MEASUREMENT OF THE SUPPORT RESISTANCE OF SHORTWALL CHOCKS AND ITS APPLICATIONS

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ABSTRACT

For an adequate design of the shortwall face support, it is necessary to understand fully the support-roof interaction. A series of studies has been carried out at a shortwall panel to develop the methods of monitoring support resistance and determining load density of the chocks. Various aspects of applications, for improvement of chock design and understanding of roof conditions, are discussed.

INTRODUCTION

Shortwall mining method is a relatively new technique in the United States coal mining industry. In comparison with longwall mining method, its development and application are not encouraging[1, 2]. One of the major causes of unsuccessful operation comes from ground control problems. The lack of understanding of the support-roof interaction resulted in improper chock design. A series of studies has been carried out at the shortwall panel in Valley Camp No. 3 Coal Mine near Triadelphia, WV.

The methods of monitoring support resistance and determining load density of the chocks were developed, and their applications are discussed in this paper.

Shortwall Mining at Valley Camp No. 3 Mine

Valley Camp No. 3 Mine is located in the northern panhandle of West Virginia. The thickness of the coal seam (Pittsburgh Seam) ranges from 5 to 6 feet. The shortwall panel, located under rugged and hilly topography, has an overburden whose thickness ranges from 800 to 950 feet. The typical stratigraphic columns are shown in Fig. 1. The first 12 to 15 feet immediately above the coal seam is shale with irregular coal partings and clay veins.

The shortwall panel was 150 feet wide by 2,655 feet long. The panel employed retreating shortwall mining method with advancing tail entry (Fig. 2). In the head entry side there were 6 rows of chain pillars, while the tail entry was constructed by setting cribs in a regular interval as the face advanced. As shown in Fig. 2, roof falls occurred frequently at the cross-cut areas. The roof falls resulted in dome shaped voids, which measured 1-20 feet wide and 1-15 feet high. In the panel roof falls were made along the clay veins. The roof falls were very severe along the final working face. They covered about half of the working face, and they extended as high as 20 feet into the roof. A simplified shortwall face layout is shown in Fig. 3. Coal was mined by a Joy 12 CM continuous miner, and a loader and a shuttle car were used for face haulage. The miner cuts a web width of approximately 9 feet.

Along the face, 39 four-legged Gullic-Dobson shortwall chocks with 500-ton capacity were laid at 4 feet center. The setting pressures ranged from 1500 to 3000 psi and yield pressures were 7100 psi for the legs and 8300 psi for the front canopy. The shortwall chocks differ from the longwall chocks by having an extensible canopy in front of the front canopy for immediate roof support near the face line area.

The sequences of chock advance are shown in Fig. 4. Before the miner started to make a new cut, the ram jack of the chock was in fully extended position which is 4 feet long (Stage #1). When the miner cut beyond two chocks past the chock to be advanced, the chock was advanced to the position immediately behind the spill plate. Simultaneously, the extensible canopy was fully extended to the 4-foot length (Stage #2). Stage #3 involved extension of the ram jack and advance of the spill plate. In Stage #4 the chock was advanced to the spill plate which was then advanced to Stage #5.

For convenience of analysis, the shortwall mining activities are divided into 3 periods: Period 1 covers Stages #1 and #2; Period 2 covers Stage #3; and Period 3 covers Stages #4 and #5.

SUPPORT RESISTANCE OF THE CHOCKS

Face powered supports for shortwall or longwall panels are designed to support the immediate roof, which behaves like a cantilever beam with a soft support clamped at the front abutment. The location of the maximum abutment pressure was determined to be 10 feet ahead of the face line. Chock pressures were recorded by Weksler pressure recorders where mechanically wound clocks were attached. Chocks #6, 15, 21, 33 & 39 were selected for monitoring pressure variations (Fig. 3). In each chock, 3 separate line pressures were monitored,

References and illustrations at end of paper.

i.e., front and rear legs, and front canopy. Fig. 5 shows a typical pressure variation chart as recorded by the pressure recorders installed at Chock #21. The chart with 24-hour per revolution serves better use of establishing pressure variation trends associated with each stage of mining activities while the 7 days' chart was used to confirm the reproducibility of each pressure variation in a larger period.

The letters with arrows in Fig. 5 indicated the corresponding events of the face operations which can be summarized as follows:

A. The chock at this point was advanced and reset in preparation for the new cut, which was early in Stage #1. The setting pressure for the front leg was approximately 2600 psi and dropped rapidly to 800 psi responding to the crushing of roof steps. Thereafter it increased slowly but steadily. The trend of variation of pressures applied in the canopy was also similar to that of the front legs. Pressure in the rear leg remained extremely low.

B. At this point a new cut started at the head entry.

C. The new cut had been made to Chock #20. A surge in pressure resistance for the front canopy and front legs is shown.

D. After midnight shift, at this point, the cutting had resumed and reached Chock #21.

E., F., G. The rest of the chocks in the panel were individually lowered, advanced and reset as the cutting progressed toward the tail entry. Pressures in the front legs and front canopy stepped up more and more.

H. At this point the cutting had completed the full face.

I. The spill plate was advanced and the chock entered into Stage #3 or Period 2.

J. The advance of the chocks into Stage #4 started from the center to the sides of the face. As it proceeded and approached Chock #21, the pressures increased to a very high range.

K. At this point Chock #21 was reset. The pressure in the rear legs sustained for the first time during the day, because the immediate roof near the gob edge was intact at this moment.

However, it was noticed that the top surface of the chock canopies seldom contacted the immediate roof line completely, because the roof line was not smooth enough. A systematic underground observation showed that the point of contact at the front canopy was generally restricted to the front half when the extensible canopy was retracted. Once the extensible canopy was extended, the major contact point moved to the tip of the extensible canopy.

Based on these observations, the free body diagrams for support-roof interaction are shown in Fig. 6. The hydraulic pressures measured at the front (FL) and rear (RL) legs represent the total concentrated force at each point but those measured at the capsule (Pc) are not a direct indication of the forces applied at the front canopy; rather it reduces by an amount proportional to the relative length of the level arms.

$$Ex = \frac{18}{113} Pc = 0.159 \; Pc \qquad (1)$$

$$AME = \frac{18}{55} Pc = 0.327 \; Pc \qquad (2)$$

where,

Pc = measured pressure at the capsule (psi)
Ex = resultant force at the tip of the extensible canopy (point a) (lbs.)
AME = resultant force at point c (lbs.)

