

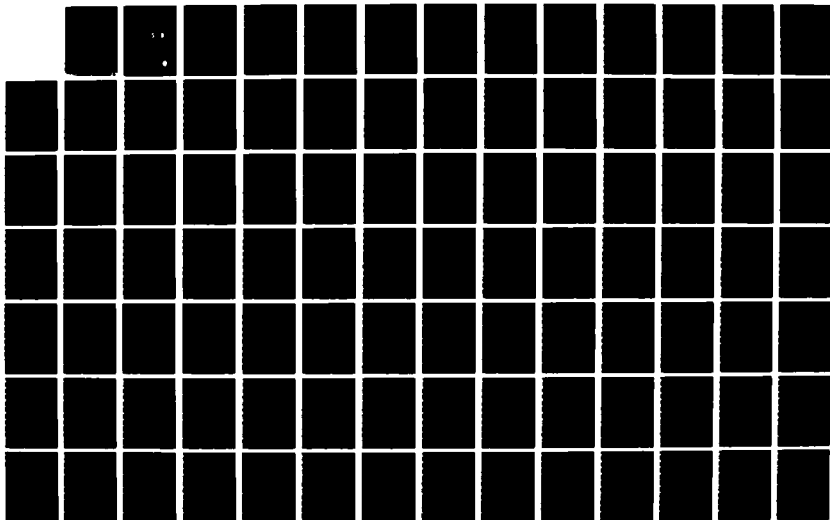
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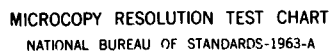
DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF  
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**DISCRIMINANT ANALYSIS OF RESPIRATORY  
SOUNDS OF PULMONARY INSUFFICIENT  
PATIENTS AND NORMAL SUBJECTS**

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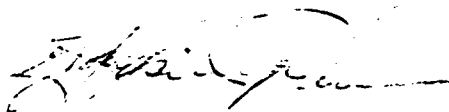
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The voluntary fully informed consent of the subjects used in this research was obtained as required by AFR 169-6.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.



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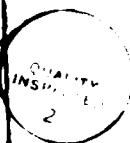
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The results of the discriminant analysis are encouraging from the standpoint that classification with mean expiratory data closely approximates results from classification with the 3 pulmonary function test variables. In addition, we concluded that classification with the mean data is better than classification with data based on each breath. Finally, from the regression studies, we concluded that there appears to be minimum or no correlation between the respiratory sound spectral parameters (MPF, FPK, and FMAX) and the three pulmonary function test parameters (FVC, FEV1, and FEV1P).

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# DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF PULMONARY INSUFFICIENT PATIENTS AND NORMAL SUBJECTS

## INTRODUCTION

Respiration is one of the physiological functions of concern when examining or treating a patient. A clinical relationship between respiratory sounds and gross respiratory pathology was established in the nineteenth century. Auscultation of respiratory sounds, however, is subjective. Due to the subjectiveness, there are varying degrees of acceptance of respiratory sounds as a clinical sign. To alleviate the problem, various researchers have studied respiratory sounds to explore and develop automated methods for analysis and diagnosis of pulmonary diseases.

The objective of this study is to determine whether respiratory sound data of normal volunteers and pulmonary insufficiency subjects can be classified as normal or abnormal pulmonary systems by discriminant analysis and if the spectral parameters for discriminating respiratory sounds correlate with clinical parameters obtained from the pulmonary function test. Patient data was obtained from the U.S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas. The classification (normal/pulmonary insufficiency) of the subjects was determined from a single pulmonary function test.

## Background

The process of respiration is of vital importance to life and includes the following mechanistic events: (1) pulmonary ventilation, the inflow and outflow of air between the atmosphere and the lung alveoli, (2) diffusion of oxygen and carbon dioxide between the alveoli and the blood, and (3) transportation of oxygen in the blood, principally in combination with hemoglobin, to the tissue capillaries where it is released for use by the cells according to their metabolic needs [17].

The foundations of respiratory medicine were laid at the beginning of the nineteenth century when Laennec [20] established the clinical relationship between respiratory sound and gross pulmonary pathology by the use of the early stethoscope. Auscultation in respiratory medicine, however, has advanced slowly since Laennec established auscultation of lung sounds as a means of diagnosing the condition of the lungs.

The slow progress is due to: (1) a variety of human factor problems, (2) the limitations of the instrumentation, (3) the lack of total understanding of the mechanism of production of respiratory sounds, and (4) the lack of understanding of the origin of the source of the sounds.

## Human Factor Problems

Respiratory sounds heard through a stethoscope can be roughly classified into two main types: First are normal respiratory sounds,

these are both inspiratory and expiratory sounds heard as the air moves in and out of the chest during normal breathing. There are two types of normal respiratory sounds. Tracheal or bronchial respiratory sounds are heard by placing the stethoscope over the trachea and listening as the patient breathes in and out with the mouth open. The sound is described as "tubular" and is similar to the sound that arises when air is blown through a tube. The other major type of respiratory sound is called vesicular. The term "vesicular" in Latin refers to little vessels. This description refers to the sound that is heard over the majority of the chest of normal persons during normal breathing. The analogy used is the sound heard by the rustle of wind in the trees [9].

The term "adventitious" is used to describe sounds not expected in the normal chest. To complicate matters, the terminology of adventitious sounds is not standard. The clinician attempts to describe the quality of sounds by adjectives that convey an idea of relative intensity and pitch. Different clinicians use the same term to describe dissimilar sounds [1,9].

Adventitious sounds are divided into those believed to have a bronchopulmonary origin and those thought to be due to pleural disease. Those of bronchopulmonary origin are further subdivided into "continuous" and "discontinuous". Sounds that last for more than a tiny fraction of the respiratory cycle are referred to as continuous. Rales, the discontinuous sounds, are further subdivided into fine, medium, and coarse. A variety of adjectives appear in the medical literature to classify these sounds further. Examples of these adjectives include dry, wet, moist, bubbling, crepitant, subcrepitant, and consonating. The terminology is subjective in its interpretation depending greatly on the hearing and experience of the clinician [1,2,12,13,25-27].

Another problem in chest auscultation is that so much information exists that it is difficult either to record it properly or to remember the observed details. On listening over a single site in the chest, it is possible to observe the intensity of both inspiration and expiration. It is also possible to grade these on a scale that may reflect normality or abnormality of the site. The clinician may also be able to record the presence or absence of various adventitious sounds and their relationship to the respiratory cycle. The duration of inspiration with respect to expiration may also be noted. If the clinician listens to one or more sites, as is common in routine chest auscultation, then there is a possibility that information may be lost due to various factors such as interruptions in the physical examination, lack of accurate record keeping, or the clarity of the clinician's initial observations [25]. The diversity of the terms used to describe respiratory sounds, together with the nonuniformity of their usage by clinicians, poses difficulties in the use of respiratory sounds as a precise indicator of the condition of the respiratory system.

### Limitations of Instrumentation

The binaural stethoscope appeared towards the middle of the nineteenth century and became popular mainly because it excludes extraneous noise [15,24]. The choice of the best chest piece remained controversial until physicians agreed that both the diaphragm and the bell were necessary for auscultation of the heart. The diaphragm and bell are combined in most stethoscopes in current use.

The stethoscope transmits the range of frequencies which includes frequencies of heart and lung sounds. By varying the pressure between the chest piece and the skin, the intensities of certain frequencies are increased while others are decreased. Low-pitched heart sounds are heard best with the bell resting lightly on the skin, while firm pressure of the bell or diaphragm increases the intensity of higher frequencies and suppresses unwanted low-pitched sounds. Respiratory sounds contain a wide range of frequencies. To compare relative frequency intensities within a particular sound spectrum, the measuring instrument should not contribute variations in intensity. The conventional stethoscope exhibits this limitation [11,25].

Sound evaluation is further complicated by the nonlinearity of the human auditory system. The ear is capable of distinguishing small differences in pitch. As the intensity of the sound increases, the sensitivity of the ear to intensity variations decreases logarithmically. The ears' perception of intensity falls off at both ends of the frequency spectrum [11]. The frequencies of sound that a young person can hear differ from the frequencies of sound that an older person can hear. The range falls between 30 and 20,000 cycles per second(cps) for a young person and 50 to 8,000 cps in old age [16]. The ear is unable to distinguish short sound bursts. A burst shorter than 3 ms will be heard only as a click regardless of the frequency [13].

Electronic instruments can be designed to exhibit a flat frequency response over the range of respiratory sound spectrum and thus overcome some of the instrumentation shortcomings. The major obstacles, however, in the acceptance and advancement of using respiratory sounds as a major clinical tool in pulmonary medicine are the lack of complete understanding of the mechanism of production of respiratory sounds, and the sources from which respiratory sounds are generated.

Since Laennec's time it has been known that pulmonary pathology can cause a change in respiratory sound. Differences exist between normal and pathological respiratory sounds. In 1976, Grassi et al. [15] used the technique of phonopneumography to analyze respiratory sounds. Phonopneumography is defined as the technique of detecting and analyzing the sounds that are produced in the bronchopulmonary area during respiration. The apparatus used was intended to provide a graphic recording of the level of the sounds the clinician perceives through the stethoscope during auscultation. The phonopneumographic records revealed that inspiration was louder than expiration in the healthy subjects. Wherever the ratio between inspiratory and expiratory peak amplitudes was

found to be highly modified, either because inspiration was much louder than normal, or because an inversion of the ratio occurred with an expiratory sound louder than inspiratory, the finding was always accompanied by pathological alteration of the pulmonary zone.

Chowdhury and Majumder [4] conducted an experiment using digital spectral analysis of respiratory sounds for the purpose of determining the clinical relationship between the frequency spectrum and the conditions of the lungs in pulmonary diagnosis. Their study included 6 normal subjects and 6 tuberculosis patients with fibrosis. The recordings of respiratory sounds were made in a quiet room with the subject in the supine position and the microphone placed on the right lung base. The Fast Fourier Transform(FFT) algorithm of Cooley and Tukey was used to obtain the normalized autospectrum of 0.25 s time segments of respiratory sound. Their analysis indicates a maximum amplitude of about 250 Hz for subjects without pathological lung history, with rapid decrease in amplitude as the frequency increases and approaches 1000 Hz. In the case of the tubercular lung, a downward frequency shift of amplitude peak and the presence of higher frequency components were observed.

Charbonneau et al. [3] developed an index which they used to discriminate between asthmatics and normal subjects. They calculated the average spectrum for inspiration and expiration and referred to it as a histogram. Four parameters for both expiratory and inspiratory histograms were calculated and the sum of the parameters was used as an index to discriminate between asthmatics and normal subjects. The parameters were: the bandwidth (taken at half of the peak amplitude), the integral over the range 60-1260 Hz, the highest significant frequency (taken to be 10% of the amplitude of the peak frequency), and the weighted mean frequency of each mean spectra. Their study included 11 normal and 10 asthmatic subjects.

#### Problems with Sound Intensity Recorded from Chest Wall

The correlation of respiratory sound intensity and the distribution of pulmonary ventilation was first studied by Leblanc et al. [21]. They concluded that the intensity of respiratory sounds varied with lung volume, flow rate, body orientation, and the site of the recording. O'Donnell and Kraman [28] and Dosani and Kraman [7] conducted studies to investigate the intensity patterns of lung sound on the chest wall. They concluded that there was a considerable intersubject and intrasubject variability in amplitude of the inspiratory vesicular sound heard on the chest wall, and that the variability was due to factors other than the distribution of ventilation and chest wall thickness. These variations happen even with normal subjects without any diseases of the lung. They believed that the other factors included the site of production of these sounds and their transmission through the airways and lung tissue. Dosani and Kraman (7) pointed out that the chest wall thickness may not have a predominant effect on the intensity. Their results showed that sound intensity at the lateral wall was similar to sound at positions near the spine where the thickness of the chest wall is greater.

## Rationale for Trachea as Site of Respiratory Sound Detection

The variability of acoustic properties of the chest wall account for the variability of sound intensity as measured at the chest wall [3,8,16,29,30]. Previous research indicates that respiratory sounds measured at the trachea undergo minimum filtering [3,8,16]. Charbonneau [3] stated that the sound level is higher at the trachea than at any other point of the chest or back and localizing the point is more precise. Therefore, recordings of the respiratory sound for this study were obtained from the area of the trachea.

## EXPERIMENTAL PROCEDURES

Data were obtained from the USAF School of Aerospace Medicine and were collected by USAF personnel at Wilford Hall USAF Medical Center on patients with pulmonary insufficiency and on normal volunteers. Patients were classified from results of their pulmonary function test (PFT). The experimental procedure used by the U.S. Air Force for data collection was as follows.

The patient was instrumented with a pulmonary flowmeter that was comprised of two Fleisch pneumotachometers with a Rudolph valve between them and connected to a mouthpiece. One pneumotachometer was used to transduce the inspiratory flow rate and the other one was used to transduce the expiratory flow rate. The pneumotachometer devices had pressure taps that were connected to Validyne pressure transducers. An electronic stethoscope was held at the anterior cervical triangle for the detection of respiratory sounds. The patient breathed through the flowmeter exclusively, using a nose clip to prevent nose breathing. A minimum of 5 min of recording time for each patient was collected to allow the patient to become accustomed to the apparatus and to establish a normal breathing pattern. The respiratory sounds and the flow rate were transduced and recorded on an FM analog tape recorder.

### Experimental Procedure for Data Analysis

The magnetic tapes were under contract to Texas A&M University, Bioengineering Department for data analysis. Since the classification (normal/pulmonary insufficiency) of the subject, number of subjects, and location of each subject in relation to the time code was not well controlled by the U.S. Air Force, the study results suffered. Of the 35 subjects, only 24 could be identified. Not all subject records contained their PFT or their classification.

The equipment used in the analysis of the magnetic tapes consisted of the following components:

- Ampex 2200 FM analog tape recorder
- Datum Time Code Generator/Reader Model 9300
- 20-Hz, 1800-Hz low-pass filters
- 100-Hz high-pass filter

- A/D Multiprogrammer (HP 6942A)
- Tektronix 5A22N Differential Amplifier
- Tektronix 5111A Storage Oscilloscope
- Tektronix 2236 (100 MHz) Storage Oscilloscope

The arrangement of the equipment used for analysis of inspiratory and expiratory data is shown in Figure 1.

### Inspiratory Data Analysis

As shown in Figure 1, the respiratory sound signal and the inspiratory flow-rate signal were monitored simultaneously on an oscilloscope. The magnetic tape speed was 3-3/4 in./s. Recordings were made with standard Inertial Rate Integrating Gyro (IRIG) intermediate band record/reproduce amplifiers with a cutoff frequency (3 dB) at 19 kHz and a signal-to-noise ratio of 35 dB (root-mean-square(rms) signal-rms noise). Channel 10 of the FM recorder was connected to the time decoder to display the recorded time. The time decoder was monitored until a valid time code was displayed, indicating a subject's data were recorded on Channel 2 (inspiratory flow data) and on Channel 4 (respiratory sound data) of the magnetic tape. Then, the time code and signals were simultaneously monitored and the total length of the subject's inspiratory data was recorded. The total length of time was assumed to be the time between the beginning of a time code and the time when the time code cleared. Then, the time of each inspiratory breath was also recorded. A calibration procedure was performed on the inspiratory flow-rate signal to calculate the gain that was used. Transducer transfer gain (volts/liters/second) is multiplied times recording gain ( $G_r$ ) and playback equipment gain ( $G_p$ ) to yield "overall gain" ( $G_t$ ). Voltage levels divide by  $G_t$  results in physical units of flow in liters/second. This value was used in making the graphs of flow vs. time. Flow in voltage levels (or analog to digital (A/D) counts) were used to trigger collection of respiratory sounds. For a specific inspiratory breath the signal on the magnetic tape was viewed on an oscilloscope and the voltage of the signal was recorded. The signal from the output of the 20-Hz filter for the same inspiratory breath was viewed on another oscilloscope simultaneously and the voltage of the signal was recorded. The gain was calculated by the ratio of the voltage recorded from the output of the 20-Hz filter to the voltage recorded directly off the magnetic tape. The value of the gain was necessary in determining the correct inspiratory flow rate. This procedure was done prior to inspiratory data collection for each new subject.

The inspiratory flow-rate signal was taken from Channel 2 of the FM recorder and fed into the 20-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and the analog input box for manual triggering. The output of the analog input box was then fed into Channel 2 of the A/D converter.

The inspiratory sound signal was taken from Channel 4 of the FM recorder and fed into a 100-Hz high-pass filter followed by a 1800-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and into Channel 1 of the A/D converter. After calibration

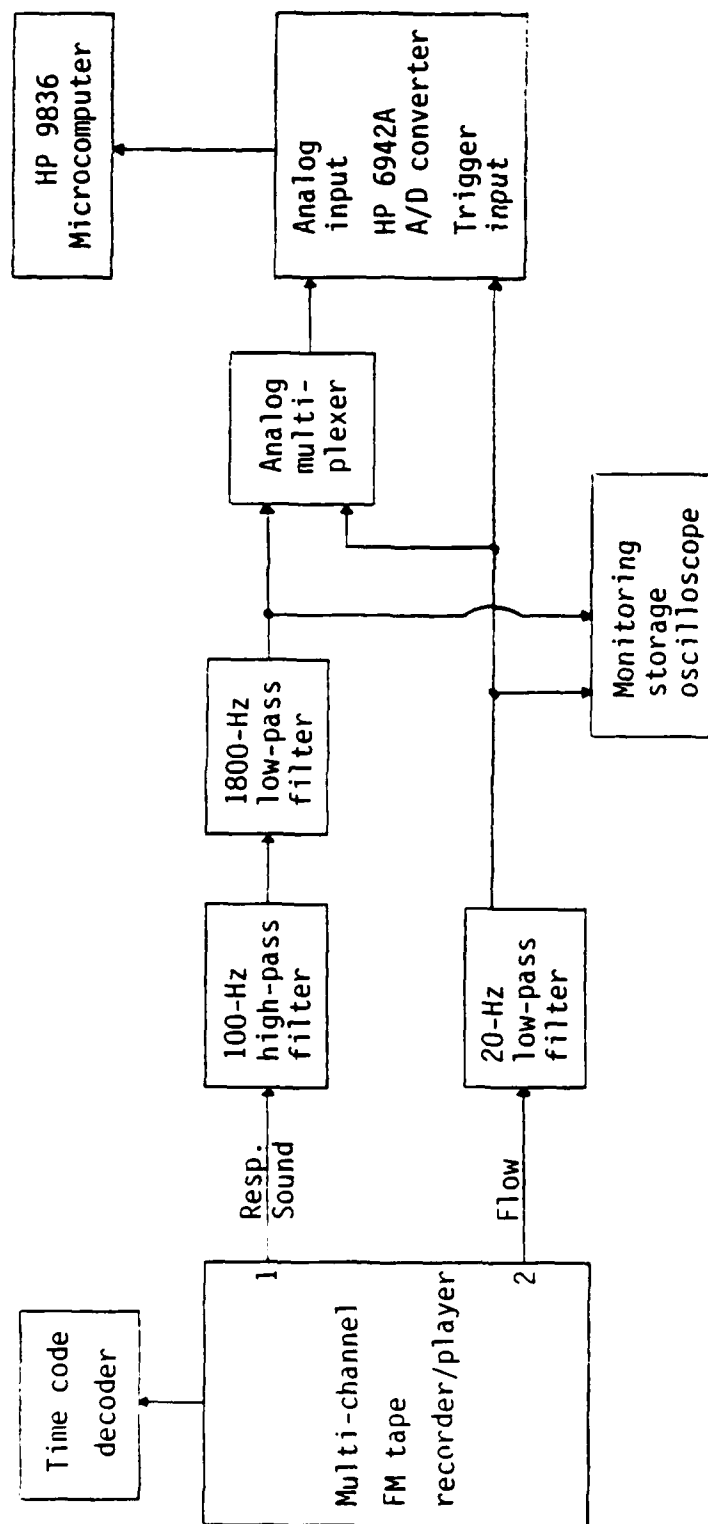


Figure 1. Block diagram of equipment setup.

of the flow data and random selection of four breaths, data collection began.

The HP-9836 desktop microcomputer was programmed to monitor the inspiratory flow rate via the A/D channel and begin data collection when the flow rate reached a predetermined level. The level was determined by viewing the signal on the oscilloscope. Data collection was handled by the multiplexed A/D channel at the sampling rate of 8192 samples per second. By choosing a sampling rate of 8192 samples per second, the result was to sample each analog channel (respiratory sound and flow rate) at 4096 samples per second. The program was modified to be interactive; therefore, it allowed for versatility in the processing of recorded data with large variabilities. The program prompted the operator for changes of the flow rate trigger level, the duration of data collection, the number of repetitions, the data file name, the data file structure, and the sampling rate. The program also had additional flexibility that allowed the operator to decide whether or not to save the data that was collected. Much of the data contained extraneous noises (i.e., talking, babies crying, door slamming, etc.).

The voltage level at which the A/D converter started collecting data was displayed on the screen. If the level was acceptable with the trigger level that was set (within 0.2 V), then the data were saved and stored on the diskette. The data file names used were the respective time codes of the breaths collected. This procedure continued until 4 inspiratory breaths of each subject had been collected, digitized, and stored on diskettes for further signal processing.

#### Expiratory Data Analysis

As shown in Figure 1, both the expiratory flow-rate signal and the expiratory sound signal were monitored simultaneously on an oscilloscope. The same procedure for locating the inspiratory data was used to locate expiratory data.

A calibration procedure was then performed on the expiratory flow-rate signal to calculate the gain that was used. For a specific expiratory breath, the signal off the magnetic tape was viewed on an oscilloscope and the voltage of the signal was recorded. The signal from the output of the 20-Hz filter for the same expiratory breath was viewed on an oscilloscope and the voltage of the signal was recorded. The gain was calculated by the ratio of the voltage recorded from the output of the 20-Hz filter to the voltage recorded directly off the magnetic tape. The value of the gain was necessary in determining the correct expiratory flow rate. This procedure was done prior to expiratory data collection for each new subject.

The expiratory flow-rate signal was taken from Channel 3 of the FM recorder and fed into the differential amplifier of the oscilloscope. The differential amplifier was used to balance the direct current (DC) offset by adjusting the DC step attenuation balance and the position knob. The filter setting was DC. This step was needed because the expiratory flow

transducer that was used had a 1.4 V DC offset. The output of the oscilloscope was fed into the input of the 20-Hz filter, and the output of the 20-Hz filter was fed into both the oscilloscope for monitoring and the analog input box for manual triggering. The output of the analog input box was then fed into Channel 2 of the A/D converter. The respiratory sound signal was taken from Channel 4 of the FM recorder and fed into a 100-Hz high-pass filter followed by a 1800-Hz low-pass filter. The output of the filter was fed into both the oscilloscope for monitoring and into Channel 1 of the A/D converter.

The same procedure of expiratory data collection using the HP-9836 microcomputer and A/D converter as noted for the inspiratory data collection was used. This procedure continued until 4 expiratory breaths of each subject had been collected, digitized, and stored on diskettes for further signal processing.

### QUANTITATIVE ANALYSIS

The Fourier series is used to represent arbitrary periodic functions by an infinite series of sinusoids of harmonically related frequencies to study the time domain responses in networks. The Fourier series expressed as a linear combination of harmonically related complex exponentials can be written in the form:

$$x(t) = \sum a_k e^{-jk\omega_0 t} \quad (1)$$

$$a_k = 1/T_0 \int x(t) e^{-jk\omega_0 t} dt \quad (2)$$

where  $k = 1, 2, \dots, \infty$ .

Equation (1) is often referred to as the synthesis equation and equation (2) as the analysis equation. The coefficients,  $a_k$ , are often called the Fourier series coefficients or the spectral coefficients of  $x(t)$ . These complex coefficients measure the portion of the signal  $x(t)$  that is at each harmonic of the fundamental component. The fundamental frequency is defined as  $\omega_0$ , and the fundamental period is  $T_0 = 2\pi/\omega_0$ .

The Fourier series method, however, has limitations in analyzing linear systems for the following reasons: 1) The Fourier series can be used for inputs which are periodic; however, most inputs in practice are nonperiodic. 2) The method applies only to systems that are stable. A stable system is a system whose natural response decays in time.

The first limitation can be overcome since we can represent the nonperiodic input in terms of exponential components. A method of accomplishing this function is the Fourier transform. For instance, consider the nonperiodic function  $f(t)$  which we would like to represent in terms of exponential components. To do this, we constructed a periodic function  $f_T(t)$  with a period  $T$ , where the function  $f(t)$  is repeated every  $T$  seconds. The period  $T$ , is considered large enough so there is no overlapping between pulse shapes of  $f(t)$ . The new function is a periodic

function and can be represented with an exponential Fourier series as follows:

$$f_T(t) = \sum F_n e^{jn\omega_0 t} \quad (3)$$

$$\text{where } \omega_0 = 2\pi/T, \quad (4)$$

$$\text{and } F_n = 1/T \int f_T(t) e^{-jn\omega_0 t} dt \quad (5)$$

The next process is to evaluate the function as the period increases to infinity. As  $T$  becomes infinite, the pulses repeat after an infinite interval. Therefore,  $f_T(t)$  and  $f(t)$  are identical in the limit, and the Fourier series representing the periodic function  $f_T(t)$  will also represent  $f(t)$ .

In the limit, as  $T$  approaches infinity,  $\omega$  approaches zero. Therefore,  $\omega_0$  can be denoted as  $\delta\omega$ . Then:  $T = 2\pi/\omega_0 = 2\pi/\delta\omega$  and,

$$TF_n = \int f_T(t) e^{-jn\delta\omega t} dt \quad (6)$$

$TF_n$  is a function of  $jn\delta\omega$ , so let  $TF = F(jn\delta\omega)$ . Equation (3) becomes:

$$f_T(t) = \sum F_n e^{jn\omega_0 t} \quad (7)$$

$$= \sum [F(jn\delta\omega)/T] e^{(jn\delta\omega)t} \quad (8)$$

$$= \sum \{ [F(jn\delta\omega)/2\pi] \delta\omega \} e^{(jn\delta\omega)t} \quad (9)$$

In the limit, as  $T$  approaches infinity,  $\delta\omega$  approaches zero, and  $f_T(t)$  approaches  $f(t)$ . Then:

$$f(t) = \lim f_T(t) = \lim 1/2\pi F(jn\delta\omega) e^{jn\delta\omega t} \delta\omega \quad (10)$$

is by definition:

$$f(t) = 1/2\pi \int F(j\omega) e^{j\omega t} d\omega \quad (11)$$

Equation (11) is known as the inverse Fourier transform. Recall equation (5):

$$F_n = 1/T \int f_T(t) e^{-jn\omega_0 t} dt \quad (12)$$

$$= F(jn\delta\omega)/T \quad (13)$$

then

$$F(j\omega) = \lim \int f_T(t) e^{-jn\delta\omega t} dt \quad (14)$$

$$F(j\omega) = \int f(t) e^{-j\omega t} dt \quad (15)$$

Equation (15) is known as the direct Fourier transform. The result is that

$$F(j\omega) = \int f(t) e^{-j\omega t} dt \quad (16)$$

is the representation of the nonperiodic function  $f(t)$  in terms of exponential functions. The amplitude of the component of any frequency  $\omega$  is proportional to  $F(j\omega)$ . In analogy with the terminology used for the Fourier series coefficient of a periodic signal, the transform  $F(j\omega)$  of an aperiodic signal  $f(t)$  is commonly referred to as the spectrum of  $f(t)$ , as it provides the information concerning how  $f(t)$  is composed of sinusoidal signals at different frequencies.

