. 1. Location of measuring plates of dust deposition on contour of path in protective zone (Malich et al., 2013)

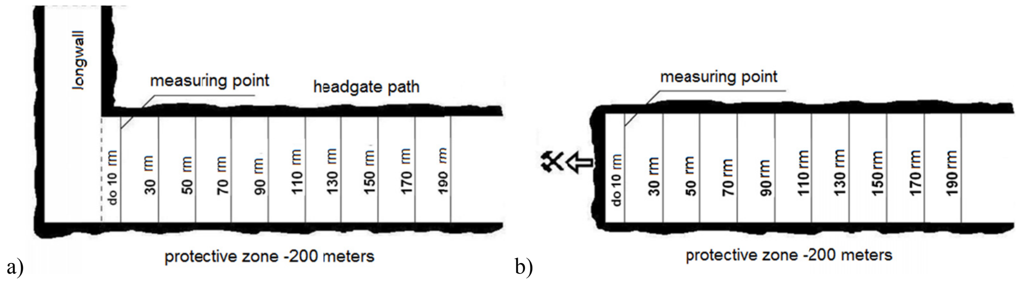


Fig. 2. Location of sample spot to measure volume of mine dust deposition: a) in vicinity of active longwall fronts, b) in paths faces (Malich et al., 2013)

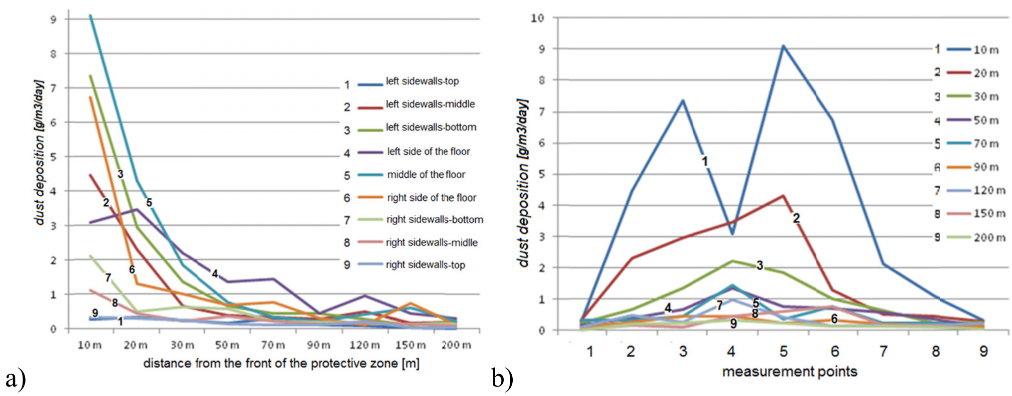


Fig. 3. Volume of dust deposition in ventilation path of longwall II: a) at length of protective zone, b) in cross-sections of protective zones (Prostański et al., 2015)

Measurements of dust deposition volume in conveying path of longwalls I and II were taken in protective zones and measurements of dust concentration with optical meters were taken outside protective zones in a considerable distance. Consequently further analysis were abandoned. Decrease of volume of dust deposition in top parts of path with concurrent decrease of its concentration as goes farther from source were observed in other six path under analysis. Results of measurement were approximated with power function. This reflected forming of characteristics related to dust transfer in path at length of protective zone.

Influence of path cross-section was included by referring of volume dust deposition and concentration to 1 m^3 of path. Measured air flow velocity in each path amounted about 2 m/s (locally increased to 2,5 m/s where cross-section decreased).

3. Analysis of research′ results

Forming of volume of dust deposition and concentration in air was presented on the graphs in order to compare their forming at distance from dusting source (Fig. 4).

Due to observed forming obtained results of measurement of volume of dust deposition and dust concentration in air were approximated with use of power function. Which enabled its presenting (Fig. 5) and inventing relations between these values. Which enabled assessing predicted volume of dust deposition in protective zone depending on its concentration.

Power function describing volume of dust deposition and dusting were presented by specifying linear determination coefficient.

- Ventilation path of longwall I, (Fig. 5a),

  Volume of dust deposition: $y = 22.02*x^{-0.91}$ (1)

  Coefficient of determination: $R^2 = 0.89893$

  Dust concentration: $y = 274.05*x^{-0.95}$ (2)

  Coefficient of determination $R^2 = 0.98$

- Research excavation, (Fig. 5b),

  Volume of dust deposition: $y = 14.97*x^{-0.86}$ (3)

  Coefficient of determination: $R^2 = 0.83$

  Dust concentration: $y = 35.34*x^{-0.23}$ (4)

  Coefficient of determination: $R^2 = 0.99$

- Ventilation path ściany II, (Fig. 5c),

  Volume of dust deposition: $y = 7.28*x^{-0.55}$ (5)

