frequency component is twice that of the high frequency component. In this particular example, the particle velocity for each frequency component can be measured directly from the waveform. Figure 44 represents a more complex waveform which results when two frequency components are present, having equal particle velocities, but different phase relationships. It would not be possible to analyze this waveform by direct measurements, since the peak level is dependent on not only the particle velocity of each component but also on the phase relationship.

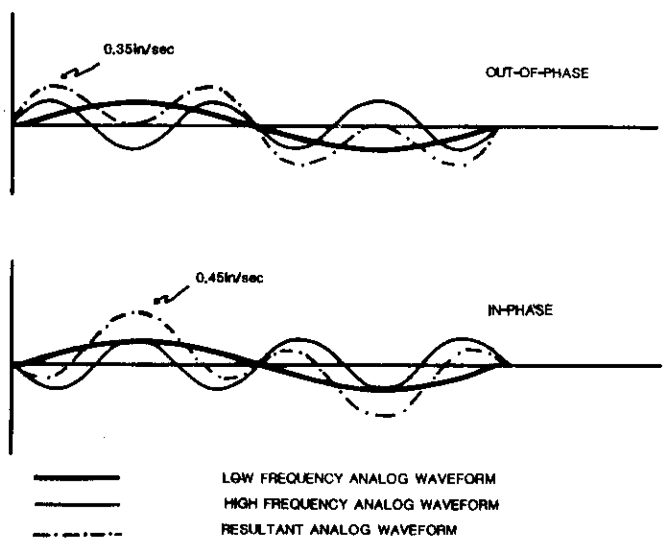


Figure 44.
Analog waveform with two frequencies
showing the effect of phase relationships.

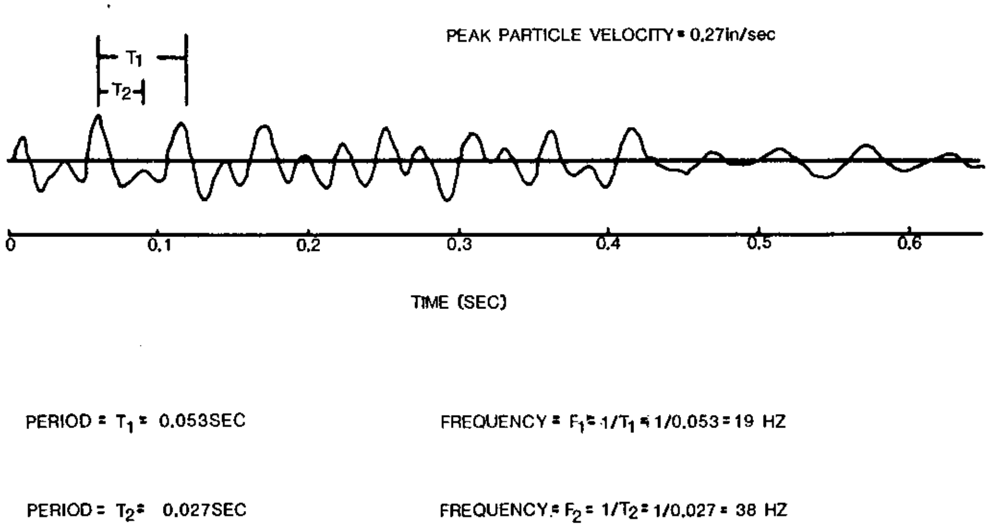


Figure 45.
Calculation of frequency for a waveform
with two predominant frequencies.

Figure 45 is an actual blast vibration record containing two frequency components. The period for one frequency is .053 seconds (19 Hz) and for the second frequency the period is .027 seconds (38 Hz). Calculating the particle velocity for each of these frequencies is more difficult than for a simple wave having only one frequency present.

One method of determining the particle velocity of each of the frequency components would be to filter the original waveform to pass only that frequency to which it is desired to assign a particle velocity. If the blast vibration waveform has been recorded on magnetic tape, then analog or digital filtering would be done to selectively pass those frequencies of interest. The waveform in Figure 44 has been filtered using digital methods to first pass only the 38 Hz component, and then to pass only the 19 Hz component. These results are shown in Figure 46. The Fourier amplitude spectrum for this blast (Figure 47) shows similar results, in that the amplitude of each of the two frequencies are approximately equal.

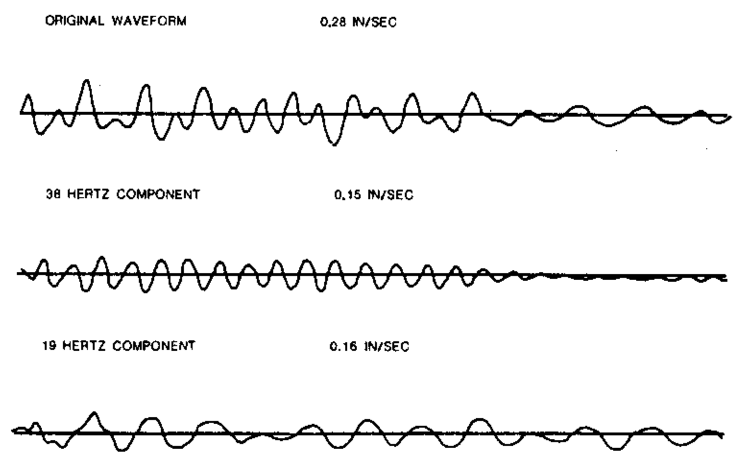


Figure 46.
Results of digital filtering.

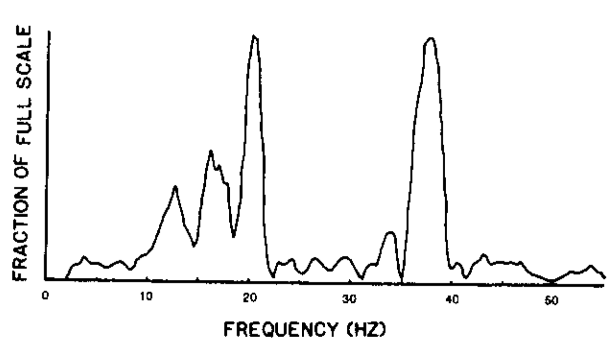


Figure 47.
Fourier amplitude spectrum for a waveform with two predominant frequencies.

An even more complex waveform is shown in Figure 48. The Fourier amplitude spectrum shows three frequencies present: 8, 19 and 42 Hz. The results of digital filtering show the particle velocities associated with each frequency.

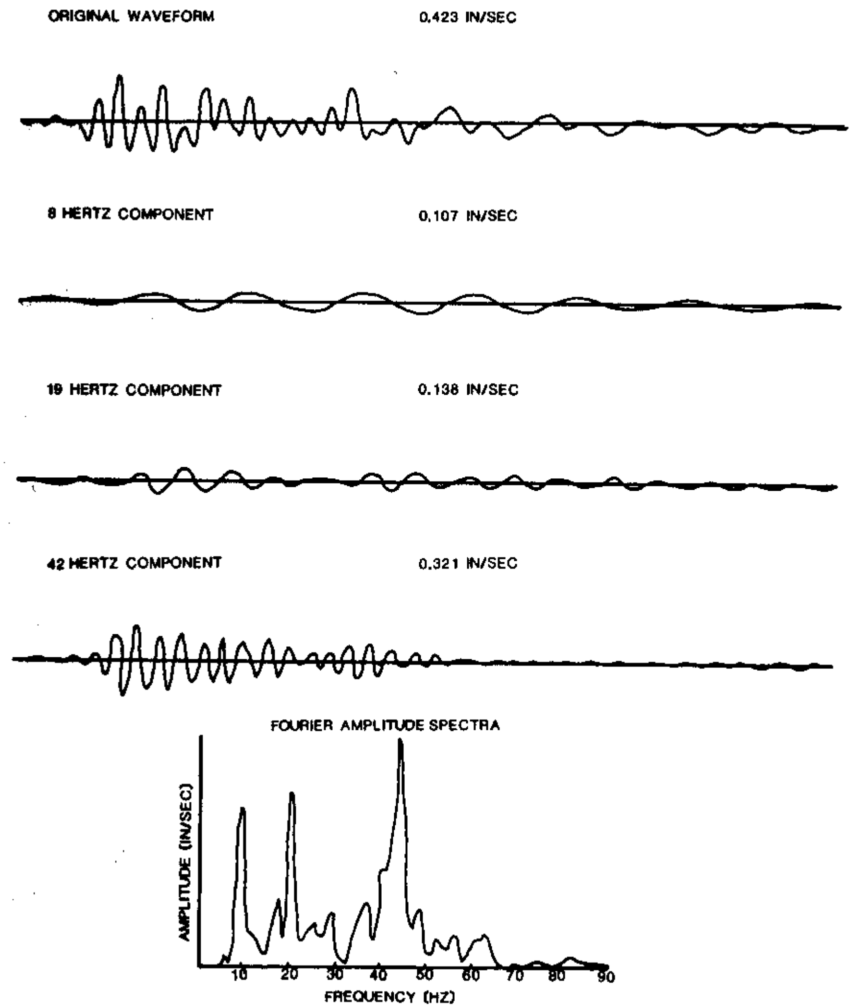


Figure 48.
Analysis of blast vibration waveform
with three frequency components.

An alternative method to determine the frequency content of a waveform would be to calculate a response spectrum. These response spectra can be used to predict how structures will respond to blasting vibrations. A structure is defined as a single degree of freedom model having mass, stiffness and damping. The actual values of mass and stiffness need not be known, since the effect of both factors determine the system's natural frequency. The model needs only to be defined in terms of natural frequency and damping. Damping is a measure of the frictional loss of energy in the structure as it vibrates. The response spectrum, while it can be used to determine the dominant frequencies present in the ground motion, contains much useful information on how the structure is responding.

The response method calculates the maximum relative motion between the ground and a structure of a specific natural frequency. The range of structure natural frequencies for which this maximum relative motion has been calculated on Figure 49 is 3 to 50 Hz. The response spectrum normalized to the maximum peak particle velocity can than be used to estimate the particle velocity contributions from the various frequency components. As can be seen on Figure 49, the normalized response spectrum gives conservative approximations of the peak particle velocities calculated by the use of digital filters.

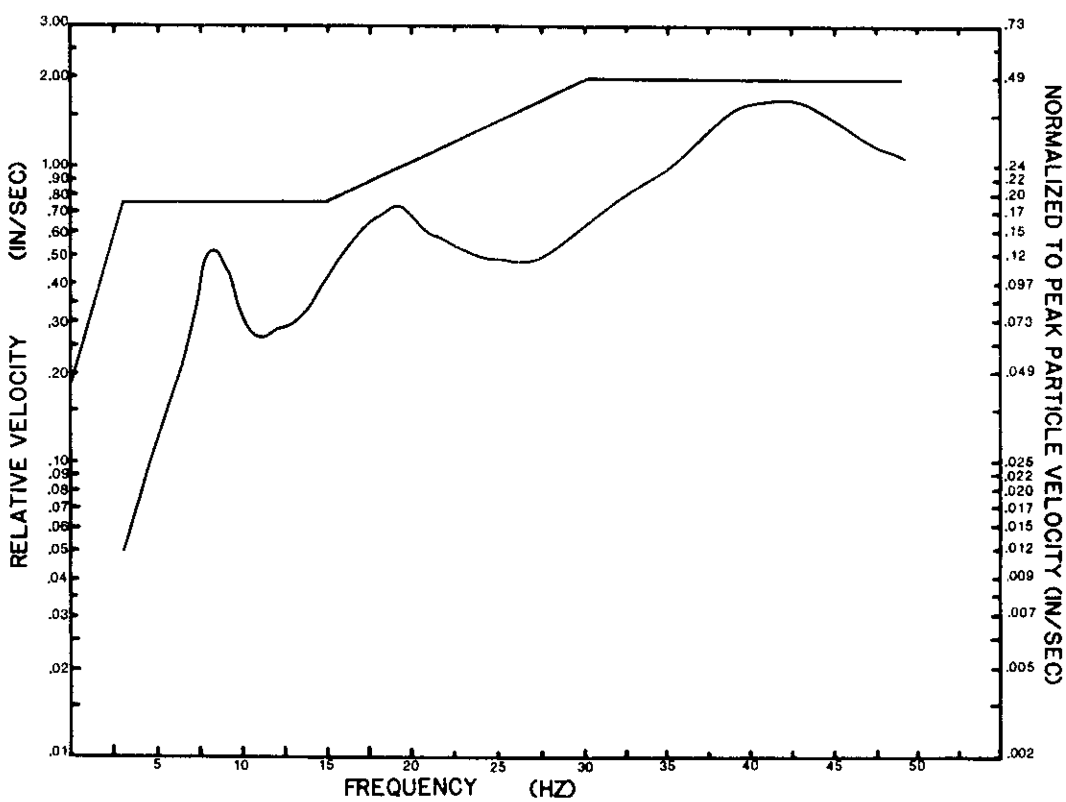


Figure 49.
Response spectrum of a blast vibration waveform with three frequency components.

Further information on this subject may be found in the Medearis report "The Development of Rational Damage Criteria for Low Rise Structures Subject to Blasting Vibrations", and in the Dowding report "Cracking and Construction Blasting". In addition to these, the reader is referred to the two leading Bureau of Mines publications, RI 8485 and RI 8507, that deal specifically with frequency considerations.

In concluding this chapter, it is appropriate to refer again to the preamble to the Rules and Regulations (Federal Register, Vol 48, No.46, Tuesday March 8, 1983), where on page 9800: ".... OSM acknowledges that response spectra analysis as used in the RI 8507 study (Siskind and others, 1980) and by vibration consultants provides a unique solution because it sets allowable limits accurately by predicting the range of potential damage .... This technique if applied on a case by case basis might prove to be the best substantiation of the actual damage range. In order to allow such technique, and to provide operators the option to increase velocities above the maximum limits set for general compliance, OSM has included in Section 816.67(d)(4) an alternative method using Figure 1."

CHAPTER 12

RECORD KEEPING

Records should always be made by a responsible person at the time of the event. This responsible person should be, or be delegated by, the certified blaster, under whose direction all blasting must be conducted. A blaster is required to be present at all shots, together with at least one other person [Section 816.61(c)(3)].