The second limitation applies to nonstationary data from a system. During normal respiration the respiratory system is stable. If the signal from a system is stationary, the system may be assumed to be stable. Weak stationarity is shown in the ergodic sense by averaging several records of an individual at one time and averaging another set from the same subject at a different time, if the means and autocorrelation are invariant the data is weakly stationary. This procedure was shown in the statistics in reference 34. Hence, for this study the data is assumed to be stationary, which is the case for mean data, but not necessarily for individual sample data.

In the study, the respiratory signal was conditioned by the use of the analog filters previously discussed in the experimental procedures. The 100-Hz high-pass filter and the 1800-Hz low-pass filter were thus acting together as a band-pass filter. The respiratory sound data and flow data were digitized, separated using the separation program, and stored on diskettes for the Fast Fourier Transform (FFT) analysis. The respiratory sound signal was digitized at a rate of 4096 samples/second. The sampling rate was chosen to avoid "aliasing" of the spectra. The literature indicates that the highest frequency of normal respiratory sound is about 1500 Hz, and this may be higher for abnormal subjects. The Nyquist sampling criteria requires that the Nyquist frequency be at least twice the highest frequency of interest of the signal being sampled. The first 1024 samples, which correspond to 0.25 s of real-time data, were transformed by the Cooley-Tukey FFT algorithm.

When only a finite segment of the signal is observed, the process is equivalent to multiplying the signal by a rectangular window function. In the frequency domain, this multiplication becomes a convolution between the desired spectrum and that of the window. As a result, the frequency spectrum is distorted, and the spectral components "leak" away from their time frequencies and are distributed over the total spectrum [32]. A rectangular window function is not accurate in describing the signal, and therefore produces signal discontinuities at the boundaries. The FFT will add all harmonics to simulate the fast rising edge of the window, and this is inaccurate in representing the signal. Frequency distortion occurs when part of the true frequency is distributed to the side lobes. A rectangular window results in a sharper cutoff, more narrow main lobe, but the 1st side lobe is only -13 dB down with the remaining side lobes decreasing at -6 dB/octave. The Hanning window, which is often called the cosine window, reduces the side lobe level to -32 dB with a -18 dB/octave roll-off in the side lobes. A suitable window function needs to be chosen to minimize the "spectral leakage". The window chosen was a 10% cosine tapered window. This window forces the first data point to zero, and the

rising edge of the window is a cosine function. A correction factor of  $G_i = G_i/0.875$  is applied to the spectrum resulting from the modified cosine window as suggested by Bendat. Discontinuities in general lead to the "Gibbs phenomenon" which infers that even with an infinite Fourier series there will be a 9% error at the discontinuities.

The power spectrum is computed from the square of the resulting Fourier coefficients.

$$G_i = C_i^2 = (a_i + jb_i)(a_i - jb_i) \quad (17)$$

$$G_i = C_i^2 = a_i^2 + b_i^2 \quad (18)$$

#### Calculation of Parameters

Three indices of measure were calculated from the power spectrum. These parameters were the mean frequency of the power spectrum (MPF), the frequency of the maximum power (FPK), and the highest frequency at which the power in the spectrum equals or is less than 10% of the maximum power (FMAX). The rationale for selecting these parameters is:

- (1) In descriptive statistics, the mean (MPF) corresponds to the central tendency of the distribution.
- (2) The peak value (FPK) or the mode of a distribution corresponds to the most frequent occurrence of an event, in this case the power within the respiratory sound spectrum.
- (3) The highest frequency (FMAX) at which the power in the spectrum becomes 10% of the peak power corresponds to a rough bandwidth from DC to the frequency at which the power contents remain 10 dB below FMAX in the spectrum. This parameter may also be used as an indicator of the correctness in the selection of the Nyquist sampling frequency. In addition, Charbonneau et al. [3] used the FMAX parameter as part of a linear function to discriminate normal patients from asthmatic patients.

The mean frequency of the power spectra was calculated from the equation:

$$MPF = \sum C_i^2 \cdot F_i / \sum C_i^2 \quad (19)$$

where  $i$  is the index 0, 1, 2, ..., N-1.

$F_i$  is the frequency at index  $i$ , and  $C_i$  is the Fourier coefficient at index  $i$ . The coefficient  $C_i$  is computed from the FFT:

$$C_i = a_i^2 + b_i^2 \quad (20)$$

where  $a_i$  is the real component of the Fourier coefficient at index  $i$ , and  $b_i$  is the imaginary component of the Fourier coefficient at index  $i$ .

The next parameter calculated by the program is the frequency of the FMAX of the power spectrum. A sorting routine is used to locate the FMAX and the index at which the FMAX occurred. The peak frequency then becomes

$$FP = I \cdot FR \quad (21)$$

where I is the index 0, 2, ..., N-1, and FR is the frequency resolution (FR). The FR is calculated from the period or window length in time, that is:

$$FR = 1/(0.25 \text{ s}) = 4 \text{ Hz} \quad (22)$$

The final parameter, the highest frequency at 10% of the FMAX, is calculated in a manner similar to the calculation of the frequency of the FMAX. Again, a sorting routine is used to find the index at which the power becomes 10% of the FMAX; then the frequency is calculated from the index.

#### DISCRIMINANT ANALYSIS

A basic problem in clinical diagnosis is that of assessing and classifying individuals based on a number of physiological attributes. This process requires well-defined, mutually exclusive classes, to one of which the individual in question must belong.

Several decision-making procedures, varying somewhat in approach, complexity, and overall effectiveness, are applicable to the classification of observed data. Discriminant analysis is a method of assigning an observation to 1 of 2 or more distinct groups. Discriminant analysis is often viewed as a technique for the description and testing of between-group differences [5]. Yet others view discriminant analysis as a problem of assigning an unknown observation to a group with low-error rate [19].

The basic idea of the discriminant analysis problem is that we assume that the initial data can be classified correctly (i.e., in defining the groups) and some variables exist that permit the groups to be established. Unfortunately there is little theory to guide the selection of measurement variables.

A second fundamental requirement is a method of assessing or assigning group membership. One approach is based on the concept of generalized distance developed by Mahalanobis [23] in lieu of the concept of ordinary geometric (Euclidean) distance. The generalized distance is a measure of group or profile dissimilarity [33], i.e., the larger the generalized distance [23] the greater the dissimilarity between profiles.

Discriminant programs available at Texas A&M University are statistical packages within the Statistical Analysis System (SAS) [31]. The basic SAS discriminant procedures used in this study were stepwise discriminant (STEPDISC), canonical discriminant (CANDISC), and discriminant analysis (DISCRIM), respectively. The STEPDISC and CANDISC programs were used first to evaluate subsets of variables. The CANDISC, a

dimension reduction technique, is related to principal components and canonical correlation. The CANDISC procedure finds linear combination of the variables that best summarizes the differences among the classes. In addition, this procedure computes scores for each observation on the linear combination. The STEPDISC tries to find a subset of variables that best reveals differences among the classes. After a subset of variables is selected with the STEPDISC or CANDISC procedure, the discriminant procedure, DISCRIM, may be used to classify the observations into two or more known classes [31].

#### Stepwise Discriminant Analysis Program

The STEPDISC program performs the stepwise discriminant analysis which selects a subset of variables to form a discriminant model by forward selection, backward elimination, and stepwise selection. Variables are chosen on the basis of either criteria:

- The significance level of an F-test from an analysis of covariance, or
- The squared partial correlation for predicting the variable under consideration from the class variable.

The stepwise selection begins with no variable in the model. The variable that contributes the most to the discriminatory power of the model as measured by Wilks' lambda criterion is entered first. After all variables of the model have been tested by the criterion for entry into the model, the stepwise selection stops. Stepwise discriminant models are not necessarily the best possible models since Wilks' lambda may not be the best measure of discriminatory power. To guard against inclusion of variables that do not contribute to the discriminatory power of the model, it is customary to specify or select a minimum significance level.

#### Canonical Discriminant Analysis Program

The CANDISC analysis is a dimension-reduction technique related to principal component analysis and canonical correlation. The CANDISC program computes and tests Mahalanobis distances (23), performs univariate and multivariate analysis of variance, and derives a linear combination of variables, called the first canonical correlation, that has the highest possible multiple correlation within groups. The coefficients of the linear combination are the canonical coefficients. The variable defined by the linear combination is the first canonical variable. The second canonical correlation is obtained by finding the linear combination uncorrelated with the first canonical variable. The number of canonical variables equals the number of variables or the number of groups minus one, whichever is smaller. The output of the program includes the univariate statistics, covariance matrices, the Mahalanobis distances (23) between classes, multivariate statistics, the canonical coefficients, and plots of paired canonical variables. These plots are an aid to visual interpretation of group differences [31].

### Discriminant Analysis Program

The DISCRIM program develops a discriminant model (classification criterion) by means of the generalized squared distance under the assumption that each class has a multivariate normal distribution. The generalized squared distance of observation vector  $X_i$  to group or class  $j$  is obtained from the equation:

$$D_j^2(X_i) = (X_i - X_j)' \text{COV}_j^{-1} (X_i - X_j) + \text{Log}_e |\text{COV}_j| \quad (23)$$

if the within-group covariance matrices,  $\text{COV}_j$ , are used  $X_j$  is the means of the variables in the group  $j$ . The criterion is based on either the individual within-group covariance matrices or the pooled covariance matrix. The DISCRIM program then computes linear or quadratic discriminant functions and places each observation (multivariate) into the class from which the distance is the smallest. The output of the program includes the within covariance matrices, within correlation coefficients, pooled covariance matrix, test of homogeneity of within covariance matrices, generalized squared distances, and a classification summary or confusion matrix. The tests of homogeneity determine whether the criterion is based on the within group covariance matrices or the pooled covariance matrix [31].

### RESULTS AND DISCUSSION

This section presents the results of the discriminant analysis programs STEPDISC, CANDISC, and DISCRIM. The STEPDISC and CANDISC analysis were used to gain an insight as to which combination of variables would be most useful in revealing the differences among the classes. Then the linear discriminant analysis was used to classify: (1) a set of data, the "training set", and (2) a separate set of data not used in the training set, the "classification set" or the "test set".

#### STEPDISC Results

The stepwise linear discriminant analysis was performed on the expiratory portion of respiratory sound data for: (1) 4 classes with 4 variables, (2) 3 classes with 4 variables for each sound spectrum, and (3) 3 classes with mean values of the 4 variables from the average of 10 or more spectra for a subject. The 4 classes consisted of 2 abnormal groups and 2 normal groups. This analysis followed one of the possible cluster analysis groupings found by Lessard et al. [22]. The 3 class cases consisted of 2 abnormal groups and 1 normal group. Two class cases consisted of abnormal and normal groups. When 4 variables were used, flow rate was included. In all cases the 3 respiratory sound spectral variables (MPF, FPK, and FMAX) were used.

In the STEPDISC analysis of 4 classes with 4 variables, the first variable entered was the mean frequency of the respiratory spectrum (MPF) because of its high-squared correlation ( $R^2$ ) value (Fig. 2). In the second step, the peak frequency (FPK) was entered (Fig. 2), and in the

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 3.258

| VARIABLE | R**2   | F       | PROB > F | TOLERANCE |
|----------|--------|---------|----------|-----------|
| MPF      | 0.6963 | 197.182 | 0.0001   | 1.0000    |
| FPK      | 0.1788 | 18.722  | 0.0001   | 1.0000    |
| FMAX     | 0.5672 | 112.719 | 0.0001   | 1.0000    |
| FLOW     | 0.0647 | 5.947   | 0.0007   | 1.0000    |

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.30369130 F(3.258) = 197.182 PROB > F = 0.0000  
PILLAI'S TRACE = 0.696309 F(3.258) = 197.182 PROB > F = 0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.23210290

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 3.258

| VARIABLE | R**2   | F       | PROB > F |
|----------|--------|---------|----------|
| MPF      | 0.6963 | 197.182 | 0.0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3.257

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F | TOLERANCE |
|----------|-----------------|--------|----------|-----------|
| FPK      | 0.1450          | 14.527 | 0.0001   | 0.7277    |
| FMAX     | 0.0644          | 5.897  | 0.0008   | 0.2806    |
| FLOW     | 0.0312          | 2.760  | 0.0420   | 0.9652    |

VARIABLE FPK WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FPK

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.25965893 F(6.514) = 82.450 PROB > F = 0.0000  
PILLAI'S TRACE = 0.806752 F(6.516) = 58.144 PROB > F = 0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.26891730

Figure 2. STEPDISC result of 4 classes with 4 variables; steps 1 and 2 for expiratory data.

third step, the flow rate was entered in lieu of the FMAX (Fig. 3). An examination of the stepwise selection summary indicates that the squared correlation value ( $R^2$ ) of the flow variable is low and the significance level of the F test from an analysis of covariance is not low (0.0313), indicating that flow may not contribute a great amount to the discriminating power (Fig. 4).

When the same expiratory sound data is analyzed by the STEPDISC program for the 3 classes with the 4 variables, MPF is selected in the first step (Fig. 5) and FPK is selected in the second step (Fig. 5). Flow rate and FMAX were not selected because the significance levels of the F test were high (Fig. 6), if a third variable were used the FMAX would be selected. The stepwise selection summary is given in Figure 6.

In the last case, the means of the spectral variables and the mean flow for each subject were used as input data into the STEPDISC program instead of the variables from each quarter-second spectrum. Results for the 3 classes, 4 variable analysis with a mean data set (Appendix E) are given in Figures 7 through 9. The variables selected in order of discriminating power are the MPF, FPK, and FMAX, respectively. Flow was not selected as a discriminant variable as indicated in the selection summary (Fig. 9).

In the next series of runs, the classes were reduced to 2 groups (normal and abnormal) with 4 variables and 3 variables (flow rate excluded). In the STEPDISC run with 2 classes with 4 variables during expiration, all 4 variables were entered as shown in Figures 10 through 12. For this case, FPK has the least discriminant power (Fig. 12). In the case of 2 classes with 4 variables during inspiration, the MPF was entered in the first step (Fig. 13) followed by the FMAX (Fig. 13). The flow rate was included as a variable, but FPK was not (Fig. 14). Selection summary is given in Figure 15.

In the case of 2 classes, with 3 variables (flow rate excluded) during expiration, the variables FPK, FMAX, and MPF were selected respectively even though the MPF had a high squared correlation ( $R^2$ ) value and a F test significance level of 0.0001 as is shown in the stepwise selection summary (Fig. 15). For inspiratory data, the variables MPF and FMAX were selected; and the FPK was not entered (Fig. 15).

Table 1 is a summary of respiratory sound variable discriminating power. We noted that the MPF is the variable with the most discriminating power for all expiration studies except the 2 classes, 4 variables case. For the inspiration studies, the FMAX bandwidth was the most discriminating variable. The second most discriminating variable during expiration is the FPK or mode of the spectrum. Flow does not appear to be a strong discriminating variable. This result is in agreement with results presented by Wong [34] in which he suggests that the frequency spectra of respiratory sounds are independent of respiratory flow rate if the flow rate is about or greater than normal respiratory flow rate of about 0.75 to 1.0 L/s.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 3,257

| VARIABLE | PARTIAL<br>R**2 | F       | PROB > F |
|----------|-----------------|---------|----------|
| MPF      | 0.6838          | 185.271 | 0.0001   |
| FPK      | 0.1450          | 14.527  | 0.0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3,256

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FMAX     | 0.0150          | 1.297 | 0.2752   | 0.1725    |
| FLOW     | 0.0338          | 2.987 | 0.0313   | 0.7153    |

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FPK FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.25087637 F(9,623.187) = 52.974 PROB > F = 0.0000  
PILLAI'S TRACE = 0.822477 F(9,774) = 32.483 PROB > F = 0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.27415892

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 3,256

| VARIABLE | PARTIAL<br>R**2 | F       | PROB > F |
|----------|-----------------|---------|----------|
| MPF      | 0.6792          | 180.697 | 0.0001   |
| FPK      | 0.1473          | 14.740  | 0.0001   |
| FLOW     | 0.0338          | 2.987   | 0.0313   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 3,255

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FMAX     | 0.0148          | 1.275 | 0.2829   | 0.1721    |

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

Figure 3. STEPDISC result of 4 classes with 4 variables; steps 3 and 4 for expiratory data.

| STEPWISE SELECTION: SUMMARY |         |                     |              |                           |                |             |                  |                  |                                                |
|-----------------------------|---------|---------------------|--------------|---------------------------|----------------|-------------|------------------|------------------|------------------------------------------------|
| STEP                        | ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R <sup>2</sup> | F<br>STATISTIC | PROB ><br>F | WILKS'<br>LAMBDA | PROB ><br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
| 1                           | MPF     |                     | 1            | 0.6963                    | 197.182        | 0.0001      | 0.30369130       | 0.0000           | 0.23210290                                     |
| 2                           | FPK     |                     | 2            | 0.1450                    | 14.527         | 0.0001      | 0.25965893       | 0.0000           | 0.26891730                                     |
| 3                           | FLOW    |                     | 3            | 0.0338                    | 2.987          | 0.0313      | 0.25087637       | 0.0000           | 0.27415892                                     |

Figure 4. STEPDISC result selection summary of 4 classes; with 4 variables for expiratory data.

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 2.259

| VARIABLE | R**2   | F       | PROB > F | TOLERANCE |
|----------|--------|---------|----------|-----------|
| MPF      | 0.5544 | 161.147 | 0.0001   | 1.0000    |
| FPK      | 0.0876 | 12.438  | 0.0001   | 1.0000    |
| FMAX     | 0.4775 | 118.329 | 0.0001   | 1.0000    |
| FLOW     | 0.0272 | 3.622   | 0.0281   | 1.0000    |

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.44555783 F(2,259) = 161.147 PROB > F = 0.0000  
PILLAI'S TRACE = 0.554442 F(2,259) = 161.147 PROB > F = 0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.27722108

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 2.259

| VARIABLE | R**2   | F       | PROB > F |
|----------|--------|---------|----------|
| MPF      | 0.5544 | 161.147 | 0.0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2.258

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F | TOLERANCE |
|----------|-----------------|--------|----------|-----------|
| FPK      | 0.1450          | 21.874 | 0.0001   | 0.7277    |
| FMAX     | 0.0636          | 8.769  | 0.0002   | 0.2806    |
| FLOW     | 0.0016          | 0.203  | 0.8164   | 0.9652    |

VARIABLE FPK WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FPK

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.38095991 F(4,516) = 80.002 PROB > F = 0.0000  
PILLAI'S TRACE = 0.649629 F(4,518) = 62.299 PROB > F = 0.0000

AVERAGE SQUARED CANONICAL CORRELATION = 0.32481441

Figure 5. STEPDISC result of 3 classes with 4 variables; steps 1 and 2 for expiratory data.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 2.258

| VARIABLE | PARTIAL<br>R**2 | F       | PROB > F |
|----------|-----------------|---------|----------|
| MPF      | 0.5825          | 179.946 | 0.0001   |
| FPK      | 0.1450          | 21.874  | 0.0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2.257

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FMAX     | 0.0141          | 1.839 | 0.1611   | 0.1725    |
| FLOW     | 0.0040          | 0.516 | 0.5978   | 0.7153    |

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

STEPWISE SELECTION: SUMMARY

| STEP | VARIABLE<br>ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R**2 | F<br>STATISTIC | PROB ><br>F | WILKS'<br>LAMBDA | PROB ><br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
|------|---------------------|---------------------|--------------|-----------------|----------------|-------------|------------------|------------------|------------------------------------------------|
| 1    | MPF                 |                     | 1            | 0.5544          | 161.147        | 0.0001      | 0.44555783       | 0.0000           | 0.27722108                                     |
| 2    | FPK                 |                     | 2            | 0.1450          | 21.874         | 0.0001      | 0.38095991       | 0.0000           | 0.32481441                                     |

Figure 6. STEPDISC result of 3 classes with 4 variables; step 3 and the selection summary for expiratory data.

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 2,8

| VARIABLE | R**2   | F      | PROB > F | TOLERANCE |
|----------|--------|--------|----------|-----------|
| MMPF     | 0.7379 | 11.259 | 0.0047   | 1.0000    |
| MFPK     | 0.2681 | 1.465  | 0.2869   | 1.0000    |
| MFMAX    | 0.7378 | 11.253 | 0.0047   | 1.0000    |
| MFLOW    | 0.0452 | 0.189  | 0.8311   | 1.0000    |

VARIABLE MMPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MMPF

MULTIVARIATE STATISTICS

|                |              |          |        |                   |
|----------------|--------------|----------|--------|-------------------|
| WILKS' LAMBDA  | = 0.26214565 | F(2,8) = | 11.259 | PROB > F = 0.0047 |
| PILLAI'S TRACE | = 0.737854   | F(2,8) = | 11.259 | PROB > F = 0.0047 |

AVERAGE SQUARED CANONICAL CORRELATION = 0.36892718

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 2,8

| VARIABLE | R**2   | F      | PROB > F |
|----------|--------|--------|----------|
| MMPF     | 0.7379 | 11.259 | 0.0047   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2,7

| VARIABLE | PARTIAL R**2 | F     | PROB > F | TOLERANCE |
|----------|--------------|-------|----------|-----------|
| MFPK     | 0.6482       | 6.449 | 0.0258   | 0.5064    |
| MFMAX    | 0.1970       | 0.858 | 0.4640   | 0.1689    |
| MFLOW    | 0.0044       | 0.015 | 0.9848   | 0.9563    |

VARIABLE MFPK WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MMPF MFPK

MULTIVARIATE STATISTICS

|                |              |           |       |                   |
|----------------|--------------|-----------|-------|-------------------|
| WILKS' LAMBDA  | = 0.09222430 | F(4,14) = | 8.025 | PROB > F = 0.0011 |
| PILLAI'S TRACE | = 1.094258   | F(4,16) = | 1.833 | PROB > F = 0.0011 |

AVERAGE SQUARED CANONICAL CORRELATION = 0.54712884

Figure 7. STEPDISC result of 3 classes with 4 variables; steps 1 and 2 for mean expiratory data.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL. DF = 2.7

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MMPF     | 0.8740          | 24.275 | 0.0007   |
| MFPK     | 0.6482          | 6.449  | 0.0258   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY. DF = 2.6

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| MFMAX    | 0.4831          | 2.803 | 0.1381   | 0.0315    |
| MFLOW    | 0.0159          | 0.049 | 0.9530   | 0.4979    |

VARIABLE MFMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED  
MMPF MFPK MFMAX

MULTIVARIATE STATISTICS

|                            |           |       |                   |
|----------------------------|-----------|-------|-------------------|
| WILKS' LAMBDA = 0.04767531 | F(6,12) = | 7.160 | PROB > F = 0.0020 |
| PILLAI'S TRACE = 1.166006  | F(6,14) = | 3.262 | PROB > F = 0.0320 |

AVERAGE SQUARED CANONICAL CORRELATION = 0.58300295

Figure 8. STEPDISC result of 3 classes with 4 variables; step 3 for mean expiratory data.

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 2.6

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MMPF     | 0.7721          | 10.164 | 0.0118   |
| MFPK     | 0.7735          | 10.247 | 0.0116   |
| MFMAX    | 0.4831          | 2.803  | 0.1381   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 2.5

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| MFLOW    | 0.0136          | 0.035 | 0.9663   | 0.0285    |

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

STEPWISE SELECTION: SUMMARY

| STEP | VARIABLE<br>ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R**2 | F<br>STATISTIC | PROB ><br>F | WILKS<br>LAMBDA | PROB ><br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
|------|---------------------|---------------------|--------------|-----------------|----------------|-------------|-----------------|------------------|------------------------------------------------|
| 1    | MMPF                |                     | 1            | 0.7379          | 11.259         | 0.0047      | 0.26214565      | 0.0047           | 0.36892719                                     |
| 2    | MFPK                |                     | 2            | 0.6482          | 6.449          | 0.0258      | 0.09222430      | 0.0014           | 0.51712884                                     |
| 3    | MFMAX               |                     | 3            | 0.4831          | 2.803          | 0.1381      | 0.04767531      | 0.0020           | 0.58300295                                     |

Figure 9. STEPDISC result of 3 classes with 4 variables; step 4 and the selection summary for mean expiratory data.

STEPWISE SELECTION: STEP 1

STATISTICS FOR ENTRY, DF = 1, 642

| VARIABLE | R**2   | F      | PROB > F | TOLERANCE |
|----------|--------|--------|----------|-----------|
| MPF      | 0.0166 | 10.840 | 0.0010   | 1.0000    |
| FPK      | 0.0226 | 14.875 | 0.0001   | 1.0000    |
| FMAX     | 0.0080 | 5.177  | 0.0232   | 1.0000    |
| FLOW     | 0.0533 | 36.117 | 0.0001   | 1.0000    |

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED  
FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.94673959 F(1,642) = 36.117 PROB > F = 0.0001  
PILLAI'S TRACE = 0.053260 F(1,642) = 36.117 PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.05326041

STEPWISE SELECTION: STEP 2

STATISTICS FOR REMOVAL, DF = 1, 642

| VARIABLE | R**2   | F      | PROB > F |
|----------|--------|--------|----------|
| FLOW     | 0.0533 | 36.117 | 0.0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 641

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F | TOLERANCE |
|----------|-----------------|--------|----------|-----------|
| MPF      | 0.0211          | 13.815 | 0.0002   | 0.9972    |
| FPK      | 0.0205          | 13.145 | 0.0003   | 0.9977    |
| FMAX     | 0.0055          | 3.557  | 0.0598   | 0.9943    |

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.92676581 F(2,641) = 25.326 PROB > F = 0.0001  
PILLAI'S TRACE = 0.073234 F(2,641) = 25.326 PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.07323419

Figure 10. STEPDISC result of 2 classes with 4 variables; steps 1 and 2 for each expiration.

# STEPWISE SELECTION STEP 3

STATISTICS FOR REMOVAL, DF = 1, 641

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MPF      | 0 0211          | 13 815 | 0 0002   |
| FLOW     | 0 0576          | 39 168 | 0 0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 640

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F | TOLERANCE |
|----------|-----------------|--------|----------|-----------|
| FPK      | 0 0085          | 5 518  | 0 0191   | 0 8268    |
| FMAX     | 0 0678          | 46 517 | 0 0001   | 0 4793    |

VARIABLE FMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED  
MPF FMAX FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0 86397018 F(3,640) = 33 589 PROB > F = 0 0001  
PILLAI'S TRACE = 0 136030 F(3,640) = 33 589 PROB > F = 0 0001

AVERAGE SQUARED CANONICAL CORRELATION = 0 13602982

# STEPWISE SELECTION STEP 4

STATISTICS FOR REMOVAL, DF = 1, 640

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MPF      | 0 0824          | 57 443 | 0 0001   |
| FMAX     | 0 0678          | 46 517 | 0 0001   |
| FLOW     | 0 0550          | 37 253 | 0 0001   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 639

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FPK      | 0 0042          | 2 706 | 0 1004   | 0 4140    |

VARIABLE FPK WILL BE ENTERED

ALL VARIABLES HAVE BEEN ENTERED

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0 86032625 F(4,639) = 25 935 PROB > F = 0 0001  
PILLAI'S TRACE = 0 139674 F(4,639) = 25 935 PROB > F = 0 0001

Figure 11. STEPDISC result of 2 classes with 4 variables; steps 3 and 4 for each expiration.