  Coefficient of determination: $R^2 = 0.82$

  Dust concentration: $y = 19.21*x^{-0.22}$ (6)

  Coefficient of determination: $R^2 = 1$

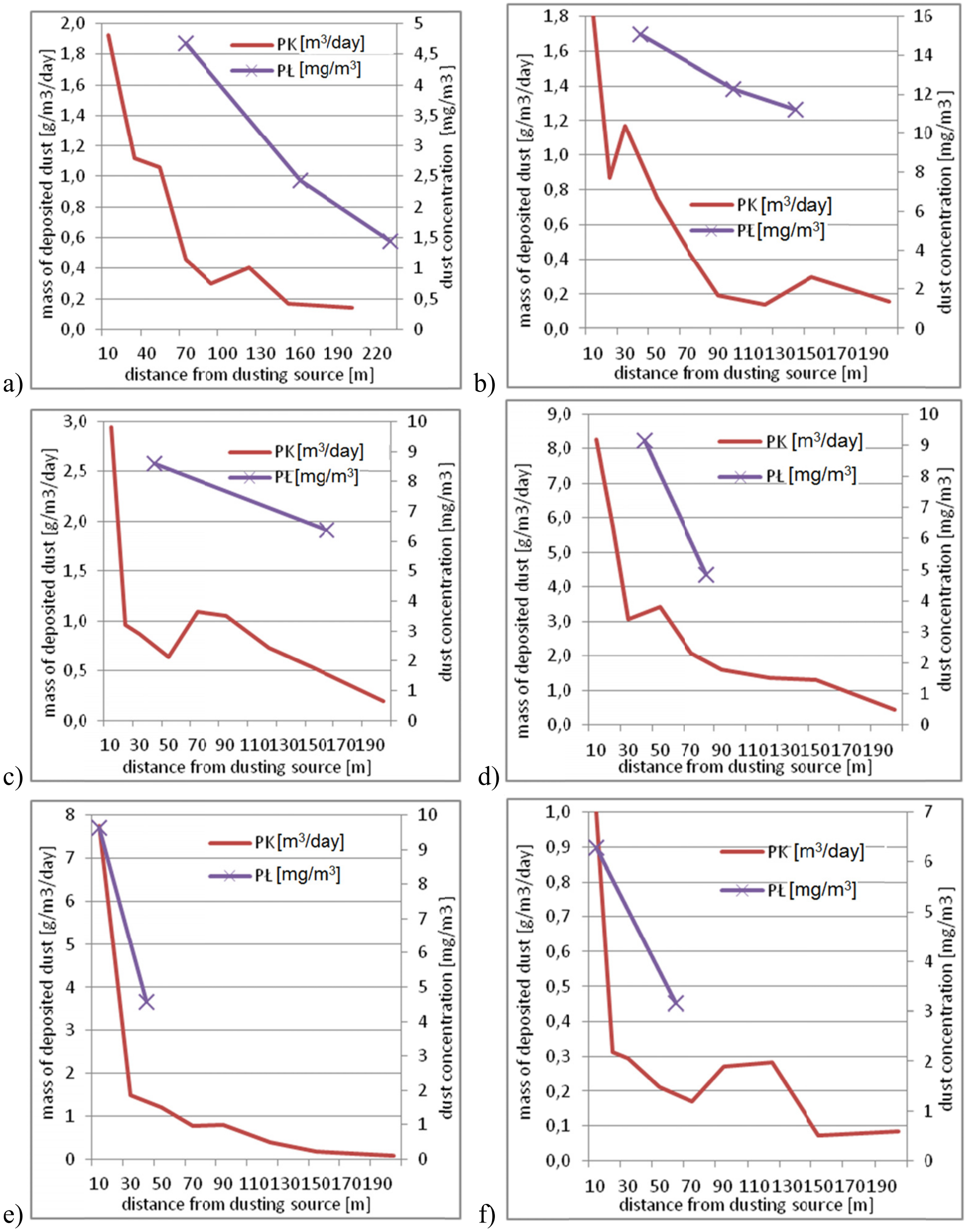
- Research downcast, (Fig. 5d),

  Volume of dust deposition: $y = 10.57*x^{-0.39}$ (7)