It goes without saying that a blast vibration seismogram alone, unsupported by adequate records, is virtually useless. Even when the instrument itself can be programmed to record the date and time automatically, or when the sound channel possesses a 'VOICE' function to permit verbal comments and information to be recorded on the magnetic tape together with the blast, seismograph records must be supported by proper written records.

All blasting operations, whether or not they are subject to any regulations, must always be fully documented. This is quite apart from any consideration of compliance with OSMRE regulations. It is simple common sense to insist on a complete record keeping program wherever and whenever explosives are concerned. The risk of litigation is very real, and this risk alone should convince operators that good, clear, and complete records are essential. In the event of litigation, they are certain to be called into evidence; and as evidence they should be absolutely unassailable.

OSMRE regulations, in fact, establish a minimum standard for what should be regarded as the essentials of adequate blast and vibration records (Section 816.68):

- They must be kept at least 3 years. It is wise to keep them for much longer.
- They must contain the name of the operator conducting the blast.
- They must include the location, date and time of the blast.
- They must be signed by the certified blaster conducting the blast, and show his or her name and certification number.
- They must identify the nearest dwelling, public building, school, church, community or institutional building outside the permit area (except those described in Section 816.67(e)) and establish the direction and distance from the nearest blast hole to that nearest structure.

- They must note weather conditions, including those which may cause possible adverse blasting effects.
- They must record the type of material blasted.
- They must incorporate sketches of the blast pattern, including number of holes, burden, spacing, decks and delay pattern.
- They must specify the diameter and depth of holes, and the type and length of stemming.
- They must record the types of explosives used, the total weight of explosive used per hole, and the maximum weight of explosives detonated in any one 8 millisecond period.
- They must specify the initiation system.
- They must provide details of mats or other protections used.

These details must always be provided for any blast, irrespective of whether or not vibration monitoring is to take place.

If vibration monitoring is required by OSMRE regulations, then the following information must also be included in the records:

- Type of instrument; sensitivity (or "range setting") and calibration signal or certification of annual calibration.
- Exact location of instrument, and the date, time and distance from the blast.
- Name of the person and firm (can be the operator) taking the reading.
- Name of the person and firm (can be the operator) analyzing the seismographic record.
- The vibration level and/or airblast recorded.

The above vibration monitoring records are also the minimum necessary to support any seismogram or airblast recording, even if monitoring is not required by regulation. If monitoring is carried out, for whatever reason, it cannot be over emphasized that proper records must be kept. Attempts have been made in the past to reconstruct "blast records" from explosives supply invoices, and to develop support for seismograms from memory. Such poor record keeping must never be tolerated. In the event of litigation, the absence of such documentation places a defendant in an extremely precarious position.

One point that sometimes causes a certain amount of confusion, and that can lead to argument, is the "shot to structure or instrument" distance. The regulations require recording the direction and distance from the <u>nearest blast hole</u> to the <u>nearest structure</u>. From the point of view of vibration data collection and vibration prediction, where the scaled distance is the basic criterion, it is important to measure the distance from the center of the group or row of holes that represent the maximum charge weight per 8 ms delay. It may be that two or more groups of holes having similar charge weights per delay may have to be considered. In that event, the distance recorded would be that distance - and charge weight per delay - that resulted in the lowest scaled distance. In most cases, only academic differences will be observed; but in case significant differences do appear, <u>both</u> distances should be recorded and identified.

REPORT OF BLASTING OPERATION

County:________ Twp:__________

State: ____________________

Permit:________ Mine ID#______

Today's Date:________ Time of blast:________ (Military) (Time) Location of blast:____________________

Supervisor, in-charge of blast: Name:______________ Signature:____________________ Lic.#________

Distance form nearest hole to: (Circle one) Dwelling, School, Church, Commercial or Institutional bldg.:__________ft. (Do not Include) (Company Owned or) (Leased Property)

Direction to property: N S E W Weather Conditions at time of blast:( ) Cloudy_____, Clear_____, Partial Overcase________

Temp.______, Barometric Reading______, Wind Description__________ Remarks____________________

Material blasted:( ) Overburden______, Parting_____, Other______ Explain____________________

Total number of holes shot:________ Burden_______ft. Spacing________ft.

Depth of holes: From:__________ft TO __________ft. Diameter of holes:______________inches.

Type of explosives used:( ) AN-FO-Bagged_____, Bulk_____, Other_____ Explain____________________

____________________ Total weight of Explosives used:______________# Decking: Yes No

Max. pounds detonated within any 8 ms period:________# Max. number of holes detonated with any 8ms period:__________

Method of detonation:( ) Nonel_____, Electric cap_____, Other_____, Explain____________________

Type of circuit used:( ) Series_____, Parallel_____, Nonel_____, Other_____ Explain____________________

Stemming information: Type used:____________, Depth:__________ft., Was protective cover used? Yes No

Type of delay detonator used:________________. Minimum delay periods______________millisecond.

Distance from nearest hole to seistector:__________ft. Exact location of seistector:____________________

Name of mine personnel servicing seistector: (print)____________________

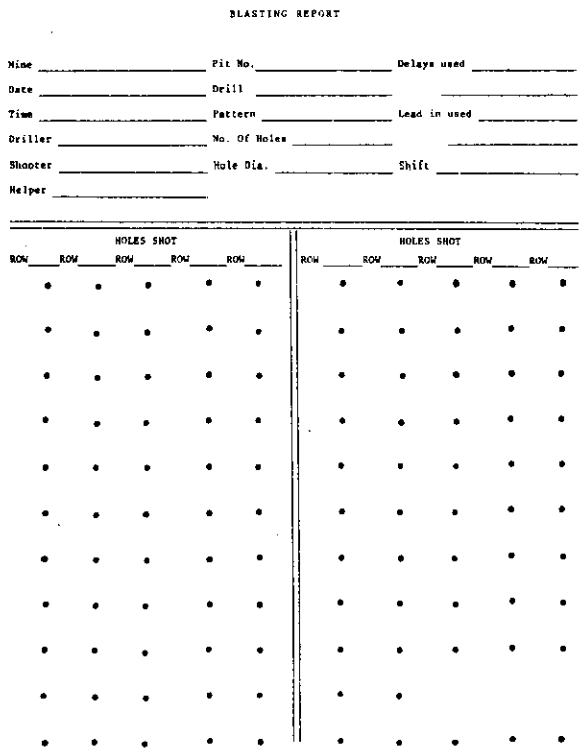
To be completed at a later date:

Name of firm analyzing seistector print-outs:____________________

Name of person analyzing print-outs:____________________

Seistector reading of this blast:____________________

Figure 50.
Typical blast record form.



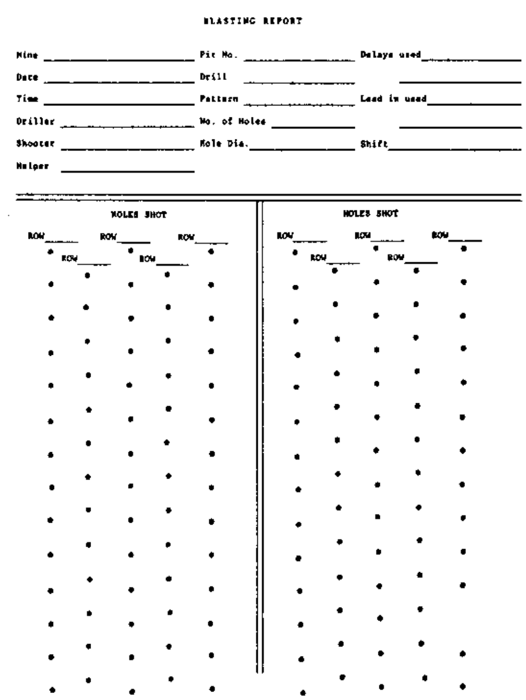
BLASTING REPORT

Mine ____ Pit No. ____ Delays used ____
Date ____ Drill ____ ____
Time ____ Pattern ____ Lead in used ____
Driller ____ No. Of Holes ____ ____
Shooter ____ Hole Dia. ____ Shift ____
Helper ____

HOLES SHOT
ROW ____ ROW ____ ROW ____ ROW ____ ROW ____

HOLES SHOT
ROW ____ ROW ____ ROW ____ ROW ____ ROW ____

Figure 51.
Blasting report (1).



BLASTING REPORT

Mine ____ Pit No. ____ Delays used ____
Date ____ Drill ____ ____
Time ____ Pattern ____ Lead in used ____
Driller ____ No. of Holes ____ ____
Shooter ____ Hole Dia. ____ Shift ____
Helper ____

HOLES SHOT
ROW ____ ROW ____ ROW ____ ROW ____ ROW ____

HOLES SHOT
ROW ____ ROW ____ ROW ____ ROW ____ ROW ____

Figure 52.
Blasting report (2).

Figure 50, on page 103, shows a typical blast record form that provides the operator with an efficient and complete record of each event. It can include seismograph records, and can be used in conjunction with Figures 51 and 52, opposite, to provide sketches of the blast and delay pattern.

Figure 53, below, shows a representative blast and seismograph analysis form, as provided by a consultant for use with his instrumentation. Figure 54, on page 106 shows another example of this, with a slightly different format. In this case, the form is provided with carbon copies which may be retained with the operators blast records.

VIBRA-TECH BLAST AND SEISMOGRAPH ANALYSIS

Company ____________ Operation: Name ____________ Coal ☐ Quarry ☐ Constr. ☐
____________ State ____________ Other ____________

BLAST DATA

Shot No. ______ Burden ______ ft. Total Explosives ______ lbs. Max Explo./Delay ______ lbs. Delay Nos. ______
Date ______ Spacing ______ ft ______ ______ lbs. Max. Holes/Delay ______ Delay Mfr ______
Time ______ Diameter ______ in. ______ ______ lbs. Dist Nearest Bldg. ______ ft. No. of Timer Circuits ______
No. Holes ______ Stemming ______ ft. ______ ______ lbs Dir Nearest Bldg. ______ Timer Interval ______ ms
Depth ______ ft. Stem. Type ______ ______ ______ lbs. Weather ______ Blaster ______
Exact Blast Location ______ Blaster's Comments ______

SEISMOGRAPH DATA

Exact Location of Seis ______ Dist To Seis. ______ ft
Seis. No ______ Cassette No. ______ Operator ______ Meters { Particle Velocity ______ ips
Range ______ ips Trigger Level ______ ips Witness ______ Air Overpressure ______ dBl

VIBRATION MEASUREMENTS

(FOR VIBRA TECH USE ONLY) (FOR VIBRA TECH USE ONLY)
Transverse ______ in/sec. Peak Ground Vibration is (within) (in excess of) ______ limit of ______ in/sec.
Vertical ______ in/sec Peak Air Overpressure is (within) (in excess of) ______ limit of ______ decibels
Longitudinal ______ in/sec. Analyst's Remarks ______
Overpressure ______ dBl ______ Analysis By: ______

(USE REVERSE SIDE FOR BLAST DIAGRAM)

Figure 53.
Typical blast and seismograph record form (1).

Pre-blast and post-blast surveys also need very careful record documentation. Whether the initial survey employs written or tape recorded notes, it is essential that complete contemporaneous records be kept that will:

- Identify the property, property owner, and date and time of the survey.
- Identify the person making the survey, and the operator.
- Determine the condition of the structure, document any pre-existing defects and positively relate any photographic or separate tape records to the body of the report. (Figure 55 shows typical pre-blast inspection forms that can be employed for the written methods of defect recording.)
- Assign identification numbers to all photographic negatives as they are exposed, retaining these numbers through to the final report. Any unused, or spoiled frames should be explained.
- Identify particularly historic or fragile buildings or specially valuable and fragile contents that might be particularly vulnerable to blast vibrations, as discussed in this Manual on page 9, and as required under Section 850.13(b)(10)(iii).

Recording #______ Client: ______ Job Location:______

Reported By: ______ Title:______ Seis.#______ Camera #______

BLAST DATA		SEISMIC DATA	
Date	______	Seis. Range 0.25 1.0 4.0 (circle setting)	
Time	______	Digital Readout:	FOR USE BY VME ONLY
No. of Holes	______	L______	L______
Max. #/Delay	______	V______	V______
Total Chg.	______	T______	T______
Distance	______	R______	R______
Location of shot point______			Sound ______
			Scale______
Comments ______		Test Location ______	

FOR VME USE ONLY: REPORTED BY: ______ DATE: ______ COMMENTS: ______

Figure 54.
Typical blast and seismograph record form (2).