# STEPWISE SELECTION STEP 5

STATISTICS FOR REMOVAL. DF = 1, 639

| VARIABLE | PARTIAL<br>R <sup>2</sup> | F      | PROB > F |
|----------|---------------------------|--------|----------|
| MPF      | 0 0608                    | 41 352 | 0 0001   |
| FPK      | 0 0042                    | 2 706  | 0 1001   |
| FMAX     | 0 0637                    | 43 463 | 0 0001   |
| FLOW     | 0 0530                    | 35 746 | 0 0001   |

NO VARIABLES CAN BE REMOVED

NO FURTHER STEPS ARE POSSIBLE

# STEPWISE SELECTION SUMMARY

| STEP | VARIABLE<br>ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R <sup>2</sup> | F<br>STATISTIC | PROB<br>F | WILKS<br>LAMBDA | PROB<br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
|------|---------------------|---------------------|--------------|---------------------------|----------------|-----------|-----------------|----------------|------------------------------------------------|
| 1    | FLOW                |                     | 1            | 0 0533                    | 36 117         | 0 0001    | 0 94673959      | 0 0001         | 0 05326041                                     |
| 2    | MPF                 |                     | 2            | 0 0211                    | 13 815         | 0 0002    | 0 92676581      | 0 0001         | 0 07323419                                     |
| 3    | FMAX                |                     | 3            | 0 0678                    | 46 517         | 0 0001    | 0 86397018      | 0 0001         | 0 13602982                                     |
| 4    | FPK                 |                     | 4            | 0 0042                    | 2 706          | 0 1001    | 0 860332625     | 0 0001         | 0 13967175                                     |

Figure 12. STEPDISC result of 2 classes with 4 variables;  
step 5 and the selection summary for each expiration.

STEPWISE SELECTION STEP 1

STATISTICS FOR ENTRY, DF = 1, 559

| VARIABLE | R**2   | F     | PROB > F | TOLERANCE |
|----------|--------|-------|----------|-----------|
| MPF      | 0.0158 | 8.979 | 0.0029   | 1.0000    |
| FPK      | 0.0142 | 8.047 | 0.0047   | 1.0000    |
| FMAX     | 0.0001 | 0.081 | 0.7761   | 1.0000    |
| FLOW     | 0.0121 | 6.875 | 0.0090   | 1.0000    |

VARIABLE MPF WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.98419152 F(1,559) = 8.979 PROB > F = 0.0029  
PILLAI'S TRACE = 0.015808 F(1,559) = 8.979 PROB > F = 0.0029

AVERAGE SQUARED CANONICAL CORRELATION = 0.01580848

STEPWISE SELECTION STEP 2

STATISTICS FOR REMOVAL, DF = 1, 559

| VARIABLE | R**2   | F     | PROB > F |
|----------|--------|-------|----------|
| MPF      | 0.0158 | 8.979 | 0.0029   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 558

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F | TOLERANCE |
|----------|-----------------|--------|----------|-----------|
| FPK      | 0.0033          | 1.873  | 0.1717   | 0.6709    |
| FMAX     | 0.0215          | 12.235 | 0.0005   | 0.3668    |
| FLOW     | 0.0158          | 8.959  | 0.0029   | 0.9881    |

VARIABLE FMAX WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FMAX

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.96307548 F(2,558) = 10.697 PROB > F = 0.0001  
PILLAI'S TRACE = 0.036925 F(2,558) = 10.697 PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.03692452

Figure 13. STEPDISC result of 2 classes with 4 variables;  
steps 1 and 2 for each inspiration.

STEPWISE SELECTION: STEP 3

STATISTICS FOR REMOVAL, DF = 1, 558

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MPF      | 0.0368          | 21.310 | 0.0001   |
| FMAX     | 0.0215          | 12.235 | 0.0005   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 557

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FPK      | 0.0006          | 0.354 | 0.5521   | 0.2642    |
| FLOW     | 0.0134          | 7.586 | 0.0061   | 0.3646    |

VARIABLE FLOW WILL BE ENTERED

THE FOLLOWING VARIABLE(S) HAVE BEEN ENTERED:  
MPF FMAX FLOW

MULTIVARIATE STATISTICS

WILKS' LAMBDA = 0.95013546 F(3,557) = 9.744 PROB > F = 0.0001  
PILLAI'S TRACE = 0.049865 F(3,557) = 9.744 PROB > F = 0.0001

AVERAGE SQUARED CANONICAL CORRELATION = 0.04986454

STEPWISE SELECTION: STEP 4

STATISTICS FOR REMOVAL, DF = 1, 557

| VARIABLE | PARTIAL<br>R**2 | F      | PROB > F |
|----------|-----------------|--------|----------|
| MPF      | 0.0375          | 21.682 | 0.0001   |
| FMAX     | 0.0191          | 10.847 | 0.0011   |
| FLOW     | 0.0134          | 7.586  | 0.0061   |

NO VARIABLES CAN BE REMOVED

STATISTICS FOR ENTRY, DF = 1, 556

| VARIABLE | PARTIAL<br>R**2 | F     | PROB > F | TOLERANCE |
|----------|-----------------|-------|----------|-----------|
| FPK      | 0.0010          | 0.536 | 0.4646   | 0.2641    |

NO VARIABLES CAN BE ENTERED

NO FURTHER STEPS ARE POSSIBLE

Figure 14. STEPDISC result of 2 classes with 4 variables; steps 3 and 4 for each inspiration.

| STEPWISE SELECTION SUMMARY |         |                     |              |                           |                |             |                  |                  |                                                |
|----------------------------|---------|---------------------|--------------|---------------------------|----------------|-------------|------------------|------------------|------------------------------------------------|
| STEP                       | ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R <sup>2</sup> | F<br>STATISTIC | PROB ><br>F | WILKS'<br>LAMBDA | PROB <<br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
| 1                          | MPF     |                     | 1            | 0.0158                    | 8.979          | 0.0029      | 0.98419152       | 0.0029           | 0.01580848                                     |
| 2                          | FMA     |                     | 2            | 0.0215                    | 12.235         | 0.0005      | 0.96307548       | 0.0001           | 0.03692452                                     |
| 3                          | FIOW    |                     | 3            | 0.0134                    | 7.586          | 0.0061      | 0.95013546       | 0.0001           | 0.04986454                                     |

| STEPWISE SELECTION SUMMARY |         |                     |              |                           |                |             |                  |                  |                                                |
|----------------------------|---------|---------------------|--------------|---------------------------|----------------|-------------|------------------|------------------|------------------------------------------------|
| STEP                       | ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R <sup>2</sup> | F<br>STATISTIC | PROB ><br>F | WILKS'<br>LAMBDA | PROB <<br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
| 1                          | FPK     |                     | 1            | 0.0226                    | 14.875         | 0.0001      | 0.97735543       | 0.0001           | 0.02264457                                     |
| 2                          | FMA     |                     | 2            | 0.0161                    | 10.509         | 0.0012      | 0.96159031       | 0.0001           | 0.03840969                                     |
| 3                          | MPF     |                     | 3            | 0.0553                    | 37.435         | 0.0001      | 0.90845296       | 0.0001           | 0.09154704                                     |

| STEPWISE SELECTION SUMMARY |         |                     |              |                           |                |             |                  |                  |                                                |
|----------------------------|---------|---------------------|--------------|---------------------------|----------------|-------------|------------------|------------------|------------------------------------------------|
| STEP                       | ENTERED | VARIABLE<br>REMOVED | NUMBER<br>IN | PARTIAL<br>R <sup>2</sup> | F<br>STATISTIC | PROB ><br>F | WILKS'<br>LAMBDA | PROB <<br>LAMBDA | AVERAGE<br>SQUARED<br>CANONICAL<br>CORRELATION |
| 1                          | MPF     |                     | 1            | 0.0158                    | 8.979          | 0.0029      | 0.98419152       | 0.0029           | 0.01580848                                     |
| 2                          | FMA     |                     | 2            | 0.0215                    | 12.235         | 0.0005      | 0.96307548       | 0.0001           | 0.03692452                                     |

Figure 15. Stepwise selection summaries:

(a) The selection summary for 2 classes with 4 variables during each inspiration, (b) the selection summary for 2 classes with 3 variables during each expiration, and (c) the selection summary for 2 classes with 3 variables during each inspiration.

Table 1. SUMMARY OF RANK ORDER OF VARIABLE DISCRIMINATING POWER

| Resp.<br>mode | Number<br>classes | No.<br>var. | Data<br>set | Order |      |      |     | Ref<br>Fig. No. |
|---------------|-------------------|-------------|-------------|-------|------|------|-----|-----------------|
|               |                   |             |             | 1     | 2    | 3    | 4   |                 |
| Exp           | 4                 | 4           | Each        | MPF   | FPK  | FLOW |     | 2-4             |
| Exp           | 3                 | 4           | Each        | MPF   | FPK  |      |     | 5-6             |
| Exp           | 3                 | 4           | Mean        | MPF   | FPK  | FMAX |     | 7-9             |
| Exp           | 2                 | 4           | Each        | FMAX  | FLOW | MPF  | FPK | 10-12           |
| Ins           | 2                 | 4           | Each        | FMAX  | MPF  | FLOW |     | 13-15           |
| Exp           | 2                 | 3           | Each        | MPF   | FPK  | FMAX |     | 15              |
| Ins           | 2                 | 3           | Each        | FMAX  | MPF  |      |     | 15              |

---

Exp = expiratory  
Ins = inspiratory

### CANDISC Results

The canonical discriminant program was initially run on the expiratory sound data with 4 classes and 4 variables. The means of the variables for a subject were used as input data to the CANDISC program. Table 2 shows the resulting Mahalanobis distances (23) between classes 0-3. There is less separation between abnormal class 0 and normal class 1, than between the 2 normal classes 1 and 3. Abnormal class 2 has the greatest separation from all other classes. This separation may also be readily seen in the plot of canonical variables CAN1 vs. CAN3 (Fig. 16).

Table 2. MAHALANOBIS DISTANCE BETWEEN CLASSES

| Class | 0     | 1     | 2     | 3     |
|-------|-------|-------|-------|-------|
| 0     | .     | 3.58  | 16.02 | 2.92  |
| 1     | 3.58  | .     | 13.24 | 6.10  |
| 2     | 16.02 | 13.24 | .     | 18.88 |
| 3     | 2.92  | 6.10  | 18.88 | .     |

Note:

Normal: classes 1 & 3

Abnormal: classes 0 & 2

Table 3 is a summary of Mahalanobis distances (23) between classes for the 2 class cases (normal vs. abnormal). The table also shows that the distance between groups increases when the variables were averaged and were the greatest when the average flow was added as a fourth variable. This result appears to disagree with results from the stepwise linear analysis which did not include flow as a strong discriminant variable (except one case during inspiration - Fig. 15).

### DISCRIM Results

Before running the discriminant analysis program (DISCRIM), the data was divided into 2 subsets, a "training" (contains 7 abnormals and 5 normals) set and an independent "test" set for classification with the discriminants obtained from the training set (Appendix A, direct set). In addition, the data was analyzed with the sets reversed, i.e., the training set became the independent test set and the test set was used as the

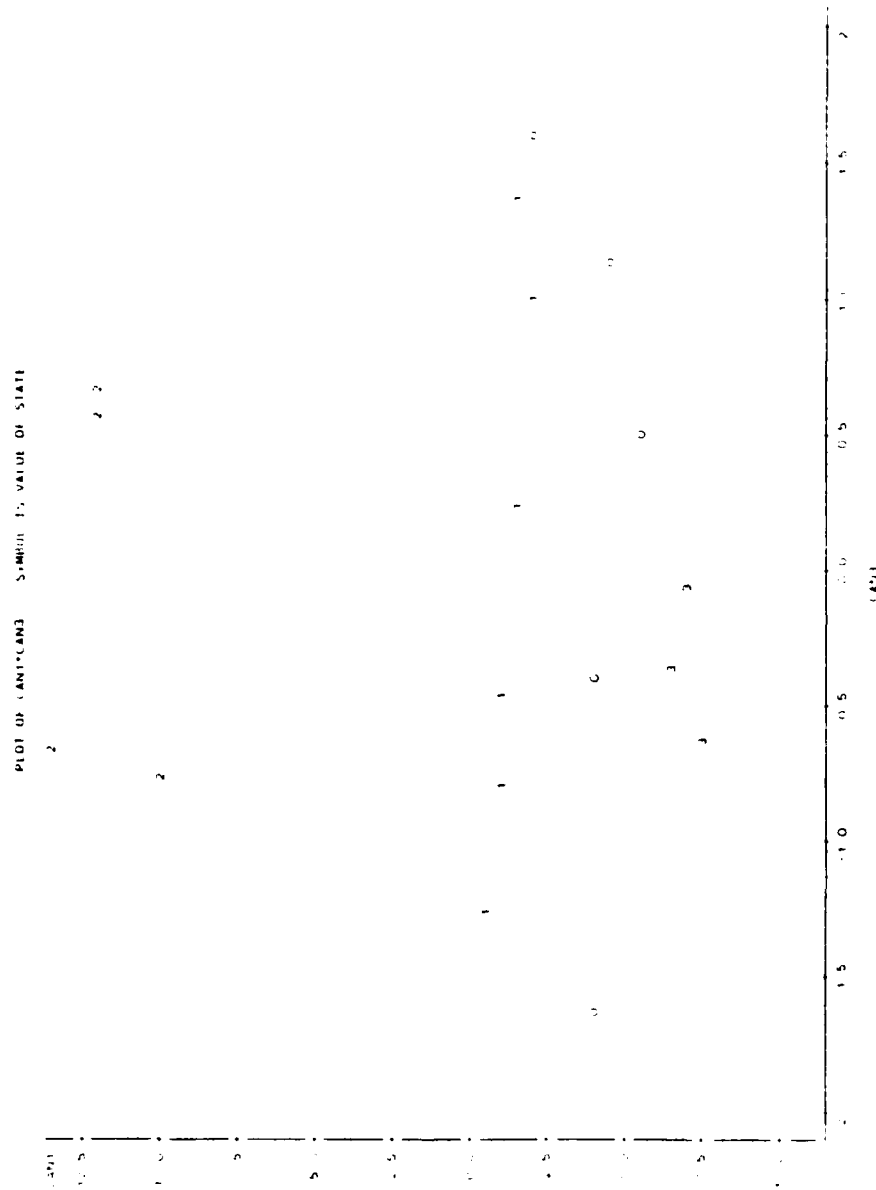


Figure 16. Plot of canonical variables CAN1 vs. CAN3 from CANDISC program results on mean expiratory data with 4 classes and 4 variables.

Table 3. SUMMARY OF MAHALANOBIS DISTANCES BETWEEN CLASSES FOR 2 CLASSES  
(NORMAL AND ABNORMAL)

|             | Expiration |        | Inspiration |        |
|-------------|------------|--------|-------------|--------|
|             | Each       | Mean   | Each        | Mean   |
| 4 variables | -          | 2.0899 | -           | 1.3738 |
| 3 variables | 0.6481     | 1.4475 | 0.3963      | 0.5310 |

training set. Runs with this data set are referred to as "reversed". As before, the data is in individual (1/4-s epoch) spectral variables or in averaged variables form. The terminology "each" is used when discussing data derived from the individual spectrum, and "mean" when discussing data derived from the average variables from numerous segments of breaths measured from a subject. Classification summaries of training and classification test data sets were obtained for "each" expiration (Appendix A), and inspiration (Appendix B) direct and reversed data sets.

For 2 classes (normal and abnormal), 3 parameters from each spectrum of expiration (Appendix A, Direct data set), Table 4 presents the classification summaries for the training and the classification sets. The number of correctly classified expiratory breaths from the training set are contained in the main diagonal, e.g., 170 and 89 = 259 correctly classified out of 348 or about 74.4%; off diagonal values are classification errors. For the training set, 54 abnormal expirations were misclassified as normal, and 35 normal expirations were misclassified as abnormal for a total of 89 out of 348 or 25.6% error.

Classification of the expiratory data reversed resulted in the summary Table 5. Approximately 40% of the training set is misclassified; this error increases to about 60% for new data (the classification test set).

Results of the discriminant analysis of "each" inspiratory sounds with direct and reversed data sets are presented in Tables 6 and 7. In both cases the training sets have fewer misclassified data points than the classification test set. Discriminant results are a little better with the direct data set than with reversed data set.

In addition, classification summaries were obtained from "mean" data sets given in Appendixes C and D. Tables 8 and 9 present the

Table 4. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, DIRECT DATA SET:  
EACH

---

| Training Set                                  |     |     |       |
|-----------------------------------------------|-----|-----|-------|
| Number of observations classified into class: |     |     |       |
| Class                                         | 0   | 1   | Total |
| 0                                             | 170 | 54  | 224   |
| 1                                             | 35  | 89  | 124   |
| Total                                         | 205 | 143 | 348   |
| Misclassified 25.6%                           |     |     |       |

| Classification Set                            |     |     |       |
|-----------------------------------------------|-----|-----|-------|
| Number of observations classified into class: |     |     |       |
| Class                                         | 0   | 1   | Total |
| 0                                             | 97  | 68  | 165   |
| 1                                             | 76  | 55  | 131   |
| Total                                         | 173 | 123 | 296   |
| Misclassified 48.6%                           |     |     |       |

---

Class 0 = Abnormal, Class 1 = Normal.

Table 5. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, REVERSED DATA SET:  
EACH

---

| Training Set                                  |    |     |       |
|-----------------------------------------------|----|-----|-------|
| Number of observations classified into class: |    |     |       |
| Class                                         | 0  | 1   | Total |
| 0                                             | 56 | 109 | 165   |
| 1                                             | 9  | 122 | 131   |
| Total                                         | 65 | 231 | 296   |
| Misclassified 39.9%                           |    |     |       |

| Classification Set                            |     |     |       |
|-----------------------------------------------|-----|-----|-------|
| Number of observations classified into class: |     |     |       |
| Class                                         | 0   | 1   | Total |
| 0                                             | 61  | 163 | 224   |
| 1                                             | 45  | 79  | 124   |
| Total                                         | 106 | 242 | 348   |
| Misclassified 59.8%                           |     |     |       |

---

Class 0 = Abnormal, Class 1 = Normal.

Table 6. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, DIRECT DATA SET:  
EACH

---

| Training Set                                  |     |     |       |
|-----------------------------------------------|-----|-----|-------|
| Number of observations classified into class: |     |     |       |
| Class                                         | 0   | 1   | Total |
| 0                                             | 151 | 30  | 181   |
| 1                                             | 48  | 86  | 134   |
| Total                                         | 199 | 116 | 315   |
| Misclassified 24.8%                           |     |     |       |

| Classification Set                            |    |     |       |
|-----------------------------------------------|----|-----|-------|
| Number of observations classified into class: |    |     |       |
| Class                                         | 0  | 1   | Total |
| 0                                             | 44 | 84  | 128   |
| 1                                             | 49 | 69  | 118   |
| Total                                         | 93 | 153 | 246   |
| Misclassified 54.1%                           |    |     |       |

---

Class 0 = Abnormal, Class 1 = Normal.

Table 7. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, REVERSED DATA SET: EACH

---

| Training Set                                  |    |     |       |
|-----------------------------------------------|----|-----|-------|
| Number of observations classified into class: |    |     |       |
| Class                                         | 0  | 1   | Total |
| 0                                             | 51 | 77  | 128   |
| 1                                             | 10 | 108 | 118   |
| Total                                         | 61 | 185 | 246   |
| Misclassified 35.4%                           |    |     |       |

| Classification Set                            |     |     |       |
|-----------------------------------------------|-----|-----|-------|
| Number of observations classified into class: |     |     |       |
| Class                                         | 0   | 1   | Total |
| 0                                             | 48  | 133 | 181   |
| 1                                             | 54  | 80  | 134   |
| Total                                         | 102 | 213 | 315   |
| Misclassified 59.4%                           |     |     |       |

---

Class 0 = Abnormal, Class 1 = Normal.

classification summaries for expiratory sounds with direct and reversed data sets (Appendix C). The results of classifying new data are about the same with either data set. The overall classification accuracy is about 80%. Classification summaries for inspiratory sounds with direct and reversal data sets (Appendix D) are given in Tables 10 and 11. In both cases, the accuracy for the training sets are better than classification accuracy for the test sets. The overall classification accuracy is about 67% with the direct and about 80% with the reversed data set.

To compare results obtained with the respiratory sound parameters to a standard pulmonary classification scheme, 3 pulmonary function test parameters provided by U.S. Air Force medical center were used to classify the subjects. The pulmonary function test parameters used as input variables to the discriminant analysis program were forced vital capacity (FVC), forced expiratory volume at 1 s (FEV1), and the ratio of forced expiratory volume at 1 s to forced vital capacity expressed in percentage (FEV1P). This data should correspond to classification with the mean data set since the pulmonary function test is per subject rather than per breath. The results of using the pulmonary function test parameters with direct and reversed data sets, Appendix E, are given in Tables 12 and 13. Note the similarity in results with the "mean" expiratory data (Tables 8 and 9) and the PFT results (Tables 12 and 13). This similarity may be explained by the fact that the pulmonary function test is per subject as is the mean of several breaths, and that the pulmonary function test is based primarily on measurements during forced expiration. There was an overall 20.8% error in classifying patients by the 3 parameters from the pulmonary function tests. The error may be caused by the classes, as seen by the standard 3 parameters, not being mutually exclusive, the data may be incorrectly classified, or not enough standard variables provided for evaluation.

Table 14 is a summary of all the discriminant classification runs. The upper half of the table presents percentage correctly classified and the lower half presents the total percent error in classification. As indicated by this table, classification with the mean data resulted in improved accuracy. The improved accuracy may be the result of better estimators due to smoothing of variability by averaging.

#### Regression Analysis

Multiple regression analysis was performed to determine if the spectral parameters for discriminating breath sounds correlate with the clinical data obtained by the pulmonary function test. In general, regression analysis fits least-square estimates to a linear regression model of the form:

$$y_i = W_0 + W_1X_{1i} + W_2X_{2i} + \dots + \epsilon_i \quad (24)$$

where  $y_i$  is the dependent variable that can be predicted by a linear combination of the weighted independent variables  $X$ 's for the observations  $i = 1, 2, \dots, n$ . The principle of least squares is used to produce estimates for the weighting factors ( $W$ 's) that are the best linear

Table 8. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, DIRECT DATA SET:  
MEAN

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 7 | 0 | 7     |
| 1     | 1 | 4 | 5     |
| Total | 8 | 4 | 12    |

Misclassified 8.3%

Classification Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 5 | 2 | 7     |
| 1     | 2 | 3 | 5     |
| Total | 7 | 5 | 12    |

Misclassified 33.3%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 9. CLASSIFICATION SUMMARY OF EXPIRATORY SOUND, REVERSED DATA SET:  
MEAN

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 5 | 2 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 5 | 7 | 12    |

Misclassified 16.7%

Classification Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 4 | 3 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 4 | 8 | 12    |

Misclassified 25%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 10. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, DIRECT DATA SET:  
MEAN

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 6 | 1 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 6 | 6 | 12    |

Misclassified 8.3%

Classification Set

Number of observations classified into class:

| Class | 0 | 1  | Total |
|-------|---|----|-------|
| 0     | 1 | 6  | 7     |
| 1     | 1 | 4  | 5     |
| Total | 2 | 10 | 12    |

Misclassified 58.3%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 11. CLASSIFICATION SUMMARY OF INSPIRATORY SOUND, REVERSED DATA  
SET: MEAN

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 7 | 0 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 7 | 5 | 12    |

Misclassified 0.0%

Classification Set

Number of observations classified into class:

| Class | 0  | 1 | Total |
|-------|----|---|-------|
| 0     | 7  | 0 | 7     |
| 1     | 5  | 0 | 5     |
| Total | 12 | 0 | 12    |

Misclassified 41.7%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 12. CLASSIFICATION SUMMARY OF PFT, DIRECT DATA SET

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 7 | 0 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 7 | 5 | 12    |

Misclassified 0.0%

Classification Set

Number of observations classified into class:

| Class | 0  | 1 | Total |
|-------|----|---|-------|
| 0     | 7  | 0 | 7     |
| 1     | 5  | 0 | 5     |
| Total | 12 | 0 | 12    |

Misclassified 41.7%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 13. CLASSIFICATION SUMMARY OF PFT, REVERSED DATA SET

---

Training Set

Number of observations classified into class:

| Class | 0 | 1 | Total |
|-------|---|---|-------|
| 0     | 6 | 1 | 7     |
| 1     | 0 | 5 | 5     |
| Total | 6 | 6 | 12    |

Misclassified 8.3%

Classification Set

Number of observations classified into class:

| Class | 0  | 1 | Total |
|-------|----|---|-------|
| 0     | 7  | 0 | 7     |
| 1     | 4  | 1 | 5     |
| Total | 11 | 1 | 12    |

Misclassified 33.3%

---

Class 0 = Abnormal, Class 1 = Normal.

Table 14. SUMMARY OF CLASSIFICATION ACCURACY

| Overall Percentage Correctly Classified |        |      |         |          |      |         |
|-----------------------------------------|--------|------|---------|----------|------|---------|
| Data Set                                | Direct |      |         | Reversed |      |         |
| Type                                    | Train  | Test | Overall | Train    | Test | Overall |
| Each expiration                         | 77.4   | 51.4 | 63.8    | 60.1     | 40.2 | 49.4    |
| Each inspiration                        | 75.2   | 45.9 | 62.4    | 64.6     | 40.6 | 51.2    |
| Mean expiration                         | 91.7   | 66.7 | 79.2    | 83.3     | 75.0 | 79.2    |
| Mean inspiration                        | 91.7   | 41.7 | 66.7    | 100.0    | 58.3 | 79.2    |
| PFT                                     | 100.0  | 58.3 | 79.2    | 91.7     | 66.7 | 79.2    |
| Overall Percentage Misclassified        |        |      |         |          |      |         |
| Each expiration                         | 25.6   | 48.6 | 36.2    | 39.9     | 59.8 | 50.6    |
| Each inspiration                        | 24.8   | 54.1 | 37.6    | 35.4     | 59.4 | 48.8    |
| Mean expiration                         | 8.3    | 33.3 | 20.8    | 16.7     | 25.0 | 20.8    |
| Mean inspiration                        | 8.3    | 58.3 | 33.3    | 0.0      | 41.7 | 20.8    |
| PFT                                     | 0.0    | 41.7 | 20.8    | 8.3      | 33.3 | 20.8    |

unbiased estimates under classical statistical assumptions. The regression programs available at Texas A&M University are statistical packages within the SAS [31]. The program outputs a summary of the statistics for each dependent variable to each independent variable or combination of independent variables and plots of each dependent variable vs. each independent variable. Typical plots of a first order model for FVC as the dependent variable and the mean frequency of the spectral parameter (MPF) are given for expiration and inspiration in Figures 17 and 18 respectively. In both cases, the predicted linear fit are almost horizontal lines indicating that there is almost no relationship between the dependent and independent variables. This linear fit is backed up by the low R-square values which are 0.0025 and 0.0140. Table 15 summarizes the R-square values for the dependent variables and the independent variables used in the regression model. Expiratory data set used for the regression analysis is given in Appendix F and the inspiratory data set in Appendix G. In all cases the low values of R-square results indicates that this is minimal correlation or relationship between the 3 respiratory sound parameters and the 3 pulmonary function test parameters. Thus, pulmonary function test parameters (i.e., FVC or FEV1 or FEV1P) cannot be predicted by any combination of respiratory sound parameters (MPF, FPK, FMAX).