The total support resistance of the chock is the summation of the forces at the front and rear legs and the load Ex resulted by Pc, i.e.,

$$Tex = 2A\,(Pr + Pf) + 0.159 \; APc \qquad (3)$$

$$Tun = 2A\,(Pr + Pf) + 0.327 \; APc \qquad (4)$$

where,

Tex = total support resistance for extended condition (lbs.)
Tun = total support resistance for unextended condition (lbs.)
Pr = measured pressure at the rear legs (psi)
Pf = measured pressure at the front legs (psi)
A = cross-sectional area of the hydraulic cylinders ($in.^2$)

The total resultant force applied on the chock can be found by taking the moment about the clamped point Lo. The algebraic sum of the moments must be zero for an equilibrium condition, which results in the relationship:

$$Lex = \frac{641\;Pr + 558\;Pf + 22.9\;Pc}{2\;(Pr + Pf) + .159\;Pc} \qquad (5)$$

$$Lun = \frac{564\;Pr + 480\;Pf + 56.6\;Pc}{2\;(Pr + Pf) + .329\;Pc} \qquad (6)$$

where,

Lex = distance of the resultant force from the front abutment when extensible canopy is fully extended (in.)
Lun = distance of the resultant force from the front abutment when extensible canopy is fully retracted (in.)

The total support resistance for each period of each chock monitored was calculated by using Eqs. 3 and 4. It was then divided by the supporting area of each chock to obtain load density (LD) (Fig. 7). The average load density for the 3 periods is defined as the mean load density (MLD).

As shown in Fig. 7, load density and mean load density vary with the periods in which the chock is operated. Load density is higher for Period 1 than Periods 2 and 3. The data also indicated that load density and mean load density vary with the location of the chock along the panel face. A lower load density is recorded at the chocks near the head entry (Chocks #6 through #15), while a higher load density is recorded for the chocks near the tail entry. The ısymmetrical distribution of the load density is ›arently related to the panel layout (retreating :hod with advancing tail entry).

The load density for after weekend condition is ḥ highest of all measured, especially those near the ll entry. This could be attributed to the fact that ›r the weekend the cantilever beams deflect and drop :e weight on the support. Conversely, the load den- :y under the bad roof condition was considerably ver, because the canopy lost full contact with the nediate roof.

The tip loads at the extensible canopy were also :ermined for each period and "after weekend" condi-)ns (Fig. 8). With the exception of those near the ıd entry and tail entry, the tip loads are much ;her for Period 1 than Periods 2 and 3. The tip ıd after the chock has been advanced (Periods 2 and never regained the top values achieved in Period 1. ḥ maximum recorded tip load was 17.1 tons for Chock 5 in Period 1, which was far below the rated tip ıd of 25 tons.

Using Eqs. 5 and 6, the locations of the total sultant force for each period of the chocks were :ermined (Fig. 9). Again it varies not only with ḥ locations of the chocks but also with the periods operation. The average location of the total resul- ıt force in Period 1 was about 10.4 feet from the :e, while it moved toward the gob at 12.9 feet from ḥ face for Periods 2 and 3. Under the bad roof con- :ion the location of the resultant force is closer the face (10.4 feet) whereas over the weekend, it ved further back toward the gob (14.9 feet from the :e). The location of the total resultant force is indication of the length of the cantilever beam. ḥ longer the beam is, the farther it is from the :e. The cantilever beam is shorter in Period 1 when ḥ immediate roof causes the location of the total sultant force to move toward the face. Similarly, en a bad roof or roof fall is encountered, the fective length of the roof beam becomes shortened :ause of the high degree of fractures. On the ner hand, the standstill waiting time over the week- d allows the immediate roof to deteriorate all the y to the main roof which deflects and applies more ıd on the chock. This accounts for the fact that ḥ location of resultant force for the after weekend riod is the farthest from the face.

The location of the resultant force is also depen- nt on the integrity of the immediate roof. When the nediate roof is weak, the roof breaks immediately hind the chocks. Further deterioration at the end the roof beam causes the rear legs to extend after ḥ chocks are advanced and set. This way the pressure the rear leg will decrease and the location of the sultant force will move forward.

PLICATIONS

The data for determining support resistance can be sily acquired in a continuous manner with simple uipment. Analyses of the mode and magnitude of sup- rt resistance for the chocks reveal the following:

1. Understanding the overall picture of ground response to the chocks: The length and thickness of the immediate roof which rests on the chocks can be estimated.

2. Estimation of required chock capacity: From the continuous monitoring of load density, its complete range including the maximum value can be defined. For example, Fig. 7 indicates that the normal ranges of load density were 1-3 tsf, and that the maximum load density was 4.1 tsf which corresponds to a total load of approximately 200 tons per chock. A 500-ton chock as used was obviously overdesigned.

3. Balance of the support resistance: In order to make the chocks stable, it is required to make the applied load equal for every leg. Uneven load will cause the chocks to tilt or misalign. By tilting, the toe of the chocks tends to punch into the floor where floor strength is low. Also, the uneven load will cause stress concentration, which might exceed the design capacity of a particular part. The uneven load distribution can be determined by calculating the location of the resultant force. The optimum location would be in the middle between the rear and front legs. For instance, the locations of the resultant force at the shortwall panel in Valley Camp No. 3 Mine were mostly closer to the face. To cope with this problem, chock setting time had to be longer than was usually practiced. This way, the portion of the immediate roof about the rear leg can be fully consolidated.

4. Setting pressure: The effect of setting pressure was not fully studied during the study period. However, two setting pressures (2300 and 2900 psi) were used in this panel. The preliminary results indicated that a higher load density was reached for the higher setting pressure. Further study for this matter is necessary for determining the optimum level of setting pressure.

5. Predicting bad roofs: Whenever a bad roof was encountered, the chock pressure dropped and the location of the total resultant forces moved closer toward the working face. From this principle, a bad roof can be predicted and remedial measures can be taken before the weak roof falls.

CONCLUSIONS

A method of determining support resistance is developed based on pressure recording from the shortwall chocks and its applications are discussed. The method is relatively simple and economical so that continuous monitoring system can be made in order to achieve the optimum operating conditions and predict bad roofs.

ACKNOWLEDGEMENTS

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REFERENCES

1. Syd S. Peng and Duk-Won Park, Shortwall Mining in the U.S.: A Record of Failure and Success, Coal Mining and Processing, Dec., 1977, pp. 54-59.

2. Kenneth P. Katen, Analysis of United States Shortwall Mining Practice, Mining Congress Journal, Jan., 1979, pp. 62-69.