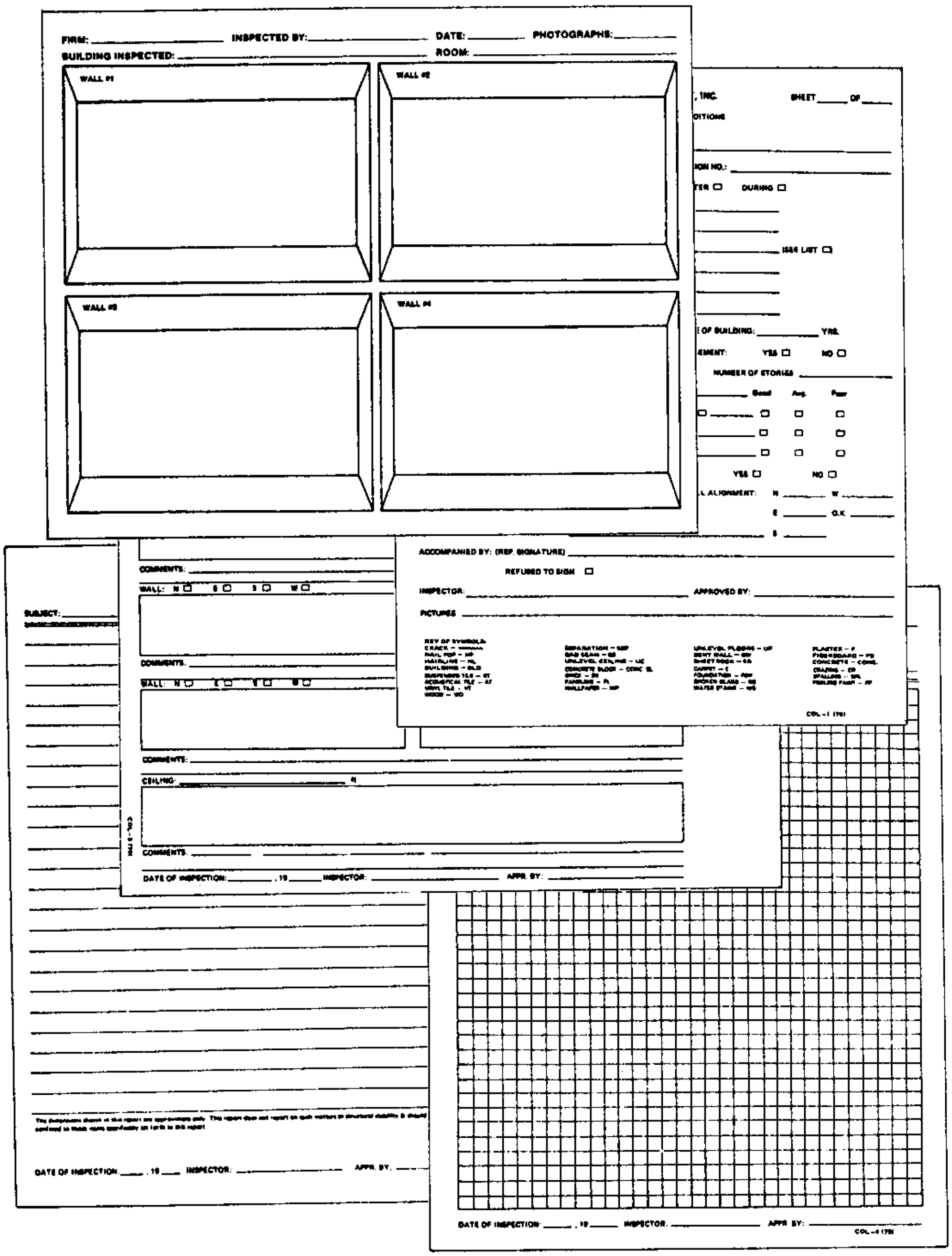


Figure 55.
Typical pre-blast inspection forms.

CHAPTER 13

CITIZEN INTERESTS: RIGHTS, PROTECTION AND INFORMATION

This section of the OSMRE Blasting Guidance Manual is specifically directed to the Citizen, whose safety and property are protected by the OSMRE regulations. All the other sections are for the information and guidance of the Mine Operator, so that he may properly comply with the requirements of the regulations, and therefore ensure the safety of the citizen's person and property. This section will provide the citizen with information on his rights under the law, how the regulations will protect and assist him, where he may go to obtain protection, and information on just what to expect in terms of perceived blasting effects, and what to look for when blast vibration damage is suspected.

RIGHTS AND PROTECTIONS UNDER OSMRE REGULATIONS

LONG TERM: Initially, before a mine is permitted, the citizen is free to exercise the most powerful right that he has, during the actual permitting process, to express any objections he may have to the mine being there in the first place. Since this manual is to guide those involved in an existing mine, miners or citizens, the premise will be made that the mine has been permitted, and is, or shortly will be, in operation.

The citizen is assured that public or private lands which are subject to surface mining will be reclaimed and returned to substantially the same form and condition as they were prior to the mining operation. Obviously, the time element involved will be long term, since many mines will have "lives" of ten, fifteen, or twenty years, and even longer in some cases. The State Regulatory Authority or OSMRE will be able to advise on the projected length of time that any mine is planned to remain in operation.

When mined land is reclaimed, the law requires that the original contours are restored to as practical an extent as possible, that the original water courses, and availability of surface and ground water, are not changed, inside or outside the permit area. Local features and wildlife habitat such as rocky outcrops have to be restored in a reasonable manner, while topsoil must be replaced and vegetation must be reseeded. That these regulations are in fact proving both practical and effective can be evidenced by a visit to virtually any modern surface coal mine, particularly in the Western grasslands. The public are frequently unaware that the land that they are viewing has already been mined through and reclaimed: at first glance it is frequently taken for virgin, unmined land.

SHORT TERM: The law also provides protection for the citizen from the short term effects of surface coal mining. These short term effects largely derive from the "adverse effects" of blasting that are specifically addressed, to the mine operator, in Chapter 3 of this Manual. Although the long term effects and protections mentioned on the preceding page refer to permitting, reclamation and non-blast considerations that are strictly outside the scope of this Manual, the short term effects - generally from blasting - are very much within its scope, and are therefore discussed in detail for the benefit of, and better understanding by, the citizen. From the citizen's point of view - understandably sometimes somewhat different from that of the mine operator - the protection provided by the regulations can be summarized as follows:

- The prevention of injury to persons.
- The prevention of damage to private property outside the Permit Area.
- The prevention of damage to public property outside the Permit Area.

The citizen will notice, however, that this does not provide any real degree of protection against annoyance. This is understood, and this particular point will be discussed - hopefully to the citizen's satisfaction - later in this chapter.

THE PREVENTION OF INJURY TO PERSONS

Explosives themselves are a great deal safer to use and to handle than most people generally imagine. This is not to say that explosives are not potentially dangerous: of course they are, and they should only be used by experienced and trained personnel, working under the supervision of a Certificated Blaster. Dynamite is now very little used in production blasting anymore except as a "primer" to detonate or initiate the main charge, most probably a "blasting agent" rather than a "high explosive". A stick of dynamite, however it might be portrayed in an adventure movie, is in fact considerably safer to handle than is a gallon can of gasoline! The main risk that might be incurred from handling dynamite, particularly with bare hands on a hot day, would be to develop a very severe headache, due to absorption of nitro-glycerine through the skin! Accidents can happen, however, and it is for that reason, amongst others, that OSMRE demands proper experience and training. The citizen will not be exposed to this risk, of course, and therefore the only possible way in which personal injury could result would be from "flyrock".

Flyrock and the dangers attendant to it are described in Chapters 3 and 4, pages 20 and 21, and 30 and 31. Flyrock can even cause death, and therefore the regulations take this hazard very seriously indeed, as it is without doubt the most dangerous single adverse effect of blasting.

Having established that, how do the regulations protect the citizen? Since there is no practical way to guarantee that flyrock will never occur - some "fly" or "throw" is actually normal to most blasting operations, and blasting mats or dirt cover have to be used for maximum control - the obvious way to eliminate the danger is to prevent flyrock from occurring where people can be present, or to prevent people from being where flyrock might present a danger. The regulations therefore mandate that flyrock must travel no more than half the distance to the nearest occupied dwelling or other structure, beyond the posted blasting control area, or beyond the permit boundary. This is also the fundamental reason why unauthorized persons are not permitted to be inside these areas.

Any citizen who is threatened by flyrock outside these areas has immediate cause for reporting a violation of regulations.

It would be difficult to imagine how the other two adverse effects of blasting, ground motion and air blast, could cause personal injury under any normal circumstances, certainly to any person who was not a member of a blasting crew, and when an accidental detonation did not take place. From the viewpoint of the citizen, it is reasonable to assert that the only risks presented by these effects would be to property.

THE PREVENTION OF DAMAGE TO PROPERTY

Without question, the most common single cause of damage to property resulting from blasting operations is due to flyrock. Obviously, the regulations to protect the citizen from injury will also protect his property from damage, and should damage occur from flyrock, it is also evidence of a violation of the regulations. The evidence is also virtually indisputable, except, as noted on Page 31, in the case of windshield glass breakage, or hail damage to vehicles.

While ground motion, or vibration, is the second most common cause of damage, it is nevertheless only truthful to point out that actual damage due to blast vibrations is in fact quite rare. This is mentioned as much to stress the very careful and conservative nature of the OSMRE regulations on vibration limitations, than to defend the mine operator.

These limitations, shown on pages 22-25 of this manual, allow under some circumstances up to 2.0 inches per second particle velocity, and under others as low as 0.2 inches per second, because of the different damage effects of ground motion of varying frequencies. This also explains the apparent anomaly of permitting higher velocities at short distances, because the frequencies of ground motion are higher at short distances, and higher frequency vibrations have been found to be less damaging. Although the Bureau of Mines research which forms much of the basis for the OSMRE regulations has shown that there is a possibility of minor damage at velocities even slightly below 1.0 inch per second, in normal conditions, with properly constructed buildings, damage is unlikely to appear at velocities under 3.0 inches per second. Whenever damage is referred to in this context, it is also necessary to remember that minor, threshold, cosmetic damage is what is meant. (See Chapter 4, page 29.) When major, structural damage, such as the collapse of brickwork, extensive and serious cracking threatening structural integrity, or concrete cracking is found (apart from the small drying-out or temperature cracks to be found in virtually all concrete) then either the ground motion exceeded 3 or 4 inches per second, or some other reason exists for the damage. See "CAUSES OF STRUCTURAL DEFECTS" on pages 4 to 6 of this manual.

If an operator is in compliance with the regulations, the citizen's house will be effectively protected from damage, even when the blasting vibrations are repeated on a daily basis over a period of years. It is a relatively simple thing to check on whether an operator <u>is</u> in compliance, and that is by measuring - or "monitoring" - the vibrations over a period of time. Many mine operators own or rent monitoring instruments, and most will readily accede to a request from a householder to monitor vibrations in this way. Blast vibration consultants, too, will be happy to carry out this service, either in person, or simply by means of an instrument rental for a short period. Most available instruments are very easy to use, and are quite impartial: they will accurately report a vibration level regardless of who owns them, or who switches them on!

If velocities in excess of the regulatory levels are recorded, then regardless of the method of regulatory compliance that the operator has chosen (See Chapter 9, page 73), it will be apparent that the operator is in violation of the regulations. This is because the "scaled distance" option is so safe and conservative that it is almost impossible to exceed regulatory vibration levels when it is used. In any case, should this situation arise, subsequent seismic tests would be able to establish this possibility. If the operator is using one of the velocity limitation options, then there would be no question at all.

Where airblast is concerned, although this is the effect that causes the most annoyance of all, it is also the effect that causes the least damage. Airblast that can cause even minor damage is so much higher - some 10 to 15 times higher - than the maximum allowed under the OSMRE regulations, that it can virtually be discounted as a possible cause of damage. In any event, whenever airblast <u>does</u> cause damage, it always shows up first as broken window panes. If a building suffers structural damage, and it does not have any broken windows, then the cause was other than airblast.

This, then, is one area of the regulations where annoyance plays as much a part in the thinking behind the regulations as does damage. It does not totally eliminate the problem, but it does bring it within reasonable bounds. Airblast can be monitored, in the same way as ground motion, and if an airblast level is measured at an occupied dwelling that is in excess of the regulatory limits, then the mine operator is in violation of the regulations.

In fairness to the operator, it might also be stated that airblast is the most difficult of all the adverse effects of blasting to control, because of the many weather and atmospheric variables, and other factors outside the control of the mine operator. OSMRE does not of course condone at any time any breach of the regulations, and any such recorded breaches constitute violations regardless of the circumstances. OSMRE does however concede that an occasional airblast violation does not automatically indicate unwillingness to comply on the part of the operator.

PRE-BLAST SURVEYS

The OSMRE regulations are quite clear and specific on the rights of the citizen when it comes to the question of pre-blast surveys. Sections 816.62 (a), (b), & (c) require that a mine operator notify <u>all</u> residents living within a half mile radius of the mine permit area, at least thirty days before the blasting program is to begin, on how to request a pre-blast survey. The resident, or the owner of the property, may request that such a survey of his home be carried out, and this request may be made either to the mine operator, or to the regulatory authority. The mine operator may carry out the survey, or he may employ others to do this on his behalf. If he employs a third party in this way, that person is likely to be a professional consultant who is experienced in this type of survey. In either event, it will be carried out at no charge to the resident or owner of the property. The survey must be prompt, and the report of the survey, a copy of which must be supplied to the person requesting the survey, must also be prompt. If the resident or owner disagrees with the content of the survey, a detailed description of the areas of disagreement may be submitted to both the operator and the Regulatory Authority.

Updated reports of any additions, modifications or renovations must also be surveyed and provided by the operator to the resident or owner, if requested.

The pre-blast survey provides one of the most powerful protections and controls that it is possible to have on the often argued question of damage liability. A householder may be certain in his own mind that a particular crack or defect is the direct result of blasting activity at the neighboring mine. If a pre-blast survey does not record such damage, and inspection and investigation of his complaint shows the defect to be there, then there can be no further argument. Note that in this case the purpose of the survey is not to determine whether the operator is in violation of the regulations or not. The operator is in compliance with the regulations, merely by carrying out the surveys as required. The survey itself simply determines whether any subsequent damage complaints are actually damage or not: obviously, if the determination is that the damage was caused by the blasting operation, then it is the operator's responsibility to repair or recompense the householder for that damage. OSMRE, however, cannot compel a mine operator to repair or recompense the householder. Restitution is often a legal matter.

The pre-blast survey also protects the mine operator from unjustified damage claims. Whatever defects are recorded prior to a blasting program cannot subsequently be claimed as blast vibration damage. A resident or owner does not <u>have</u> to submit to or request a preblast survey, but if he declines such a service it might well weaken any subsequent claim he might then make for damage he claims was suffered due to that blasting.

BLASTING TIMES AND SCHEDULES

Another protection provided to the citizen by the OSMRE regulations is the requirement that blasting take place in accordance with published schedules, and within specified hours. Blasting schedules must be published in a local newspaper at least ten days, but not more than thirty days, before the start of a blasting program. Copies of the schedule must be distributed to local governments and public utilities, as well as to all local residents within a half mile of the blasting site as described in the schedule. The operator must republish and redistribute the schedule at least every 12 months, at least ten days but not more than thirty days before blasting, whenever the schedule area or blasting times differ significantly from the previous information.