## CONCLUSIONS

The objectives of this study were to determine whether respiratory sound data of normal volunteers and pulmonary insufficient subjects can be classified by DISCRIM analysis, and to determine if the spectral parameters for discriminating respiratory sounds correlate with the clinical parameters obtained from the pulmonary function test. Three DISCRIM analysis programs and a regression analysis package were used in the study.

The conclusions from the DISCRIM analysis are:

- Variables with the most discriminating power are MPF, FPK, and FMAX. Flow was not a good discriminator.
- Results of the CANDISC program indicated that the Mahalanobis distances (23) between the 2 classes (normal and abnormal) increase when variables were averaged (i.e., mean data set).
- Classification with the mean data is better than classification with data based on each breath. This data may be expected since the mean data set consist of estimators that have been smoothed by averaging thus reducing the variability. The only caution with accepting results from the mean data is the low number of samples in both normal and abnormal classes (12 each).
- Classification with the pulmonary function test parameters indicates that the classes may not have been classified 100% correctly by the rater or raters. This error in classification affects the outcome and accuracy of the discriminant program.
- Overall PFT direct rendered  $19/24 = 79.2\%$  correct and  $5/24 = 20.8\%$  error which is the same as mean expiration data direct ( $19/24 = 79.2\%$  overall correct). In addition the reverse PFT rendered  $19/24 = 79.2\%$  correct and  $5/24 = 20.8\%$  error whereas mean expiration

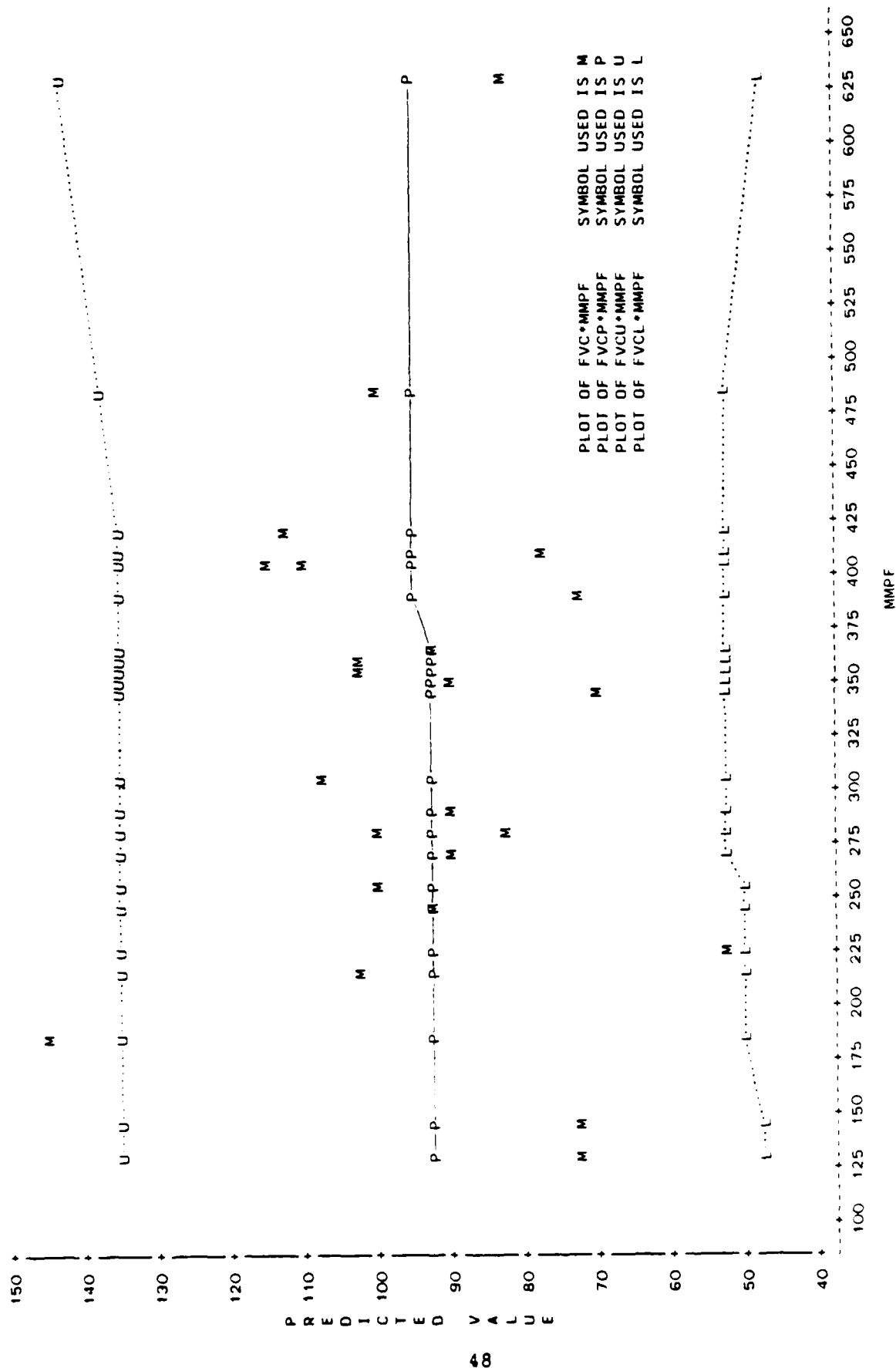


Figure 17. Regression analysis plot of first order model for FVC vs. MPF during expiration.

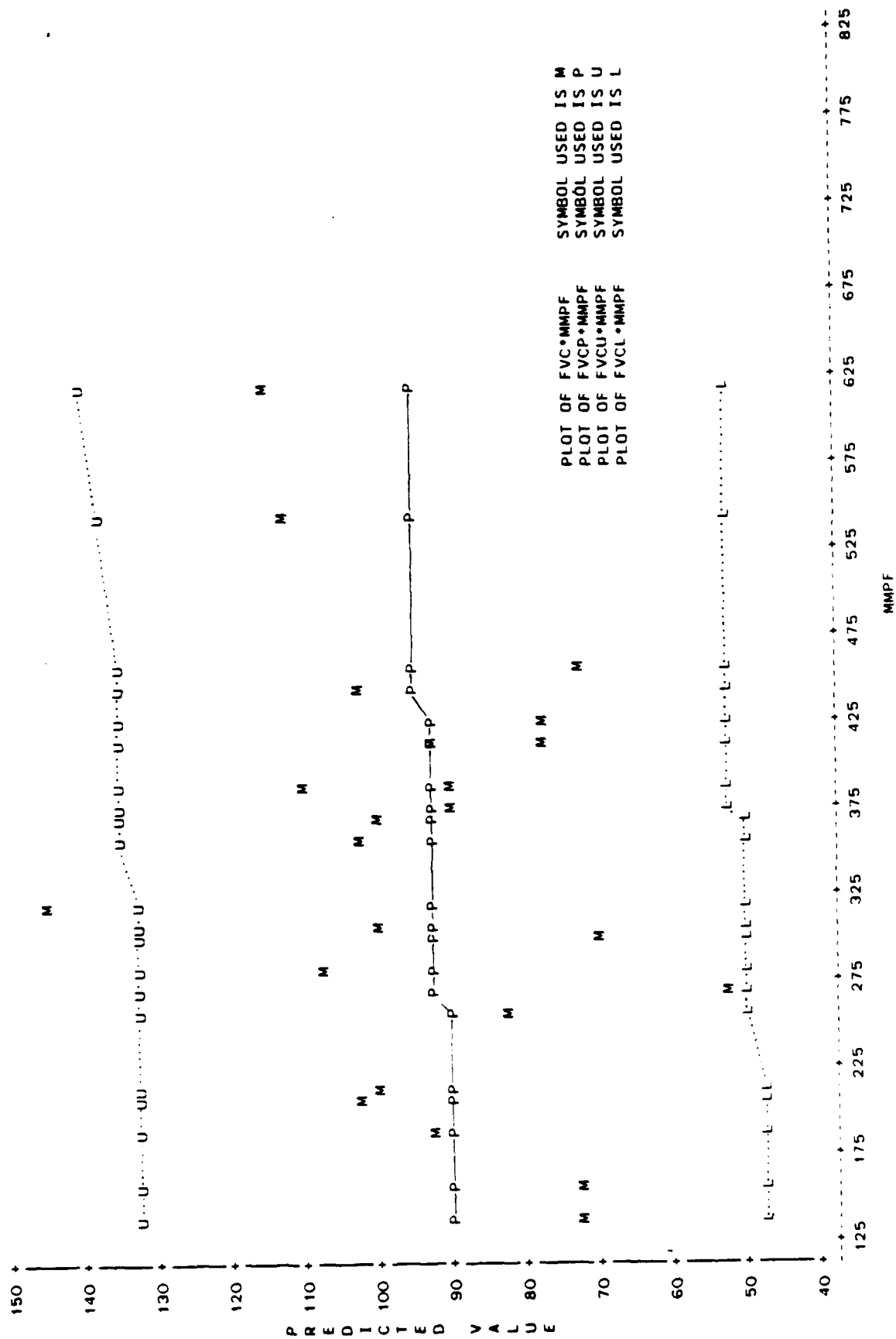


Figure 18. Regression analysis plot of first order model for FVC vs. MPF during inspiration.

Table 15. SUMMARY OF R-SQUARE VALUES OF REGRESSION MODELS

| Mean data: Expiration, N = 24   |                          |        |        |        |
|---------------------------------|--------------------------|--------|--------|--------|
| No. of<br>ind. var.<br>in model | Independent<br>variables | FVC    | FEV1   | FEV1P  |
| 1                               | MPF                      | 0.0025 | 0.0107 | 0.0091 |
| 1                               | FPK                      | 0.0166 | 0.0449 | 0.0073 |
| 1                               | FMAX                     | 0.0070 | 0.0132 | 0.1063 |
| 2                               | MPF, FPK                 | 0.0168 | 0.0450 | 0.0310 |
| 2                               | FPK, FMAX                | 0.0359 | 0.0863 | 0.1527 |
| 2                               | MPF, FMAX                | 0.0621 | 0.1638 | 0.2303 |
| 3                               | MPF, FPK, FMAX           | 0.0712 | 0.1853 | 0.2405 |

| Mean data: Inspiration, N = 24 |                |        |        |        |
|--------------------------------|----------------|--------|--------|--------|
| 1                              | MPF            | 0.0140 | 0.0082 | 0.0214 |
| 1                              | FPK            | 0.0014 | 0.0034 | 0.0025 |
| 1                              | FMAX           | 0.0108 | 0.0008 | 0.0712 |
| 2                              | MPF, FPK       | 0.0201 | 0.0085 | 0.0298 |
| 2                              | FPK, FMAX      | 0.0120 | 0.0035 | 0.0930 |
| 2                              | MPF, FMAX      | 0.0147 | 0.0410 | 0.1859 |
| 3                              | MPF, FPK, FMAX | 0.0250 | 0.0531 | 0.1968 |

reversed set also rendered  $19/24 = 79.2\%$  correct and  $5/24 = 20.8\%$  error.

Thus, results of classification with expiratory data approximates results of classification with the PFT variables. This stands to reason since the pulmonary function test is based on forced expiration measurements.

Conclusions from the regression studies are:

- The respiratory sound variable, peak frequency or mode of the spectrum (FPK) contributes the least to multiple regression.
- There is minimal or no correlation between the respiratory sound spectral parameters (MPF, FPK, FMAX) and the 3 pulmonary function test parameters (FVC, FEV1, FEV1P).

#### RECOMMENDATIONS

The results of the DISCRIM analysis are encouraging from the standpoint that classification with mean expiratory data closely approximates results from classification with the 3 pulmonary function test variables. Much has been learned from these studies -- for example, (1) better controls are needed during collection of data to reduce the variability; (2) since cardiac valve sounds may be heard with the respiration, the contribution of the valve sounds must be examined and eliminated, or reduced to decrease variability; and (3) other parameters from the respiratory spectra must be added and evaluated.

Each subject should be screened with a full pulmonary function test. These results should be classified by at least 3 experts in pulmonary function. Disagreements should not be used in the initial evaluation. Records and data in which full agreement is reached initially should only be used. The raters should be interviewed to establish which parameters and in what order were the parameters used in classification. Twelve or more subjects are necessary per class. To start, the classes should be mutually exclusive. Finally, the expansion of parameters should also include expansion of respiratory sound parameters, i.e., the spectral energy in broad frequency bands (100-150, 150-200, etc), the second and third movements of the distribution about zero. In short, we recommended that the study be repeated under contractor control from start to finish as soon as possible.

## REFERENCES

1. Bunin, N. and Loudon, R. Lung sound terminology in case reports. *Chest* 76:690-692,1979.
2. Cabot, R. C. and Dodge, H. F. Frequency characteristics of heart and lung sounds. *JAMA* 84:1793-1795,1925.
3. Charbonneau, G., J. L. Racineux, M. Sudraud, and E. Tukchais. An accurate recording system and its use in breath sounds spectral analysis. *J. Appl. Physiol.* 55:1120-1127,1983.
4. Chowdhury, S. K. and Majumder, A. K. Digital spectrum analysis of respiratory sound. *IEEE Trans. Biomed. Eng.* 28:784-788,1981.
5. Cooley, W. W. and Lohnes, P. R. Multivariate procedures for the behavioral sciences. New York: John Wiley and Sons, Inc., 1962.
6. Cover, T. M. and Hart, P. E. Nearest neighbor pattern classification. *IEEE Trans. Info. Theory*, IT-13: 21-27, 1967.
7. Dosani, R. and Kraman, S. S. Lung sound intensity variability in normal man. *Chest* 84:628-631,1983.
8. Druzgalski, C. Breath sounds in pulmonary diagnosis. *IEEE Frontiers of Eng. in Health Care* 383-385,1981.
9. Ertel, P. Y., M. Lawrence, R. K. Brown and A. M. Stern. Stethoscope acoustics. *Circulation* 33:889 (1966).
10. Fisher, R. A. The use of multiple measurements in taxonomic problems. *Ann Engenics*, 7:179-188, 1936.
11. Fletcher, H. and Munson, W. Loudness, its definition, measurement and calculation. *J. Acoust. Soc. Amer.* 5:82-108,1933.
12. Forgacs, Paul, Nathoo, A. R., and Richardson, H. D. Breath sounds. *Thorax* 26:288-295,1971.
13. Forgacs, Paul. The functional significance of clinical signs in diffuse airway obstruction. *Brit. J. Dis. Chest* 65:170,1971.
14. Forgacs, Paul. *Lung Sounds*. p.56, London: Balliere Tindall, 1978.
15. Grassi, C. et al. Normal and pathological respiratory sounds analyzed by means of a new phonopneumographic apparatus. *Respiration* 33:315-324,1976.
16. Gavriely, N., Y. Palti, and G. Alroy. Spectral characteristics of normal breath sounds. *J. Appl. Physiol.* 50:307-314,1981.
17. Guyton, A. C. *Textbook of Medical Physiology*. Sixth Edition,

Philadelphia: W.B.Saunders Co., 1981

18. Kshirsagar, A. M. *Multivariate analysis*. New York: Marcel Dekker, 1972.
19. Lachenbruch, P. A. *Discriminant analysis*. New York: Hafner Press, 1975.
20. Laennec, R. T. H. *A Treatise On The Disease Of The Chest And Mediate Auscultation*. Translated from the French edition by John Forbes. New York: Samuel Wood and Sons, 1935.
21. Leblanc, P. Breath sounds and distribution of pulmonary ventilation. *Am. Rev. Resp. Dis.* 102:10-16, 1970.
22. Lessard, C. S., Wolf, B. A, and Wong, W. C. Cluster analysis of respiratory sounds of pulmonary insufficient patients and normal subjects. USAFSAM-TR-86-13, October 1986.
23. Mahalanobis, P. C. On the generalized distance in statistics. *Proc. Nat. Inst. Sci. India*, 12:49-55, 1936.
24. Morris, S. The advent and development of the binaural stethoscope. *Practitioner* 199:674, 1967.
25. Murphy, R. Human factors in chest auscultations. *Human Factors in Health Care*. Lexington; MA: D. C. Heath and Co., 1975.
26. Murphy, R. Auscultations of the lung: past lessons, future possibilities. *Thorax* 36:99-107, 1981.
27. Nath, A. R. and Capel, L. H. Inspiratory crackles - early and late. *Thorax* 29:223, 1974.
28. O'Donnell, D. M. and Kraman, S. S. Vesicular lung sound amplitude mapping by automated flow-gated phonopneumography. *J. Appl. Physiol.* 53:603-609, 1982.
29. Ploysongsang, Y., R. R. Martin, and W. R. D. Ross. Breath sounds and regional ventilation. *Am. Rev. Resp. Dis.* 116:187-199, 1978.
30. Ploysongsang, Y., P. T. Macklem and W. R. D. Ross. Distribution of regional ventilation measured by breath sounds. *Am. Rev. Resp. Dis.* 117:657-664, 1978.
31. *SAS User's Guide*. Statistics Version 5 edition. Gary, N. C.: SAS Institute Inc., 1985.
32. Stanley, W. D. *Digital Signal Processing*. Reston Publ. Co.: Reston, VA; 279-280, 1975.
33. Tatsuoaka, M. M. *Selected topics in advanced statistics: classification*

*procedures.* Institute for Personality and Ability Testing, Champaign, ILL., 1974.

34. Wong, W. C. *Thesis.* Correlation of Respiration Flow Rate with Frequency Spectrum of Respiratory Sound at Trachea of Normal Young Adults. Texas A&M University, College Station; 1984.

## APPENDIX A

### EXPIRATION DIRECT DATA SET: EACH

#### Calibration or Training Set

7 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+  
#

5 Normals (STATE=1)

H  
I  
V  
W  
\*

DATA EXP;  
 TITLE 'POWER SPECTRA DATA ON EXPIRATORY SOUND';  
 COMMENT STATE: NORMAL= 1 ABNORMAL= 0;  
 COMMENT DIRECT CALIBRATION DATA;  
 INPUT ID \$ FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;  
 CARDS;

|   |    |    |     |   |      |       |       |        |
|---|----|----|-----|---|------|-------|-------|--------|
| P | 73 | 32 | 44  | 0 | 1.14 | 247.6 | 96.0  | 280.0  |
| P | 73 | 32 | 44  | 0 | 1.57 | 275.6 | 104.0 | 248.0  |
| P | 73 | 32 | 44  | 0 | 1.61 | 192.4 | 80.0  | 272.0  |
| P | 73 | 32 | 44  | 0 | 1.51 | 229.5 | 80.0  | 260.0  |
| P | 73 | 32 | 44  | 0 | 1.31 | 300.5 | 100.0 | 324.0  |
| P | 73 | 32 | 44  | 0 | 1.30 | 180.6 | 108.0 | 260.0  |
| P | 73 | 32 | 44  | 0 | 1.13 | 154.1 | 80.0  | 172.0  |
| P | 73 | 32 | 44  | 0 | 1.11 | 352.9 | 64.0  | 260.0  |
| P | 73 | 32 | 44  | 0 | 1.05 | 236.4 | 60.0  | 172.0  |
| P | 73 | 32 | 44  | 0 | 1.0  | 365.4 | 108.0 | 264.0  |
| P | 73 | 32 | 44  | 0 | 1.17 | 436.5 | 172.0 | 260.0  |
| P | 73 | 32 | 44  | 0 | 1.79 | 341.7 | 128.0 | 1016.0 |
| P | 73 | 32 | 44  | 0 | 1.97 | 367.9 | 172.0 | 620.0  |
| P | 73 | 32 | 44  | 0 | 1.91 | 351.6 | 148.0 | 592.0  |
| P | 73 | 32 | 44  | 0 | 1.74 | 365.4 | 96.0  | 1316.0 |
| P | 73 | 32 | 44  | 0 | 1.54 | 286.6 | 108.0 | 560.0  |
| P | 73 | 32 | 44  | 0 | 1.31 | 312.0 | 104.0 | 580.0  |
| P | 73 | 32 | 44  | 0 | 1.16 | 450.3 | 172.0 | 1376.0 |
| P | 73 | 32 | 44  | 0 | 1.03 | 367.6 | 100.0 | 420.0  |
| P | 73 | 32 | 44  | 0 | 0.95 | 336.5 | 172.0 | 600.0  |
| P | 73 | 32 | 44  | 0 | 0.68 | 484.6 | 172.0 | 1164.0 |
| P | 73 | 32 | 44  | 0 | 1.21 | 527.1 | 172.0 | 1376.0 |
| P | 73 | 32 | 44  | 0 | 1.54 | 514.9 | 160.0 | 1416.0 |
| P | 73 | 32 | 44  | 0 | 1.60 | 625.3 | 156.0 | 1376.0 |
| P | 73 | 32 | 44  | 0 | 1.64 | 475.8 | 208.0 | 1360.0 |
| P | 73 | 32 | 44  | 0 | 1.57 | 383.5 | 148.0 | 612.0  |
| P | 73 | 32 | 44  | 0 | 1.40 | 397.5 | 172.0 | 1256.0 |
| P | 73 | 32 | 44  | 0 | 1.32 | 459.0 | 160.0 | 1332.0 |
| P | 73 | 32 | 44  | 0 | 1.12 | 490.7 | 172.0 | 1288.0 |
| P | 73 | 32 | 44  | 0 | 1.08 | 439.7 | 172.0 | 1336.0 |
| P | 73 | 32 | 44  | 0 | 0.65 | 581.9 | 172.0 | 1276.0 |
| P | 73 | 32 | 44  | 0 | 1.44 | 554.5 | 180.0 | 1440.0 |
| P | 73 | 32 | 44  | 0 | 1.88 | 604.6 | 120.0 | 1388.0 |
| P | 73 | 32 | 44  | 0 | 1.72 | 478.9 | 196.0 | 1372.0 |
| P | 73 | 32 | 44  | 0 | 1.57 | 364.1 | 108.0 | 532.0  |
| P | 73 | 32 | 44  | 0 | 1.42 | 271.9 | 100.0 | 636.0  |
| P | 73 | 32 | 44  | 0 | 1.34 | 473.0 | 172.0 | 1452.0 |
| P | 73 | 32 | 44  | 0 | 1.21 | 436.6 | 172.0 | 1360.0 |
| P | 73 | 32 | 44  | 0 | 1.10 | 379.1 | 80.0  | 1056.0 |
| P | 73 | 32 | 44  | 0 | 1.05 | 565.2 | 292.0 | 1372.0 |
| + | 72 | 58 | 124 | 0 | 1.12 | 140.2 | 92.0  | 120.0  |
| + | 72 | 58 | 124 | 0 | 1.37 | 90.4  | 92.0  | 112.0  |
| + | 72 | 58 | 124 | 0 | 1.23 | 241.7 | 100.0 | 140.0  |
| + | 72 | 58 | 124 | 0 | 1.19 | 186.1 | 80.0  | 124.0  |
| + | 72 | 58 | 124 | 0 | 1.29 | 152.6 | 112.0 | 180.0  |
| + | 72 | 58 | 124 | 0 | 1.08 | 209.7 | 108.0 | 148.0  |

|   |    |     |     |   |      |       |       |        |
|---|----|-----|-----|---|------|-------|-------|--------|
| + | 72 | 58  | 124 | 0 | 0.80 | 190.6 | 72.0  | 140.0  |
| + | 72 | 58  | 124 | 0 | 0.78 | 129.3 | 72.0  | 180.0  |
| + | 72 | 58  | 124 | 0 | 0.62 | 116.4 | 64.0  | 128.0  |
| + | 72 | 58  | 124 | 0 | 0.99 | 121.2 | 108.0 | 188.0  |
| + | 72 | 58  | 124 | 0 | 1.46 | 133.1 | 88.0  | 128.0  |
| + | 72 | 58  | 124 | 0 | 1.52 | 135.6 | 104.0 | 188.0  |
| + | 72 | 58  | 124 | 0 | 1.35 | 138.4 | 120.0 | 164.0  |
| + | 72 | 58  | 124 | 0 | 1.38 | 114.4 | 104.0 | 152.0  |
| + | 72 | 58  | 124 | 0 | 1.23 | 133.0 | 88.0  | 192.0  |
| + | 72 | 58  | 124 | 0 | 0.84 | 124.6 | 112.0 | 156.0  |
| + | 72 | 58  | 124 | 0 | 0.92 | 127.7 | 88.0  | 148.0  |
| + | 72 | 58  | 124 | 0 | 1.55 | 110.4 | 96.0  | 136.0  |
| + | 72 | 58  | 124 | 0 | 1.42 | 113.4 | 96.0  | 140.0  |
| + | 72 | 58  | 124 | 0 | 1.65 | 132.6 | 96.0  | 164.0  |
| + | 72 | 58  | 124 | 0 | 1.74 | 112.4 | 96.0  | 172.0  |
| + | 72 | 58  | 124 | 0 | 1.31 | 103.0 | 104.0 | 120.0  |
| + | 72 | 58  | 124 | 0 | 1.03 | 144.9 | 104.0 | 144.0  |
| + | 72 | 58  | 124 | 0 | 0.91 | 123.1 | 68.0  | 176.0  |
| + | 72 | 58  | 124 | 0 | 0.64 | 106.4 | 80.0  | 112.0  |
| + | 72 | 58  | 124 | 0 | 0.71 | 144.4 | 88.0  | 136.0  |
| + | 72 | 58  | 124 | 0 | 0.85 | 110.2 | 84.0  | 132.0  |
| + | 72 | 58  | 124 | 0 | 0.90 | 109.5 | 84.0  | 144.0  |
| + | 72 | 58  | 124 | 0 | 0.94 | 109.5 | 92.0  | 144.0  |
| + | 72 | 58  | 124 | 0 | 1.01 | 103.9 | 104.0 | 160.0  |
| + | 72 | 58  | 124 | 0 | 1.07 | 120.6 | 112.0 | 160.0  |
| + | 72 | 58  | 124 | 0 | 1.11 | 118.5 | 96.0  | 168.0  |
| + | 72 | 58  | 124 | 0 | 1.04 | 117.8 | 84.0  | 140.0  |
| * | 99 | 105 | 105 | 1 | 0.69 | 431.7 | 112.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.06 | 413.2 | 112.0 | 124.0  |
| * | 99 | 105 | 105 | 1 | 1.22 | 592.8 | 260.0 | 1408.0 |
| * | 99 | 105 | 105 | 1 | 1.22 | 431.0 | 112.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.14 | 473.2 | 108.0 | 484.0  |
| * | 99 | 105 | 105 | 1 | 1.14 | 373.5 | 112.0 | 172.0  |
| * | 99 | 105 | 105 | 1 | 1.13 | 534.5 | 112.0 | 1316.0 |
| * | 99 | 105 | 105 | 1 | 1.15 | 519.9 | 112.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.18 | 531.5 | 112.0 | 1036.0 |
| * | 99 | 105 | 105 | 1 | 1.29 | 603.6 | 108.0 | 1476.0 |
| * | 99 | 105 | 105 | 1 | 1.29 | 394.7 | 112.0 | 124.0  |
| * | 99 | 105 | 105 | 1 | 1.28 | 476.2 | 112.0 | 776.0  |
| * | 99 | 105 | 105 | 1 | 1.26 | 478.9 | 112.0 | 560.0  |
| * | 99 | 105 | 105 | 1 | 1.20 | 471.8 | 112.0 | 1280.0 |
| * | 99 | 105 | 105 | 1 | 1.18 | 342.4 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.04 | 536.3 | 260.0 | 1376.0 |
| * | 99 | 105 | 105 | 1 | 1.27 | 459.5 | 108.0 | 256.0  |
| * | 99 | 105 | 105 | 1 | 1.24 | 562.2 | 108.0 | 1312.0 |
| * | 99 | 105 | 105 | 1 | 1.27 | 535.5 | 112.0 | 1332.0 |
| * | 99 | 105 | 105 | 1 | 1.21 | 543.2 | 172.0 | 1372.0 |
| * | 99 | 105 | 105 | 1 | 1.15 | 560.3 | 172.0 | 1344.0 |
| * | 99 | 105 | 105 | 1 | 1.08 | 389.9 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.07 | 538.4 | 172.0 | 512.0  |
| * | 99 | 105 | 105 | 1 | 0.75 | 575.6 | 108.0 | 1280.0 |
| * | 99 | 105 | 105 | 1 | 1.05 | 523.8 | 112.0 | 260.0  |

