SUMMARY OF JAPANESE COAL AND GAS OUTBURST EXPERIENCES AND MEASURES TAKEN AGAINST THE PROBLEM

By M. Ujihara 1 and K. Higuchi 2

ABSTRACT

In this paper, the history of Japanese coal and gas outbursts is presented and circumstances and countermeasures at the time of outbursts are summarized statistically. Then the present methods for prevention used practically in Japan are introduced. From statistics, it was reconfirmed that Japanese coal and gas outbursts have occurred frequently in the district of geological disturbance, symptoms immediately before outburst occurrence were the phenomena in connection with failure of a coal seam and outbursts have occurred many times when the number of boreholes had not been sufficient to degas. One of the principal protective method adopted in Japan is the large diameter gas drainage boring which also possesses a stress relief effect. There is a tendency to make diameter of borehole larger to increase both stress relief and degassing effects.

INTRODUCTION

Japan consists of 4 large islands. The islands that have coal basins at where outbursts have occurred are Hokkaido and Kyushu. The first Japanese outburst occurred in the seam road heading, 573 m depth under the surface of Mikeyotsuyama Colliery in Nov., 1926. In advance to this outburst, rock sounds had been perceived then 5 tons of pulverized coal was ejected. In Japan, 920 outbursts have been recorded from 1926 to 1985. In many cases, volume of ejected coal was not more than 200 m$^3$ and volume of outburst gas was not more than 5000 m$^3$. However, in the incident that occurred in a long wall face of Utsuvinai Colliery on 17th, Jun., 1971, the volume of ejected coal was 941 m$^3$ and gas quantity was 164 608 m$^3$, 30 workers lost their lives and the mine was closed. On 16th, Oct., 1981, the most disastrous and largest scale outburst occurred in a gate road heading of Yubari Shin Colliery, the volume of ejected coal was 4000 m$^3$ and the total gas volume was 600 000 m$^3$. The depth of the site was 1 139 m under the surface, the thickness of coal seam was 6.6 m and the degree of the seam inclination was 24. Moreover, the disaster was followed by the underground fire and by the gas explosion about ten hours later than the outburst event. The death toll in the disaster was 93. As the detail of the disaster was broadcasted on national TV network, peoples in our country were shocked greatly. To prevent these incidents, the Government has invested more than 600 millions yen a year and researches concerning coal mine safety have been continued.

STATISTICS OF COAL AND GAS OUTBURSTS IN JAPAN

Figure 1 shows the change of the number of outbursts per year and also the change of annual occurrence rate per 10$^6$ ton of coal production. According to the figure, the number of accidents per year has a peak between 1959 and 1963 and the number itself has decreased recently, however the occurrence rate per unit coal production has not decreased. It can be said a development of protection techniques and bad geological condition in deeper area may be balanced each other.

Table 1 shows the relation between depth of outburst place and ejected coal volume. Outbursts in Japan began to occur in the range of 100 - 200 m under the surface. A trend of increase of the number of outbursts was seen at about 300 m under the surface. In the deeper area more than 700 m level, the number of occurrence has rather decreased. It is due to the development of protection techniques and also to the decrease of deep working places. In Japan, Horonal Colliery is the deepest coal mine of which depth is 1 195 m. In this colliery, rock and gas outbursts occurred many times but coal and gas outbursts have not occurred since 1971. In Hokkaido, there is another one colliery, Ashibetou Colliery, of which development has been advanced to 1 045 m level under the surface. The Colliery has never experienced outburst at all. It is natural that the more the depth of working increases, the higher the rock pressure becomes. However, the experience in these collieries shows that only the rock pressure is not essential cause of coal and gas outbursts.

Table 2 shows the relation among excavation methods, the scale of outburst and the number of outburst. Right hand end column of the table

1. Associate professor, Fac. of Eng., Hokkaido University, Dr. Eng., a member of MMJ.
2. Professor, Fac. of Eng., Hokkaido University, Dr. Eng., a director of MMJ and a member of AIMM.