All blasting must take place during daylight hours unless more restrictive times are specified. If night-time blasting is approved by the regulatory authority, it must be based on evidence from the operator that the public will be protected from adverse noise and other impacts.

All other unscheduled or night-time blasts can only be conducted on an emergency basis, for reasons of operator or public health or safety. In such a case, the operator must notify all residents within half a mile by audible signals, and he must document the reasons for, and conditions of, the unscheduled blast. A typical example of such an unscheduled blast might be that the operator had loaded a shot, but had to vacate the area for safety reasons, say due to a thunderstorm. If night had fallen before the thunderstorm had ceased to threaten, and the operator felt that it was an unacceptable hazard to leave the loaded shot overnight, then he would be justified in carrying out the unscheduled blast, provided of course that he made notification of the blast and documented it properly, as required by the OSMRE regulations.

PERCEIVED BLAST VIBRATION EFFECTS

Thus far in this chapter vibration intensities have been referred to, unavoidably, in terms of "particle velocity". Normally, when a member of the public hears someone - mine operator, government official or consultant - speak of vibrations in unintelligible language - "point six five inches per second" - he cannot help but consider that it is just so much "gobbledygook" and that perhaps the "experts" are even trying to hide things from him. Why can't they speak in terms that everyone understands? Unfortunately, no-one has yet invented terms for this rather specialized field that everyone does understand.

What can be done in this chapter, however, that may at least alleviate this problem, is to discuss in simple everyday terms the way that human beings feel or perceive blasting vibrations.

First, there is no doubt at all that some people can feel vibrations almost as low as instruments can measure them. It is often commented that human senses are very dull compared to those of animals, though it is not often realized how keen in fact some of these human senses are! The sense of touch, for instance. Stretch a human hair across a smooth surface, or overlap two thin sheets of paper, and run a finger across, and few people will have any problem at all in feeling just two or three thousandths of an inch! Although many people these days - especially the young - have reduced hearing ability, the human body as a whole is astonishingly sensitive to ground vibrations. Levels can be felt that present absolutely no danger at all to structures. In fact, houses are vibrating much of the time to one extent or another. People, particularly heavy ones, or active children, generate motion that at times approaches - or even exceeds - the limits set by OSMRE. Climbing or descending stairs, jumping, door slamming or even just walking across a floor can cause considerable motion in a structure. The fact is that when people themselves are in motion, they do not notice any movement in the structure of their homes.

So how do most people react to, and actually feel blast vibrations? The most obvious effect is usually the airblast. Since it does not always contain frequencies that humans can best hear, it is not always a very loud event. It is usually perceived as anything from a dull thump to a loud bang. A loud bang is not always a "high" airblast, and conversely, a dull thump may in fact be one. It might even be inaudible! The house may well react, or respond, the structure may creak, the windows may rattle, and, if a person is not expecting it, it may be quite startling. It is most unlikely ever to cause damage.

Ground motion, or ground vibration, can be experienced in different ways. A very low frequency vibration, such as might be experienced from a large blast on a mine a long way off, might not be recognized as a vibration, only as sense of unease, or even a passing feeling of slight giddiness. Higher frequency and higher intensity motion is much more obvious and recognizable, particularly if the structure responds. Humans are frequently disturbed by vibration levels that are perfectly permissible under the OSMRE regulations. This is discussed in the manual under the heading of "HUMAN SUBJECTIVE TOLERANCE" in Chapter 5, pages 35, 36 and 37.

When vibration levels occur which approach or exceed the regulation limitations, there is no doubt at all that most people find this unpleasant, and their cause for alarm is normally quite justified. It is the reason why most consultants advise their clients to try to keep well below the regulatory levels, and only plan to risk approaching them when blasting in those locations must be carried out.

A common complaint involves the rattling of crockery. When a person is at rest in his home, and the vibration from a nearby mine blast causes the crockery to rattle, then he is disturbed by this, and frequently worries about whether such a vibration could have caused any damage to his home. In investigating such complaints, however, it is sometimes noticeable that the crockery rattles simply when a person walks across the floor. When this is pointed out, it may be that that person, in motion, just did not realize that this was happening. Sometimes, though, the person admits that knowing that the rattling is due to a normal household activity is not worrying, but when it happens due to action of explosives, then who knows what that might have done!

Apart from the normal activity of the occupants, a structure is subjected to daily, seasonal and incidental outside causes of motion. Some are very slight, and unnoticeable to the casual observer, such as daily and seasonal temperature changes. The structure, however, is nevertheless affected by such temperature, and therefore dimensional, changes. Seasonal moisture differences can cause the ground the house is built on to expand and contract. More obvious causes of structural movement are high winds, thunderstorms, and earthquakes. Nearby highways or railroads, and of course airports, can all cause vibrations.

Even unoccupied dwellings, if left undisturbed, will eventually deteriorate to the point of collapse.

ACTUAL BLAST VIBRATION EFFECTS

One very important consideration concerns the response of a structure to a blast vibration. This has already been referred to briefly above. Rather like the wine glass that was shattered by the opera singer holding a sustained note, a structure has a "natural" frequency at which it will vibrate when "excited". When an incoming ground motion is at that same natural frequency, then the structure is "excited", and the resulting response can well exceed the intensity of the incoming ground motion. This again is the reason why the regulations permit higher vibrations at high frequencies than they do at low frequencies. Because of this also, since this phenomenon has already been taken into account, the regulations control the incoming ground motion only. From the point of view of perception, therefore, a person will be less disturbed by a blast when he is outside his house than when he is inside it. From the viewpoint of actual effects, however, the citizen may well have noticed the potted plants on his window sill vibrate, and he may consider it reasonable to request that vibration measurements be taken on the window sill. The mine operator would be justified in declining that request, as it would only measure the response of the structure at that point, and not be a valid measurement of ground motion under the OSMRE regulations.

When frequencies are very low, about 4 to 12 Hz, and structures respond, then the maximum danger of actual damage occurring exists. A small possibility exists of damage at velocities even below 1.0 inch per second, which accounts for the low velocities allowed on the Blasting Level Chart, Figure 12 on page 24 of this manual. As frequencies increase, the likelihood of structural response decreases, and the allowable limits increase. The actual effect of a ground vibration close to, but not exceeding 2.0 inches per second, at a frequency at or above 30 Hz would be a highly <u>perceptible</u> vibration, and probably a very annoying one, but one that would not cause damage.

Incidentally, ground motion has to be far above these levels to threaten wells or aquifers, although these problems are frequently feared and complained of.

ANNOYANCE

The above discussion on perceived and actual vibration effects has had the central theme of annoyance running through it. Unfortunately, annoyance is very difficult to quantify, and it is further complicated by the fact that not all human beings are annoyed by the same things. Some of us simply do not worry about things that drive others crazy. It can also help to recognize that as far as a local surface mine is concerned, the citizen who originally tended to benefit from the operation, and who did not oppose the application, will be far less annoyed by the operation than the citizen who did oppose that operation, and who had to watch it become an established operation in the face of his objections.

Citizen Interests

For those who do find that they are annoyed by surface mining, and cannot help but be annoyed by surface mining, the following is a sincere discussion that they will hopefully find of some consolation, and that may even lead the way to a reconciliation with that annoyance.

Certainly as far as the the airblast limitations are concerned, annoyance was very definitely considered when the regulations were written. The airblast allowed by OSMRE is less than half the level allowed by OSHA for impulsive noise. Except in emergencies, or when specifically approved by the Regulatory Authority, as already discussed, no blasting is allowed at night, and the published schedules and notification system ensure that people are not taken by surprise or startled by the blasting.

Ground vibration presents a rather more difficult problem where annoyance is concerned, since humans are so sensitive, and can perceive - and be annoyed by - remarkably low, though certainly not damaging, levels of vibration. In order that explosives be used efficiently as a tool for breaking rock, it is sometimes necessary to generate vibrations that not only can be distinctly felt, but that some people might find find highly annoying. These can be perfectly legal levels, within OSMRE regulatory limits, and quite safe, presenting absolutely no risk of damage. Nevertheless, for many people, they can, and do, annoy.

A possible solution to the problem lies in efforts to establish and maintain good relations between the citizen and the mine operator. It is normal, of course, for the operator to promote such relations, but in order for the maximum mutual benefit to be derived from such efforts, the citizen should attempt to extend his own hand no matter how difficult this may at first seem to be. An unbiased attempt to achieve mutual understanding is often a good first step.

Understanding that the viewpoint of the operator is going to be significantly different than that of the citizen, and that this does not automatically signify an adversary situation, is a considerable step towards achieving good mine operator and citizen relations. Whereas it is sometimes the case that the citizen feels forced into an adversary situation by the mine, it can be that the mine, or at least some of its personnel, can feel precisely the same pressures. While the citizen feels that the mine threatens his peace, his environment, his residence, and his quality of life, the mine personnel can also feel threatened by citizen complaints, which seem to jeopardize their very livelihoods. If the accounts that they make of the same situation might be widely disparate, and would seem to prove that one or the other just cannot be telling the truth, patience and understanding may well show that this is not the case: both are being entirely truthful by their own lights.

Witness the blaster who tells the consultant arriving at the blasting site: "Those people on top of the hill! They're giving me fits! I've told them that there is nothing to worry about, but they complain every time I shoot! You will have to do something about them!"

The consultant sets up his instrument at their house, and finds that they are quite nice people, but rather afraid of the blasting. There is nothing strange about that.

They say to the consultant: "That dynamiting is getting on our nerves - the house shakes every time it goes off! The man that's doing it told us that there was nothing to worry about, but you should feel it when he blasts! You will have to do something about it, for we are worried about the damage it must be doing to the house!"

The consultant explains to them that he is there to make sure that the house is not damaged: that is what the instrument is for. The blaster, who has, and uses his own instrument, did not bother to explain this - after all, they were too busy complaining! The consultant also tells them that although the vibrations will not harm the house, they will certainly feel the motion, and may be bothered by it. He tells them that they will feel the vibrations much more strongly if they remain inside the house, and suggests that they stay outdoors.

The shot is fired, and the consultant notes the vibration levels: 0.15 inches per second, not nearly enough to cause any damage, but certainly enough for the people to feel, and even to alarm them if they are inside the house and there is any real degree of structural response.

They say to the consultant: "That was not as bad as you said it was going to be! But why did the blaster say we would feel nothing at all?"

The explanation is simply that the blaster, who is entirely familiar and comfortable with blasting and explosives, had told them merely what he believed to be true, that it was nothing to worry about, and that they wouldn't feel a thing. Once that was explained to the householders, together with the comment that the blaster had never been inside the house when he fired his shots, then a mutual understanding was established, and the foundation was laid for a better relationship in the future.

The whole direction of this manual to the Mine Operator is to enable him to comply with the OSMRE regulations, and therefore to minimize the adverse effects of that operation. It is certain that the citizen's safety and property will be protected. It is not always possible to control the physical effects of blasting operations to such an extent that people will not be aware of the activity. Mining does have some adverse effects, and the annoyance that derives from those effects is genuinely regretted. One cannot build highways and bridges or new developments or, for that matter, permit and operate mines without causing annoyance to some. These are all legal and even desirable activities, benefiting the majority of the people, and are sometimes essential to all of us. Certainly we are all dependent on our future energy supplies, and perhaps coal is even a more acceptable source of energy to most people than nuclear sources are. Some of this coal mining activity will cause annoyance. But with care and understanding, one can at least try to remove some of the sharpest edges from that annoyance.

ACTUAL BLAST DAMAGE CRITERIA

The Bureau of Mines research on blast vibration damage is detailed and extensive. Among the conclusions drawn by RI 8507 (see page 29 of this manual for this document's definition of threshold damage due to blast produced ground vibration) are the following:

- Home construction is also a factor in the minimum expected damage levels. Gypsumboard (Drywall) interior walls are more damage resistant than older, plaster on wood lath construction.

- Practical, safe criteria for blasts that generate low-frequency ground ground vibrations are 0.75 in/sec for modern gypsumboard houses and 0.50 in/sec for plaster on lath interiors. For frequencies above 40 Hz, a safe particle velocity maximum of 2.0 in/sec is recommended for all houses.

- All homes eventually crack because of a variety of environmental stresses, including humidity and temperature changes, settlement from consolidation and variations in ground moisture, wind and even water absorption from tree roots. Consequently there may be no absolute minimum damage threshold when the vibration (from any cause, for instance slamming a door) could in some case precipitate a crack about to occur.

- Human reactions to blasting can be the limiting factor. Vibration levels can be felt that are considerably lower than those required to produce damage. Human reaction to vibration is dependent on event duration as well as level. Particle velocities of 0.5 in/sec . . . (1-sec vibration) . . . should be tolerable to about 95 pct of the people perceiving it as "distinctly perceptible".

This, amongst other things, at least tells us that the Bureau of Mines research personnel experienced considerable difficulty quantifying and qualifying blast vibration damage! What sort of difficulty will the layman have when attempting to determine if he has suffered blast damage?

First, he will have to have been considerably startled or disturbed by the high level of the vibration, if he was there to observe it. If he was, and he actually observed damage occur, then he will have no doubts at all, and will be able to testify quite confidently.

Secondly, he will have to look for small, almost hairline cracks that are fresh, without dust, spider webs, insect detritus or paint inside them. Small fallen flakes of paint or plaster will be an indication, as will be the widening of existing cracks. One problem in determining whether an existing crack has widened, of course, derives from whether its original dimension was either known or recorded. Imagination <u>can</u> cause cracks to widen, especially if the observer is distressed.

Thirdly, he may observe cracks in the jointing paper covering the separations between gypsum wall and ceiling panels. Again, he should make sure that these are in fact fresh, for many such small imperfections can pass unnoticed for years until the householder fears that blasting may be harming his house, and he starts looking for signs of damage.

Many of these small cracks will typically run from the corners of openings such as doors or windows, or follow separations between building elements. Outside brickwork cracks, normally in the mortar between the bricks, will also follow the same pattern, running from the corners of openings, and also from lintel tops, or below sills. A "stairstep" crack is quite typical in brickwork, though a stairstep crack running diagonally from ground level near a corner to the wall corner above ground level, very often indicates settlement rather than blast damage.