|   |     |     |     |   |      |       |       |        |
|---|-----|-----|-----|---|------|-------|-------|--------|
| * | 99  | 105 | 105 | 1 | 1.05 | 484.6 | 172.0 | 1316.0 |
| * | 99  | 105 | 105 | 1 | 1.08 | 361.0 | 112.0 | 172.0  |
| * | 99  | 105 | 105 | 1 | 1.13 | 419.3 | 108.0 | 172.0  |
| * | 99  | 105 | 105 | 1 | 1.16 | 463.6 | 112.0 | 260.0  |
| * | 99  | 105 | 105 | 1 | 1.07 | 524.8 | 112.0 | 500.0  |
| # | 70  | 74  | 106 | 0 | 0.46 | 386.5 | 116.0 | 1372.0 |
| # | 70  | 74  | 106 | 0 | 0.64 | 414.9 | 112.0 | 588.0  |
| # | 70  | 74  | 106 | 0 | 0.71 | 404.2 | 176.0 | 652.0  |
| # | 70  | 74  | 106 | 0 | 0.80 | 400.1 | 92.0  | 632.0  |
| # | 70  | 74  | 106 | 0 | 0.89 | 378.8 | 156.0 | 724.0  |
| # | 70  | 74  | 106 | 0 | 0.95 | 401.1 | 132.0 | 672.0  |
| # | 70  | 74  | 106 | 0 | 0.92 | 391.3 | 144.0 | 1180.0 |
| # | 70  | 74  | 106 | 0 | 0.98 | 170.1 | 80.0  | 152.0  |
| # | 70  | 74  | 106 | 0 | 0.97 | 291.1 | 116.0 | 260.0  |
| # | 70  | 74  | 106 | 0 | 0.59 | 188.0 | 72.0  | 260.0  |
| # | 70  | 74  | 106 | 0 | 0.74 | 127.6 | 84.0  | 172.0  |
| # | 70  | 74  | 106 | 0 | 0.92 | 244.9 | 152.0 | 568.0  |
| # | 70  | 74  | 106 | 0 | 0.97 | 202.7 | 92.0  | 260.0  |
| # | 70  | 74  | 106 | 0 | 0.99 | 219.4 | 148.0 | 572.0  |
| # | 70  | 74  | 106 | 0 | 0.96 | 254.2 | 92.0  | 568.0  |
| # | 70  | 74  | 106 | 0 | 0.88 | 286.4 | 136.0 | 604.0  |
| # | 70  | 74  | 106 | 0 | 0.84 | 249.1 | 72.0  | 556.0  |
| # | 70  | 74  | 106 | 0 | 0.94 | 163.5 | 124.0 | 168.0  |
| # | 70  | 74  | 106 | 0 | 0.70 | 417.1 | 112.0 | 640.0  |
| # | 70  | 74  | 106 | 0 | 0.92 | 289.0 | 116.0 | 372.0  |
| # | 70  | 74  | 106 | 0 | 1.05 | 368.5 | 116.0 | 596.0  |
| # | 70  | 74  | 106 | 0 | 1.22 | 451.9 | 116.0 | 676.0  |
| # | 70  | 74  | 106 | 0 | 1.20 | 438.5 | 108.0 | 652.0  |
| # | 70  | 74  | 106 | 0 | 1.18 | 497.3 | 556.0 | 676.0  |
| # | 70  | 74  | 106 | 0 | 1.02 | 459.5 | 576.0 | 644.0  |
| # | 70  | 74  | 106 | 0 | 0.97 | 465.0 | 88.0  | 1136.0 |
| # | 70  | 74  | 106 | 0 | 1.14 | 357.5 | 112.0 | 568.0  |
| # | 70  | 74  | 106 | 0 | 0.27 | 361.7 | 108.0 | 260.0  |
| # | 70  | 74  | 106 | 0 | 0.38 | 360.9 | 92.0  | 1144.0 |
| # | 70  | 74  | 106 | 0 | 0.68 | 451.5 | 108.0 | 676.0  |
| # | 70  | 74  | 106 | 0 | 0.85 | 414.2 | 100.0 | 1352.0 |
| # | 70  | 74  | 106 | 0 | 1.05 | 435.2 | 108.0 | 1144.0 |
| # | 70  | 74  | 106 | 0 | 1.27 | 359.3 | 148.0 | 568.0  |
| # | 70  | 74  | 106 | 0 | 1.19 | 402.4 | 144.0 | 632.0  |
| # | 70  | 74  | 106 | 0 | 1.13 | 417.8 | 492.0 | 1148.0 |
| # | 70  | 74  | 106 | 0 | 1.08 | 388.0 | 112.0 | 632.0  |
| Q | 102 | 83  | 81  | 0 | 1.10 | 279.3 | 80.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 1.70 | 417.0 | 600.0 | 608.0  |
| Q | 102 | 83  | 81  | 0 | 1.65 | 337.0 | 584.0 | 616.0  |
| Q | 102 | 83  | 81  | 0 | 1.40 | 246.2 | 92.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 1.10 | 142.2 | 88.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 0.82 | 217.7 | 96.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 0.60 | 146.9 | 116.0 | 600.0  |
| Q | 102 | 83  | 81  | 0 | 0.43 | 95.2  | 64.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 0.23 | 131.0 | 124.0 | 600.0  |
| Q | 102 | 83  | 81  | 0 | 1.03 | 147.8 | 68.0  | 600.0  |
| Q | 102 | 83  | 81  | 0 | 1.53 | 288.4 | 600.0 | 600.0  |

|   |     |     |     |   |      |       |       |       |
|---|-----|-----|-----|---|------|-------|-------|-------|
| Q | 102 | 83  | 81  | 0 | 1.63 | 306.3 | 92.0  | 612.0 |
| Q | 102 | 83  | 81  | 0 | 1.39 | 195.7 | 80.0  | 604.0 |
| Q | 102 | 83  | 81  | 0 | 1.11 | 249.5 | 96.0  | 608.0 |
| Q | 102 | 83  | 81  | 0 | 0.84 | 107.0 | 76.0  | 104.0 |
| Q | 102 | 83  | 81  | 0 | 0.61 | 244.1 | 84.0  | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.41 | 148.4 | 112.0 | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.33 | 97.5  | 60.0  | 108.0 |
| Q | 102 | 83  | 81  | 0 | 1.01 | 161.5 | 84.0  | 600.0 |
| Q | 102 | 83  | 81  | 0 | 1.69 | 319.7 | 88.0  | 620.0 |
| Q | 102 | 83  | 81  | 0 | 1.79 | 315.3 | 96.0  | 612.0 |
| Q | 102 | 83  | 81  | 0 | 1.52 | 177.3 | 72.0  | 604.0 |
| Q | 102 | 83  | 81  | 0 | 1.16 | 217.4 | 92.0  | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.91 | 118.0 | 64.0  | 164.0 |
| Q | 102 | 83  | 81  | 0 | 0.68 | 281.1 | 600.0 | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.48 | 171.9 | 128.0 | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.32 | 101.1 | 72.0  | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.77 | 112.9 | 64.0  | 132.0 |
| Q | 102 | 83  | 81  | 0 | 1.52 | 311.3 | 104.0 | 628.0 |
| Q | 102 | 83  | 81  | 0 | 1.65 | 272.1 | 76.0  | 612.0 |
| Q | 102 | 83  | 81  | 0 | 1.57 | 350.1 | 204.0 | 616.0 |
| Q | 102 | 83  | 81  | 0 | 1.32 | 273.9 | 92.0  | 604.0 |
| Q | 102 | 83  | 81  | 0 | 1.06 | 153.8 | 108.0 | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.73 | 249.1 | 88.0  | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.49 | 190.1 | 600.0 | 600.0 |
| Q | 102 | 83  | 81  | 0 | 0.36 | 98.0  | 64.0  | 600.0 |
| X | 93  | 78  | 85  | 0 | 1.11 | 290.3 | 160.0 | 732.0 |
| X | 93  | 78  | 85  | 0 | 1.34 | 356.5 | 196.0 | 772.0 |
| X | 93  | 78  | 85  | 0 | 1.05 | 272.3 | 120.0 | 624.0 |
| X | 93  | 78  | 85  | 0 | 0.92 | 323.5 | 96.0  | 688.0 |
| X | 93  | 78  | 85  | 0 | 0.79 | 268.1 | 156.0 | 636.0 |
| X | 93  | 78  | 85  | 0 | 0.57 | 328.5 | 188.0 | 648.0 |
| X | 93  | 78  | 85  | 0 | 1.00 | 240.0 | 104.0 | 604.0 |
| X | 93  | 78  | 85  | 0 | 0.88 | 262.1 | 116.0 | 560.0 |
| X | 93  | 78  | 85  | 0 | 0.78 | 199.0 | 96.0  | 180.0 |
| X | 93  | 78  | 85  | 0 | 0.61 | 174.6 | 80.0  | 120.0 |
| X | 93  | 78  | 85  | 0 | 0.87 | 235.5 | 136.0 | 600.0 |
| X | 93  | 78  | 85  | 0 | 0.78 | 230.5 | 108.0 | 260.0 |
| X | 93  | 78  | 85  | 0 | 0.74 | 222.9 | 96.0  | 416.0 |
| X | 93  | 78  | 85  | 0 | 0.65 | 141.0 | 112.0 | 164.0 |
| X | 93  | 78  | 85  | 0 | 0.52 | 206.0 | 100.0 | 260.0 |
| X | 93  | 78  | 85  | 0 | 0.41 | 277.2 | 104.0 | 448.0 |
| X | 93  | 78  | 85  | 0 | 0.85 | 248.5 | 112.0 | 520.0 |
| X | 93  | 78  | 85  | 0 | 0.89 | 217.2 | 100.0 | 496.0 |
| X | 93  | 78  | 85  | 0 | 0.83 | 271.2 | 88.0  | 596.0 |
| X | 93  | 78  | 85  | 0 | 0.72 | 182.6 | 96.0  | 172.0 |
| V | 101 | 106 | 104 | 1 | 1.11 | 132.2 | 88.0  | 144.0 |
| V | 101 | 106 | 104 | 1 | 1.73 | 208.8 | 108.0 | 396.0 |
| V | 101 | 106 | 104 | 1 | 1.74 | 203.8 | 116.0 | 180.0 |
| V | 101 | 106 | 104 | 1 | 1.57 | 206.1 | 104.0 | 160.0 |
| V | 101 | 106 | 104 | 1 | 1.42 | 223.9 | 96.0  | 348.0 |
| V | 101 | 106 | 104 | 1 | 1.27 | 146.7 | 100.0 | 144.0 |
| V | 101 | 106 | 104 | 1 | 1.06 | 162.8 | 112.0 | 160.0 |

|   |     |     |     |   |      |       |       |        |
|---|-----|-----|-----|---|------|-------|-------|--------|
| V | 101 | 106 | 104 | 1 | 0.87 | 150.2 | 104.0 | 164.0  |
| V | 101 | 106 | 104 | 1 | 1.51 | 434.6 | 628.0 | 648.0  |
| V | 101 | 106 | 104 | 1 | 1.61 | 336.6 | 628.0 | 644.0  |
| V | 101 | 106 | 104 | 1 | 1.43 | 343.6 | 620.0 | 636.0  |
| V | 101 | 106 | 104 | 1 | 1.23 | 387.7 | 628.0 | 632.0  |
| V | 101 | 106 | 104 | 1 | 1.03 | 298.0 | 620.0 | 640.0  |
| V | 101 | 106 | 104 | 1 | 0.83 | 237.9 | 116.0 | 628.0  |
| V | 101 | 106 | 104 | 1 | 1.92 | 353.9 | 104.0 | 740.0  |
| V | 101 | 106 | 104 | 1 | 2.07 | 362.8 | 120.0 | 636.0  |
| V | 101 | 106 | 104 | 1 | 1.35 | 328.1 | 116.0 | 636.0  |
| V | 101 | 106 | 104 | 1 | 0.95 | 283.4 | 116.0 | 636.0  |
| V | 101 | 106 | 104 | 1 | 0.66 | 225.5 | 104.0 | 628.0  |
| V | 101 | 106 | 104 | 1 | 1.66 | 426.3 | 620.0 | 640.0  |
| V | 101 | 106 | 104 | 1 | 1.61 | 396.7 | 616.0 | 628.0  |
| V | 101 | 106 | 104 | 1 | 1.04 | 369.1 | 620.0 | 628.0  |
| V | 101 | 106 | 104 | 1 | 0.69 | 271.8 | 616.0 | 624.0  |
| V | 101 | 106 | 104 | 1 | 0.51 | 238.4 | 108.0 | 624.0  |
| W | 107 | 114 | 106 | 1 | 0.26 | 343.3 | 108.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.41 | 300.1 | 112.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.48 | 352.4 | 108.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.46 | 341.7 | 128.0 | 520.0  |
| W | 107 | 114 | 106 | 1 | 0.37 | 295.5 | 108.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.29 | 313.5 | 112.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.63 | 475.7 | 260.0 | 1404   |
| W | 107 | 114 | 106 | 1 | 0.55 | 430.0 | 180.0 | 1212.0 |
| W | 107 | 114 | 106 | 1 | 0.78 | 395.1 | 260.0 | 1056.0 |
| W | 107 | 114 | 106 | 1 | 0.78 | 231.6 | 124.0 | 288.0  |
| W | 107 | 114 | 106 | 1 | 0.56 | 348.2 | 176.0 | 528.0  |
| W | 107 | 114 | 106 | 1 | 0.35 | 148.9 | 84.0  | 192.0  |
| W | 107 | 114 | 106 | 1 | 0.53 | 211.3 | 124.0 | 320.0  |
| W | 107 | 114 | 106 | 1 | 0.49 | 205.4 | 120.0 | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.49 | 270.6 | 172.0 | 384.0  |
| W | 107 | 114 | 106 | 1 | 0.43 | 381.6 | 172.0 | 388.0  |
| W | 107 | 114 | 106 | 1 | 0.34 | 323.4 | 84.0  | 260.0  |
| W | 107 | 114 | 106 | 1 | 0.34 | 244.8 | 148.0 | 348.0  |
| W | 107 | 114 | 106 | 1 | 0.54 | 250.4 | 88.0  | 600.0  |
| W | 107 | 114 | 106 | 1 | 0.55 | 297.9 | 140.0 | 632.0  |
| W | 107 | 114 | 106 | 1 | 0.47 | 232.4 | 116.0 | 364.0  |
| W | 107 | 114 | 106 | 1 | 0.36 | 288.8 | 108.0 | 628.0  |
| H | 83  | 76  | 91  | 0 | 0.64 | 225.1 | 104.0 | 560.0  |
| H | 83  | 76  | 91  | 0 | 0.99 | 127.3 | 96.0  | 120.0  |
| H | 83  | 76  | 91  | 0 | 1.12 | 389.4 | 588.0 | 616.0  |
| H | 83  | 76  | 91  | 0 | 1.30 | 402.6 | 584.0 | 612.0  |
| H | 83  | 76  | 91  | 0 | 1.26 | 158.4 | 92.0  | 588.0  |
| H | 83  | 76  | 91  | 0 | 1.05 | 413.6 | 588.0 | 608.0  |
| H | 83  | 76  | 91  | 0 | 1.05 | 241.0 | 80.0  | 588.0  |
| H | 83  | 76  | 91  | 0 | 0.89 | 328.8 | 592.0 | 592.0  |
| H | 83  | 76  | 91  | 0 | 0.66 | 257.3 | 76.0  | 596.0  |
| H | 83  | 76  | 91  | 0 | 0.22 | 94.6  | 84.0  | 112.0  |
| H | 83  | 76  | 91  | 0 | 0.94 | 354.8 | 588.0 | 596.0  |
| H | 83  | 76  | 91  | 0 | 1.20 | 323.0 | 592.0 | 608.0  |
| H | 83  | 76  | 91  | 0 | 1.48 | 399.8 | 584.0 | 612.0  |

|   |     |     |    |   |      |       |       |       |
|---|-----|-----|----|---|------|-------|-------|-------|
| T | 83  | 76  | 91 | 0 | 1.48 | 234.2 | 84.0  | 600.0 |
| T | 83  | 76  | 91 | 0 | 1.25 | 414.6 | 588.0 | 600.0 |
| T | 83  | 76  | 91 | 0 | 0.99 | 193.6 | 112.0 | 584.0 |
| T | 83  | 76  | 91 | 0 | 0.96 | 114.4 | 80.0  | 592.0 |
| T | 83  | 76  | 91 | 0 | 0.69 | 393.4 | 592.0 | 604.0 |
| T | 83  | 76  | 91 | 0 | 0.84 | 128.8 | 100.0 | 112.0 |
| T | 83  | 76  | 91 | 0 | 1.05 | 357.2 | 584.0 | 604.0 |
| T | 83  | 76  | 91 | 0 | 1.29 | 317.9 | 228.0 | 608.0 |
| T | 83  | 76  | 91 | 0 | 1.38 | 155.4 | 88.0  | 456.0 |
| T | 83  | 76  | 91 | 0 | 1.34 | 364.3 | 584.0 | 616.0 |
| T | 83  | 76  | 91 | 0 | 1.08 | 235.7 | 92.0  | 592.0 |
| T | 83  | 76  | 91 | 0 | 0.83 | 368.1 | 592.0 | 608.0 |
| T | 83  | 76  | 91 | 0 | 0.67 | 318.9 | 76.0  | 600.0 |
| T | 83  | 76  | 91 | 0 | 0.28 | 121.5 | 76.0  | 148.0 |
| T | 83  | 76  | 91 | 0 | 0.85 | 390.3 | 592.0 | 592.0 |
| T | 83  | 76  | 91 | 0 | 1.12 | 360.3 | 584.0 | 592.0 |
| T | 83  | 76  | 91 | 0 | 1.32 | 305.8 | 124.0 | 600.0 |
| T | 83  | 76  | 91 | 0 | 1.26 | 379.4 | 584.0 | 596.0 |
| T | 83  | 76  | 91 | 0 | 1.15 | 249.2 | 96.0  | 596.0 |
| T | 83  | 76  | 91 | 0 | 1.08 | 198.9 | 116.0 | 588.0 |
| T | 83  | 76  | 91 | 0 | 1.02 | 397.2 | 588.0 | 600.0 |
| T | 83  | 76  | 91 | 0 | 0.95 | 253.2 | 100.0 | 592.0 |
| T | 83  | 76  | 91 | 0 | 0.54 | 165.5 | 100.0 | 592.0 |
| U | 73  | 66  | 90 | 0 | 0.91 | 156.0 | 96.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 0.88 | 222.3 | 172.0 | 560.0 |
| U | 73  | 66  | 90 | 0 | 1.06 | 234.4 | 84.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 1.29 | 129.7 | 108.0 | 148.0 |
| U | 73  | 66  | 90 | 0 | 1.32 | 156.5 | 88.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 0.91 | 262.0 | 96.0  | 520.0 |
| U | 73  | 66  | 90 | 0 | 0.68 | 114.7 | 104.0 | 172.0 |
| U | 73  | 66  | 90 | 0 | 0.96 | 118.4 | 92.0  | 100.0 |
| U | 73  | 66  | 90 | 0 | 1.01 | 158.3 | 72.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 1.03 | 137.5 | 100.0 | 160.0 |
| U | 73  | 66  | 90 | 0 | 0.99 | 114.2 | 80.0  | 124.0 |
| U | 73  | 66  | 90 | 0 | 0.89 | 102.9 | 80.0  | 172.0 |
| U | 73  | 66  | 90 | 0 | 0.90 | 102.1 | 96.0  | 136.0 |
| U | 73  | 66  | 90 | 0 | 0.99 | 115.1 | 92.0  | 132.0 |
| U | 73  | 66  | 90 | 0 | 0.99 | 134.2 | 104.0 | 172.0 |
| U | 73  | 66  | 90 | 0 | 0.99 | 96.9  | 96.0  | 112.0 |
| U | 73  | 66  | 90 | 0 | 1.07 | 115.0 | 96.0  | 168.0 |
| U | 73  | 66  | 90 | 0 | 0.39 | 173.9 | 116.0 | 260.0 |
| U | 73  | 66  | 90 | 0 | 0.97 | 131.5 | 80.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 1.24 | 173.3 | 96.0  | 260.0 |
| U | 73  | 66  | 90 | 0 | 1.37 | 106.4 | 68.0  | 128.0 |
| U | 73  | 66  | 90 | 0 | 1.27 | 112.8 | 80.0  | 120.0 |
| U | 73  | 66  | 90 | 0 | 0.90 | 169.0 | 96.0  | 260.0 |
| H | 114 | 110 | 96 | 1 | .75  | 446.5 | 172.0 | 260.0 |
| H | 114 | 110 | 96 | 1 | .85  | 452.7 | 108.0 | 260.0 |
| H | 114 | 110 | 96 | 1 | .78  | 460.5 | 172.0 | 260.0 |
| H | 114 | 110 | 96 | 1 | .63  | 364.5 | 112.0 | 260.0 |
| H | 114 | 110 | 96 | 1 | .46  | 477.9 | 172.0 | 500.0 |
| H | 114 | 110 | 96 | 1 | .35  | 444.0 | 112.0 | 776.0 |

|   |     |     |     |   |     |       |       |        |
|---|-----|-----|-----|---|-----|-------|-------|--------|
| H | 114 | 110 | 96  | 1 | .21 | 442.5 | 260.0 | 1360.0 |
| H | 114 | 110 | 96  | 1 | .55 | 440.8 | 108.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .60 | 482.0 | 124.0 | 1268.0 |
| H | 114 | 110 | 96  | 1 | .67 | 338.1 | 172.0 | 256.0  |
| H | 114 | 110 | 96  | 1 | .55 | 425.3 | 112.0 | 300.0  |
| H | 114 | 110 | 96  | 1 | .41 | 439.4 | 108.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .31 | 414.1 | 112.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .39 | 466.2 | 172.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .41 | 432.3 | 172.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .41 | 415.7 | 112.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .42 | 382.7 | 260.0 | 1400.0 |
| H | 114 | 110 | 96  | 1 | .39 | 410.2 | 172.0 | 348.0  |
| H | 114 | 110 | 96  | 1 | .52 | 316.9 | 172.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .53 | 357.1 | 112.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .59 | 429.2 | 172.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .61 | 246.8 | 112.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .61 | 367.8 | 172.0 | 260.0  |
| H | 114 | 110 | 96  | 1 | .58 | 296.9 | 92.0  | 260.0  |
| I | 112 | 118 | 105 | 1 | .78 | 429.8 | 636.0 | 744.0  |
| I | 112 | 118 | 105 | 1 | .80 | 396.3 | 144.0 | 744.0  |
| I | 112 | 118 | 105 | 1 | .67 | 421.8 | 608.0 | 624.0  |
| I | 112 | 118 | 105 | 1 | .58 | 425.1 | 160.0 | 708.0  |
| I | 112 | 118 | 105 | 1 | .55 | 433.7 | 604.0 | 672.0  |
| I | 112 | 118 | 105 | 1 | .42 | 431.1 | 604.0 | 736.0  |
| I | 112 | 118 | 105 | 1 | .86 | 441.9 | 192.0 | 776.0  |
| I | 112 | 118 | 105 | 1 | .80 | 446.2 | 604.0 | 712.0  |
| I | 112 | 118 | 105 | 1 | .70 | 452.9 | 608.0 | 692.0  |
| I | 112 | 118 | 105 | 1 | .67 | 458.3 | 628.0 | 704.0  |
| I | 112 | 118 | 105 | 1 | .61 | 445.0 | 608.0 | 668.0  |
| I | 112 | 118 | 105 | 1 | .51 | 316.2 | 112.0 | 628.0  |
| I | 112 | 118 | 105 | 1 | .29 | 397.1 | 112.0 | 772.0  |
| I | 112 | 118 | 105 | 1 | .56 | 379.1 | 84.0  | 744.0  |
| I | 112 | 118 | 105 | 1 | .61 | 431.9 | 612.0 | 708.0  |
| I | 112 | 118 | 105 | 1 | .62 | 451.4 | 608.0 | 748.0  |
| I | 112 | 118 | 105 | 1 | .52 | 488.7 | 612.0 | 664.0  |
| I | 112 | 118 | 105 | 1 | .46 | 386.8 | 96.0  | 748.0  |
| I | 112 | 118 | 105 | 1 | .73 | 345.6 | 112.0 | 776.0  |
| I | 112 | 118 | 105 | 1 | .81 | 514.6 | 668.0 | 784.0  |
| I | 112 | 118 | 105 | 1 | .76 | 486.9 | 664.0 | 788.0  |
| I | 112 | 118 | 105 | 1 | .86 | 298.3 | 112.0 | 784.0  |
| I | 112 | 118 | 105 | 1 | .77 | 378.0 | 124.0 | 728.0  |
| I | 112 | 118 | 105 | 1 | .81 | 431.2 | 588.0 | 724.0  |