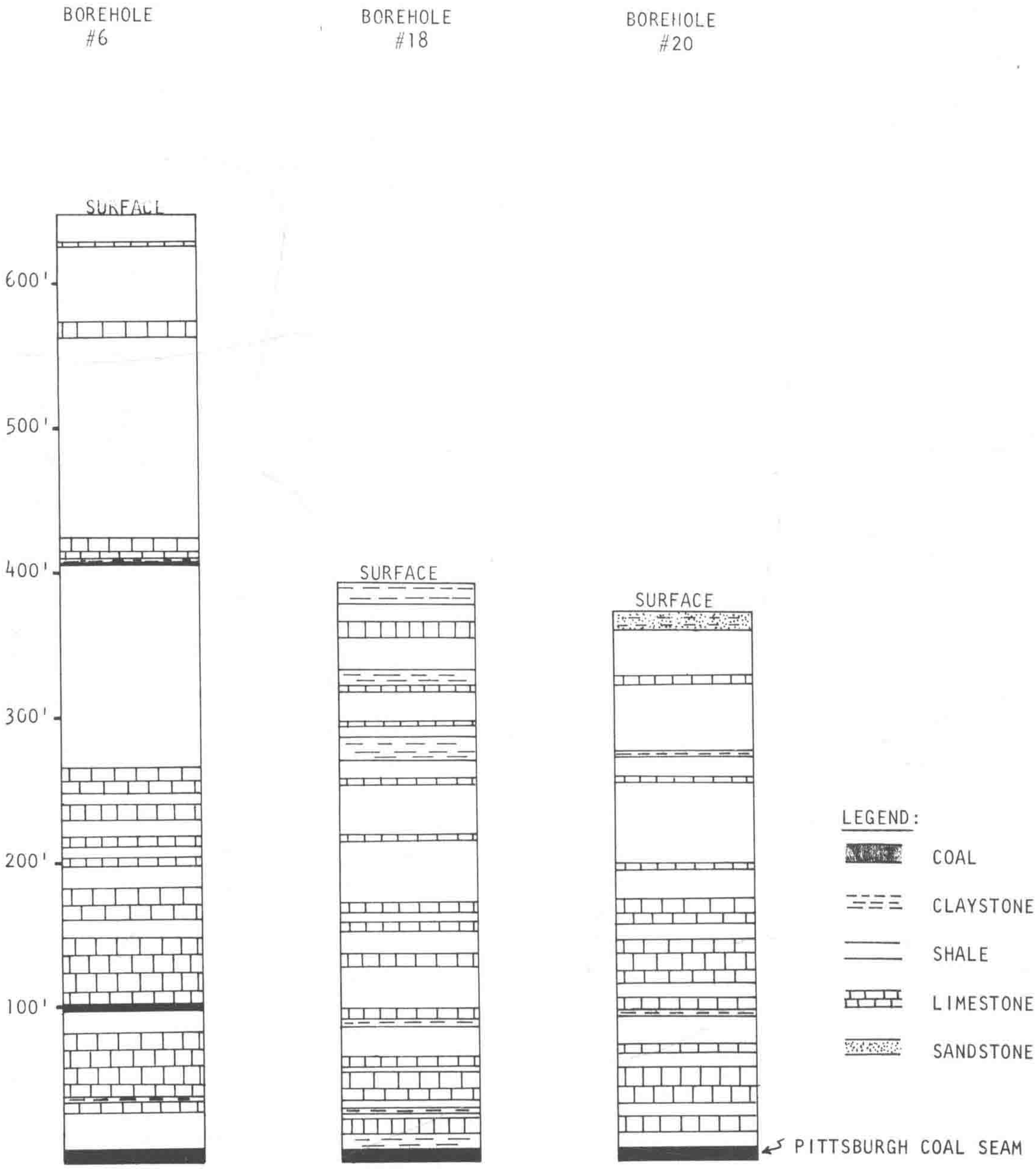


Fig. 1 - Typical stratigraphic columns near the shortwall panel.