Concrete, particularly reinforced concrete, is very resistant to blast vibration damage. Cracks will not normally appear in concrete below perhaps 10.0 inches per second, a velocity that is not only far higher than OSMRE regulations permit, but that would normally cause undisputed and quite extensive cracks to occur to plaster, gypsumboard and brickwork. Damage to concrete is therefore normally accompanied not only by exceptionally high velocities, but also by other, and obvious damage.

Whenever the citizen suspects, therefore, that his home is suffering from the effects of excessive blast vibrations, he should without delay carefully and thoroughly inspect the whole structure - or engage an expert to inspect it - or, within the terms of the OSMRE regulations and the comments on page 10 of this manual, request a post-blast survey. He should document, and measure, or mark and date, every crack, so that widening or lengthening of cracks becomes a matter of documentation and not mere imagination. If he is sufficiently expert in photography, he can support any evidence he may find with good, clear, photographs, but he must also document the photographs carefully so that no possible confusion can arise as to identification or location.

In fact, any concerned citizen, even if he is quite distant from the mine, and is not able to feel any vibrations, ground motion or airblast, should nevertheless inspect his home carefully from time to time. He will be able to see that his home presently has more defects than he might otherwise have imagined, and, should the mining operation approach closer, or use heavier explosive loading, when the vibrations will then become perceptible, he will be spared much worry and speculation.

SPECIFIC COMPLAINT PROCEDURES

STATES WITH APPROVED STATE PROGRAMS

If residents or homeowners believe that their property has been damaged, or that there has been a violation of any of the blasting regulations, they may register a formal complaint with the the State Regulatory Authority who has jurisdiction over the program.

A person may request an inspection of the mine where blasting is taking place. The request for an inspection should be a signed, written statement (or an oral report followed by a signed written statement) giving the State reason to believe that a violation exists. The statement should set forth a phone number and address where the person can be contacted.

The identity of any person supplying information to the State shall remain confidential if requested by the person. If the person elects to accompany the inspector on the inspection, anonymity cannot be guaranteed.

Within a specific period of time which varies from State to State, the person requesting the inspection must be informed of the results of that inspection, and a description of any enforcement action that was taken.

The complainant will be informed of the informal and formal review rights that he may have under State law and regulation if he is not satisfied by the action of the State. It must be kept in mind at this point that the inspection may take the form of a special investigation which may include the taking of seismographic readings. This very often can take several weeks.

Citizen Interests

Should the complainant not receive satisfaction from the State Regulatory Authority, he may request an inspection/investigation by the Office of Surface Mining Reclamation and Enforcement (OSMRE) Field Office with responsibility for program evaluation in that State.

In this case, OSMRE will review the action of the State Regulatory Authority and determine the course of action that it will take. Should a Federal inspection result, it will be carried out according to the procedures outlined in Part B of this secton, Federal Program States.

Should OSMRE receive a complaint or request for a Federal inspection, and it is determined that the State Regulatory Authority has not been contacted, OSMRE will refer the matter to the State for resolution.

FEDERAL PROGRAM STATES

These are States where OSMRE has primary authority to regulate coal mining and reclamation operations under Public Law 95-87.

A person may request a Federal inspection by furnishing any OSMRE office with a signed, written statement (or an oral report followed by a signed, written statement) giving the reason why (s)he believes that a violation exists. This statement must set forth a phone number and address where the person can be contacted.

The identity of any person supplying information to OSMRE shall remain confidential, if requested by the person requesting the inspection. If the person elects to accompany the inspector on the inspection, anonymity cannot be guaranteed. OSMRE will keep the person's name confidential unless required to disclose the name under the Freedom of Information Act (5 U.S.C. 552) or other Federal law.

If a Federal inspection is conducted, the complainant will be notified in advance when the inspection is to take place, and will be allowed to accompany the inspector during the inspection.

Within 10 days of the Federal inspection, or, if there is no Federal inspection, within 15 days of receipt of the person's written complaint, the Office will send to the person the following:

1. A description of the enforcement action, which may consist of copies of the Federal inspection report and all Notices of Violation and Cessation Orders.

2. If no Federal inspection was conducted, an explanation of the reason why.

3. An explanation of the person's right, if any, to informal review of the action or inaction of the Agency.

If a person is not satisfied with a decision or the results of an investigation into his complaints, he may ask the Director, OSMRE in writing for an informal review. The Agency has 30 days from the receipt of that request to inform the person of the results of that review.

The results of the informal review will also advise a person of his rights to formal review under Section 525 of Public Law 95-87.

The OSMRE will give copies of all materials associated with the results of the inspection/investigation to the person alleged to be in violation, except that the name of the person supplying information shall be removed unlss disclosue is required under the Freedom of Information Act, or if the person did not request confidentiality.

REGULATORY AUTHORITIES

OSMRE: WESTERN FIELD OFFICES

FIELD OFFICE & ADDRESS:	TELEPHONE NO:	RESPONSIBLE FOR:
Office of Surface Mining Reclamation & Enforcement Kansas City Field Office 1103 Grand Avenue, Rm. 502 Kansas City, MO 64106	(816) 374-5527	Iowa, Kansas, Missouri & Nebraska
Office of Surface Mining Reclamation & Enforcement Room 216 219 Central Avenue, N.W. Albuquerque, NM 87102	(505) 766-1486	Arizona, California, Colorado, New Mexico & Utah
Office of Surface Mining Reclamation & Enforcement Tulsa Field Office 333 West 4th St., Rm. 3432 Tulsa, OK 74103	(918) 581-7927	Arkansas, Louisiana, Oklahoma & Texas

Office of Surface Mining Reclamation & Enforcement Casper Field Office 100 East B St., Rm. 2128 Casper, WY 82601-1918	(307) 261-5776	Alaska, Idaho, Montana, North Dakota, Oregon, South Dakota, Washington & Wyoming

WESTERN FIELD OPERATIONS

Administrator Office of Surface Mining Reclamation & Enforcement Brooks Towers, 2nd Floor 1020 15th Street Denver, CO 80202	(303) 844-5421	All States west of the Mississippi River

OSMRE: EASTERN FIELD OFFICES

FIELD OFFICE & ADDRESS:	TELEPHONE NO:	RESPONSIBLE FOR:
Birmingham Field Office Office of Surface Mining 228 West Valley Ave., Rm. 302 Homewood, AL 35209	(205) 254-0890	Alabama, Georgia and Mississippi
Springfield Field Office Office of Surface Mining 600 East Monroe St., Rm. 20 Springfield, IL 62701	(217) 492-4495	Illinois
Indianapolis Field Office Office of Surface Mining 46 East Ohio St., Rm. 520 Indianapolis, IN 46204	(317) 269-2626	Indiana
Lexington Field Office Office of Surface Mining 340 Legion Dr., Suite 28 Lexington, KY 40504	(606) 233-7327	Kentucky
Columbus Field Office Office of Surface Mining 2242 S. Hamilton Rd., Rm. 202 Columbus, OH 43232	(614) 866-0578	Ohio & Michigan
Harrisburg Field Office Harrisburg Transportation Center 3rd Floor, Suite 3C 4th & Market Sts. Harrisburg, PA 17101	(717) 782-4036	Pennsylvania, Rhode Island, Massachusetts

Knoxville Field Office Office of Surface Mining 530 Gay St., S.W., Suite 400 Knoxville, TN 37902	(615) 673-4504	Tennessee
Big Stone Gap Field Office Office of Surface Mining P.O. Box 626 Big Stone Gap, VA 24219	(703) 523-4303	Virginia & North Carolina
Charleston Field Office Office of Surface Mining 603 Morris Street Charleston, WV 25301	(304) 347-7158	West Virginia & Maryland

EASTERN FIELD OPERATIONS

Administrator Office of Surface Mining 10 Parkway Center Pittsburg, PA 15220	(412) 937-2828	All States east of the Mississippi River

WESTERN STATE REGULATORY AGENCIES

STATE	AGENCY:	ADDRESS:	TELEPHONE:
AK	Department of Natural Resources	Pouch M Juneau, AK 99811	(907) 456-2400
AR	Department of Pollution Control and Ecology	8001 National Drive Little Rock, AR 72209	(501) 562-7444
CO	Department of Natural Resources Division of Mined Land Reclamation	423 Centennial Bldg. 1313 Sherman St. Room 424 Denver, CO 80203	(303) 866-3567
IA	Department of Soil Conservation	Wallace State Office Building Des Moines, IA 50319	(515) 281-5851
KS	Mined Land Conservation & Reclamation Board	107 West 11th St. P.O. Box 1418 Pittsburg, KS 66762	(316) 231-8540
LA	Department of Natural Resources	Office of Conservation P.O. Box 44275 Baton Rouge, LA 70804-4275	(504) 342-5528

MO	Land Reclamation Commission	117 East Dunkin P.O. Box 176 Jefferson City, MO 65102	(314) 751-4041
MT	Department of State Lands	Capitol Station 1625 11th Avenue Helena, MT 59620	(406) 444-2074
NM	Energy & Minerals Department	Mining & Minerals Division 525 Camino de las Marquez Santa Fe, NM 87501	(505) 827-5974
ND	Public Service Commission	Capitol Building Bismarck, ND 58505	(701) 224-2249
OK	Department of Mines	4040 N. Lincoln Blvd. Suite 107 Oklahoma City, OK 73105	(405) 521-3859
OR	Dept. of Geology & Mineral Indus.	1129 S. Santiam Rd. Albany, OR 97321	(503) 967-2039
TX	Railroad Commission of Texas	P.O. Drawer 12967 Capitol Station Austin, TX 78711	(512) 463-6900
UT	Dept. of Natural Resources, Div. of Oil, Gas & Mining	3-Triad Center #350 355 West N. Temple Salt Lake City, UT 84180-1203	(801) 538-5340
WY	Deptartment of Environmental Quality, Div. of Land Quality	Equality State Bank Building 3rd Floor 122 W. 125th St. Cheyenne, WY 82002	(307) 777-7756

EASTERN STATE REGULATORY AGENCIES

AL	Alabama Surface Mining Commission	Box 2390 Jasper, AL 35502-2390	(205) 221-4130
GA	Surface Mined Land Reclamation Program	P.O. Box 233 Macon, GA 31202	(912) 744-3346
KY	Natural Resources & Environmental Protection Cabinet	6th Floor Capitol Plaza Tower Frankfort, KY 40601	(502) 564-2141

and:	Department of Surface Mining Reclamation & Enforcement	3rd Floor Capitol Plaza Tower Frankfort, KY 40601	(502) 564-6940
MD	Energy Administrator	Tawes State Office Building 580 Taylor Avenue Annapolis, MD 21401	(301) 269-2788
and:	Dept. of Natural Resources, Bureau of Mines	69 Hill Street Frostburg, MD 21532	(301) 689-4136
MI	Dept. of Natural Resources	Stevens T. Mason Bldg. P.O. Box 30028 Lansing, MI 48909	(517) 373-2329
MS	Dept. of Natural Resources	2380 Hwy. 80 West Jackson, MS 39216	(601) 961-5099
and:	Bureau of Geology Div. of Mining & Reclamtion	2525 Northwest St. P.O. Box 5348 Jackson, MS 39216	(601) 354-6228
OH	Dept. of Natural Resources	1885 Fountain Square Bldg. D-3 Columbus, OH 43224	(614) 265-1092
PA	Department of Environmental Resources	P.O. Box 2063 Harrisburg, PA 17120	(717) 787-2267
TN	Bureau of Environment Dept. of Health & Environment	T.E.R.R.A. Bldg. 150 9th Ave. North Nashville, TN 37203	(615) 741-3657
VA	Dept. of Mines, Minerals & Energy	2201 W. Board St. Richmond, VA 23220	(804) 257-0330
WV	Dept. of Energy	1615 Washington St. E. Charleston, WV 25311	(304) 348-3500

APPENDIX 'A'

REGRESSION ANALYSIS

(i) Notes on data collection.

(ii) Notes on data recording.

(iii) OSMRE Approved regression analysis program: LISTING.

(iv) OSMRE Approved regression analysis program: USE.

(v) OSMRE Approved regression analysis program: EXAMPLE.

(vi) Notes on Vibra-Tech regression analysis program.

(vii) Example of V-T regression analysis:
(same data as in (v) above)

(viii) Example of regression curves, and "blaster aid" curves
(V-T Analysis, same data)

(ix) V-T regression analysis calculator program.

APPENDIX 'A': REGRESSION ANALYSIS

(i) NOTES ON DATA COLLECTION:

In addition to the rules outlined in Chapter 9, pages 77-78, the fundamental principle in good data collection is simple common sense. The supporting principle is consistency. When it is remembered that these are basically exercises in comparisons, then these fundamentals become obvious.

To commence any analysis exercise of this type, the area in which the analysis is to be performed should be documented and studied. All the examples in this Appendix will be based on the fictitious Blackrock Coal Company, of Blackrock, Wyorado, and the studies and analyses based on their #2 Pit Overburden will be typical of a small surface mine operation in the West, but, of course, will also be fictitious.