Expiration Direct Data Set: Each

Test Set

7 Abnormals (STATE=0)

M  
C  
D  
G  
S  
B  
E

5 Normals (STATE=1)

K  
L  
F  
Y  
N

DATA EXP;  
 TITLE 'POWER SPECTRA DATA ON EXPIRATORY SOUND';  
 COMMENT STATE: NORMAL= 1 ABNORMAL= 0;  
 COMMENT DIRECT TEST DATA;  
 INPUT ID S FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;  
 CARDS;

|   |    |    |    |   |      |       |       |        |
|---|----|----|----|---|------|-------|-------|--------|
| B | 82 | 70 | 85 | 0 | .99  | 707.3 | 172.0 | 1480.0 |
| B | 82 | 70 | 85 | 0 | 1.0  | 651.7 | 412.0 | 1476.0 |
| B | 82 | 70 | 85 | 0 | .90  | 799.8 | 152.0 | 1440.0 |
| B | 82 | 70 | 85 | 0 | .77  | 777.6 | 172.0 | 1468.0 |
| B | 82 | 70 | 85 | 0 | .65  | 723.7 | 172.0 | 1448.0 |
| B | 82 | 70 | 85 | 0 | 1.12 | 665.0 | 572.0 | 1488.0 |
| B | 82 | 70 | 85 | 0 | 1.18 | 603.4 | 172.0 | 1068.0 |
| B | 82 | 70 | 85 | 0 | 1.12 | 636.0 | 172.0 | 1364.0 |
| B | 82 | 70 | 85 | 0 | 0.93 | 634.7 | 116.0 | 1472.0 |
| B | 82 | 70 | 85 | 0 | .74  | 797.9 | 172.0 | 1404.0 |
| B | 82 | 70 | 85 | 0 | .62  | 756.8 | 108.0 | 1388.0 |
| B | 82 | 70 | 85 | 0 | .58  | 782.1 | 172.0 | 1456.0 |
| B | 82 | 70 | 85 | 0 | .71  | 730.7 | 172.0 | 1464.0 |
| B | 82 | 70 | 85 | 0 | .90  | 720.2 | 956.0 | 1048.0 |
| B | 82 | 70 | 85 | 0 | 0.80 | 614.1 | 112.0 | 1044.0 |
| B | 82 | 70 | 85 | 0 | .63  | 648.7 | 112.0 | 1456.0 |
| B | 82 | 70 | 85 | 0 | .52  | 606.3 | 172.0 | 1300.0 |
| B | 82 | 70 | 85 | 0 | .46  | 661.4 | 108.0 | 1456.0 |
| B | 82 | 70 | 85 | 0 | .40  | 646.2 | 172.0 | 1404.0 |
| B | 82 | 70 | 85 | 0 | .90  | 489.3 | 596.0 | 980.0  |
| B | 82 | 70 | 85 | 0 | .80  | 479.1 | 620.0 | 680.0  |
| B | 82 | 70 | 85 | 0 | .74  | 443.5 | 584.0 | 636.0  |
| B | 82 | 70 | 85 | 0 | .62  | 454.6 | 288.0 | 700.0  |
| B | 82 | 70 | 85 | 0 | .52  | 427.1 | 592.0 | 688.0  |
| B | 82 | 70 | 85 | 0 | .44  | 278.9 | 112.0 | 604.0  |
| C | 77 | 78 | 99 | 0 | .64  | 323.9 | 332.0 | 604.0  |
| C | 77 | 78 | 99 | 0 | 1.1  | 414.1 | 412.0 | 684.0  |
| C | 77 | 78 | 99 | 0 | 1.03 | 396.0 | 452.0 | 616.0  |
| C | 77 | 78 | 99 | 0 | .83  | 429.5 | 436.0 | 624.0  |
| C | 77 | 78 | 99 | 0 | .63  | 311.4 | 124.0 | 620.0  |
| C | 77 | 78 | 99 | 0 | .65  | 354.5 | 468.0 | 612.0  |
| C | 77 | 78 | 99 | 0 | .83  | 440.0 | 592.0 | 620.0  |
| C | 77 | 78 | 99 | 0 | .97  | 441.5 | 472.0 | 632.0  |
| C | 77 | 78 | 99 | 0 | .86  | 464.2 | 464.0 | 632.0  |
| C | 77 | 78 | 99 | 0 | .70  | 384.8 | 460.0 | 620.0  |
| C | 77 | 78 | 99 | 0 | .68  | 328.6 | 592.0 | 616.0  |
| C | 77 | 78 | 99 | 0 | 1.00 | 475.5 | 600.0 | 620.0  |
| C | 77 | 78 | 99 | 0 | 1.00 | 476.9 | 600.0 | 624.0  |
| C | 77 | 78 | 99 | 0 | 1.00 | 447.8 | 604.0 | 604.0  |
| C | 77 | 78 | 99 | 0 | .89  | 464.8 | 592.0 | 628.0  |
| C | 77 | 78 | 99 | 0 | .73  | 414.3 | 608.0 | 632.0  |
| C | 77 | 78 | 99 | 0 | .39  | 217.6 | 76.0  | 584.0  |
| C | 77 | 78 | 99 | 0 | .99  | 475.8 | 600.0 | 620.0  |
| C | 77 | 78 | 99 | 0 | .99  | 473.3 | 600.0 | 624.0  |
| C | 77 | 78 | 99 | 0 | .99  | 459.9 | 604.0 | 604.0  |
| C | 77 | 78 | 99 | 0 | .89  | 459.9 | 592.0 | 616.0  |

|   |     |     |    |   |     |       |       |        |
|---|-----|-----|----|---|-----|-------|-------|--------|
| C | 77  | 78  | 99 | 0 | .73 | 336.6 | 104.0 | 620.0  |
| D | 102 | 100 | 97 | 0 | .44 | 443.3 | 240.0 | 1360.0 |
| D | 102 | 100 | 97 | 0 | .48 | 457.8 | 284.0 | 432.0  |
| D | 102 | 100 | 97 | 0 | .45 | 495.6 | 172.0 | 1196.0 |
| D | 102 | 100 | 97 | 0 | .45 | 434.7 | 260.0 | 1264.0 |
| D | 102 | 100 | 97 | 0 | .41 | 432.3 | 240.0 | 1252.0 |
| D | 102 | 100 | 97 | 0 | .52 | 270.5 | 100.0 | 392.0  |
| D | 102 | 100 | 97 | 0 | .52 | 385.3 | 272.0 | 1292.0 |
| D | 102 | 100 | 97 | 0 | .48 | 400.3 | 244.0 | 1336.0 |
| D | 102 | 100 | 97 | 0 | .43 | 363.1 | 172.0 | 760.0  |
| D | 102 | 100 | 97 | 0 | .57 | 278.2 | 292.0 | 660.0  |
| D | 102 | 100 | 97 | 0 | .57 | 259.8 | 172.0 | 596.0  |
| D | 102 | 100 | 97 | 0 | .56 | 276.4 | 240.0 | 600.0  |
| D | 102 | 100 | 97 | 0 | .50 | 236.2 | 172.0 | 600.0  |
| D | 102 | 100 | 97 | 0 | .47 | 288.9 | 160.0 | 612.0  |
| D | 102 | 100 | 97 | 0 | .48 | 328.4 | 228.0 | 708.0  |
| D | 102 | 100 | 97 | 0 | .45 | 311.0 | 236.0 | 632.0  |
| E | 90  | 72  | 81 | 0 | .34 | 257.9 | 68.0  | 564.0  |
| E | 90  | 72  | 81 | 0 | .40 | 305.8 | 96.0  | 604.0  |
| E | 90  | 72  | 81 | 0 | .38 | 345.9 | 596.0 | 612.0  |
| E | 90  | 72  | 81 | 0 | .37 | 129.5 | 104.0 | 128.0  |
| E | 90  | 72  | 81 | 0 | .35 | 162.1 | 104.0 | 148.0  |
| E | 90  | 72  | 81 | 0 | .29 | 152.7 | 96.0  | 196.0  |
| E | 90  | 72  | 81 | 0 | .30 | 305.4 | 96.0  | 720.0  |
| E | 90  | 72  | 81 | 0 | .26 | 379.0 | 140.0 | 676.0  |
| E | 90  | 72  | 81 | 0 | .28 | 473.2 | 676.0 | 692.0  |
| E | 90  | 72  | 81 | 0 | .29 | 558.7 | 676.0 | 724.0  |
| E | 90  | 72  | 81 | 0 | .29 | 194.8 | 100.0 | 144.0  |
| E | 90  | 72  | 81 | 0 | .31 | 215.9 | 112.0 | 496.0  |
| E | 90  | 72  | 81 | 0 | .35 | 206.4 | 108.0 | 536.0  |
| E | 90  | 72  | 81 | 0 | .30 | 184.5 | 92.0  | 184.0  |
| E | 90  | 72  | 81 | 0 | .41 | 262.7 | 104.0 | 612.0  |
| E | 90  | 72  | 81 | 0 | .46 | 223.6 | 212.0 | 548.0  |
| E | 90  | 72  | 81 | 0 | .55 | 319.2 | 204.0 | 608.0  |
| E | 90  | 72  | 81 | 0 | .51 | 285.5 | 192.0 | 604.0  |
| E | 90  | 72  | 81 | 0 | .48 | 331.3 | 196.0 | 616.0  |
| E | 90  | 72  | 81 | 0 | .28 | 154.4 | 92.0  | 176.0  |
| E | 90  | 72  | 81 | 0 | .43 | 296.4 | 108.0 | 608.0  |
| E | 90  | 72  | 81 | 0 | .43 | 206.0 | 104.0 | 608.0  |
| E | 90  | 72  | 81 | 0 | .50 | 286.4 | 184.0 | 624.0  |
| E | 90  | 72  | 81 | 0 | .52 | 289.2 | 208.0 | 620.0  |
| E | 90  | 72  | 81 | 0 | .52 | 271.2 | 204.0 | 604.0  |
| E | 90  | 72  | 81 | 0 | .46 | 253.4 | 220.0 | 616.0  |
| F | 146 | 141 | 97 | 1 | .47 | 150.0 | 100.0 | 168.0  |
| F | 146 | 141 | 97 | 1 | .62 | 246.1 | 112.0 | 588.0  |
| F | 146 | 141 | 97 | 1 | .53 | 211.2 | 100.0 | 576.0  |
| F | 146 | 141 | 97 | 1 | .54 | 129.4 | 100.0 | 148.0  |
| F | 146 | 141 | 97 | 1 | .56 | 197.2 | 92.0  | 200.0  |
| F | 146 | 141 | 97 | 1 | .52 | 203.8 | 104.0 | 492.0  |
| F | 146 | 141 | 97 | 1 | .48 | 135.4 | 112.0 | 196.0  |
| F | 146 | 141 | 97 | 1 | .73 | 181.1 | 120.0 | 236.0  |
| F | 146 | 141 | 97 | 1 | .73 | 210.4 | 176.0 | 248.0  |

|   |     |     |     |   |      |       |       |        |
|---|-----|-----|-----|---|------|-------|-------|--------|
| F | 146 | 141 | 97  | 1 | .68  | 181.6 | 160.0 | 220.0  |
| F | 146 | 141 | 97  | 1 | .66  | 180.8 | 164.0 | 240.0  |
| F | 146 | 141 | 97  | 1 | .70  | 210.7 | 168.0 | 592.0  |
| F | 146 | 141 | 97  | 1 | .75  | 189.8 | 156.0 | 444.0  |
| F | 146 | 141 | 97  | 1 | .71  | 207.5 | 160.0 | 600.0  |
| F | 146 | 141 | 97  | 1 | .58  | 149.9 | 88.0  | 456.0  |
| F | 146 | 141 | 97  | 1 | .52  | 164.2 | 152.0 | 476.0  |
| F | 146 | 141 | 97  | 1 | .45  | 192.2 | 100.0 | 284.0  |
| F | 146 | 141 | 97  | 1 | .38  | 226.2 | 148.0 | 576.0  |
| F | 146 | 141 | 97  | 1 | .31  | 216.6 | 176.0 | 604.0  |
| F | 146 | 141 | 97  | 1 | .27  | 200.8 | 108.0 | 532.0  |
| F | 146 | 141 | 97  | 1 | .31  | 238.5 | 116.0 | 632.0  |
| F | 146 | 141 | 97  | 1 | .31  | 166.3 | 84.0  | 548.0  |
| F | 146 | 141 | 97  | 1 | .41  | 145.6 | 80.0  | 184.0  |
| F | 146 | 141 | 97  | 1 | .44  | 151.3 | 108.0 | 240.0  |
| F | 146 | 141 | 97  | 1 | .58  | 156.4 | 100.0 | 180.0  |
| F | 146 | 141 | 97  | 1 | .64  | 175.0 | 112.0 | 188.0  |
| F | 146 | 141 | 97  | 1 | .63  | 189.0 | 128.0 | 176.0  |
| F | 146 | 141 | 97  | 1 | .66  | 203.2 | 136.0 | 464.0  |
| F | 146 | 141 | 97  | 1 | .43  | 173.0 | 92.0  | 172.0  |
| F | 146 | 141 | 97  | 1 | .47  | 175.4 | 88.0  | 168.0  |
| G | 91  | 78  | 118 | 0 | .63  | 180.8 | 132.0 | 264.0  |
| G | 91  | 78  | 118 | 0 | .77  | 286.5 | 224.0 | 780.0  |
| G | 91  | 78  | 118 | 0 | .87  | 249.5 | 176.0 | 696.0  |
| G | 91  | 78  | 118 | 0 | .85  | 253.5 | 156.0 | 720.0  |
| G | 91  | 78  | 118 | 0 | .77  | 201.3 | 84.0  | 252.0  |
| G | 91  | 78  | 118 | 0 | .52  | 117.7 | 80.0  | 124.0  |
| G | 91  | 78  | 118 | 0 | .89  | 324.4 | 204.0 | 608.0  |
| G | 91  | 78  | 118 | 0 | 1.05 | 338.3 | 216.0 | 788.0  |
| G | 91  | 78  | 118 | 0 | .97  | 341.4 | 176.0 | 620.0  |
| G | 91  | 78  | 118 | 0 | .74  | 356.9 | 212.0 | 668.0  |
| G | 91  | 78  | 118 | 0 | .60  | 405.2 | 168.0 | 760.0  |
| G | 91  | 78  | 118 | 0 | .45  | 318.7 | 108.0 | 720.0  |
| G | 91  | 78  | 118 | 0 | .48  | 330.2 | 204.0 | 772.0  |
| G | 91  | 78  | 118 | 0 | .69  | 330.9 | 200.0 | 768.0  |
| G | 91  | 78  | 118 | 0 | .64  | 370.0 | 172.0 | 708.0  |
| G | 91  | 78  | 118 | 0 | .50  | 370.4 | 168.0 | 752.0  |
| G | 91  | 78  | 118 | 0 | .19  | 338.3 | 196.0 | 728.0  |
| G | 91  | 78  | 118 | 0 | .19  | 320.6 | 188.0 | 716.0  |
| G | 91  | 78  | 118 | 0 | .48  | 309.3 | 164.0 | 696.0  |
| G | 91  | 78  | 118 | 0 | .69  | 190.7 | 108.0 | 176.0  |
| G | 91  | 78  | 118 | 0 | .64  | 179.2 | 100.0 | 184.0  |
| S | 92  | 95  | 103 | 0 | 1.05 | 227.4 | 96.0  | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.35 | 238.8 | 92.0  | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.38 | 267.9 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.25 | 262.9 | 100.0 | 536.0  |
| S | 92  | 95  | 103 | 0 | 1.03 | 316.6 | 56.0  | 1328.0 |
| S | 92  | 95  | 103 | 0 | 0.83 | 593.5 | 120.0 | 1356.0 |
| S | 92  | 95  | 103 | 0 | 0.88 | 354.1 | 120.0 | 1340.0 |
| S | 92  | 95  | 103 | 0 | 0.88 | 129.6 | 100.0 | 168.0  |
| S | 92  | 95  | 103 | 0 | 1.14 | 516.1 | 92.0  | 976.0  |
| S | 92  | 95  | 103 | 0 | 1.04 | 329.7 | 76.0  | 772.0  |

|   |     |     |     |   |      |       |       |        |
|---|-----|-----|-----|---|------|-------|-------|--------|
| S | 92  | 95  | 103 | 0 | 0.86 | 221.3 | 112.0 | 496.0  |
| S | 92  | 95  | 103 | 0 | 0.80 | 543.7 | 600.0 | 952.0  |
| S | 92  | 95  | 103 | 0 | 0.74 | 284.8 | 80.0  | 776.0  |
| S | 92  | 95  | 103 | 0 | 0.61 | 202.3 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.17 | 361.8 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.58 | 291.7 | 120.0 | 604.0  |
| S | 92  | 95  | 103 | 0 | 1.68 | 360.3 | 108.0 | 760.0  |
| S | 92  | 95  | 103 | 0 | 1.58 | 423.3 | 580.0 | 836.0  |
| S | 92  | 95  | 103 | 0 | 1.49 | 400.2 | 120.0 | 660.0  |
| S | 92  | 95  | 103 | 0 | 1.25 | 351.5 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 0.80 | 384.7 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.68 | 695.6 | 120.0 | 1392.0 |
| S | 92  | 95  | 103 | 0 | 1.80 | 636.0 | 120.0 | 1428.0 |
| S | 92  | 95  | 103 | 0 | 1.50 | 581.1 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.22 | 362.8 | 120.0 | 612.0  |
| S | 92  | 95  | 103 | 0 | 1.00 | 266.2 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 0.94 | 292.6 | 88.0  | 260.0  |
| Y | 101 | 113 | 113 | 1 | 0.59 | 432.5 | 112.0 | 172.0  |
| Y | 101 | 113 | 113 | 1 | 0.70 | 442.8 | 112.0 | 236.0  |
| Y | 101 | 113 | 113 | 1 | 0.78 | 523.5 | 108.0 | 1348.0 |
| Y | 101 | 113 | 113 | 1 | 0.78 | 411.5 | 108.0 | 204.0  |
| Y | 101 | 113 | 113 | 1 | 0.74 | 402.5 | 112.0 | 228.0  |
| Y | 101 | 113 | 113 | 1 | 0.65 | 428.5 | 172.0 | 1364.0 |
| Y | 101 | 113 | 113 | 1 | 0.64 | 484.4 | 112.0 | 532.0  |
| Y | 101 | 113 | 113 | 1 | 0.58 | 381.1 | 108.0 | 176.0  |
| Y | 101 | 113 | 113 | 1 | 0.52 | 442.1 | 112.0 | 172.0  |
| Y | 101 | 113 | 113 | 1 | 1.15 | 170.6 | 100.0 | 268.0  |
| Y | 101 | 113 | 113 | 1 | 1.55 | 303.6 | 252.0 | 580.0  |
| Y | 101 | 113 | 113 | 1 | 1.32 | 184.5 | 88.0  | 380.0  |
| Y | 101 | 113 | 113 | 1 | 1.18 | 246.5 | 164.0 | 612.0  |
| Y | 101 | 113 | 113 | 1 | 1.01 | 136.0 | 104.0 | 156.0  |
| Y | 101 | 113 | 113 | 1 | 0.78 | 166.9 | 76.0  | 196.0  |
| Y | 101 | 113 | 113 | 1 | 0.63 | 130.2 | 116.0 | 144.0  |
| Y | 101 | 113 | 113 | 1 | 0.48 | 138.6 | 80.0  | 168.0  |
| Y | 101 | 113 | 113 | 1 | 1.28 | 171.0 | 96.0  | 152.0  |
| Y | 101 | 113 | 113 | 1 | 1.58 | 278.1 | 88.0  | 672.0  |
| Y | 101 | 113 | 113 | 1 | 1.47 | 202.5 | 92.0  | 504.0  |
| Y | 101 | 113 | 113 | 1 | 1.30 | 234.7 | 76.0  | 508.0  |
| Y | 101 | 113 | 113 | 1 | 1.19 | 166.4 | 88.0  | 244.0  |
| Y | 101 | 113 | 113 | 1 | 1.03 | 190.2 | 92.0  | 268.0  |
| Y | 101 | 113 | 113 | 1 | 0.89 | 143.5 | 120.0 | 168.0  |
| Y | 101 | 113 | 113 | 1 | 0.75 | 130.9 | 92.0  | 140.0  |
| Y | 101 | 113 | 113 | 1 | 1.34 | 305.2 | 88.0  | 736.0  |
| Y | 101 | 113 | 113 | 1 | 1.57 | 245.7 | 112.0 | 616.0  |
| Y | 101 | 113 | 113 | 1 | 1.28 | 229.2 | 160.0 | 328.0  |
| Y | 101 | 113 | 113 | 1 | 1.11 | 144.7 | 108.0 | 280.0  |
| Y | 101 | 113 | 113 | 1 | 0.95 | 171.3 | 88.0  | 260.0  |
| Y | 101 | 113 | 113 | 1 | 0.86 | 111.5 | 104.0 | 148.0  |
| Y | 101 | 113 | 113 | 1 | 0.74 | 107.6 | 84.0  | 160.0  |
| Y | 101 | 113 | 113 | 1 | 0.61 | 111.0 | 76.0  | 152.0  |
| K | 102 | 105 | 104 | 1 | .47  | 331.5 | 188.0 | 608.0  |
| K | 102 | 105 | 104 | 1 | .67  | 322.0 | 176.0 | 600.0  |

|   |     |     |     |   |     |       |       |       |
|---|-----|-----|-----|---|-----|-------|-------|-------|
| K | 102 | 105 | 104 | 1 | .71 | 365.2 | 496.0 | 608.0 |
| K | 102 | 105 | 104 | 1 | .68 | 377.4 | 180.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | .55 | 288.9 | 172.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | .55 | 407.3 | 596.0 | 608.0 |
| K | 102 | 105 | 104 | 1 | .62 | 363.6 | 588.0 | 616.0 |
| K | 102 | 105 | 104 | 1 | .62 | 361.2 | 160.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | .52 | 319.8 | 596.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | .48 | 348.7 | 596.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | .58 | 412.0 | 476.0 | 596.0 |
| K | 102 | 105 | 104 | 1 | .61 | 377.7 | 588.0 | 592.0 |
| K | 102 | 105 | 104 | 1 | .58 | 379.6 | 588.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | .48 | 360.8 | 192.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | .30 | 354.1 | 472.0 | 616.0 |
| K | 102 | 105 | 104 | 1 | .50 | 366.1 | 460.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | .51 | 350.8 | 168.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | .49 | 402.7 | 588.0 | 608.0 |
| K | 102 | 105 | 104 | 1 | .48 | 409.1 | 592.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | .37 | 332.3 | 148.0 | 596.0 |
| L | 110 | 102 | 92  | 1 | .72 | 366.3 | 464.0 | 592.0 |
| L | 110 | 102 | 92  | 1 | .68 | 416.5 | 476.0 | 608.0 |
| L | 110 | 102 | 92  | 1 | .63 | 421.8 | 524.0 | 600.0 |
| L | 110 | 102 | 92  | 1 | .58 | 420.4 | 452.0 | 588.0 |
| L | 110 | 102 | 92  | 1 | .62 | 440.6 | 500.0 | 604.0 |
| L | 110 | 102 | 92  | 1 | .64 | 439.3 | 532.0 | 576.0 |
| L | 110 | 102 | 92  | 1 | .64 | 410.6 | 468.0 | 612.0 |
| L | 110 | 102 | 92  | 1 | .57 | 350.1 | 516.0 | 588.0 |
| L | 110 | 102 | 92  | 1 | .56 | 439.6 | 516.0 | 572.0 |
| L | 110 | 102 | 92  | 1 | .94 | 399.2 | 500.0 | 620.0 |
| L | 110 | 102 | 92  | 1 | .90 | 376.8 | 488.0 | 596.0 |
| L | 110 | 102 | 92  | 1 | .85 | 405.3 | 484.0 | 616.0 |
| L | 110 | 102 | 92  | 1 | .79 | 400.9 | 492.0 | 624.0 |
| L | 110 | 102 | 92  | 1 | .75 | 409.9 | 152.0 | 620.0 |
| L | 110 | 102 | 92  | 1 | .74 | 385.3 | 496.0 | 560.0 |
| L | 110 | 102 | 92  | 1 | .78 | 418.8 | 492.0 | 600.0 |
| L | 110 | 102 | 92  | 1 | .83 | 403.3 | 484.0 | 612.0 |
| L | 110 | 102 | 92  | 1 | .76 | 407.7 | 460.0 | 600.0 |
| L | 110 | 102 | 92  | 1 | .71 | 401.9 | 476.0 | 580.0 |
| L | 110 | 102 | 92  | 1 | .67 | 421.3 | 492.0 | 608.0 |
| M | 53  | 38  | 68  | 0 | .86 | 144.6 | 88.0  | 600.0 |
| M | 53  | 38  | 68  | 0 | .92 | 234.8 | 68.0  | 612.0 |
| M | 53  | 38  | 68  | 0 | .94 | 216.5 | 108.0 | 604.0 |
| M | 53  | 38  | 68  | 0 | .91 | 219.7 | 72.0  | 608.0 |
| M | 53  | 38  | 68  | 0 | .87 | 290.7 | 92.0  | 604.0 |
| M | 53  | 38  | 68  | 0 | .81 | 198.7 | 112.0 | 512.0 |
| M | 53  | 38  | 68  | 0 | .74 | 214.5 | 96.0  | 432.0 |
| M | 53  | 38  | 68  | 0 | .70 | 160.4 | 108.0 | 136.0 |
| M | 53  | 38  | 68  | 0 | .76 | 173.3 | 80.0  | 596.0 |
| M | 53  | 38  | 68  | 0 | .82 | 198.8 | 92.0  | 600.0 |
| M | 53  | 38  | 68  | 0 | .81 | 165.2 | 72.0  | 116.0 |
| M | 53  | 38  | 68  | 0 | .82 | 226.2 | 124.0 | 596.0 |
| M | 53  | 38  | 68  | 0 | .84 | 193.8 | 72.0  | 604.0 |
| M | 53  | 38  | 68  | 0 | .84 | 238.5 | 108.0 | 596.0 |

|   |    |    |     |   |      |       |       |       |
|---|----|----|-----|---|------|-------|-------|-------|
| M | 53 | 38 | 68  | 0 | .74  | 212.8 | 104.0 | 600.0 |
| M | 53 | 38 | 68  | 0 | .46  | 117.9 | 108.0 | 140.0 |
| M | 53 | 38 | 68  | 0 | .86  | 228.0 | 88.0  | 604.0 |
| M | 53 | 38 | 68  | 0 | .88  | 228.8 | 68.0  | 592.0 |
| M | 53 | 38 | 68  | 0 | 1.12 | 351.6 | 576.0 | 616.0 |
| M | 53 | 38 | 68  | 0 | 1.14 | 287.8 | 84.0  | 616.0 |
| M | 53 | 38 | 68  | 0 | .97  | 336.0 | 464.0 | 608.0 |
| M | 53 | 38 | 68  | 0 | .91  | 265.8 | 100.0 | 596.0 |
| M | 53 | 38 | 68  | 0 | .82  | 171.2 | 92.0  | 140.0 |
| M | 53 | 38 | 68  | 0 | .90  | 216.0 | 96.0  | 580.0 |
| M | 53 | 38 | 68  | 0 | .86  | 279.3 | 88.0  | 596.0 |
| M | 53 | 38 | 68  | 0 | .84  | 237.4 | 84.0  | 600.0 |
| M | 53 | 38 | 68  | 0 | .81  | 277.6 | 100.0 | 612.0 |
| M | 53 | 38 | 68  | 0 | .75  | 243.2 | 76.0  | 604.0 |
| N | 91 | 97 | 107 | 1 | .39  | 325.1 | 172.0 | 608.0 |
| N | 91 | 97 | 107 | 1 | .49  | 316.8 | 200.0 | 596.0 |
| N | 91 | 97 | 107 | 1 | .54  | 306.7 | 212.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | .53  | 328.1 | 200.0 | 628.0 |
| N | 91 | 97 | 107 | 1 | .50  | 382.6 | 596.0 | 612.0 |
| N | 91 | 97 | 107 | 1 | .50  | 258.5 | 116.0 | 608.0 |
| N | 91 | 97 | 107 | 1 | .50  | 354.4 | 596.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | .49  | 326.1 | 604.0 | 604.0 |
| N | 91 | 97 | 107 | 1 | .44  | 348.7 | 172.0 | 612.0 |
| N | 91 | 97 | 107 | 1 | .54  | 359.8 | 456.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | .57  | 340.9 | 132.0 | 620.0 |
| N | 91 | 97 | 107 | 1 | .56  | 346.0 | 132.0 | 608.0 |
| N | 91 | 97 | 107 | 1 | .50  | 391.0 | 488.0 | 596.0 |
| N | 91 | 97 | 107 | 1 | .45  | 498.2 | 608.0 | 736.0 |
| N | 91 | 97 | 107 | 1 | .56  | 339.2 | 280.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | .73  | 339.1 | 240.0 | 596.0 |
| N | 91 | 97 | 107 | 1 | .76  | 351.5 | 312.0 | 604.0 |
| N | 91 | 97 | 107 | 1 | .71  | 344.4 | 132.0 | 624.0 |
| N | 91 | 97 | 107 | 1 | .70  | 352.5 | 264.0 | 680.0 |
| N | 91 | 97 | 107 | 1 | .65  | 297.4 | 468.0 | 564.0 |
| N | 91 | 97 | 107 | 1 | .59  | 316.4 | 120.0 | 596.0 |
| N | 91 | 97 | 107 | 1 | .53  | 314.5 | 112.0 | 608.0 |
| N | 91 | 97 | 107 | 1 | .60  | 393.8 | 456.0 | 580.0 |
| N | 91 | 97 | 107 | 1 | .81  | 375.1 | 528.0 | 624.0 |
| N | 91 | 97 | 107 | 1 | .87  | 392.7 | 492.0 | 612.0 |
| N | 91 | 97 | 107 | 1 | .91  | 372.8 | 440.0 | 628.0 |
| N | 91 | 97 | 107 | 1 | .93  | 373.1 | 416.0 | 636.0 |
| N | 91 | 97 | 107 | 1 | .87  | 373.1 | 468.0 | 620.0 |