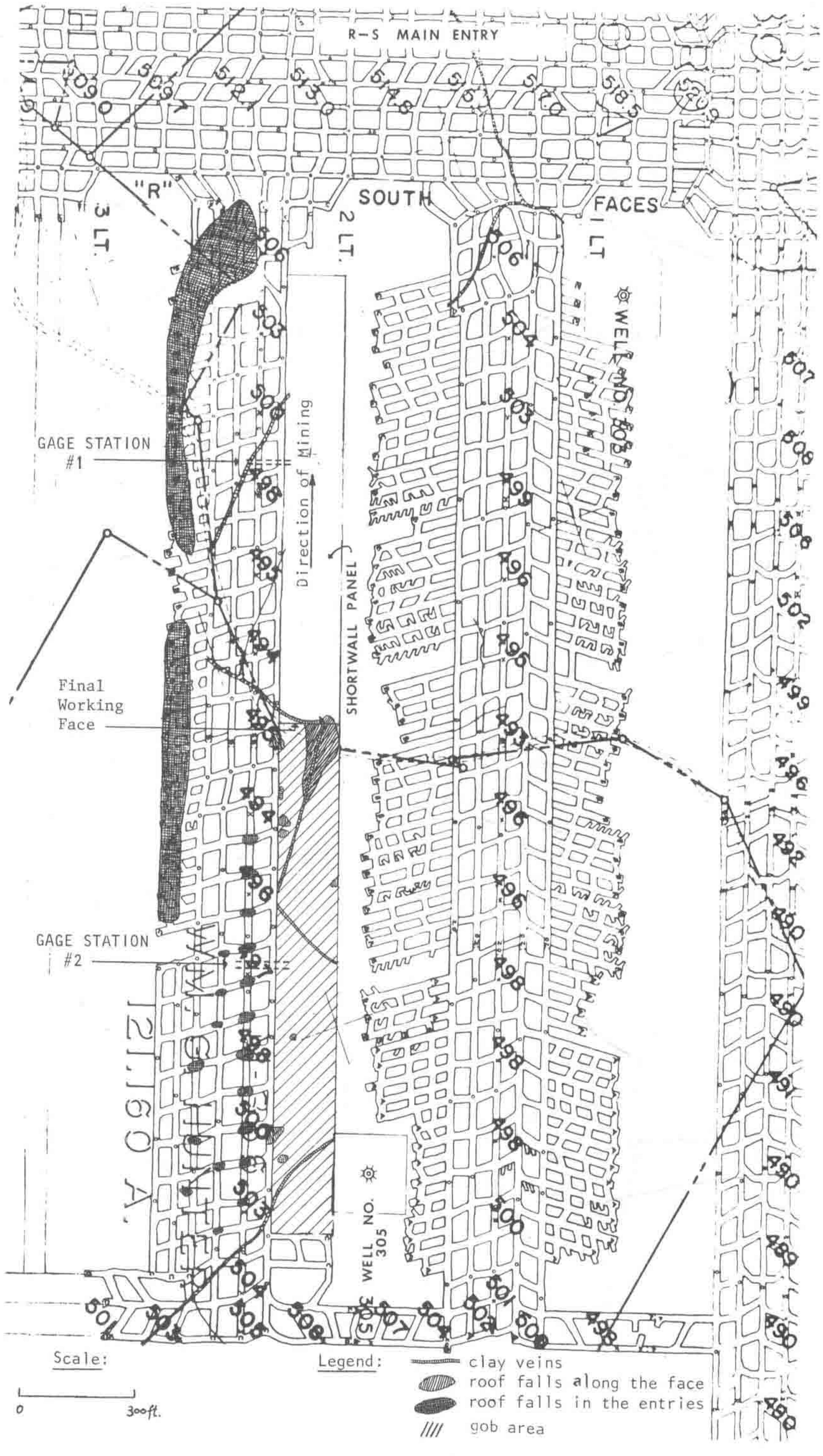


FIG. 2 - SHORTWALL PANEL LAYOUT WITH CLAY VEINS AND ROOF FALLS.

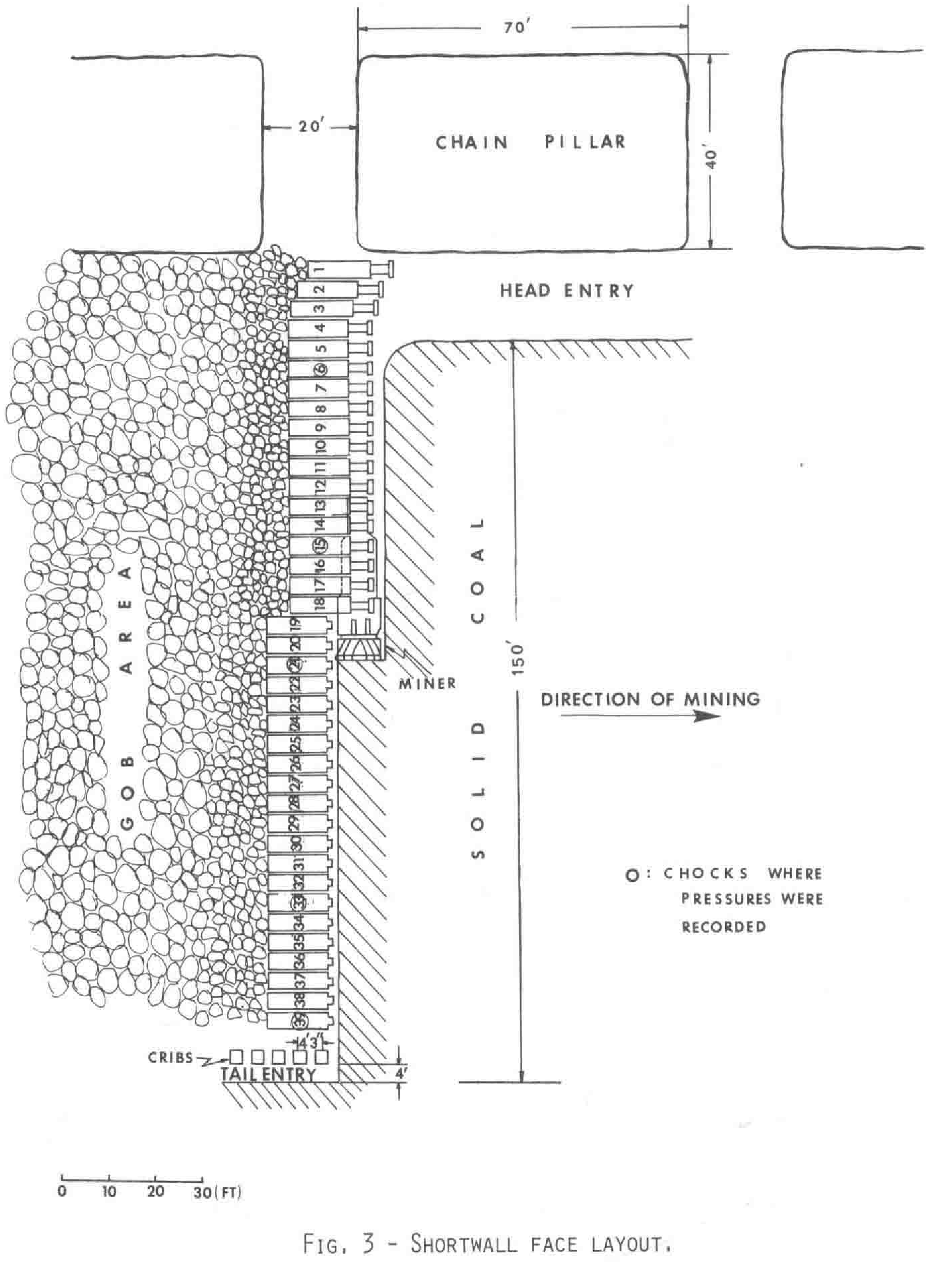


FIG. 3 - SHORTWALL FACE LAYOUT.