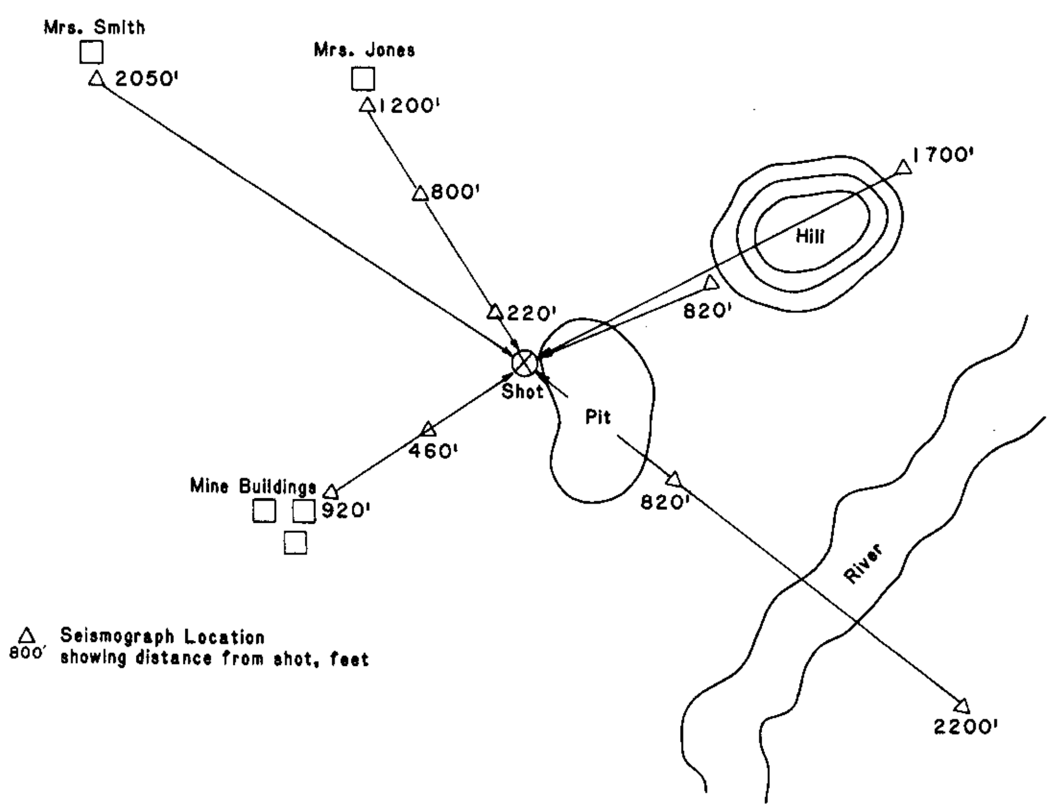


Figure 56.
"Eaglefeather Mine, Blackrock, Wyorado."

Appendix 'A': Regression analysis

Let it be assumed that the area surrounding the Blackrock #2 Pit be as shown in Figure 56, on the previous page. The pit itself is some 1000 ft. northeast of the mine complex, and the major terrain features are a hill, 500 ft. high, 1000 ft. northeast of the pit, and a river 1600 ft. southeast of it. Seismograph readings have been taken at all of the marked seismograph locations, for both coal and overburden shots, and the results have not seemed to have brought any real help. The attenuation formula developed did not offer any real advantage over the scaled distance rule - or over the DuPont Handbook formula, and the co-efficient of determination - the "goodness of fit" - at a disappointing .56 looked more like a "badness of fit".

This is a situation that does not encourage much enthusiasm about the accuracy of statistical prediction techniques!

First: COAL and OVERBURDEN results (as well as PRE-SPLIT results) must be separated, and analyzed separately.

Second: Look again at Figure 56.

There may be valid reasons why it was desirable to take measurements behind the hill 1700 ft. from the blast, and across the river 2200 ft. from it. The possibility of complaints at those sites is one very good reason to monitor. The facts that the open pit and a hill lie between one site and the blast, and the open pit and a river lie between the other site and the blast are also very good reasons why those results should be excluded from any regression analysis.

In fact, both seismograph positions across the pit from the shot, at 820 ft. distance, are also less than desirable. In this instance, the area generally behind the blasting location should again be separated from the area in front and across the pit, unless of course consistent results indicate that the vibration attenuation characteristics are similar in the two areas. This is unlikely.

If the western half of the area is selected for the study, it can then be recognized that:

(a) the topography and geology are generally similar;

(b) no vibration-absorbing features: pit, hill, or river, are present to cause untypically low results; and

(c) the remainder of the area contains all significant or critical structures: the mine complex itself, and both the Smith and Jones residences, where complaints have originated in the past.

Allowing that, for the sake of convenience, all overburden blasting will take place in the marked 'shot' area, and that the explosive charge weight per delay will vary from 50-1500 lbs., if the data collected is confined to this general area, and if the rules set down in Chapter 9 are followed, then the results will be much more encouraging.

A new vibration prediction analysis may now be performed:

(ii) NOTES ON DATA RECORDING:

Again, reference should be made to Chapter 9, and also to Chapter 12. It has been already agreed that distances and explosive charge weights will be measured and not guessed. Asking some blasters for exact, measured distances and charge weights is often something of a problem, and will give an indication of how seldom these two vital measurements are known, for certain. It is essential however that the number of unknown factors be reduced as much as possible; hence, NO GUESSING!

What is the goal of the analysis? If it is to determine the suitability of a low scaled distance, or to predict a velocity at a low scaled distance, then <u>some</u> of the data at least must be measured at or below these <u>low</u> scaled distances. Although the likelihood of real damage at a high scaled distance - say 100 or more - is virtually non-existent, it is a fact that householders can and do complain at those high scaled distances. If damage complaints are to be countered by reference to, and prediction made at high scaled distances, then <u>some</u> of the data, at least, must be measured at or above these <u>high</u> scaled distances. Even if the vibration traces are flat, some recordings should be made at high scaled distances. This points again to the major disadvantage of the seismically triggered unit. It is very convenient and sometimes essential when measuring close in to the blast, at a low scaled distance, but at a high scaled distance it may not record at all! Under complaint situations, a flat trace, made at the time the shot was fired, is much better than no record at all, even when it is noted that the instrument did not trigger.

Again, if it is desired to predict into a high particle velocity range, some at least of the data should be recorded at, or very near to, the highest velocity desired. Maximum charge weights per delay for reliable prediction should not greatly exceed charge weights in the gathered data, as also minimum distances predicted should not be very much less than the actual closest distances at which vibrations were measured. While it is recognized that the fundamental numerical operator in this is the non-dimensional scaled distance, and as such it <u>should</u> apply to <u>any</u> distance or charge weight, nevertheless large excursions from experimentally gathered distances or charge weights imply significantly different blasthole diameters. Significantly altered shot geometry can have an effect on the vibration levels (see Chapter 3, page 22, Control of Adverse Effects). To this extent, therefore, care and common sense must be exercised not to extrapolate too far beyond the limits of the gathered data.

In accordance with all of the foregoing principles, therefore, the vibration data collection exercise has been carried out, and the Blackrock Coal Company finds that it is in possession of 31 good data points.

The following computer programs will perform regression analyses on this data, first using the OSMRE approved program, designed specifically to satisfy the requirements of the Modified Scaled Distance Formula regulation. The same data will also be processed using Vibra-Tech Engineers' simpler general purpose regression program, and comparisons and comments made on the derived output. Both programs, incidentally, produce identical formulas and predictions.