APPENDIX B

INSPIRATION DIRECT DATA SET: EACH

Calibration or Training Set

7 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+  
#

5 Normals (STATE=1)

H  
I  
V  
W  
\*

DATA BREATH:

TITLE 'POWER SPECTRA DATA ON INSPIRATORY SOUND';

COMMENT STATE: NORMAL= 1 ABNORMAL= 0;

COMMENT DIRECT CALIBRATION DATA;

INPUT ID \$ FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;

CARDS;

|   |     |    |    |   |      |       |        |        |
|---|-----|----|----|---|------|-------|--------|--------|
| P | 73  | 32 | 44 | 0 | 1.28 | 255.5 | 84.0   | 280.0  |
| P | 73  | 32 | 44 | 0 | 2.19 | 416.2 | 92.0   | 260.0  |
| P | 73  | 32 | 44 | 0 | 2.29 | 539.4 | 172.0  | 1416.0 |
| P | 73  | 32 | 44 | 0 | 2.47 | 822.6 | 1316.0 | 1448.0 |
| P | 73  | 32 | 44 | 0 | 2.59 | 475.0 | 180.0  | 1348.0 |
| P | 73  | 32 | 44 | 0 | 2.76 | 350.2 | 172.0  | 1404.0 |
| P | 73  | 32 | 44 | 0 | 2.76 | 361.6 | 176.0  | 528.0  |
| P | 73  | 32 | 44 | 0 | 2.65 | 505.5 | 172.0  | 1296.0 |
| P | 73  | 32 | 44 | 0 | 2.40 | 407.9 | 152.0  | 1276.0 |
| P | 73  | 32 | 44 | 0 | 2.55 | 427.7 | 172.0  | 1344.0 |
| P | 73  | 32 | 44 | 0 | 2.64 | 442.9 | 168.0  | 1356.0 |
| P | 73  | 32 | 44 | 0 | 2.64 | 301.0 | 96.0   | 260.0  |
| P | 73  | 32 | 44 | 0 | 2.21 | 275.8 | 172.0  | 260.0  |
| P | 73  | 32 | 44 | 0 | 1.17 | 749.0 | 116.0  | 1416.0 |
| P | 73  | 32 | 44 | 0 | 2.15 | 775.1 | 180.0  | 1484.0 |
| P | 73  | 32 | 44 | 0 | 2.54 | 334.0 | 172.0  | 408.0  |
| P | 73  | 32 | 44 | 0 | 2.89 | 291.2 | 172.0  | 268.0  |
| P | 73  | 32 | 44 | 0 | 2.98 | 314.9 | 172.0  | 240.0  |
| P | 73  | 32 | 44 | 0 | 2.44 | 301.0 | 116.0  | 504.0  |
| P | 73  | 32 | 44 | 0 | 1.64 | 380.2 | 104.0  | 1340.0 |
| P | 73  | 32 | 44 | 0 | 2.03 | 585.7 | 172.0  | 1332.0 |
| P | 73  | 32 | 44 | 0 | 2.33 | 547.1 | 172.0  | 1252.0 |
| P | 73  | 32 | 44 | 0 | 2.52 | 434.5 | 164.0  | 1316.0 |
| P | 73  | 32 | 44 | 0 | 2.61 | 633.2 | 164.0  | 1464.0 |
| P | 73  | 32 | 44 | 0 | 2.48 | 452.0 | 156.0  | 624.0  |
| Q | 102 | 83 | 81 | 0 | .56  | 103.5 | 64.0   | 144.0  |
| Q | 102 | 83 | 81 | 0 | 1.13 | 328.0 | 112.0  | 600.0  |
| Q | 102 | 83 | 81 | 0 | 1.39 | 235.0 | 80.0   | 616.0  |
| Q | 102 | 83 | 81 | 0 | 1.37 | 175.1 | 60.0   | 604.0  |
| Q | 102 | 83 | 81 | 0 | 1.22 | 235.3 | 100.0  | 612.0  |
| Q | 102 | 83 | 81 | 0 | 1.07 | 137.8 | 68.0   | 612.0  |
| Q | 102 | 83 | 81 | 0 | .99  | 276.4 | 112.0  | 604.0  |
| Q | 102 | 83 | 81 | 0 | .86  | 125.7 | 104.0  | 600.0  |
| Q | 102 | 83 | 81 | 0 | .71  | 94.5  | 68.0   | 600.0  |
| Q | 102 | 83 | 81 | 0 | .73  | 142.9 | 100.0  | 600.0  |
| Q | 102 | 83 | 81 | 0 | 1.19 | 343.2 | 600.0  | 624.0  |
| Q | 102 | 83 | 81 | 0 | 1.47 | 247.0 | 88.0   | 632.0  |
| Q | 102 | 83 | 81 | 0 | 1.43 | 173.2 | 64.0   | 604.0  |
| Q | 102 | 83 | 81 | 0 | 1.29 | 315.8 | 104.0  | 680.0  |
| Q | 102 | 83 | 81 | 0 | 1.39 | 140.5 | 60.0   | 140.0  |
| Q | 102 | 83 | 81 | 0 | 1.11 | 269.7 | 88.0   | 608.0  |
| Q | 102 | 83 | 81 | 0 | 1.07 | 119.3 | 96.0   | 116.0  |
| Q | 102 | 83 | 81 | 0 | .68  | 99.5  | 84.0   | 600.0  |
| Q | 102 | 83 | 81 | 0 | .98  | 156.0 | 120.0  | 600.0  |
| Q | 102 | 83 | 81 | 0 | 1.35 | 324.3 | 100.0  | 632.0  |
| Q | 102 | 83 | 81 | 0 | 1.57 | 224.3 | 100.0  | 624.0  |

|   |     |     |    |   |      |       |       |        |
|---|-----|-----|----|---|------|-------|-------|--------|
| Q | 102 | 83  | 81 | 0 | 1.60 | 220.6 | 64.0  | 628.0  |
| Q | 102 | 83  | 81 | 0 | 1.62 | 453.0 | 604.0 | 620.0  |
| Q | 102 | 83  | 81 | 0 | 1.43 | 161.9 | 92.0  | 608.0  |
| Q | 102 | 83  | 81 | 0 | 1.11 | 158.1 | 60.0  | 608.0  |
| Q | 102 | 83  | 81 | 0 | .95  | 126.8 | 100.0 | 108.0  |
| Q | 102 | 83  | 81 | 0 | .70  | 101.5 | 64.0  | 600.0  |
| Q | 102 | 83  | 81 | 0 | .68  | 144.1 | 88.0  | 156.0  |
| Q | 102 | 83  | 81 | 0 | 1.31 | 229.0 | 56.0  | 620.0  |
| Q | 102 | 83  | 81 | 0 | 1.55 | 338.3 | 600.0 | 640.0  |
| Q | 102 | 83  | 81 | 0 | 1.70 | 197.3 | 100.0 | 620.0  |
| Q | 102 | 83  | 81 | 0 | 1.61 | 205.2 | 64.0  | 620.0  |
| Q | 102 | 83  | 81 | 0 | 1.58 | 376.7 | 608.0 | 608.0  |
| Q | 102 | 83  | 81 | 0 | 1.48 | 194.3 | 80.0  | 612.0  |
| Q | 102 | 83  | 81 | 0 | 1.14 | 199.7 | 116.0 | 624.0  |
| Q | 102 | 83  | 81 | 0 | 1.03 | 110.2 | 96.0  | 108.0  |
| Q | 102 | 83  | 81 | 0 | .91  | 124.9 | 60.0  | 608.0  |
| H | 114 | 110 | 96 | 1 | 1.20 | 577.1 | 260.0 | 1372.0 |
| H | 114 | 110 | 96 | 1 | 1.10 | 569.9 | 260.0 | 1400.0 |
| H | 114 | 110 | 96 | 1 | 1.00 | 657.1 | 260.0 | 1472.0 |
| H | 114 | 110 | 96 | 1 | .78  | 622.2 | 260.0 | 1228.0 |
| H | 114 | 110 | 96 | 1 | .94  | 640.3 | 204.0 | 1348.0 |
| H | 114 | 110 | 96 | 1 | 0.91 | 541.0 | 196.0 | 1472.0 |
| H | 114 | 110 | 96 | 1 | 0.87 | 656.3 | 260.0 | 1268.0 |
| H | 114 | 110 | 96 | 1 | 0.86 | 618.9 | 172.0 | 1360.0 |
| H | 114 | 110 | 96 | 1 | .86  | 686.1 | 260.0 | 1364.0 |
| H | 114 | 110 | 96 | 1 | .79  | 689.2 | 260.0 | 1380.0 |
| H | 114 | 110 | 96 | 1 | 1.3  | 610.7 | 204.0 | 1340.0 |
| H | 114 | 110 | 96 | 1 | 1.2  | 604.8 | 260.0 | 1468.0 |
| H | 114 | 110 | 96 | 1 | .90  | 685.1 | 260.0 | 1460.0 |
| H | 114 | 110 | 96 | 1 | .70  | 673.0 | 260.0 | 1424.0 |
| H | 114 | 110 | 96 | 1 | .94  | 623.9 | 172.0 | 1432.0 |
| H | 114 | 110 | 96 | 1 | .93  | 555.0 | 172.0 | 1404.0 |
| H | 114 | 110 | 96 | 1 | .87  | 620.0 | 172.0 | 1348.0 |
| H | 114 | 110 | 96 | 1 | .77  | 513.1 | 172.0 | 260.0  |
| H | 83  | 76  | 91 | 0 | .63  | 419.7 | 260.0 | 1224.0 |
| H | 83  | 76  | 91 | 0 | .97  | 285.1 | 104.0 | 592.0  |
| H | 83  | 76  | 91 | 0 | 1.02 | 98.7  | 92.0  | 136.0  |
| H | 83  | 76  | 91 | 0 | 1.12 | 303.6 | 88.0  | 596.0  |
| H | 83  | 76  | 91 | 0 | 1.06 | 105.1 | 92.0  | 132.0  |
| H | 83  | 76  | 91 | 0 | 1.17 | 271.4 | 100.0 | 592.0  |
| H | 83  | 76  | 91 | 0 | 1.08 | 299.5 | 588.0 | 596.0  |
| H | 83  | 76  | 91 | 0 | .96  | 100.4 | 92.0  | 124.0  |
| H | 83  | 76  | 91 | 0 | .73  | 134.1 | 76.0  | 592.0  |
| H | 83  | 76  | 91 | 0 | .98  | 403.1 | 592.0 | 604.0  |
| H | 83  | 76  | 91 | 0 | 1.09 | 147.2 | 104.0 | 592.0  |
| H | 83  | 76  | 91 | 0 | 1.18 | 347.1 | 592.0 | 600.0  |
| H | 83  | 76  | 91 | 0 | 1.20 | 179.5 | 96.0  | 588.0  |
| H | 83  | 76  | 91 | 0 | 1.15 | 122.6 | 100.0 | 144.0  |
| H | 83  | 76  | 91 | 0 | 1.08 | 357.4 | 588.0 | 592.0  |
| H | 83  | 76  | 91 | 0 | .57  | 256.7 | 128.0 | 600.0  |
| H | 83  | 76  | 91 | 0 | .82  | 164.7 | 128.0 | 208.0  |
| H | 83  | 76  | 91 | 0 | .83  | 160.3 | 120.0 | 588.0  |

|   |     |     |     |   |       |       |       |        |
|---|-----|-----|-----|---|-------|-------|-------|--------|
| H | 83  | 76  | 91  | 0 | .94   | 415.8 | 584.0 | 600.0  |
| H | 83  | 76  | 91  | 0 | .99   | 245.8 | 108.0 | 600.0  |
| H | 83  | 76  | 91  | 0 | 1.08  | 149.9 | 104.0 | 588.0  |
| H | 83  | 76  | 91  | 0 | 1.23  | 344.0 | 128.0 | 592.0  |
| H | 83  | 76  | 91  | 0 | .88   | 308.5 | 116.0 | 600.0  |
| H | 83  | 76  | 91  | 0 | .86   | 209.8 | 116.0 | 592.0  |
| H | 83  | 76  | 91  | 0 | .96   | 347.3 | 96.0  | 600.0  |
| H | 83  | 76  | 91  | 0 | 1.05  | 193.3 | 112.0 | 584.0  |
| H | 83  | 76  | 91  | 0 | 1.09  | 413.4 | 240.0 | 1224.0 |
| H | 83  | 76  | 91  | 0 | 1.09  | 317.6 | 100.0 | 1224.0 |
| H | 83  | 76  | 91  | 0 | 1.052 | 170.0 | 108.0 | 584.0  |
| H | 83  | 76  | 91  | 0 | 1.09  | 399.2 | 252.0 | 608.0  |
| H | 83  | 76  | 91  | 0 | .69   | 364.1 | 116.0 | 1224.0 |
| D | 73  | 66  | 90  | 0 | .85   | 208.9 | 84.0  | 644.0  |
| D | 73  | 66  | 90  | 0 | .90   | 350.3 | 88.0  | 1352.0 |
| D | 73  | 66  | 90  | 0 | .80   | 160.6 | 100.0 | 172.0  |
| D | 73  | 66  | 90  | 0 | .75   | 226.8 | 84.0  | 588.0  |
| D | 73  | 66  | 90  | 0 | .36   | 225.2 | 100.0 | 260.0  |
| D | 73  | 66  | 90  | 0 | .60   | 102.5 | 88.0  | 116.0  |
| D | 73  | 66  | 90  | 0 | 1.10  | 98.6  | 96.0  | 104.0  |
| D | 73  | 66  | 90  | 0 | 1.17  | 177.7 | 108.0 | 220.0  |
| D | 73  | 66  | 90  | 0 | 1.00  | 99.6  | 100.0 | 108.0  |
| D | 73  | 66  | 90  | 0 | .88   | 146.4 | 52.0  | 260.0  |
| D | 73  | 66  | 90  | 0 | .82   | 207.5 | 96.0  | 260.0  |
| D | 73  | 66  | 90  | 0 | .96   | 100.7 | 96.0  | 140.0  |
| D | 73  | 66  | 90  | 0 | .98   | 140.6 | 96.0  | 208.0  |
| D | 73  | 66  | 90  | 0 | .98   | 190.0 | 88.0  | 260.0  |
| D | 73  | 66  | 90  | 0 | .73   | 97.1  | 92.0  | 132.0  |
| D | 73  | 66  | 90  | 0 | .31   | 123.2 | 96.0  | 204.0  |
| D | 73  | 66  | 90  | 0 | .89   | 164.1 | 80.0  | 264.0  |
| D | 73  | 66  | 90  | 0 | 1.06  | 97.5  | 52.0  | 144.0  |
| D | 73  | 66  | 90  | 0 | .98   | 115.3 | 88.0  | 124.0  |
| D | 73  | 66  | 90  | 0 | .91   | 165.5 | 96.0  | 260.0  |
| D | 73  | 66  | 90  | 0 | .81   | 93.8  | 96.0  | 116.0  |
| D | 73  | 66  | 90  | 0 | .43   | 110.5 | 92.0  | 172.0  |
| V | 101 | 106 | 104 | 1 | .90   | 206.6 | 76.0  | 604.0  |
| V | 101 | 106 | 104 | 1 | 1.32  | 240.5 | 100.0 | 612.0  |
| V | 101 | 106 | 104 | 1 | 1.56  | 303.0 | 100.0 | 620.0  |
| V | 101 | 106 | 104 | 1 | 1.70  | 266.3 | 124.0 | 628.0  |
| V | 101 | 106 | 104 | 1 | 1.63  | 300.1 | 100.0 | 624.0  |
| V | 101 | 106 | 104 | 1 | 1.46  | 392.6 | 600.0 | 652.0  |
| V | 101 | 106 | 104 | 1 | 1.20  | 214.3 | 96.0  | 620.0  |
| V | 101 | 106 | 104 | 1 | .72   | 175.0 | 120.0 | 260.0  |
| V | 101 | 106 | 104 | 1 | 1.38  | 440.7 | 624.0 | 652.0  |
| V | 101 | 106 | 104 | 1 | 1.80  | 443.6 | 616.0 | 652.0  |
| V | 101 | 106 | 104 | 1 | 1.89  | 450.4 | 624.0 | 652.0  |
| V | 101 | 106 | 104 | 1 | 1.82  | 351.2 | 116.0 | 684.0  |
| V | 101 | 106 | 104 | 1 | 1.61  | 481.2 | 632.0 | 656.0  |
| V | 101 | 106 | 104 | 1 | 1.10  | 247.2 | 104.0 | 172.0  |
| V | 101 | 106 | 104 | 1 | .80   | 162.8 | 132.0 | 156.0  |
| V | 101 | 106 | 104 | 1 | 1.46  | 197.4 | 140.0 | 284.0  |
| V | 101 | 106 | 104 | 1 | 2.06  | 315.0 | 104.0 | 692.0  |

|   |     |     |     |   |      |       |       |       |
|---|-----|-----|-----|---|------|-------|-------|-------|
| V | 101 | 106 | 104 | 1 | 2.35 | 315.2 | 156.0 | 656.0 |
| V | 101 | 106 | 104 | 1 | 2.18 | 262.3 | 104.0 | 176.0 |
| V | 101 | 106 | 104 | 1 | 1.70 | 228.5 | 92.0  | 668.0 |
| V | 101 | 106 | 104 | 1 | .70  | 157.1 | 104.0 | 208.0 |
| V | 101 | 106 | 104 | 1 | .97  | 272.4 | 88.0  | 632.0 |
| V | 101 | 106 | 104 | 1 | 1.77 | 494.9 | 628.0 | 640.0 |
| V | 101 | 106 | 104 | 1 | 2.17 | 433.5 | 644.0 | 644.0 |
| V | 101 | 106 | 104 | 1 | 2.08 | 366.9 | 628.0 | 676.0 |
| V | 101 | 106 | 104 | 1 | 1.60 | 295.6 | 112.0 | 684.0 |
| V | 101 | 106 | 104 | 1 | .62  | 170.2 | 120.0 | 184.0 |
| W | 107 | 114 | 106 | 1 | .78  | 395.2 | 260.0 | 548.0 |
| W | 107 | 114 | 106 | 1 | 1.23 | 358.0 | 112.0 | 552.0 |
| W | 107 | 114 | 106 | 1 | 1.10 | 453.4 | 128.0 | 348.0 |
| W | 107 | 114 | 106 | 1 | 1.01 | 242.5 | 136.0 | 412.0 |
| W | 107 | 114 | 106 | 1 | .80  | 295.6 | 104.0 | 404.0 |
| W | 107 | 114 | 106 | 1 | .56  | 154.5 | 76.0  | 260.0 |
| W | 107 | 114 | 106 | 1 | .52  | 415.0 | 124.0 | 304.0 |
| W | 107 | 114 | 106 | 1 | .88  | 392.3 | 128.0 | 536.0 |
| W | 107 | 114 | 106 | 1 | .97  | 331.7 | 104.0 | 588.0 |
| W | 107 | 114 | 106 | 1 | .91  | 270.0 | 152.0 | 600.0 |
| W | 107 | 114 | 106 | 1 | .65  | 257.5 | 140.0 | 284.0 |
| W | 107 | 114 | 106 | 1 | .73  | 338.1 | 96.0  | 660.0 |
| W | 107 | 114 | 106 | 1 | .94  | 288.4 | 100.0 | 592.0 |
| W | 107 | 114 | 106 | 1 | 1.04 | 289.7 | 124.0 | 400.0 |
| W | 107 | 114 | 106 | 1 | .92  | 196.7 | 124.0 | 328.0 |
| W | 107 | 114 | 106 | 1 | .66  | 199.5 | 156.0 | 204.0 |
| W | 107 | 114 | 106 | 1 | .79  | 134.9 | 124.0 | 172.0 |
| W | 107 | 114 | 106 | 1 | 1.10 | 211.8 | 124.0 | 380.0 |
| W | 107 | 114 | 106 | 1 | 1.18 | 229.6 | 112.0 | 328.0 |
| W | 107 | 114 | 106 | 1 | 1.11 | 243.0 | 132.0 | 616.0 |
| W | 107 | 114 | 106 | 1 | .94  | 183.0 | 84.0  | 384.0 |
| X | 93  | 78  | 85  | 0 | .73  | 146.7 | 116.0 | 164.0 |
| X | 93  | 78  | 85  | 0 | .98  | 219.1 | 104.0 | 200.0 |
| X | 93  | 78  | 85  | 0 | .93  | 157.8 | 104.0 | 156.0 |
| X | 93  | 78  | 85  | 0 | .97  | 181.3 | 92.0  | 208.0 |
| X | 93  | 78  | 85  | 0 | .59  | 124.5 | 96.0  | 164.0 |
| X | 93  | 78  | 85  | 0 | .84  | 148.7 | 104.0 | 172.0 |
| X | 93  | 78  | 85  | 0 | 1.01 | 221.9 | 136.0 | 288.0 |
| X | 93  | 78  | 85  | 0 | .96  | 203.6 | 100.0 | 152.0 |
| X | 93  | 78  | 85  | 0 | .85  | 148.4 | 64.0  | 172.0 |
| X | 93  | 78  | 85  | 0 | .77  | 246.6 | 108.0 | 260.0 |
| X | 93  | 78  | 85  | 0 | .53  | 365.8 | 132.0 | 568.0 |
| X | 93  | 78  | 85  | 0 | .67  | 139.5 | 88.0  | 260.0 |
| X | 93  | 78  | 85  | 0 | 1.01 | 238.0 | 108.0 | 492.0 |
| X | 93  | 78  | 85  | 0 | 1.03 | 184.5 | 84.0  | 260.0 |
| X | 93  | 78  | 85  | 0 | .95  | 287.5 | 116.0 | 356.0 |
| X | 93  | 78  | 85  | 0 | .84  | 283.6 | 104.0 | 468.0 |
| X | 93  | 78  | 85  | 0 | .72  | 175.7 | 108.0 | 172.0 |
| X | 93  | 78  | 85  | 0 | .33  | 120.1 | 80.0  | 136.0 |
| X | 93  | 78  | 85  | 0 | .87  | 229.1 | 108.0 | 260.0 |
| X | 93  | 78  | 85  | 0 | 1.48 | 237.9 | 164.0 | 492.0 |
| X | 93  | 78  | 85  | 0 | 1.41 | 140.2 | 120.0 | 200.0 |