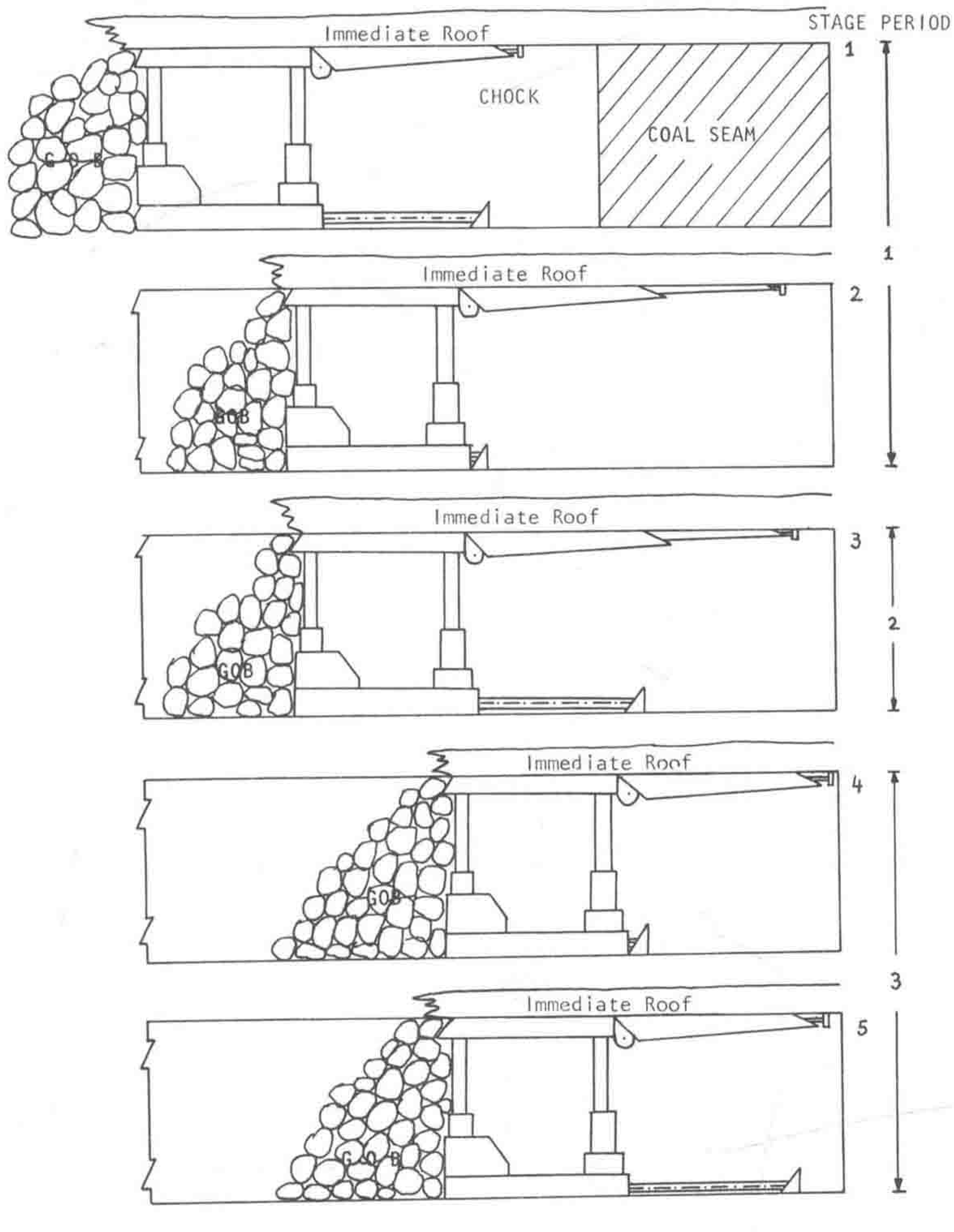
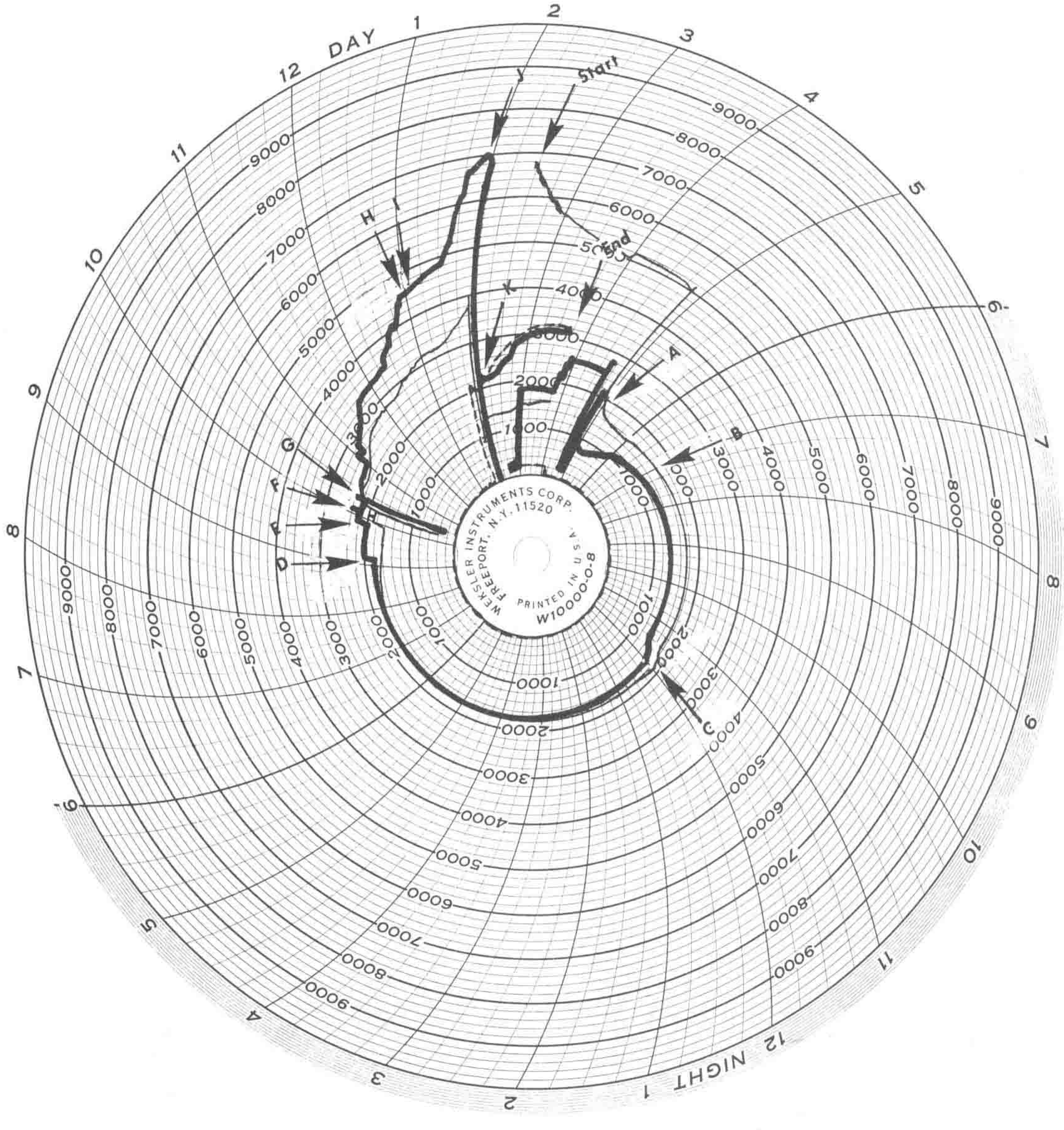


FIG. 4 - SEQUENCE OF CHOCK ADVANCE.