For those without easy access to a computer, these calculations are still possible using a programmable hand calculator. A typical regression analysis program that will run on a Ti 59 calculator is also included in this Appendix. Although the input is directly in Scaled Distance versus Velocity (Scaled Distances have to be calculated separately prior to running the program, as opposed to entering distance, charge weight and velocity), the output is precisely the same as the computer programs. Any differences that might be noted between any of these programs will be very small indeed, and will be due simply to variations in the accuracies of the operating systems. As such, they may be ignored. Any significant difference will be found to be due to an error in program or data entry.

```
10 REM *******************************************************************
20 REM
30 REM    PROGRAM "BLAST"
40 REM    Written By: Gregory L. Morlock
50 REM                U.S. Office of Surface Mining
60 REM                Western Technical Center
70 REM                1020 15th St.
80 REM                Denver, CO 80202
90 REM
100 REM
110 REM      This program performs a linear regression analysis of blast
120 REM      data and will predict peak particle velocity at a given
130 REM      distance from a blast.  Also, based upon your data, this program
140 REM      will produce a table showing the maximum charge-per-delay for
150 REM      various distances.  Three items of input data are needed per
160 REM      shot; the distance from the shot, the maximum weight of explosive
170 REM      per delay, and the measured maximum peak particle velocity.
180 REM      This program will not extrapolate peak velocities. If you need to
190 REM      know particle velocities for a certain scaled distance, you must
200 REM      have measured data above and below that scaled distance.
210 REM      The program also provides information about the 'goodness of fit'
220 REM      of the collected data.  This program also provides a
230 REM      graphical output to the screen. A minimum of 30 data pairs are
240 REM      needed for a reliable analysis (assuming that good data collection
250 REM      techniques have been adhered to) but, for non-critical purposes it
260 REM      is possible to derive results from a lesser number.
270 REM
280 REM *******************************************************************
290 KEY OFF
300 OPTION BASE 1
310 SCREEN 0: WIDTH 80: COLOR 15,1,1
320 DIM D(99),W(99),VELOC(99),DISCRP$(3),X(99),Y(99)
330 REM
340 IFLG%=0
350 CLS
360 PRINT" O S M   B L A S T   V I B R A T I O N   R E G R E S S I O N   A N A L
 Y S I S"
370 PRINT
380 REM  Choose data input method
390 PRINT"Do you want to: 1. Read data from a disk file?"
400 PRINT"                2. Update data or edit from a disk file?"
410 PRINT"                3. List files on disk?"
420 PRINT"                4. Input new data?"
430 ON ERROR GOTO 390
440 INPUT "[Default: 4] ";ANS1%
450 ON ERROR GOTO 0
460 REM
470 IF ANS1%<0 OR ANS1%>4 THEN PRINT: PRINT"?--Invalid entry. Re-enter.":
GOTO 390
480 ON ANS1% GOTO 500,550,610,690
490 GOTO 690
500 PRINT
510 INPUT "Enter file name for data file--> ",FILE$
520 IF FILE$="" GOTO 500
530 GOSUB 1090 'Readit subroutine
540 GOTO 800
550 PRINT
560 INPUT "Enter file name for data file--> ",FILE$
570 IF FILE$="" GOTO 550
580 GOSUB 1090 'Readit subroutine
```

```
590 GOSUB 1540 'Manual subroutine
600 GOTO 800
610 CLS
620 FILES
630 INPUT "Press <ENTER> to continue",ANS$
640 PRINT
650 GOTO 390
660 REM
670 REM Default call for manual data input and optional save.
680 REM
690 N%=0
700 PRINT
710 PRINT "Enter vibration study description - 3 lines -":PRINT" Should include
DATE, NAME & LOCATION"
720 PRINT
730 FOR I%=1 TO 3: LINE INPUT DISCRP$(I%)
740 NEXT I%
750 REM
760 GOSUB 1540 'Manual subroutine
770 REM
780 REM  Start Calculations
790 REM
800 SDMAX=D(1)/SQR(ABS(W(1)))
810 SDMIN=SDMAX
820 REM
830 DMAX=0: EMAX=0
840 FOR I%=1 TO N%
850 IF D(I%)>DMAX THEN DMAX=D(I%)
860 IF W(I%)>EMAX THEN EMAX=W(I%)
870 NEXT I%
880 FOR I%=1 TO N%
890  DS=D(I%)/SQR(ABS(W(I%)))
900  X(I%)=LOG(DS)
910  Y(I%)=LOG(VELOC(I%))
920  REM
930  IF DS<SDMIN THEN SDMIN=DS
940  IF DS>SDMAX THEN SDMAX=DS
950 NEXT I%
960 REM
970 GOSUB 2450 'Regres subroutine
980 REM
990 GOSUB 2900 'Outpt subroutine
1000 REM
1010 SYSTEM
1020 END
1030 REM*********************************************************************
1040 REM SUBROUTINE READIT
1050 REM
1060 REM  This subroutine will read a previously created data file from disk.
1070 REM  The data should consist of three 80 character description lines
1080 REM  followed by the data (distance, charge, velocity).
1090 PRINT
1100 PRINT"   - Reading file. Please wait -"
1110 ON ERROR GOTO 1430
1120 OPEN FILE$ FOR INPUT AS #1
1130 ON ERROR GOTO 1380
1140 REM
1150 FOR I%=1 TO 3
1160 LINE INPUT #1,DISCRP$(I%)
1170 NEXT I%
1180 REM
1190 N%=0
```

```
1200 REM
1210 REM Read loop
1220 REM
1230 ON ERROR GOTO 1380
1240 IF EOF(1) THEN GOTO 1310
1250 N%=N%+1
1260 INPUT#1,D(N%),W(N%),VELOC(N%)
1270 GOTO 1240
1280 REM
1290 REM  End loop
1300 REM
1310 ON ERROR GOTO 0
1320 CLS
1330 REM
1340 GOTO 1480
1350 REM
1360 REM Error section
1370 REM
1380 RESUME 1390
1390 PRINT
1400 PRINT"---Error while trying to read ";FILE$;" ---"
1410 PRINT:INPUT "Enter another file name for data--> ",FILE$
1420 GOTO 1090
1430 RESUME 1440
1440 PRINT
1450 PRINT"---Error while trying to open ";FILE$;" ---"
1460 PRINT:INPUT "Enter another file name for data--> ",FILE$
1470 GOTO 1090
1480 CLOSE #1
1490 RETURN
1500 REM*********************************************************************
1510 REM SUBROUTINE MANUAL
1520 REM
1530 REM This routine will allow the user to manually input data.
1540 REM Start of data input
1550 REM
1560 PRINT
1570 PRINT "DATA INPUT SECTION."
1580 PRINT
1590 PRINT "Data must be entered in consistent units:"
1600 PRINT "It is usual for distance to be in `feet´,"
1610 PRINT "charge-per-delay to be in `pounds´, and peak"
1620 PRINT "particle velocity to be in `inches-per-second.´"
1630 PRINT
1640 PRINT "Press <ENTER> key alone after entering all data."
1650 REM
1660 REM Data input loop
1670 REM
1680 REM#####################################################################
1690 N%=N%+1
1700 PRINT
1710 PRINT USING "Enter distance No. ##------------------->";N%;
1720 INPUT " ",D(N%)
1730 IF D(N%)=0 THEN GOTO 1860
1740 PRINT USING "Enter maximum charge-per-delay No. ##-->";N%;
1750 INPUT " ",W(N%)
1760 IF W(N%)=0 THEN GOTO 1860
1770 PRINT USING "Enter particle velocity No. ##---------->";N%;
1780 INPUT " ",VELOC(N%)
1790 IF VELOC(N%)=0 THEN GOTO 1860
1800 GOTO 1690
1810 REM
```

```
1820 REM End of data input loop
1830 REM
1840 REM##########################################################################
1850 REM
1860 N%=N%-1
1870 IF N%<30 THEN PRINT:PRINT "--WARNING-- A valid analysis requires 30 or more
 data pairs"
1880 REM
1890 REM Give user a chance to edit input data
1900 GOSUB 3510   Edit subroutine
1910 REM
1920 PRINT
1930 INPUT "Do you wish to save this data to disk? [Default: Y]";ANS$
1940 IF ANS$="" THEN GOTO 1980
1950 IF LEFT$(ANS$,1)="N" OR LEFT$(ANS$,1)="n" THEN RETURN
1960 IF LEFT$(ANS$,1)<>"Y" AND LEFT$(ANS$,1)<>"y" THEN PRINT:PRINT"?---Invalid i
nput. Re-enter.": GOTO 1920
1970 REM
1980 PRINT
1990 PRINT "You can write a new file or overwrite an old file."
2000 INPUT "Enter data file name--> ",FILE$
2010 IF FILE$="" THEN GOTO 1980
2020 ON ERROR GOTO 2060
2030 OPEN FILE$ FOR OUTPUT AS #1
2040 GOTO 2100
2050 REM Error recovery
2060 PRINT
2070 PRINT "---Error--could not open ";FILE$
2080 GOTO 1920
2090 REM
2100 ON ERROR GOTO 2310
2110 REM
2120 REM Write data to file
2130 REM
2140 PRINT
2150 PRINT " - Writing file.  Please Wait -"
2160 FOR I%=1 TO 3
2170  PRINT#1, USING "&";DISCRP$(I%)
2180 NEXT I%
2190 REM
2200 FOR I%=1 TO N%
2210  PRINT#1,USING "########.# #######.# #####.####";D(I%),W(I%),VELOC(I%)
2220 NEXT I%
2230 REM
2240 CLOSE #1
2250 ON ERROR GOTO 0
2260 CLS
2270 GOTO 2350
2280 REM
2290 REM Error section
2300 REM
2310 PRINT
2320 PRINT "---An error occurred while writing the data file."
2330 STOP
2340 REM
2350 RETURN
2360 REM**********************************************************************
2370 REM SUBROUTINE REGRES
2380 REM
2390 REM This subroutine performs a standard linear regression analysis.
2400 REM It finds the line Y=BO+B1X from a scattered data set.
2410 REM Input consists of the scattered data arrays X and Y and N, the
```

```
2420 REM number of data pairs.  This subroutine outputs: B0-the Y intercept;
2430 REM B1-the slope; S-the sample standard deviation; Xbar-the mean of the
2440 REM X's; SSX-the sum of the squares of X; and r-the coefficient of corr.
2450 SUMX=0
2460 SUMY=0
2470 SUMX2=0
2480 SUMXY=0
2490 SUMY2=0
2500 REM
2510 REM Calculate the sums used for calculating the sums of squares
2520 REM
2530 FOR I%=1 TO N%
2540  SUMX=SUMX+X(I%)
2550  SUMY=SUMY+Y(I%)
2560  SUMX2=SUMX2+X(I%)^2
2570  SUMY2=SUMY2+Y(I%)^2
2580  SUMXY=SUMXY+X(I%)*Y(I%)
2590 NEXT I%
2600 REM
2610 REM Calculate the sums of squares
2620 REM
2630 XN=N%
2640 IF N%<3 THEN PRINT:PRINT"---Error--- Must have more data!":STOP
2650 REM
2660 SSX=SUMX2-SUMX^2/XN
2670 SSY=SUMY2-SUMY^2/XN
2680 SSXY=SUMXY-SUMX*SUMY/XN
2690 REM
2700 REM Calculate the means
2710 REM
2720 YBAR=SUMY/XN
2730 XBAR=SUMX/XN
2740 REM
2750 REM Calculate the coefficients
2760 REM
2770 B1=SSXY/SSX
2780 B0=YBAR-B1*XBAR
2790 REM
2800 REM Calculate the sample standard deviation and the coefficient of corr.
2810 REM
2820 S=SQR((SSY-B1*SSXY)/XN)
2830 R=SSXY/SQR(SSX*SSY)
2840 REM
2850 RETURN
2860 REM*********************************************************************
2870 REM SUBROUTINE OUTPT
2880 REM This subroutine provides the output choices.
2890 REM
2900 CLS
2910 R2=R^2
2920 Q=EXP(B0+2*S)
2930 PRINT"O U T P U T   S E C T I O N"
2940 PRINT
2950 PRINT USING "The 95% confidence level equation is: PV=####.###(Ds)^##.##";Q
;B1
2960 PRINT USING "The coefficient of determination (r^2 - 'goodness of fit') is:
 #.##";R2
2970 PRINT USING "This analysis has ### data pairs.";N%
2980 IF N%<30 THEN PRINT "--WARNING-- A valid analysis requires 30 or more pairs
."
2990 REM
3000 REM Find the applicable scaled distances
```

```
3010 REM PV for 0 to 300 ft
3020 PV=1.25
3030 GOSUB 4640 'Solve subroutine
3040 IF DS1<SDMIN THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a low enough scaled distance to predict for a":PRINT" distance for 0 to 300 ft."
:GOTO 3110
3050 IF DS1>SDMAX THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a high enough scaled distance to predict for a":PRINT" distance for 0 to 300 ft.
":GOTO 3110
3060 PRINT
3070 PRINT USING "The scaled distance for 0 to 300 ft. is: ###.##";DS1
3080 REM
3090 REM PV for 301 to 5000 ft
3100 REM
3110 PV=1!
3120 GOSUB 4640 'Solve subroutine
3130 IF DS1<SDMIN THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a low enough scaled distance to predict for a":PRINT" distance for 300 to 5000 f
t.":GOTO 3200
3140 IF DS1>SDMAX THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a high enough scaled distance to predict for a":PRINT" distance for 300 to 5000
ft.":GOTO 3200
3150 PRINT
3160 PRINT USING "The scaled distance for 301 ft. to 5000 ft. is: ###.##";DS1
3170 REM
3180 REM PV for 5001 ft and beyond
3190 REM
3200 PV=.75
3210 GOSUB 4640 'Solve subroutine
3220 IF DS1<SDMIN THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a low enough scaled distance to predict for a":PRINT" distance for 5000 ft and b
eyond.":GOTO 3290
3230 IF DS1>SDMAX THEN PRINT:PRINT"---Error---":PRINT"You do not have data with
a high enough scaled distance to predict for a":PRINT" distance for 5000 ft and
beyond.":GOTO 3290
3240 PRINT
3250 PRINT USING "The scaled distance for 5001 ft. and beyond is: ###.##";DS1
3260 REM
3270 REM Ask for options
3280 REM
3290 PRINT
3300 PRINT"Do you want: 1. Calculated charge per delay for given distance?"
3310 PRINT"             2. Printed table of distance vs. charge per delay and su
mmary?"
3320 PRINT"             3. Scaled Distance for any maximum velocity?"
3330 PRINT"             4. Maximum velocity for any Scaled Distance?"
3340 PRINT"             5. Plot of data and 95% confidence level line?"
3350 PRINT"             6. Quit?"
3360 INPUT "[Default: 6]";ANS1%
3370 IF ANS1%=0 THEN GOTO 3450
3380 REM
3390 IF ANS1%<1 OR ANS1%>6 THEN PRINT:PRINT"?--Invalid input.  Re-enter.":     G
OTO 3290
3400 IF ANS1%=1 THEN GOSUB 4750: CLS:GOTO 3290
3410 IF ANS1%=2 THEN GOSUB 5200: CLS:GOTO 3290
3420 IF ANS1%=3 THEN GOSUB 6480: CLS:GOTO 3290
3430 IF ANS1%=4 THEN GOSUB 6810: CLS:GOTO 3290
3440 IF ANS1%=5 THEN GOSUB 7210: CLS:GOTO 3290
3450 RETURN
3460 REM*********************************************************************
3470 REM SUBROUTINE EDIT
3480 REM This subroutine will allow the editing and printout of input data
```

```
3490 REM Printout section
3500 REM
3510 PRINT
3520 INPUT "Do you want a print-out of the input data? [Default: N] ";ANS$
3530 IF ANS$="" THEN GOTO 3850
3540 IF LEFT$(ANS$,1)="N" OR LEFT$(ANS$,1)="n" THEN GOTO 3850
3550 IF LEFT$(ANS$,1)<>"Y" AND LEFT$(ANS$,1)<>"y" THEN PRINT:PRINT"?--Invalid in
put.  Re-enter.": GOTO 3510
3560 REM
3570 PRINT
3580 PRINT"     --  Please Wait, Writing to Printer  --"
3590 REM
3600 IPAGE%=0
3610 NCOUNT%=0
3620 REM
3630 IPAGE%=IPAGE%+1
3640 LPRINT CHR$(12); : LPRINT"Input data summary for:": LPRINT
3650 FOR I%=1 TO 3
3660  LPRINT DISCRP$(I%)
3670 NEXT I%
3680 LPRINT
3690 LPRINT USING "NOTE: Scaled Distance for reference only.
      Page,##";IPAGE%: LPRINT
3700 LPRINT "     Line No.      Distance/ft.      Charge/lb.    Peak Velocity/ips
Scaled Dist.*"
3710 REM
3720 ICOUNT%=0
3730 REM
3740 ICOUNT%=ICOUNT%+1