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986

288
Figure 1- Changes of frequency of coal and gas outbursts in Japan (1949-1985).

Table 1 - Relation between depth of outburst places and ejected coal volume.

<table>
<thead>
<tr>
<th>Ejected volume</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>600</th>
<th>800</th>
<th>1000</th>
<th>Indistinct</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth under the surface (m)</td>
<td>50</td>
<td>100</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>700</td>
<td>800</td>
<td>900</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>&lt; 100</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>100 - 200</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>200 - 300</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>300 - 400</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>400 - 500</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>500 - 600</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>600 - 700</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>700 - 800</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>800 - 900</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>900 - 1,000</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>&gt; 1,000</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2 - Relation among excavation method, ejected coal volume and the number of outbursts.

<table>
<thead>
<tr>
<th>Excavation method</th>
<th>Ejected volume</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>600</th>
<th>800</th>
<th>1,000</th>
<th>Indistinct</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divided shotfiring</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Induced shotfiring</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Indistinct</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Coal pick</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Air blaster</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

The AustIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986

289
shows that outbursts occurred most frequently after blasting and the ratio is 78% (86/110). Except blasting, 22 times out of 110 outbursts (20%) occurred during coal pick working. The scale of some outbursts occurred after blasting was more than 1,000 m³ but the scale of every outburst occurred by coal pick working was less than 500 m³. The lowest line of the table shows the total number of each scale section. It shows the scale of 70% Japanese outbursts was not larger than 200 m³.

Table 3 shows the time intervals from shotfiring to outbursts which were only occurred after blasting. Many outbursts have occurred immediately after shotfiring. This kind of outburst occurred 31 times out of 65 (48%). On the other hand some outbursts have occurred more than 60 min. later. These delayed outbursts also give us very serious problems. Establishment of infallible precaution methods is buried.

Table 4 shows the relation among ejected coal volume, the number of occurrence and the ejected distance of coal. According to the table, the ejected distance is almost proportional to the ejected volume. But in 70 cases out of 87, pushed out and buried area was within 50m from a face. When an outburst occurs, workers want to go away as far as possible because of happening of fearful condition. There may be rather dangerous case of asphyxiation if they adhere too much to go away to farther place. In many cases, if they succeed in taking refuge 50-100 m from the face, they should be able to get off the danger of burying by coal. In Japan, manager of every colliery has the duty to establish at least one air feed equipment within 25-30m from a heading. Beyond this area, the same air feed equipment should be set up in every 40 m distance. At least air feed of 0.3 m³ per minute a man is required

<table>
<thead>
<tr>
<th>Time laps after shotfiring (min)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>60</th>
<th>100</th>
<th>Indistinct</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of outbursts</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ejected volume (m³)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ejected distance (m)</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-50</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>2</td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>50-100</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>100-200</td>
<td>11</td>
<td>12</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>200-300</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>300-400</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>400-500</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>500-600</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>600-700</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>700-800</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>800-900</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>900-1000</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>&gt;1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>12</td>
<td>27</td>
<td>20</td>
<td>14</td>
<td>3</td>
<td>87</td>
</tr>
</tbody>
</table>

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986
Table 5 shows the number of outbursts in various working places and the number of boreholes drilled. In the case of 71.5 (93 times out of 131), outbursts occurred where the number of boreholes was 10 or without any borehole. In 61 cases out of 93, geological prospecting was practiced but gas drainage was not done. This means the importance of degassing for the prevention of outbursts. The table also shows that 90% of Japanese outbursts occurred in driving and only 10% of them occurred in working face of excavation. So the preventive works should be intensified particularly in driving.

In Hokkaido there are 17 collieries which have outburst experiences. Table 6 shows the number of outburst of each colliery and geological characteristics of 13 items.