DAILY RECORD

CHOCK NO. 21
START-(S)- 1-4-77
END-(E)- 1-5-77

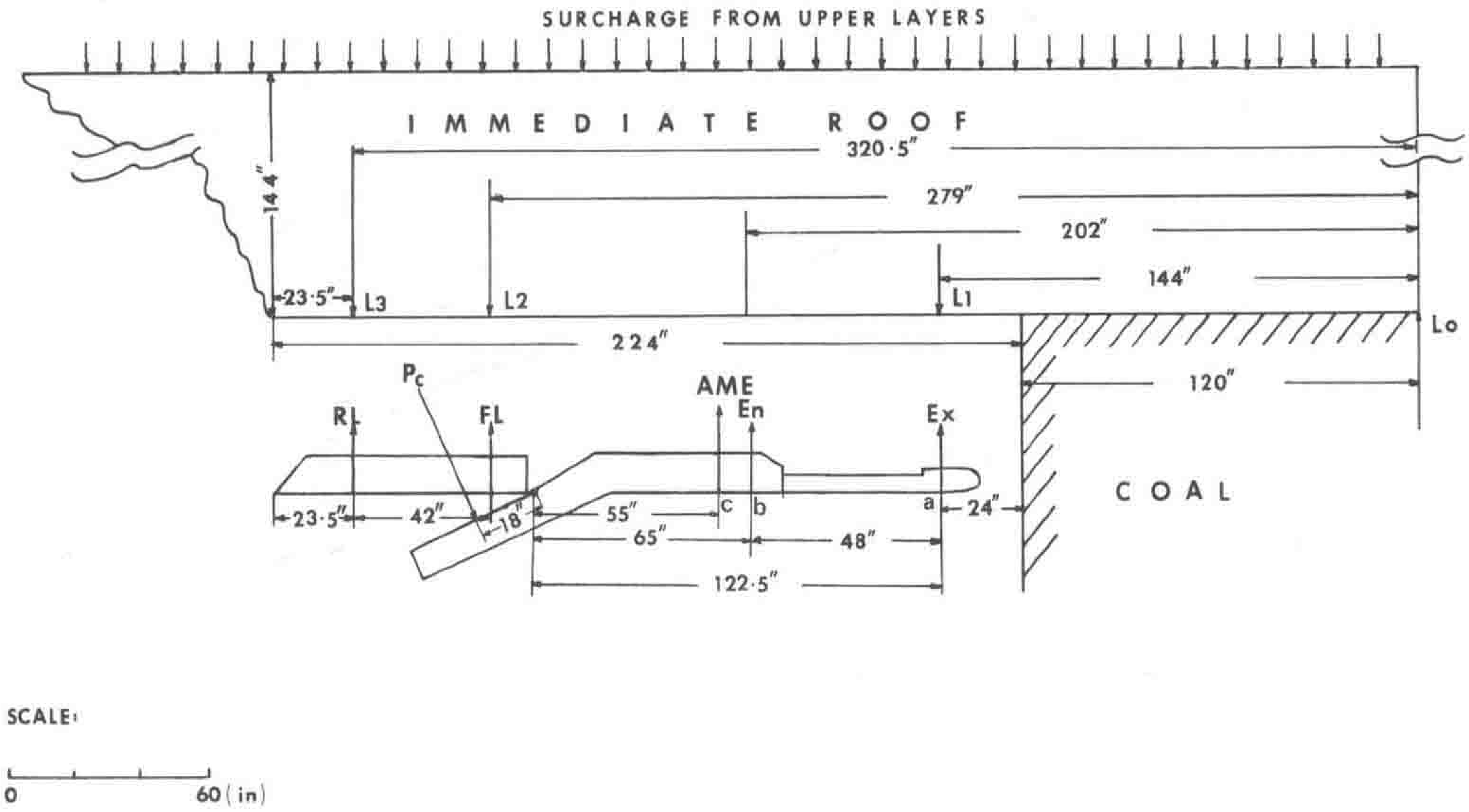


LEGEND

FRONT LEG
REAR LEG
CANOPY

FIG. 5 - TYPICAL PRESSURE VARIATION RECORDED BY A PRESSURE RECORDER SET FOR 24-HOURS PER REVOLUTION.