3750 IF ICOUNT%>50 THEN GOTO 3630
3760 NCOUNT%=NCOUNT%+1
3770 DST=D(NCOUNT%)/SQR(ABS(W(NCOUNT%)))
3780 LPRINT USING "         ###        ##########    ##########       ###########.##
     ########.#";NCOUNT%;D(NCOUNT%);W(NCOUNT%);VELOC(NCOUNT%);DST
3790 REM
3800 IF NCOUNT%<N% GOTO 3740
3810 IFLG%=1
3820 REM
3830 REM Screen printout
3840 REM
3850 NCOUNT%=0
3860 CLS
3870 PRINT DISCRP$(1)
3880 PRINT DISCRP$(2)
3890 PRINT DISCRP$(3)
3900 PRINT
3910 PRINT "* Note: Scaled Distance for reference only."
3920 PRINT "     Line No.      Distance/ft.      Charge/lb.    Peak Velocity/ips   S
caled Dist.*"
3930 PRINT
3940 REM
3950 ICOUNT%=0
3960 REM
3970 ICOUNT%=ICOUNT%+1
3980 IF ICOUNT%<16 THEN GOTO 4050
3990 INPUT "Do you want to see more data? [Default: Y]";ANS$
4000 IF ANS$="" THEN GOTO 3860
4010 IF LEFT$(ANS$,1)="N" OR LEFT$(ANS$,1)="n" THEN GOTO 4120
4020 IF LEFT$(ANS$,1)<>"Y" AND LEFT$(ANS$,1)<>"y" THEN PRINT:PRINT"?--Invalid in
put.  Re-enter.": GOTO 3990
4030 GOTO 3860
4040 REM
```

```
4050 NCOUNT%=NCOUNT%+1
4060 DST=D(NCOUNT%)/SQR(ABS(W(NCOUNT%)))
4070 PRINT USING "      ###        ##########    ##########      ###########.##
    ########.#";NCOUNT%;D(NCOUNT%);W(NCOUNT%);VELOC(NCOUNT%);DST
4080 IF NCOUNT%<N% THEN GOTO 3970
4090 REM
4100 REM Editing section
4110 REM
4120 PRINT
4130 PRINT"Do you wish to: 1. Edit vibration study description?"
4140 PRINT"                2. Edit data?"
4150 PRINT"                3. Re-print data?"
4160 PRINT"                4. Quit editing?"
4170 INPUT "[Default: 4] ";ANS1%
4180 IF ANS1%=0 THEN GOTO 4260
4190 REM
4200 IF ANS1%<1 OR ANS1%>4 THEN PRINT:PRINT"?--Invalid response.  Re-enter":   G
OTO 4120
4210 IF ANS1%=4 THEN GOTO 4260
4220 IF ANS1%=3 THEN GOTO 3510
4230 IF ANS1%=2 THEN GOSUB 4300: GOTO 4120 'Edit data
4240 IF ANS1%=1 THEN GOSUB 4490: GOTO 4120 'Edit description
4250 REM
4260 RETURN
4270 REM*****************************************************************
4280 REM EDIT DATA
4290 REM
4300 PRINT
4310 INPUT "Enter line number to edit, press <ENTER> to quit --> ",NED%
4320 IF NED%=0 THEN GOTO 4450
4330 IF NED%<1 OR NED%>N% THEN PRINT:PRINT"?---N out of range.  Re-enter.":
 GOTO 4300
4340 PRINT
4350 PRINT USING "Enter distance No. ## ------------------>";NED%;
4360 INPUT " ",D(NED%)
4370 IF D(NED%)=0 THEN GOTO 4340
4380 PRINT USING "Enter maximum charge-per-delay No. ## -->";NED%;
4390 INPUT " ",W(NED%)
4400 IF W(NED%)=0 THEN GOTO 4380
4410 PRINT USING "Enter particle velocity No. ## --------->";NED%;
4420 INPUT " ",VELOC(NED%)
4430 IF VELOC(NED%)=0 THEN GOTO 4410
4440 GOTO 4300
4450 RETURN
4460 REM*****************************************************************
4470 REM EDIT DESCRIPTION
4480 REM
4490 PRINT
4500 PRINT "The current description is:": PRINT
4510 PRINT DISCRP$(1)
4520 PRINT DISCRP$(2)
4530 PRINT DISCRP$(3)
4540 PRINT:PRINT "Input 3 new lines of description. (Follow each line by <ENTER>
 )"
4550 FOR I%=1 TO 3
4560  LINE INPUT DISCRP$(I%)
4570 NEXT I%
4580 RETURN
4590 REM ****************************************************************
4600 REM SOLVE SUBROUTINE
4610 REM This subroutine will find the scaled distance for a given particle
4620 REM velocity.  The scaled distance approximated by intersecting the
```

```
4630 REM particle velocity with the prediction line plus 2 standard devs.
4640 IF N%<3 THEN PRINT:PRINT "---Insufficient data for analysis: MUST have at l
east 3 pairs---":STOP
4650 IF N%>99 THEN PRINT:PRINT"---Too many data points.---":PRINT"Data arrays ha
ve been overwritten":STOP
4660 REM
4670 DS1=EXP((LOG(PV)-B0-2*S)/B1)
4680 REM
4690 RETURN
4700 REM*********************************************************************
4710 REM SUBROUTINE INTRAT
4720 REM This subroutine allows the user to interactively try different
4730 REM blasting scenarios and have the results printed to the screen.
4740 REM
4750 PRINT
4760 INPUT "Enter distance to critical structure. Press <ENTER> to quit--> ",DIS
TAN
4770 IF DISTAN=0 THEN GOTO 5000
4780 IF DISTAN<0 THEN PRINT:PRINT"Error -- Distance must be positive.":  GOTO
4750
4790 REM
4800 REM Find the maximum allowable particle velocity for the given distance.
4810 REM
4820 GOSUB 7140 'DISTAN SUBROUTINE
4830 REM
4840 REM Find the scaled distance for the maximum particle velocity.
4850 REM
4860 GOSUB 4640 'Solve Subroutine
4870 REM
4880 REM Check Scaled distance range
4890 REM
4900 IF DS1<SDMIN THEN GOSUB 5020: GOTO 4750
4910 IF DS1>SDMAX THEN GOSUB 5090: GOTO 4750
4920 REM
4930 REM Output results
4940 REM
4950 W=(DISTAN/DS1)^2
4960 PRINT
4970 PRINT USING "At a distance of ##### ft., you may use a";DISTAN
4980 PRINT USING "maximum charge of ###### lbs./delay";W
4990 GOTO 4750
5000 RETURN
5010 REM ***********ERROR OUTPUT********
5020 PRINT
5030 PRINT"---Error---"
5040 PRINT USING "The lowest scaled distance for your data is ###.##";SDMIN
5050 PRINT "You do not have data with a low enough scaled distance"
5060 PRINT USING "to predict for a distance of ##### ft.";DISTAN
5070 RETURN
5080 REM***********ERROR OUTPUT********
5090 PRINT
5100 PRINT"---Error---"
5110 PRINT USING "The highest scaled distance for your data is ###.##";SDMAX
5120 PRINT "You do not have data with a high enough scaled distance"
5130 PRINT USING "to predict for a distance of ##### ft.";DISTAN
5140 RETURN
5150 REM*********************************************************************
5160 REM SUBROUTINE TABLE
5170 REM This subroutine provides a table of maximum charge/delay for
5180 REM different distances
5190 REM
5200 PRINT
```

```
5210 PRINT "  -    Printing table.  Please wait.  -"
5220 REM
5230 REM Output for 0-300 ft
5240 REM
5250 PV=1.25
5260 GOSUB 4640 'SUBROUTINE SOLVE
5270 IFLG%=1
5280 REM
5290 LPRINT CHR$(12);
5300 LPRINT "OSM Charge Weight per Delay Table for 0 - 300 ft"
5310 LPRINT USING "based on ## data pairs for:";N%
5320 LPRINT DISCRP$(1)
5330 LPRINT DISCRP$(2)
5340 LPRINT DISCRP$(3)
5350 LPRINT
5360 LPRINT USING "The scaled distance for this distance range is ###.##";DS1
5370 LPRINT
5380 LPRINT "      Dist(ft)  Charge(lb)      Dist(ft)  Charge(lb)      Dist(ft)  Ch
arge(lb)"
5390 REM
5400 IF DS1<SDMIN THEN GOSUB 6320: GOTO 5570
5410 IF DS1>SDMAX THEN GOSUB 6380: GOTO 5570
5420 REM
5430 FOR I%=50 TO 132 STEP 2
5440  D1=I%
5450  D2=D1+84
5460  D3=D1+168
5470  C1=(D1/DS1)^2
5480  C2=(D2/DS1)^2
5490  C3=(D3/DS1)^2
5500  LPRINT USING "      #####  -  ######        #####  -  ######         ####
#  -  ######";D1;C1;D2;C2;D3;C3
5510 NEXT I%
5520 LPRINT
5530 IF N%<30 THEN : LPRINT"---WARNING--- A valid analysis requires 30 or more d
ata pairs."
5540 REM
5550 REM Output for 301 to 5000 ft
5560 REM
5570 PV=1!
5580 GOSUB 4640 'SUBROUTINE SOLVE
5590 REM
5600 IF C3=0 GOTO 3290
5610 IF D3=0 GOTO 3290
5620 LPRINT CHR$(12);
5630 LPRINT "OSM Charge Weight per Delay Table for 301 - 5000 ft"
5640 LPRINT USING "based on ## data pairs for:";N%
5650 LPRINT DISCRP$(1)
5660 LPRINT DISCRP$(2)
5670 LPRINT DISCRP$(3)
5680 LPRINT
5690 LPRINT USING "The scaled distance for this distance range is ###.##";DS1
5700 LPRINT
5710 LPRINT "      Dist(ft)  Charge(lb)      Dist(ft)  Charge(lb)      Dist(ft)  Ch
arge(lb)"
5720 REM
5730 IF DS1<SDMIN THEN GOSUB 6320: GOTO 5960
5740 IF DS1>SDMAX THEN GOSUB 6380: GOTO 5960
5750 REM
5760 FOR I%=350 TO 1850 STEP 50
5770  D1=I%
5780  D2=D1+1550
```

```
5790  D3=D1+3100
5800  C1=(D1/DS1)^2
5810  C2=(D2/DS1)^2
5820  C3=(D3/DS1)^2
5830  LPRINT USING "       #####  -  ######           #####  -  ######         ####
#  -  ######";D1;C1;D2;C2;D3;C3
5840 NEXT I%
5850 REM
5860 D1=5000!
5870 C1=(D1/DS1)^2
5880 LPRINT USING "                                                            #####
  -  ######";D1;C1
5890 LPRINT
5900 LPRINT"Although the above charge weights-per-delay are authorized under the
"
5910 LPRINT"regulations, they may exceed, or greatly exceed, practical limitatio
ns."
5920 IF N%<30 THEN : LPRINT"---WARNING--- A valid analysis requires 30 or more d
ata pairs."
5930 REM
5940 REM Output for 5001 ft and beyond
5950 REM
5960 PV=.75
5970 GOSUB 4640 'SUBROUTINE SOLVE
5980 REM
5990 IF C3=0 GOTO 3290
6000 IF D3=0 GOTO 3290
6010 LPRINT CHR$(12);
6020 LPRINT "OSM Charge Weight per Delay Table for 5001 ft and beyond"
6030 LPRINT USING "based on ## data pairs for:";N%
6040 LPRINT DISCRP$(1)
6050 LPRINT DISCRP$(2)
6060 LPRINT DISCRP$(3)
6070 LPRINT
6080 LPRINT USING "The scaled distance for this distance range is ###.##";DS1
6090 LPRINT
6100 LPRINT "     Dist(ft)  Charge(lb)     Dist(ft)  Charge(lb)     Dist(ft)  Ch
arge(lb)"
6110 REM
6120 IF DS1<SDMIN THEN GOSUB 6320: GOTO 6310
6130 IF DS1>SDMAX THEN GOSUB 6380: GOTO 6310
6140 REM
6150 FOR I%=5050 TO 7500 STEP 50
6160  D1=I%
6170  D2=D1+2500
6180  D3=D1+5000
6190  C1=(D1/DS1)^2
6200  C2=(D2/DS1)^2
6210  C3=(D3/DS1)^2
6220  LPRINT USING "       #####  -  ######           #####  -  ######         ####
#  -  ######";D1;C1;D2;C2;D3;C3
6230 NEXT I%
6240 LPRINT
6250 LPRINT"Although the above charge weights-per-delay are authorized under the
6260 LPRINT"regulations, they may exceed, or greatly exceed, practical limitatio
ns."
6270 IF N%<30 THEN : LPRINT"---WARNING--- A valid analysis requires 30 or more d
ata pairs."
6280 GOSUB 8350 'END SUBROUTINE
6290 REM*************ERROR OUTPUT*********
6300 CLS
6310 RETURN
```

```
6320 LPRINT
6330 LPRINT"---Error---"
6340 LPRINT USING "The minimum scaled distance for this data, ###.##,";SDMIN
6350 LPRINT"is not low enough to predict for this particle velocity."
6360 RETURN
6370 REM*************ERROR OUTPUT*********
6380 LPRINT
6390 LPRINT"---Error---"
6400 LPRINT USING "The maximum scaled distance for this data, ###.##,";SDMAX
6410 LPRINT"is not high enough to predict for this particle velocity."
6420 RETURN
6430 REM*****************************************************************
6440 REM SUBROUTINE SCALE
6450 REM This subroutine will report the scaled distance for any maximum
6460 REM particle velocity.
6470 REM
6480 PRINT
6490 INPUT "Enter maximum particle velocity. Press <ENTER> to quit.---> ",PV
6500 IF PV=0 THEN GOTO 6640
6510 REM
6520 GOSUB 4640 'SUBROUTINE SOLVE
6530 REM
6540 IF PV<0 THEN PRINT:PRINT"?--Invalid input. Particle velocity must be positi
ve.": GOTO 6480
6550 REM
6560 IF DS1<SDMIN THEN GOSUB 6660: GOTO 6480
6570 IF DS1>SDMAX THEN GOSUB 6720: GOTO 6480
6580 REM
6590 PRINT
6600 PRINT USING "For a maximum particle velocity of ##.## ips";PV
6610 PRINT USING "the scaled distance will be: ###.##";DS1
6620 GOTO 6480
6630 REM
6640 RETURN
6650 REM*************ERROR OUTPUT*********
6660 PRINT
6670 PRINT"---Error---"
6680 PRINT USING "The minimum scaled distance for this data, ###.##,";SDMIN
6690 PRINT"is not low enough to predict for this maximum particle velocity."
6700 RETURN
6710 REM*************ERROR OUTPUT*********
6720 PRINT
6730 PRINT"---Error---"
6740 PRINT USING "The maximum scaled distance for this data, ###.##,";SDMAX
6750 PRINT"is not high enough to predict for this maximum particle velocity."
6760 RETURN
6770 REM*******************************************************************
6780 REM SUBROUTINE VELO
6790 REM This subroutine will report the max. velocity for any scaled distance
6800 REM
6810 PRINT
6820 INPUT "Enter scaled distance. Press <ENTER> to quit.---> ",DS1
6830 IF DS1=0 THEN GOTO 6950
6840 IF DS1<0 THEN PRINT:PRINT"?---Invalid input. Scaled distance must be positi
ve.": GOTO 6810
6850 IF DS1<SDMIN THEN GOSUB 6970: GOTO 6810
6860 IF DS1>SDMAX THEN GOSUB 7030: GOTO 6810
6870 REM
6880 PV=EXP(B0+2*S+B1*LOG(DS1))
6890 REM
6900 PRINT
6910 PRINT USING "For a scaled distance of ###.##,";DS1
```

```
6920 PRINT USING "the maximum particle velocity will be: ##.## ips";PV
6930 REM
6940 GOTO 6810
6950 RETURN
6960 REM************ERROR OUTPUT*********
6970 PRINT
6980 PRINT"---Error---"
6990 PRINT USING "The minimum scaled distance for this data is ###.##.";SDMIN
7000 PRINT "The scaled distance input is too low."
7010 RETURN
7020 REM************ERROR OUTPUT*********
7030 PRINT
7040 PRINT"---Error---"
7050 PRINT USING "The maximum scaled distance for this data is ###.##.";SDMAX
7060 PRINT "The scaled distance input is too high."
7070 RETURN
7080 REM*******************************************************************
7090 REM SUBROUTINE PARTV
7100 REM This subroutine will return the maximum regulatory allowable particle
7110 REM velocity for a given distance.  These velocities are from
7120 REM 30 CFR 816.67, 1984
7130 REM
7140 PV=.75
7150 IF DISTAN<=5000 THEN PV=1!
7160 IF DISTAN<=300 THEN PV=1.25
7170 RETURN
7180 REM*******************************************************************
7190 REM SUBROUTINE GRAPH
7200 REM
7210 LOCATE 18,14:PRINT"Min. Ds = ";SDMIN
7220 CLS
7230 LOCATE 12,5
7240 PRINT"--- Press <ENTER> when you've finished looking at graphics ---"
7250 PRINT:PRINT
7260 INPUT "Do you have a graphics board, or a PCjr? [Default: Y] ";ANS$
7270 IF ANS$="" THEN GOTO 7320
7280 IF LEFT$(ANS$,1)="Y" OR LEFT$(ANS$,1)="y" THEN GOTO 7320
7290 IF LEFT$(ANS$,1)<>"N" AND LEFT$(ANS$,1)<>"n" THEN GOTO 7250
7300 REM Return if no graphics equipment
7310 RETURN
7320 ON ERROR GOTO 7350
7330 GOTO 7410
7340 REM Error section
7350 RESUME 7360
7360 SCREEN 0: WIDTH 80: COLOR 15,1,1: CLS
7370 PRINT:PRINT"---Error---"
7380 PRINT "Check graphics capability"
7390 ON ERROR GOTO 0
7400 RETURN
7410 SCREEN 2:CLS: IF IFLG%=1 THEN LPRINT CHR$(12);
7420 REM draw xy axis and scale for plot
7430 LINE (90,155)-(590,156),1,BF:LINE (90,25)-(92,155),1,BF
7440 LINE (90,156)-(92,158),1,BF
7450 LINE (256,156)-(258,158),1,BF
7460 LINE (422,156)-(424,158),1,BF
7470 LINE (588,156)-(590,158),1,BF
7480 LINE (90,25)-(84,26),1,BF
7490 LINE (90,67)-(84,68),1,BF
7500 LINE (90,108)-(84,109),1,BF
7510 LINE (90,155)-(84,156),1,BF
7520 LOCATE 4,6:PRINT "10.0"
7530 LOCATE 9,7:PRINT "1.0"
```