  Coefficient of determination: $R^2 = 0.58$

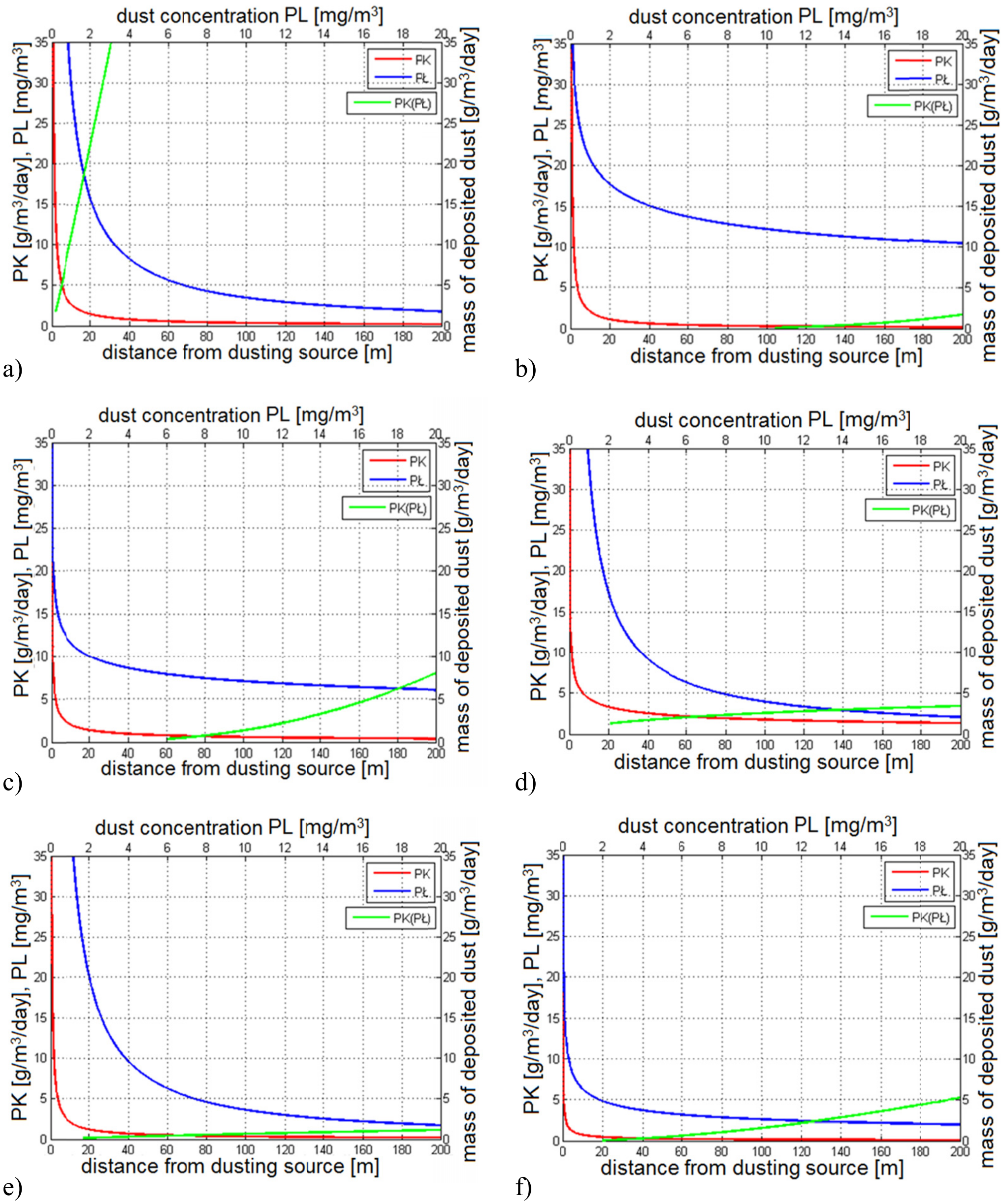
  Dust concentration: $y = 271.87*x^{-0.92}$ (8)

  Coefficient of determination: $R^2 = 1$



PK-total dust measured with plate, PL – respirabile dust measured with dust meter

Fig. 4. Results of measurements of dusting were taken with optical dust meter as well as measurements of dust deposition were taken with measuring plates in protective zone a) ventilation path of longwall I, b) research excavation, c) ventilation path of longwall II, d) research downcast, e) northern conveying path, southern conveying path (Prostański et al., 2014)



PK-total dust measured with plate, PL – respirabile dust measured with dust meter,
PK = f(PL) – Function of volume of dust deposition depending on dust concentration

Fig 5. Extrapolated results of measurement of dust concentration and approximated results of measurements of dust deposition in protective zone and function of mutual relationship a) ventilation path of longwall I, b) research excavation, c) ventilation path of longwall II, d) research downcast, e) northern conveying path, f) southern conveying path (Prostański et al., 2014)

- Northern conveying path, (Fig. 5e),

Volume of dust deposition: $y = 14.48 * x^{-0.83}$ (9)

Coefficient of determination: $R^2 = 0.96$

Dust concentration: $y = 505.09 * x^{-1.07}$ (10)

Coefficient of determination: $R^2 = 1$

- Southern conveying path, (Fig. 5f).