<table>
<thead>
<tr>
<th>Number of borehole</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coal seam road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long wall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>15</td>
<td>12</td>
<td>19</td>
<td>11</td>
<td>13</td>
<td>3</td>
<td>15</td>
<td>10</td>
<td>121</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of outbursts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of collieries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utashinai</td>
<td>150</td>
<td>27</td>
<td>10</td>
<td>12</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Sunagawa</td>
<td>88</td>
<td>37</td>
<td>9</td>
<td>7</td>
<td>43</td>
<td>4</td>
<td>14</td>
<td>3</td>
<td>23</td>
<td>30</td>
<td>6</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>218</td>
</tr>
<tr>
<td>Akahira</td>
<td>42</td>
<td>14</td>
<td>10</td>
<td>9</td>
<td>23</td>
<td>3</td>
<td>10</td>
<td>3</td>
<td>23</td>
<td>32</td>
<td>6</td>
<td>21</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>112</td>
</tr>
<tr>
<td>Kamimashimino</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>33</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>38.2</td>
</tr>
<tr>
<td>Toyosato</td>
<td>44</td>
<td>29</td>
<td>5</td>
<td>5</td>
<td>36</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>119</td>
</tr>
<tr>
<td>Hitotsumizuhai</td>
<td>14</td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>14</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>32.2</td>
</tr>
<tr>
<td>Hitomeine</td>
<td>11</td>
<td>13</td>
<td>1</td>
<td>7</td>
<td>37</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>91.3</td>
</tr>
<tr>
<td>Shiraishinai</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>36</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorachi</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horonai</td>
<td>4</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>22</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mozumi</td>
<td>5</td>
<td>14</td>
<td>7</td>
<td>9</td>
<td>32</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oyabari</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>35</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ponbetsu</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>33</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>16</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>125.0</td>
</tr>
<tr>
<td>Yobari</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.2</td>
</tr>
<tr>
<td>Fukumitsu</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>22</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.0</td>
</tr>
<tr>
<td>Shimizuakawa</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td>Inazato</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>19</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.0</td>
</tr>
</tbody>
</table>

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986 291
Table 7 shows the correlation coefficients between the number of outbursts and values of each geological characteristic that are calculated from the data in Table 6. In the table, each coefficient is arranged in the order of absolute value. The items which have extremely significant correlation coefficient are the rate of fault appearance, number of coal seams per 100 m in vertical, number of coal seams in total and number of thick coal seams. This shows that the geological condition of the place where strata and groups of coal seams are divided into various size sections by a lot of faults is most closely related to coal and gas outbursts. The reasons why the outbursts take place frequently in these districts may be estimated as follows. (1) In a certain area along with various faults lines, fragile and weak coal which is abundant of cracks containing high pressure gas exists almost in every case. (2) In the area in which the coal seams have been divided into many irregular blocks by faults, it may be difficult to degas perfectly on account of jamming of drilling rod and failure of borehole. (3) When a drift passes through large scale fault whose throw is larger than a height or width of heading, driving conditions may be similar to those of a cross cut reaching to a coal seam, then the risk of outburst may be increased. (4) Even when a drift is driven along a coal seam, it is inevitable to drive through foot or roof rocks. So practically, it may be impossible to adopt other driving methods with slight impact except blasting.

Figure 2 shows a typical type outburst which occurred unfortunately under such geological conditions. This type outburst occurred in the driving face of Utsushinohashi Colliery on 3rd, Mar., 1967. The depth was 440 m under the surface. In this zone fault was recognized about once per 10 m driving. Although the drift had been advanced along coal seam, driving was changed to rock work because of slip down of coal seam by fault. Before shotfiring, existence of fault and coal seam ahead of the heading had not been checked by boring because the drilling through rocks was difficult. Shotfiring was practiced from the heading A-A' on the figure. The number of center cut shotholes was 6 and their length was 3.5 m. The other shotholes were 37 and their length was 1.2 m and 0.511 ammonium nitrate explosives of 12.3 kg was charged. The outburst occurred 4 hours and 50 minutes after the blasting. It is considered that gas pressure in network cracks in the coal seam ahead of the heading was heightened following to gradual destruction of the coal. The low gas permeable cover rock of 1.1 m thickness supported gas pressure but might have lost the resistance finally. In this incident, 3 workers who were loading waste rocks were buried and died. A man in charge of safety could not find any symptom because the cover rock was hard. If the presence of coal seam in front of the heading was exactly prospected and local gas drainage was practiced, there were possibilities of prevention of this disaster.