A. EXTENDED CONDITION



B. UNEXTENDED CONDITION

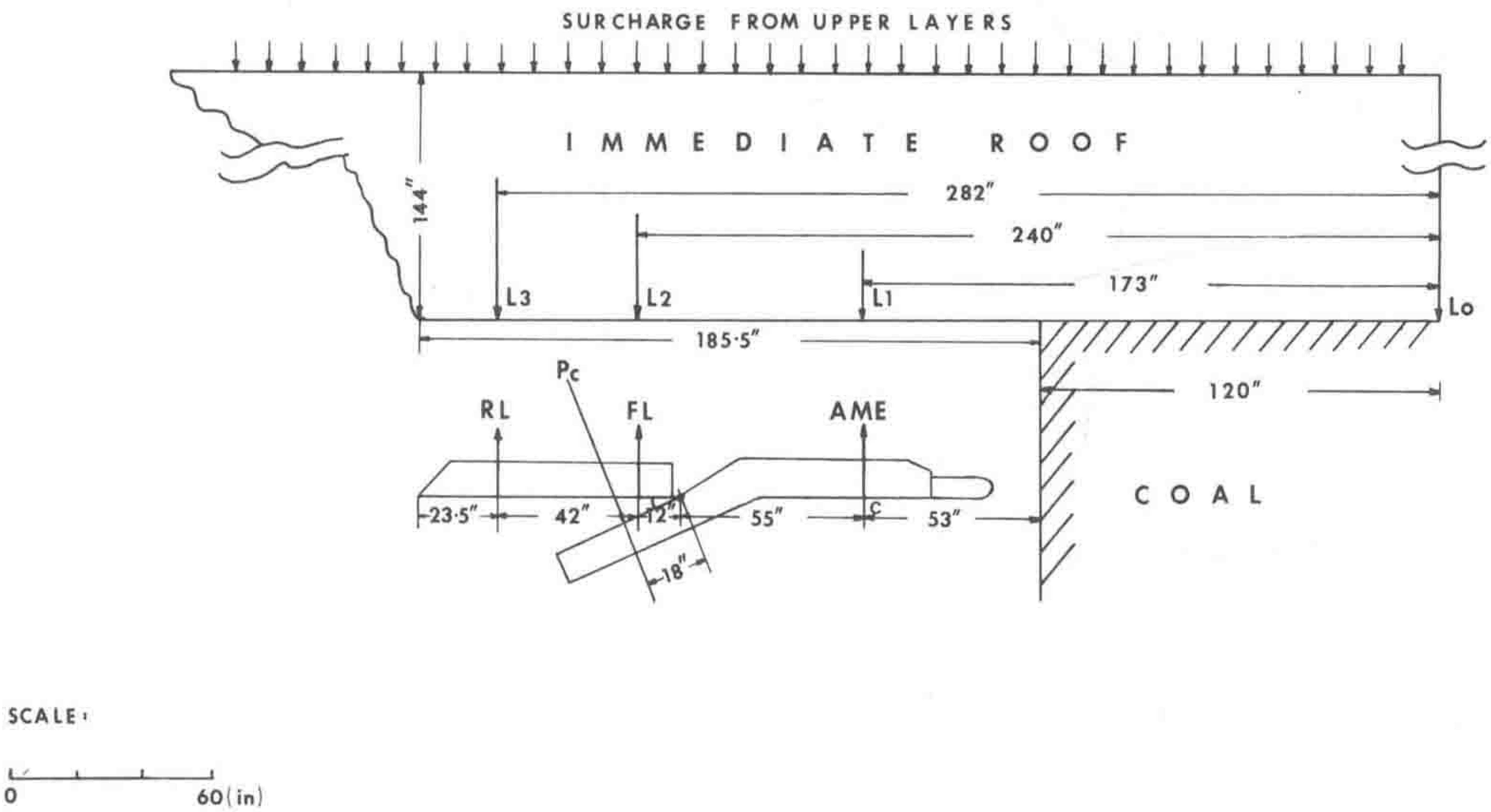


FIG. 6 - SCHEMATIC DIAGRAM FOR SUPPORT-ROOF INTERACTION.

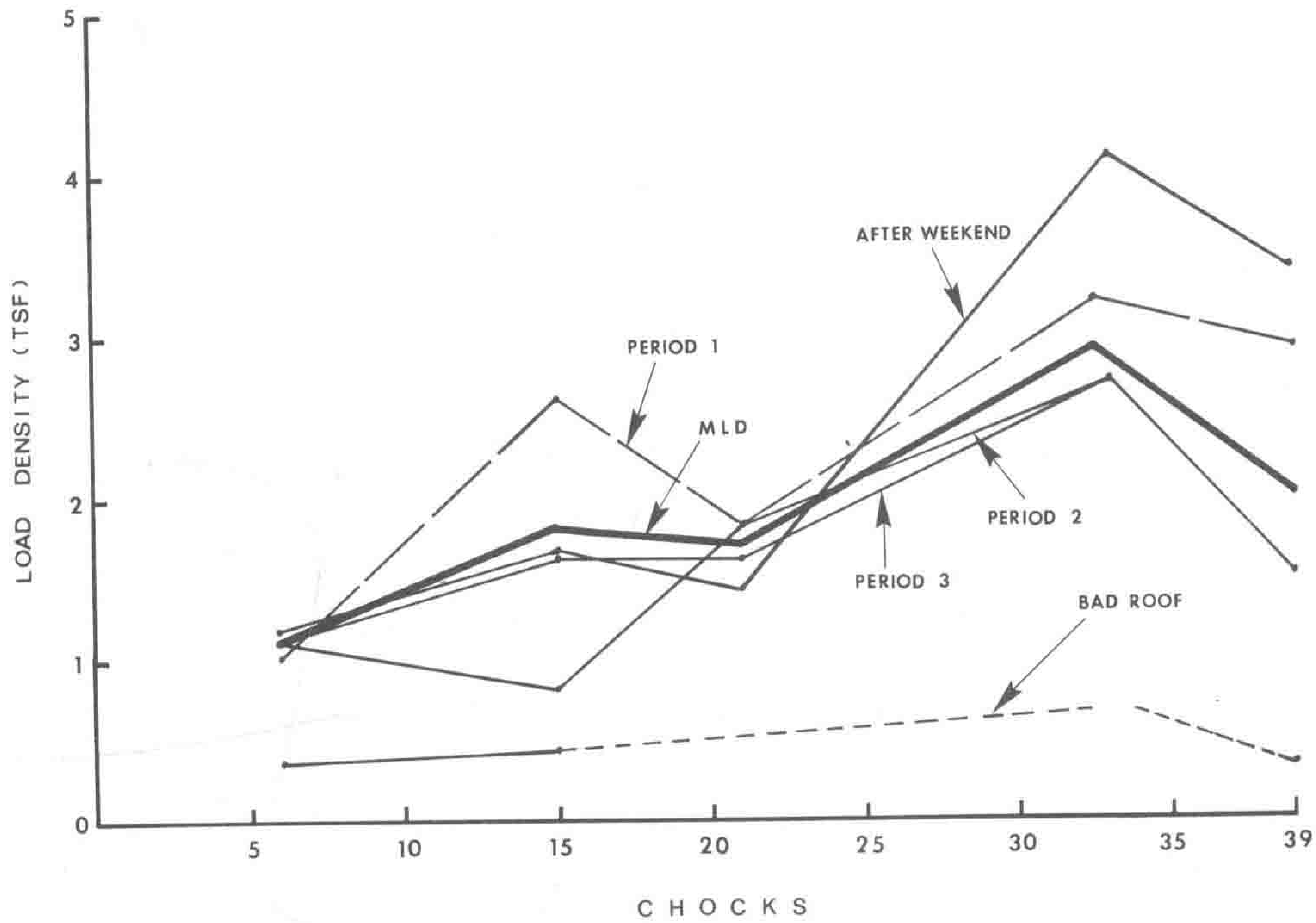


FIG. 7 - LOAD DENSITY (LD) AND MEAN LOAD DENSITY (MLD) ON CHOCKS.