Volume of dust deposition: $y = 3.34 * x^{-0.66}$ (11)

Coefficient of determination: $R^2 = 0.72$

Dust concentration: $y = 15.26 * x^{-0.38}$ (12)

Coefficient of determination: $R^2 = 1$

Equivalent characteristics reconciled on the graphs (Fig. 6), presenting volume of dust deposition depending on dust concentration in air in protective zone were presented in three groups: relations *highly growing* toward horizontal axis (Fig 7a), relations *highly growing* toward vertical axis (Fig. 7b), non-linear relations *growing* from vertical axis upward (Fig. 7c). First group includes: research downcast, northern conveying path. Second group includes: ventilation path of longwall I. Third group includes: research excavation, ventilation path of longwall II, southern conveying path. Forming of individual characteristic, may be affected by many other factors not considered in research. These factors may comprise i.a.: influence of path of support on airflow resistance, increased dusting caused flow of staff or unpredicted works in zone and production cycle dysfunction.

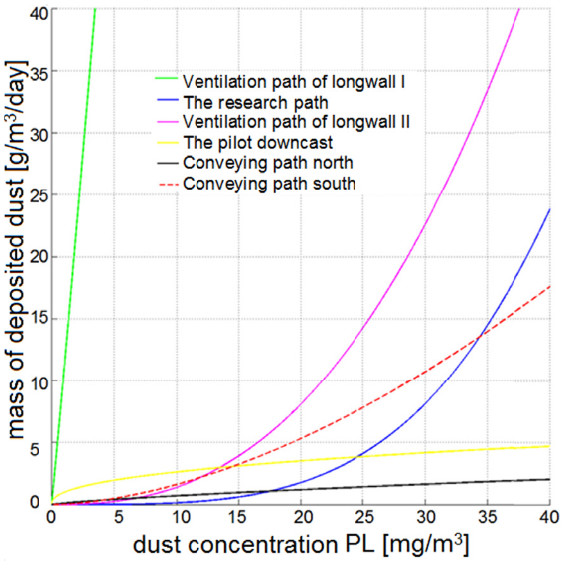


Fig. 6. Equivalent characteristics of dust deposition depending on dust concentration in air in paths under analysis (Prostański et al., 2014)

Equivalent characteristics describing volume of dust deposition depending on its concentration in air in analyzed six paths may be in a form of power function:

a) Ventilation path of longwall I, $y = 0.10*x^{0.96}$ (13)

b) The research path, $y = 17.19*x^{0.26}$ (14)

c) Ventilation path of longwall II, $y = 8.77*x^{0.39}$ (15)

d) The pilot downcast, $y = 1.032*x^{2.36}$ (16)

e) Conveying path north, $y = 15.94*x^{1.29}$ (17)

f) Conveying path south, $y = 7.59*x^{0.58}$ (18)

4. Conclusion

The following was found: the lowest mass of dust with the biggest share of respirable fraction deposited on measuring plate located the highest (Malich et al., 2013). Comparison of summary mass of dust smallest fraction from four plates located the highest is reasonable due to similar height location of dust meters and these function measured dust respirable fraction. Proper assessment of coal dust volume deposition in protective zone and concurrently degree of coal dust explosion, requires considering dust summary dust mass from all measuring plates.

Obtained relations between volume dust deposition and its concentration in air may constitute useful tool for assessment of volume coal dust explosion hazard. Said relations may be used as well to optimize prevention actions in respect to protective zone renewal (frequency renewal and volume materials). This optimization will require measurement and record of data concerning change in air dusting and process these by proper algorithm with implemented relations of model dust deposition volume on dusting changes. Dust recorder recording changes of dust concentration may by connected as well to start up driver for dusting or spraying devices or may by connected to alerting device,

Building of protective zone requires know-how of intensity of dust deposition at its entire length. Exceeding specified level of dust deposition should result in its neutralization, in order to get proper safety level.

Assessment of explosive coal dust deposition intensity should be connected with specification changes of dust concentration resulting from mining process and other conditions i.e.: ventilation, humidity, air temperature and coal properties. Hence researches of dust deposition and concentration were made in paths with maintained protective zone.

Intensity of dust deposition in relation of its concentration in air was approximated by power function. Application of solely one type of function enabled reflection of all relations in the same manner and these comparison in reference to various paths.

Extrapolation of measurements results, mathematically described, pictured as graphs, present approximated distribution and deposition of dust in protective zones. Received relation may be basis to specify criteria for building of protective zones and tools in creating work safety.

Proposed model was described as referred to share of dust quantity per volume unit with makes it independent from cross section of path.

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