Table 7 - Correlation coefficients between the number of outbursts and each geological characteristics.

<table>
<thead>
<tr>
<th>Geological characteristics</th>
<th>Correlation coefficient</th>
<th>95% confidence interval of correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of fault appearance</td>
<td>0.846</td>
<td>0.645 - 0.991</td>
</tr>
<tr>
<td>Number of coal seams per 100 m in vertical</td>
<td>0.739</td>
<td>-0.46 - 0.946</td>
</tr>
<tr>
<td>Number of coal seams</td>
<td>0.643</td>
<td>0.11 - 0.938</td>
</tr>
<tr>
<td>Number of thick coal seams</td>
<td>0.620</td>
<td>-0.203 - 0.969</td>
</tr>
<tr>
<td>Depth of strata change in vertical</td>
<td>0.447</td>
<td>-</td>
</tr>
<tr>
<td>Volume of gas flow</td>
<td>-0.450</td>
<td>-</td>
</tr>
<tr>
<td>Degree of coal seam inclination</td>
<td>0.298</td>
<td>-</td>
</tr>
<tr>
<td>Calorific value</td>
<td>0.200</td>
<td>-</td>
</tr>
<tr>
<td>Water content</td>
<td>-0.186</td>
<td>-</td>
</tr>
<tr>
<td>Ash content</td>
<td>0.089</td>
<td>-</td>
</tr>
<tr>
<td>Proximate index</td>
<td>-0.006</td>
<td>-</td>
</tr>
<tr>
<td>Fracability</td>
<td>0.331</td>
<td>-</td>
</tr>
<tr>
<td>Fuel ratio</td>
<td>0.221</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 2 - A typical type outburst in the district of geological disturbance.
Table 8 shows various kinds of symptoms that had appeared immediately before outbursts and their frequency. Main symptoms that could be observed are coal and rock falls,10), rock sounds, increase of gas concentration, break down or slip out of a coal seam, softening of the wall, creaking of a coal seam. It can be said that the symptoms most easy to be recognized are the strata failure phenomena preceding to outbursts. The number of the cases that symptoms were perceived are 24 out of 49. It is about once per two times that symptoms were noticed.

Table 8 - Symptoms of outbursts.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance of extremely soft coal</td>
<td>4</td>
</tr>
<tr>
<td>Instability of gas concentration</td>
<td>1</td>
</tr>
<tr>
<td>Changes of seam thickness</td>
<td>1</td>
</tr>
<tr>
<td>Small outbursts occurred several times</td>
<td>1</td>
</tr>
<tr>
<td>Jamming of boring rod</td>
<td>2</td>
</tr>
<tr>
<td>Coal and rock falls</td>
<td>10</td>
</tr>
<tr>
<td>Smell of petroleum</td>
<td>1</td>
</tr>
<tr>
<td>Break down or slip out of a coal seam</td>
<td>4</td>
</tr>
<tr>
<td>Fall down of wall or heading</td>
<td>2</td>
</tr>
<tr>
<td>Swelling of wall or heading</td>
<td>3</td>
</tr>
<tr>
<td>Earth vibration</td>
<td>1</td>
</tr>
<tr>
<td>Swelling of floor rock</td>
<td>2</td>
</tr>
<tr>
<td>Sinking of roof rock</td>
<td>2</td>
</tr>
<tr>
<td>Sudden attack of heavy pressure</td>
<td>2</td>
</tr>
<tr>
<td>Hardening of wall</td>
<td>4</td>
</tr>
<tr>
<td>Softening of wall</td>
<td>4</td>
</tr>
<tr>
<td>Creaking of coal seam</td>
<td>4</td>
</tr>
<tr>
<td>Rock sound</td>
<td>9</td>
</tr>
<tr>
<td>Gas blow</td>
<td>1</td>
</tr>
<tr>
<td>Delayed reduction of gas concentration</td>
<td>1</td>
</tr>
<tr>
<td>Gas concentration</td>
<td>5</td>
</tr>
<tr>
<td>No symptom</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
</tr>
</tbody>
</table>

The method of prevention of coal and gas outbursts.