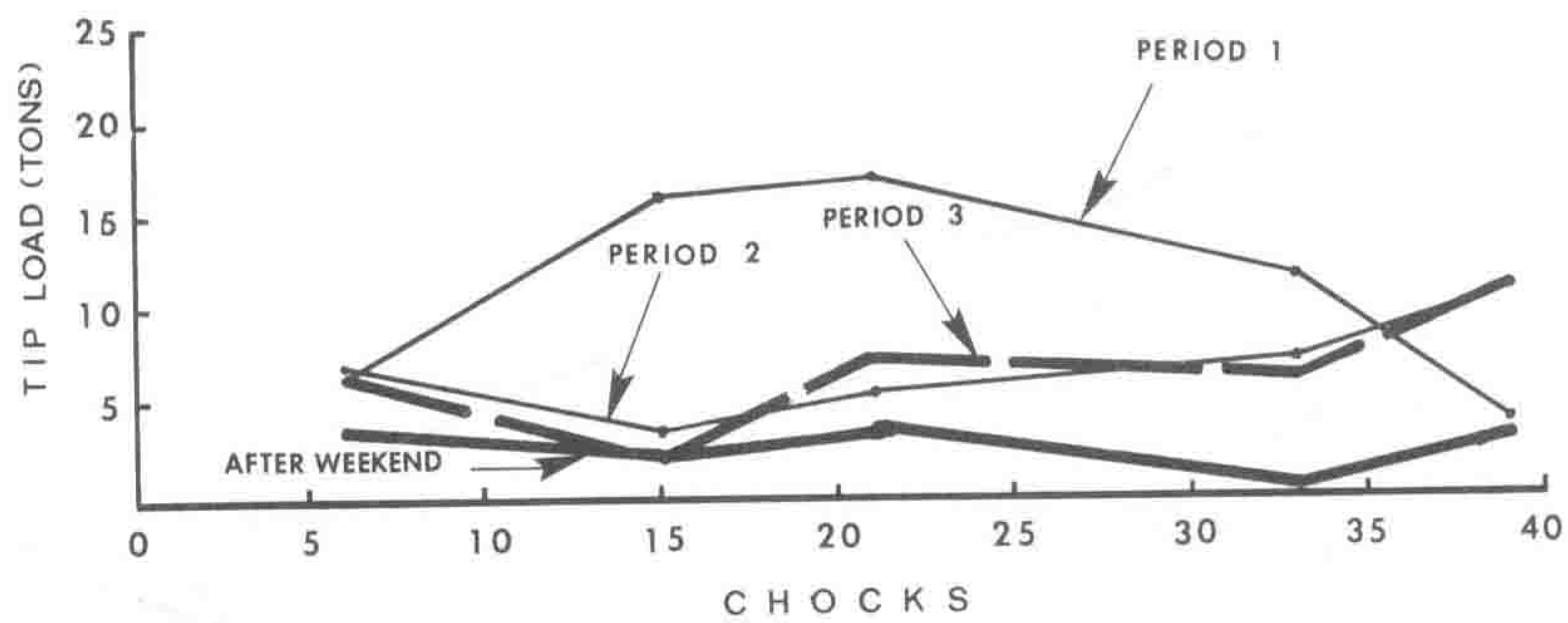


FIG. 8 - MEASURED TIP LOADS AT THE EXTENSIBLE CANOPY.

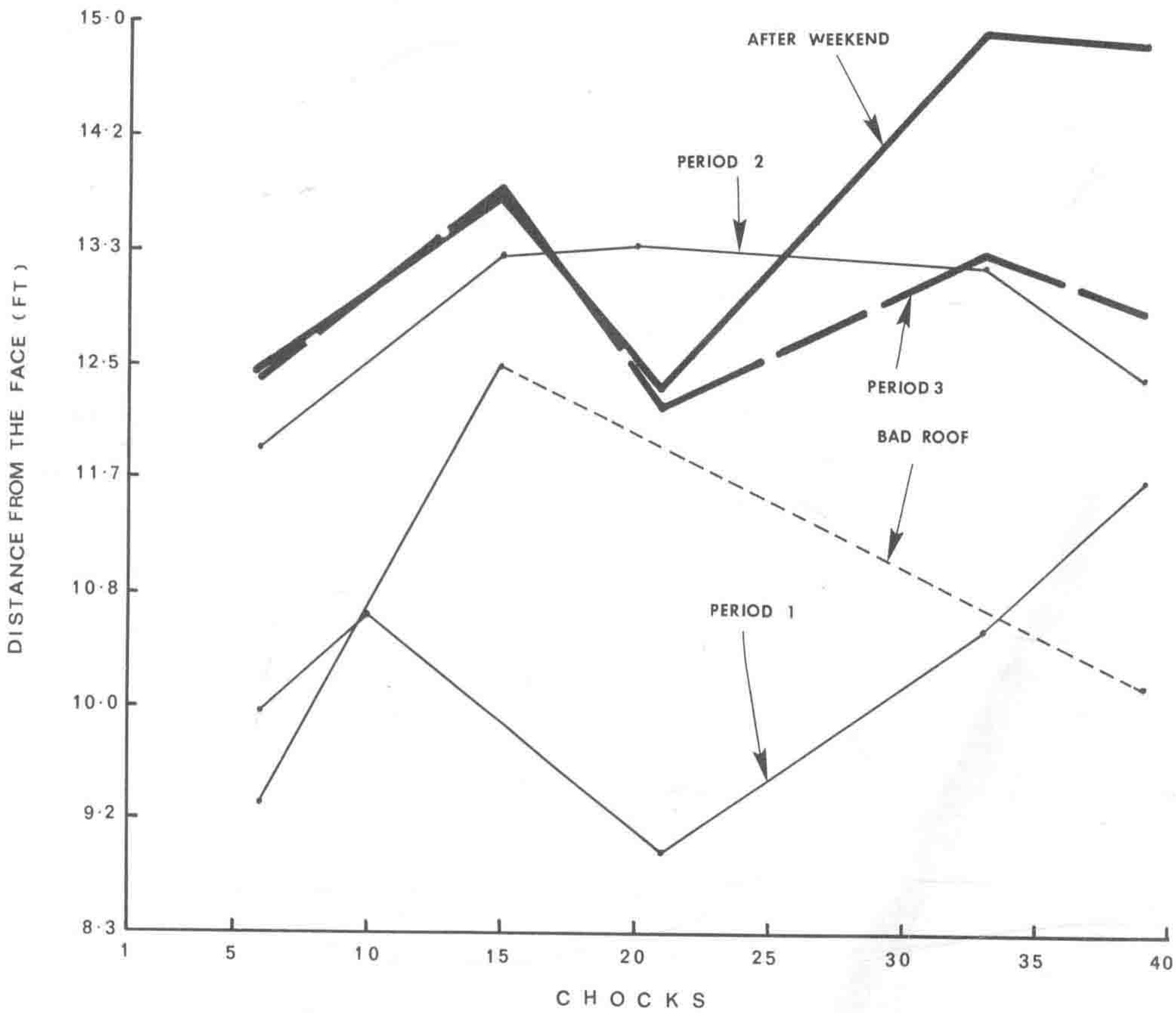


FIG. 9 - LOCATIONS OF TOTAL RESULTANT FORCES.