Preventive measures taken practically in Japan are prior excavation of a protective coal seam, gas drainage from coal seam, stress relief of coal seam, prevention of coal seam slip, divided shotfiring, control of advancing speed, evasion of stress concentration and so on.

Prior excavation of protective coal seam is practiced when several seams are grouped in narrow distance (about 100 m). Figure 3 shows an example of Sunagawa Colliery. But until now, uniform relation between the span among coal seams and safety reserved area and/or safety reserved term is not formulated.

In every Japanese colliery, gas drainage is practiced as the most effective method against outburst. There are four patterns in degassing method. Figure 4 and 5 show the schema of boring from an in seam road and that of cross measure boring respectively. These are drilled toward wide region not only for outburst prevention but also for reduction of gas flow into ventilation air. Figure 6 and 7 show the schema of the cross measure boring practiced before a cross cut reaches to a coal seam and that of in seam advancing boring respectively. Both of these borings are practiced for geological prospecting and local degassing. In these 4 types of boring, diameter of borehole is usually 60-80 mm and they are drilled as deep as possible (60-70 m). Drained gas is sent through steel pipe to the surface for power station or for other use.

Figure 8 shows the changes of average gas flow rate per a minute in a hole, gas flow rate per a minute from 31 boreholes and accumulated gas volume from 31 degasses boreholes in a panel of Sunagawa Colliery. For example, initial gas flow rate per a minute in a hole was 701/min.-hole). Two month later this flow rate decreased to 101/min.-hole) which constantly continued for several months. Usually gas drainage from a virgin coal seam is put in practice for more than 6 months and then excavation is started.

Figure 3 - Prior excavation of protective seam.
Figure 4 - In seam road degassing.

Figure 5 - Cross measure degassing boring from under seam drift.

Figure 6 - Cross measure degassing at the point of cross cut reach.

Figure 7 - Advancing boring along an In seam road.

Figure 8 - A state of gas flow from degassing boreholes (after N. Ikeda).

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986

294
Table 9 shows the gas drainage record in Sunagawa Colliery. In 1984, 1,082 degassing boreholes of which total length was 292,039 m were drilled against 980 thousands tons of coal production and danger of outburst was reduced. Main degassing methods in this colliery are cross measure boarings which are shown in figure 5 and 6. Engineers in the colliery have concluded through underground experiences that degassable radius around a hole is 5 m. Basing upon this value, they design the arrangement of boreholes.

Table 10 shows the gas drainage record of Minami Oyubari Colliery. Also in 1984, 40,270 m degassing boreholes in total were drilled against 980 thousands tons of coal production. Degassing methods adopted in this colliery are the types as shown in figure 4 and 7. As seam gas in this district is easy to permeate, average volume of gas emission per a ton coal production was 74.6 m³/ton and the ratio degassed through boreholes was 57.1 percent. Degassable radius around a borehole is estimated 10-20 m. Frequency of outburst in this district is apparently lower than that in the district in which low gas permeable seams exist.

It is evident that degassing boring is also efficient for stress relief. In Akabira Colliery, large diameter boring (250 mm diameter) has been used practically to increase stress relief effect. The place in which this method is applied is in seam road heading. Figure 9 shows a scene of operation in underground. Table 11 shows the record of large diameter boring in Akabira Colliery since 1972. In 1984, 366 large diameter boreholes of which length is 7,859 m in total were drilled and they have been used successfully to prevent outbursts. Figure 10 gives a result of stress relief effect by large diameter boring. According to the figure, volume of cuttings increased in the span 6-12 m from the face and yield zone of which maximum radius is about 1 m was created in the same span. When the man in charge of drilling in the colliery judges if the cuttings is much or not, 88.4 l/m of cuttings quantity is used as the standard value. In the early stage, boring machine was driven by air engine. In 1984, a liquid pressure driving engine was developed and the colliery has succeeded to extend average boring length to 21.7 m/ hole. At the same time, one of the authors, K. Higuchi, has developed an enlarging method of normal size borehole by water jet. Now, practical application tests and data collection of working efficiency are continued.

Figure 11 gives the schema of prevention method against slipping of inclined coal seam. As the angle of coal seam inclination in some Japanese collieries is 70-80°, there is the danger of outburst that occurs following the coal seam slipping by gravity action. For the prevention of slipping, 2 inch steel pipes are inserted to 7 boreholes in the place located several meters from the reaching point. This method has been evaluated unexpectedly effective.

---

**Table 9- The record of degassing in Sunagawa Colliery.**

( After N. Ikeda )

<table>
<thead>
<tr>
<th>Year</th>
<th>1982</th>
<th>1983</th>
<th>1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>From coal seam road</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
</tr>
<tr>
<td>Advancing</td>
<td>159,261.0</td>
<td>92,692.7</td>
<td>84,170.2</td>
</tr>
<tr>
<td>The others</td>
<td>1,773.7</td>
<td>1,793.5</td>
<td>45.5</td>
</tr>
<tr>
<td>A total</td>
<td>161,034.7</td>
<td>94,486.2</td>
<td>84,215.7</td>
</tr>
<tr>
<td>From stone drift</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
</tr>
<tr>
<td>Advancing</td>
<td>9,286.5</td>
<td>4,674.1</td>
<td>7,014.1</td>
</tr>
<tr>
<td>For degassing</td>
<td>228,619.7</td>
<td>227,955.0</td>
<td>189,068.6</td>
</tr>
<tr>
<td>The others</td>
<td>16,676.9</td>
<td>14,591.2</td>
<td>11,722.4</td>
</tr>
<tr>
<td>A total</td>
<td>244,782.1</td>
<td>242,526.2</td>
<td>207,823.3</td>
</tr>
<tr>
<td>Total</td>
<td>345,916.3</td>
<td>341,507.4</td>
<td>292,039.9</td>
</tr>
<tr>
<td>Degassing</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
<td>Drilled length (m)</td>
</tr>
<tr>
<td>From virgin area</td>
<td>20.62</td>
<td>20.41</td>
<td>20.94</td>
</tr>
<tr>
<td>From sealed area</td>
<td>26.14</td>
<td>27.55</td>
<td>28.88</td>
</tr>
<tr>
<td>Total degassed volume (m³)</td>
<td>57.76</td>
<td>56.96</td>
<td>57.82</td>
</tr>
<tr>
<td>The Number of boreholes</td>
<td>998</td>
<td>1,243</td>
<td>1,082</td>
</tr>
<tr>
<td>Total coal production (ton)</td>
<td>1,075,355</td>
<td>1,068,651</td>
<td>960,269</td>
</tr>
</tbody>
</table>

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986

295
Table 10- The record of degassing in Minami Oyubari Colliery. (After Z. Sakiyama)

<table>
<thead>
<tr>
<th>Year</th>
<th>1982</th>
<th>1983</th>
<th>1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilled length (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From virgin area</td>
<td>253.339</td>
<td>127.611</td>
<td>308.471</td>
</tr>
<tr>
<td>From disturbed area</td>
<td>82.978</td>
<td>26.378</td>
<td>34.234</td>
</tr>
<tr>
<td>Total</td>
<td>336.317</td>
<td>154.089</td>
<td>442.705</td>
</tr>
<tr>
<td>Drilling efficiency (% shift man)</td>
<td>28.5</td>
<td>30.5</td>
<td>30.3</td>
</tr>
<tr>
<td>Degassed volume (m³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From virgin area</td>
<td>40.1</td>
<td>54.2</td>
<td>55.5</td>
</tr>
<tr>
<td>From disturbed area</td>
<td>17.4</td>
<td>12.0</td>
<td>28.0</td>
</tr>
<tr>
<td>From sealed area</td>
<td>29.4</td>
<td>17.1</td>
<td>16.4</td>
</tr>
<tr>
<td>Total</td>
<td>77.9</td>
<td>84.1</td>
<td>91.9</td>
</tr>
<tr>
<td>Pure gas volume in ventilation (m³/min)</td>
<td>51.4</td>
<td>66.0</td>
<td>68.1</td>
</tr>
<tr>
<td>Total gas (m³/min)</td>
<td>129.2</td>
<td>144.9</td>
<td>161.0</td>
</tr>
<tr>
<td>Degassed ratio (%)</td>
<td>80.2</td>
<td>88.6</td>
<td>51.1</td>
</tr>
<tr>
<td>Average volume of gas emission per a ton coal production (m³/t)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Figure 9- A scene of operation of large diameter boring.

Figure 10- The effect of large diameter boring.

Table 11- The record of large diameter boring in Aishira Colliery (After S. Sudo).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total drilled length (m)</th>
<th>Number of boreholes</th>
<th>Average drilled length per a hole</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>461.5</td>
<td>58</td>
<td>12.14</td>
</tr>
<tr>
<td>1973</td>
<td>648.9</td>
<td>66</td>
<td>12.19</td>
</tr>
<tr>
<td>1974</td>
<td>256.0</td>
<td>52</td>
<td>14.92</td>
</tr>
<tr>
<td>1975</td>
<td>1,089.0</td>
<td>81</td>
<td>13.46</td>
</tr>
<tr>
<td>1976</td>
<td>4,283.5</td>
<td>315</td>
<td>13.90</td>
</tr>
<tr>
<td>1977</td>
<td>3,082.0</td>
<td>288</td>
<td>12.19</td>
</tr>
<tr>
<td>1978</td>
<td>2,147.5</td>
<td>192</td>
<td>11.18</td>
</tr>
<tr>
<td>1979</td>
<td>3,763.0</td>
<td>230</td>
<td>16.36</td>
</tr>
<tr>
<td>1980</td>
<td>5,566.0</td>
<td>552</td>
<td>14.48</td>
</tr>
<tr>
<td>1981</td>
<td>5,931.0</td>
<td>393</td>
<td>15.09</td>
</tr>
<tr>
<td>1982</td>
<td>5,846.0</td>
<td>331</td>
<td>17.64</td>
</tr>
<tr>
<td>1983</td>
<td>5,048.5</td>
<td>382</td>
<td>14.79</td>
</tr>
<tr>
<td>1984</td>
<td>7,850.7</td>
<td>366</td>
<td>21.47</td>
</tr>
</tbody>
</table>

Figure 11- Preventive method of coal seam slipping.

The AusIMM Illawarra Branch, Ground Movement and Control related to Coal Mining Symposium August 1986
CONCLUSION

Unless a coal seam contains considerable amount of gas, outbursts will never occur. According to statistics, when the number of boreholes was a few, outbursts occurred frequently. In this meaning, the statement that can be made the most important preventive measure is gas drainage. However, the gas that is able to be degassed by boring is free gas in the cracks. By using this method, it may be possible to deal with the gas in the cracks of weak coal seams. We can not degas easily. The large amount of free and adsorbed gas in innumerable micro pores in a hard coal seam can not be degassed easily. To prevent such outburst occurring following any sudden destruction of coal seam matrix and sudden flow of confined gas into cracks, it is necessary to prevent the occurrence of sudden destruction of coal seams. From such a viewpoint, it may be important to control rock pressure by using large diameter boring, water injection, stress relief blasting and excavation method to evade stress concentration. Fundamentally, the improvement of degassing and stress relief methods and elevating of working efficiency may be the basis of outburst protection.

REFERENCES

5) Y.Sakiyama: Degaassing boring in Minami Oyubari Colliery, Proceeding of Symposium "Development of recent boring techniques" (Japanese), 14th Jun., 1985.
7) S.Kinoehita, Y.Ishijima, T.Goto and N.Oda: Relief boring for preventing gas outburst in Akabira Coal Mine, 8-5-6, Proceeding of 4th Joint Meeting MMJ-ATME, 4-8th Nov., 1980.