|   |     |     |     |   |      |       |        |        |
|---|-----|-----|-----|---|------|-------|--------|--------|
| X | 93  | 78  | 85  | 0 | 1.42 | 140.1 | 104.0  | 172.0  |
| X | 93  | 78  | 85  | 0 | 1.32 | 141.7 | 116.0  | 136.0  |
| X | 93  | 78  | 85  | 0 | .96  | 131.6 | 108.0  | 192.0  |
| X | 93  | 78  | 85  | 0 | .52  | 105.5 | 84.0   | 168.0  |
| I | 112 | 118 | 105 | 1 | 1.06 | 533.6 | 584.0  | 768.0  |
| I | 112 | 118 | 105 | 1 | 1.26 | 478.0 | 616.0  | 768.0  |
| I | 112 | 118 | 105 | 1 | 1.34 | 518.1 | 588.0  | 740.0  |
| I | 112 | 118 | 105 | 1 | 1.31 | 521.9 | 608.0  | 716.0  |
| I | 112 | 118 | 105 | 1 | 1.48 | 486.6 | 632.0  | 788.0  |
| I | 112 | 118 | 105 | 1 | 1.57 | 509.1 | 448.0  | 780.0  |
| I | 112 | 118 | 105 | 1 | 1.59 | 467.5 | 452.0  | 752.0  |
| I | 112 | 118 | 105 | 1 | 1.67 | 474.6 | 680.0  | 740.0  |
| I | 112 | 118 | 105 | 1 | 1.30 | 465.9 | 600.0  | 780.0  |
| I | 112 | 118 | 105 | 1 | 1.70 | 489.1 | 456.0  | 780.0  |
| I | 112 | 118 | 105 | 1 | 1.66 | 482.4 | 592.0  | 632.0  |
| I | 112 | 118 | 105 | 1 | 1.71 | 441.6 | 476.0  | 788.0  |
| I | 112 | 118 | 105 | 1 | 1.83 | 471.0 | 456.0  | 780.0  |
| I | 112 | 118 | 105 | 1 | 1.90 | 496.9 | 536.0  | 760.0  |
| I | 112 | 118 | 105 | 1 | .64  | 565.9 | 808.0  | 1328.0 |
| I | 112 | 118 | 105 | 1 | 1.02 | 619.3 | 172.0  | 1260.0 |
| I | 112 | 118 | 105 | 1 | 1.24 | 664.8 | 256.0  | 1400.0 |
| I | 112 | 118 | 105 | 1 | 1.44 | 653.7 | 780.0  | 1136.0 |
| I | 112 | 118 | 105 | 1 | 1.34 | 689.7 | 228.0  | 1444.0 |
| I | 112 | 118 | 105 | 1 | 1.32 | 705.2 | 288.0  | 1448.0 |
| I | 112 | 118 | 105 | 1 | 1.18 | 695.3 | 260.0  | 1392.0 |
| I | 112 | 118 | 105 | 1 | 1.15 | 828.8 | 1364.0 | 1476.0 |
| I | 112 | 118 | 105 | 1 | .99  | 757.1 | 260.0  | 1484.0 |
| I | 112 | 118 | 105 | 1 | 1.70 | 458.2 | 456.0  | 776.0  |
| I | 112 | 118 | 105 | 1 | 2.2  | 368.3 | 152.0  | 776.0  |
| I | 112 | 118 | 105 | 1 | 2.3  | 477.1 | 492.0  | 772.0  |
| I | 112 | 118 | 105 | 1 | 2.4  | 442.9 | 508.0  | 780.0  |
| I | 112 | 118 | 105 | 1 | 2.42 | 439.4 | 472.0  | 1460.0 |
| I | 112 | 118 | 105 | 1 | 2.17 | 517.1 | 300.0  | 1464.0 |
| + | 72  | 58  | 124 | 0 | 1.54 | 141.5 | 108.0  | 152.0  |
| + | 72  | 58  | 124 | 0 | 1.80 | 170.4 | 104.0  | 148.0  |
| + | 72  | 58  | 124 | 0 | 1.71 | 168.8 | 80.0   | 204.0  |
| + | 72  | 58  | 124 | 0 | 1.35 | 196.3 | 68.0   | 132.0  |
| + | 72  | 58  | 124 | 0 | 1.04 | 128.7 | 96.0   | 160.0  |
| + | 72  | 58  | 124 | 0 | 1.43 | 159.5 | 116.0  | 172.0  |
| + | 72  | 58  | 124 | 0 | 1.92 | 166.7 | 104.0  | 128.0  |
| + | 72  | 58  | 124 | 0 | 1.73 | 124.2 | 104.0  | 188.0  |
| + | 72  | 58  | 124 | 0 | 1.42 | 134.7 | 108.0  | 180.0  |
| + | 72  | 58  | 124 | 0 | 1.19 | 143.7 | 84.0   | 172.0  |
| + | 72  | 58  | 124 | 0 | 1.11 | 123.7 | 92.0   | 136.0  |
| + | 72  | 58  | 124 | 0 | 1.69 | 114.6 | 104.0  | 160.0  |
| + | 72  | 58  | 124 | 0 | 1.61 | 119.9 | 120.0  | 168.0  |
| + | 72  | 58  | 124 | 0 | 1.51 | 131.7 | 96.0   | 148.0  |
| + | 72  | 58  | 124 | 0 | .78  | 178.5 | 100.0  | 148.0  |
| + | 72  | 58  | 124 | 0 | 1.48 | 116.4 | 116.0  | 160.0  |
| + | 72  | 58  | 124 | 0 | 1.62 | 106.4 | 84.0   | 152.0  |
| + | 72  | 58  | 124 | 0 | 1.95 | 134.7 | 100.0  | 148.0  |
| + | 72  | 58  | 124 | 0 | 1.72 | 131.2 | 88.0   | 156.0  |

|   |    |     |     |   |      |       |       |        |
|---|----|-----|-----|---|------|-------|-------|--------|
| + | 72 | 58  | 124 | 0 | 1.35 | 98.8  | 88.0  | 108.0  |
| * | 99 | 105 | 105 | 1 | .71  | 324.4 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | .74  | 347.2 | 128.0 | 300.0  |
| * | 99 | 105 | 105 | 1 | .88  | 368.5 | 108.0 | 204.0  |
| * | 99 | 105 | 105 | 1 | .95  | 426.3 | 120.0 | 1228.0 |
| * | 99 | 105 | 105 | 1 | .93  | 341.4 | 96.0  | 256.0  |
| * | 99 | 105 | 105 | 1 | .96  | 325.8 | 128.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | .98  | 353.1 | 108.0 | 216.0  |
| * | 99 | 105 | 105 | 1 | .98  | 344.7 | 100.0 | 216.0  |
| * | 99 | 105 | 105 | 1 | .97  | 383.1 | 112.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | .88  | 329.6 | 92.0  | 468.0  |
| * | 99 | 105 | 105 | 1 | 1.08 | 416.4 | 172.0 | 1296.0 |
| * | 99 | 105 | 105 | 1 | 1.18 | 352.1 | 108.0 | 1260.0 |
| * | 99 | 105 | 105 | 1 | 1.19 | 343.0 | 148.0 | 332.0  |
| * | 99 | 105 | 105 | 1 | 1.17 | 382.2 | 116.0 | 356.0  |
| * | 99 | 105 | 105 | 1 | 1.21 | 407.5 | 124.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.21 | 343.5 | 136.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.16 | 335.2 | 148.0 | 428.0  |
| * | 99 | 105 | 105 | 1 | 1.14 | 385.1 | 108.0 | 204.0  |
| * | 99 | 105 | 105 | 1 | 1.03 | 368.8 | 100.0 | 540.0  |
| * | 99 | 105 | 105 | 1 | .95  | 367.8 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | .66  | 351.5 | 108.0 | 380.0  |
| * | 99 | 105 | 105 | 1 | .93  | 429.3 | 120.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.01 | 387.3 | 168.0 | 492.0  |
| * | 99 | 105 | 105 | 1 | 1.03 | 346.8 | 108.0 | 472.0  |
| * | 99 | 105 | 105 | 1 | .99  | 330.6 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.01 | 410.1 | 112.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | .99  | 417.0 | 116.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.03 | 418.6 | 140.0 | 1272.0 |
| * | 99 | 105 | 105 | 1 | 1.08 | 325.9 | 108.0 | 212.0  |
| * | 99 | 105 | 105 | 1 | .97  | 392.6 | 116.0 | 172.0  |
| * | 99 | 105 | 105 | 1 | 1.12 | 403.0 | 96.0  | 500.0  |
| * | 99 | 105 | 105 | 1 | 1.12 | 364.8 | 148.0 | 276.0  |
| * | 99 | 105 | 105 | 1 | 1.06 | 392.8 | 108.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.10 | 392.6 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | 1.22 | 349.1 | 112.0 | 172.0  |
| * | 99 | 105 | 105 | 1 | 1.21 | 336.1 | 112.1 | 288.0  |
| * | 99 | 105 | 105 | 1 | 1.21 | 380.5 | 116.0 | 1224.0 |
| * | 99 | 105 | 105 | 1 | 1.12 | 355.2 | 108.0 | 260.0  |
| * | 99 | 105 | 105 | 1 | .98  | 278.5 | 112.0 | 172.0  |
| # | 70 | 74  | 106 | 0 | .75  | 314.2 | 152.0 | 364.0  |
| # | 70 | 74  | 106 | 0 | 1.19 | 288.9 | 144.0 | 632.0  |
| # | 70 | 74  | 106 | 0 | 1.23 | 308.3 | 112.0 | 292.0  |
| # | 70 | 74  | 106 | 0 | .87  | 303.4 | 88.0  | 448.0  |
| # | 70 | 74  | 106 | 0 | 0.32 | 331.4 | 112.0 | 1264.0 |
| # | 70 | 74  | 106 | 0 | 1.53 | 144.4 | 100.0 | 176.0  |
| # | 70 | 74  | 106 | 0 | 1.73 | 143.8 | 80.0  | 152.0  |
| # | 70 | 74  | 106 | 0 | 1.58 | 140.7 | 96.0  | 156.0  |
| # | 70 | 74  | 106 | 0 | 1.19 | 151.3 | 96.0  | 164.0  |
| # | 70 | 74  | 106 | 0 | 1.04 | 350.9 | 108.0 | 628.0  |
| # | 70 | 74  | 106 | 0 | 1.43 | 324.6 | 144.0 | 600.0  |
| # | 70 | 74  | 106 | 0 | 1.58 | 287.6 | 112.0 | 568.0  |

|   |    |    |     |   |      |       |       |        |
|---|----|----|-----|---|------|-------|-------|--------|
| # | 70 | 74 | 106 | 0 | 1.61 | 449.5 | 100.0 | 700.0  |
| # | 70 | 74 | 106 | 0 | 1.34 | 305.6 | 140.0 | 544.0  |
| # | 70 | 74 | 106 | 0 | .81  | 355.5 | 128.0 | 1340.0 |
| # | 70 | 74 | 106 | 0 | .65  | 408.1 | 100.0 | 1332.0 |
| # | 70 | 74 | 106 | 0 | 1.32 | 301.9 | 136.0 | 260.0  |
| # | 70 | 74 | 106 | 0 | 1.81 | 400.9 | 152.0 | 676.0  |
| # | 70 | 74 | 106 | 0 | 1.86 | 318.8 | 112.0 | 628.0  |
| # | 70 | 74 | 106 | 0 | 1.65 | 346.4 | 104.0 | 1224.0 |
| # | 70 | 74 | 106 | 0 | 1.17 | 326.9 | 112.0 | 1224.0 |

Inspiration Direct Data Set: Each

Test Set

7 Abnormals (STATE=0)

M  
C  
D  
G  
S  
B  
E

5 Normals (STATE=1)

K  
L  
F  
Y  
N

DATA BREATH;  
 TITLE 'POWER SPECTRA DATA ON INSPIRATORY SOUND';  
 COMMENT STATE: NORMAL= 1 ABNORMAL= 0;  
 COMMENT DIRECT TEST DATA;  
 INPUT ID S FVC FEV1 FEV1P STATE FLOW MPF FPK FMAX;  
 CARDS;

|   |     |     |    |   |      |        |       |        |
|---|-----|-----|----|---|------|--------|-------|--------|
| B | 82  | 70  | 85 | 0 | 1.41 | 902.7  | 1492  | 1496   |
| B | 82  | 70  | 85 | 0 | 1.41 | 704.2  | 256   | 1496   |
| B | 82  | 70  | 85 | 0 | 1.08 | 842    | 404   | 1488   |
| B | 82  | 70  | 85 | 0 | .84  | 949.1  | 424   | 1464   |
| B | 82  | 70  | 85 | 0 | 1.37 | 784.5  | 1472  | 1488   |
| B | 82  | 70  | 85 | 0 | 1.42 | 963    | 1476  | 1480   |
| B | 82  | 70  | 85 | 0 | 1.32 | 853.9  | 1436  | 1496   |
| B | 82  | 70  | 85 | 0 | 1.08 | 970    | 172   | 1496   |
| B | 82  | 70  | 85 | 0 | .77  | 1017   | 1460  | 1492   |
| B | 82  | 70  | 85 | 0 | 1.20 | 727.4  | 260   | 1464   |
| B | 82  | 70  | 85 | 0 | 1.41 | 847.5  | 172   | 1496   |
| B | 82  | 70  | 85 | 0 | 1.30 | 951.5  | 240   | 1488   |
| B | 82  | 70  | 85 | 0 | 1.08 | 1129.0 | 1468  | 1496   |
| B | 82  | 70  | 85 | 0 | 1.06 | 937.7  | 260   | 1496   |
| B | 82  | 70  | 85 | 0 | 1.38 | 870.1  | 112   | 1496   |
| B | 82  | 70  | 85 | 0 | 1.21 | 909.2  | 1320  | 1492   |
| B | 82  | 70  | 85 | 0 | 1.00 | 869.2  | 172   | 1496   |
| C | 77  | 78  | 99 | 0 | 1.34 | 402.7  | 452   | 664    |
| C | 77  | 78  | 99 | 0 | 1.34 | 369.7  | 464   | 592    |
| C | 77  | 78  | 99 | 0 | 1.30 | 329.3  | 104   | 588    |
| C | 77  | 78  | 99 | 0 | 1.20 | 399.4  | 444   | 716.0  |
| C | 77  | 78  | 99 | 0 | 1.12 | 430.7  | 696   | 736.0  |
| C | 77  | 78  | 99 | 0 | 1.09 | 454.2  | 688   | 732.0  |
| C | 77  | 78  | 99 | 0 | 0.99 | 455.4  | 600.0 | 608.0  |
| C | 77  | 78  | 99 | 0 | 0.98 | 442.0  | 568.0 | 648.0  |
| C | 77  | 78  | 99 | 0 | 1.40 | 444.8  | 588.0 | 788.0  |
| C | 77  | 78  | 99 | 0 | 1.40 | 419.4  | 436.0 | 636.0  |
| C | 77  | 78  | 99 | 0 | 1.29 | 395.2  | 472.0 | 620.0  |
| C | 77  | 78  | 99 | 0 | 1.24 | 421.7  | 160.0 | 744.0  |
| C | 77  | 78  | 99 | 0 | 1.13 | 427.9  | 680.0 | 684.0  |
| D | 102 | 100 | 97 | 0 | 1.00 | 371.7  | 108.0 | 180.0  |
| D | 102 | 100 | 97 | 0 | 1.27 | 499.1  | 100.0 | 1468.0 |
| D | 102 | 100 | 97 | 0 | 1.15 | 423.3  | 104.0 | 1336.0 |
| D | 102 | 100 | 97 | 0 | 1.02 | 672.0  | 172.0 | 1488.0 |
| D | 102 | 100 | 97 | 0 | .74  | 500.2  | 120.0 | 1432.0 |
| D | 102 | 100 | 97 | 0 | 1.19 | 470.6  | 100.0 | 1432.0 |
| D | 102 | 100 | 97 | 0 | 1.36 | 579.0  | 100.0 | 1452.0 |
| D | 102 | 100 | 97 | 0 | 1.27 | 396.0  | 104.0 | 432.0  |
| D | 102 | 100 | 97 | 0 | 1.04 | 340.7  | 104.0 | 260.0  |
| D | 102 | 100 | 97 | 0 | .99  | 614.9  | 740.0 | 1360.0 |
| D | 102 | 100 | 97 | 0 | 1.44 | 560.7  | 712.0 | 904.0  |
| D | 102 | 100 | 97 | 0 | 1.41 | 458.1  | 112.0 | 896.0  |
| D | 102 | 100 | 97 | 0 | 1.19 | 413.3  | 104.0 | 212.0  |
| D | 102 | 100 | 97 | 0 | .75  | 643.1  | 124.0 | 1460.0 |
| D | 102 | 100 | 97 | 0 | 1.25 | 394.9  | 604.0 | 796.0  |
| D | 102 | 100 | 97 | 0 | 1.54 | 258.8  | 180.0 | 600.0  |

|   |     |     |     |   |      |       |        |        |
|---|-----|-----|-----|---|------|-------|--------|--------|
| D | 102 | 100 | 97  | 0 | 1.39 | 223.6 | 104.0  | 608.0  |
| D | 102 | 100 | 97  | 0 | 1.19 | 255.3 | 108.0  | 704.0  |
| D | 102 | 100 | 97  | 0 | .84  | 372.9 | 604.0  | 612.0  |
| E | 90  | 72  | 81  | 0 | 1.00 | 364.6 | 104.0  | 648.0  |
| E | 90  | 72  | 81  | 0 | 1.07 | 390.1 | 616.0  | 708.0  |
| E | 90  | 72  | 81  | 0 | 1.08 | 368.1 | 216.0  | 704.0  |
| E | 90  | 72  | 81  | 0 | .84  | 356.1 | 116.0  | 700.0  |
| E | 90  | 72  | 81  | 0 | .80  | 323.5 | 104.0  | 612.0  |
| E | 90  | 72  | 81  | 0 | 1.18 | 354.1 | 200.0  | 624.0  |
| E | 90  | 72  | 81  | 0 | 1.21 | 351.9 | 508.0  | 624.0  |
| E | 90  | 72  | 81  | 0 | 1.16 | 318.7 | 208.0  | 624.0  |
| E | 90  | 72  | 81  | 0 | 1.10 | 302.5 | 100.0  | 600.0  |
| E | 90  | 72  | 81  | 0 | .97  | 414.2 | 612.0  | 724.0  |
| E | 90  | 72  | 81  | 0 | 1.15 | 430.0 | 608.0  | 748.0  |
| E | 90  | 72  | 81  | 0 | 1.14 | 412.7 | 192.0  | 744.0  |
| E | 90  | 72  | 81  | 0 | 1.13 | 383.7 | 104.0  | 724.0  |
| E | 90  | 72  | 81  | 0 | 1.05 | 405.1 | 108.0  | 700.0  |
| E | 90  | 72  | 81  | 0 | 1.01 | 378.0 | 208.0  | 716.0  |
| E | 90  | 72  | 81  | 0 | 1.25 | 372.0 | 100.0  | 692.0  |
| E | 90  | 72  | 81  | 0 | 1.33 | 404.3 | 224.0  | 708.0  |
| E | 90  | 72  | 81  | 0 | 1.29 | 419.1 | 228.0  | 740.0  |
| E | 90  | 72  | 81  | 0 | 1.09 | 365.7 | 200.0  | 628.0  |
| F | 146 | 141 | 97  | 1 | .50  | 315.4 | 100.0  | 512.0  |
| F | 146 | 141 | 97  | 1 | .82  | 242.8 | 120.0  | 192.0  |
| F | 146 | 141 | 97  | 1 | 1.12 | 288.2 | 104.0  | 568.0  |
| F | 146 | 141 | 97  | 1 | 1.51 | 274.0 | 104.0  | 588.0  |
| F | 146 | 141 | 97  | 1 | 1.60 | 277.2 | 108.0  | 520.0  |
| F | 146 | 141 | 97  | 1 | 1.74 | 400.0 | 100.0  | 1032.0 |
| F | 146 | 141 | 97  | 1 | 0.64 | 310.3 | 112.0  | 172.0  |
| F | 146 | 141 | 97  | 1 | 1.28 | 314.0 | 104.0  | 556.0  |
| F | 146 | 141 | 97  | 1 | 1.66 | 263.6 | 100.0  | 516.0  |
| F | 146 | 141 | 97  | 1 | 1.87 | 404.1 | 120.0  | 1048.0 |
| F | 146 | 141 | 97  | 1 | 1.88 | 620.1 | 1028.0 | 1036.0 |
| F | 146 | 141 | 97  | 1 | 1.88 | 624.7 | 1028.0 | 1036.0 |
| F | 146 | 141 | 97  | 1 | 1.80 | 216.2 | 104.0  | 176.0  |
| F | 146 | 141 | 97  | 1 | .45  | 380.4 | 100.0  | 692.0  |
| F | 146 | 141 | 97  | 1 | .72  | 302.5 | 100.0  | 628.0  |
| F | 146 | 141 | 97  | 1 | .83  | 259.9 | 100.0  | 612.0  |
| F | 146 | 141 | 97  | 1 | 1.07 | 291.9 | 100.0  | 600.0  |
| F | 146 | 141 | 97  | 1 | 1.42 | 361.5 | 168.0  | 1228.0 |
| F | 146 | 141 | 97  | 1 | 1.66 | 303.7 | 104.0  | 592.0  |
| F | 146 | 141 | 97  | 1 | 1.65 | 314.4 | 136.0  | 604.0  |
| F | 146 | 141 | 97  | 1 | 1.58 | 172.6 | 100.0  | 172.0  |
| F | 146 | 141 | 97  | 1 | 1.48 | 224.4 | 120.0  | 492.0  |
| F | 146 | 141 | 97  | 1 | .66  | 308.5 | 100.0  | 256.0  |
| F | 146 | 141 | 97  | 1 | .98  | 264.7 | 100.0  | 456.0  |
| F | 146 | 141 | 97  | 1 | 1.1  | 300.8 | 104.0  | 584.0  |
| F | 146 | 141 | 97  | 1 | 1.27 | 302.0 | 100.0  | 580.0  |
| F | 146 | 141 | 97  | 1 | 1.40 | 258.8 | 120.0  | 604.0  |
| F | 146 | 141 | 97  | 1 | 1.70 | 287.1 | 104.0  | 600.0  |
| G | 78  | 91  | 118 | 0 | .15  | 434.5 | 612.0  | 736.0  |
| G | 78  | 91  | 118 | 0 | .46  | 343.8 | 104.0  | 728.0  |

|   |     |     |     |   |      |       |       |        |
|---|-----|-----|-----|---|------|-------|-------|--------|
| G | 78  | 91  | 118 | 0 | 1.1  | 482.2 | 160.0 | 1020.0 |
| G | 78  | 91  | 118 | 0 | 1.2  | 427.7 | 228.0 | 716.0  |
| G | 78  | 91  | 118 | 0 | 1.27 | 404.6 | 192.0 | 716.0  |
| G | 78  | 91  | 118 | 0 | 1.46 | 343.7 | 208.0 | 712.0  |
| G | 78  | 91  | 118 | 0 | 1.50 | 484.0 | 236.0 | 1024.0 |
| G | 78  | 91  | 118 | 0 | 1.50 | 419.0 | 188.0 | 1016.0 |
| G | 78  | 91  | 118 | 0 | 1.48 | 368.8 | 172.0 | 760.0  |
| G | 78  | 91  | 118 | 0 | 1.25 | 425.4 | 708.0 | 764.0  |
| G | 78  | 91  | 118 | 0 | 1.45 | 457.0 | 180.0 | 780.0  |
| G | 78  | 91  | 118 | 0 | 1.36 | 497.3 | 688.0 | 740.0  |
| G | 78  | 91  | 118 | 0 | 1.21 | 406.2 | 100.0 | 748.0  |
| G | 78  | 91  | 118 | 0 | 0.72 | 513.2 | 180.0 | 844.0  |
| G | 78  | 91  | 118 | 0 | 1.16 | 436.4 | 176.0 | 756.0  |
| G | 78  | 91  | 118 | 0 | 1.04 | 381.1 | 208.0 | 772.0  |
| G | 78  | 91  | 118 | 0 | 1.17 | 427.7 | 244.0 | 744.0  |
| S | 92  | 95  | 103 | 0 | 1.60 | 278.5 | 228.0 | 676.0  |
| S | 92  | 95  | 103 | 0 | 1.52 | 208.4 | 172.0 | 304.0  |
| S | 92  | 95  | 103 | 0 | 1.38 | 183.6 | 112.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.19 | 220.7 | 120.0 | 284.0  |
| S | 92  | 95  | 103 | 0 | 1.97 | 785.3 | 928.0 | 932.0  |
| S | 92  | 95  | 103 | 0 | 2.22 | 311.2 | 104.0 | 144.0  |
| S | 92  | 95  | 103 | 0 | 2.08 | 505.4 | 172.0 | 1376.0 |
| S | 92  | 95  | 103 | 0 | 1.87 | 318.9 | 92.0  | 636.0  |
| S | 92  | 95  | 103 | 0 | 1.29 | 187.7 | 76.0  | 156.0  |
| S | 92  | 95  | 103 | 0 | 1.82 | 689.9 | 120.0 | 1436.0 |
| S | 92  | 95  | 103 | 0 | 2.18 | 589.0 | 120.0 | 1412.0 |
| S | 92  | 95  | 103 | 0 | 2.04 | 562.5 | 120.0 | 1332.0 |
| S | 92  | 95  | 103 | 0 | 1.63 | 572.4 | 120.0 | 1224.0 |
| S | 92  | 95  | 103 | 0 | .62  | 575.7 | 120.0 | 260.0  |
| S | 92  | 95  | 103 | 0 | 1.15 | 334.4 | 120.0 | 608.0  |
| S | 92  | 95  | 103 | 0 | 1.80 | 361.6 | 204.0 | 668.0  |
| S | 92  | 95  | 103 | 0 | 1.80 | 379.0 | 160.0 | 776.0  |
| S | 92  | 95  | 103 | 0 | 1.60 | 417.4 | 120.0 | 420.0  |
| S | 92  | 95  | 103 | 0 | 1.38 | 386.5 | 120.0 | 260.0  |
| Y | 101 | 113 | 113 | 1 | .69  | 447.4 | 116.0 | 1224.0 |
| Y | 101 | 113 | 113 | 1 | 1.05 | 322.0 | 112.0 | 172.0  |
| Y | 101 | 113 | 113 | 1 | 1.18 | 367.9 | 108.0 | 268.0  |
| Y | 101 | 113 | 113 | 1 | 1.21 | 481.2 | 112.0 | 260.0  |
| Y | 101 | 113 | 113 | 1 | 1.23 | 395.1 | 116.0 | 336.0  |
| Y | 101 | 113 | 113 | 1 | .97  | 324.6 | 112.0 | 184.0  |
| Y | 101 | 113 | 113 | 1 | 1.06 | 175.1 | 112.0 | 248.0  |
| Y | 101 | 113 | 113 | 1 | 1.30 | 131.0 | 88.0  | 168.0  |
| Y | 101 | 113 | 113 | 1 | 1.45 | 183.0 | 124.0 | 276.0  |
| Y | 101 | 113 | 113 | 1 | 1.57 | 170.5 | 84.0  | 260.0  |
| Y | 101 | 113 | 113 | 1 | 1.39 | 150.6 | 96.0  | 188.0  |
| Y | 101 | 113 | 113 | 1 | .87  | 144.9 | 92.0  | 136.0  |
| Y | 101 | 113 | 113 | 1 | 1.17 | 146.6 | 104.0 | 192.0  |
| Y | 101 | 113 | 113 | 1 | 1.49 | 188.2 | 112.0 | 260.0  |
| Y | 101 | 113 | 113 | 1 | 1.53 | 141.5 | 92.0  | 124.0  |
| Y | 101 | 113 | 113 | 1 | 1.48 | 161.2 | 84.0  | 428.0  |
| Y | 101 | 113 | 113 | 1 | 1.29 | 136.2 | 100.0 | 156.0  |
| Y | 101 | 113 | 113 | 1 | 1.09 | 179.3 | 96.0  | 180.0  |

|   |     |     |     |   |      |       |       |       |
|---|-----|-----|-----|---|------|-------|-------|-------|
| Y | 101 | 113 | 113 | 1 | 1.32 | 125.0 | 84.0  | 132.0 |
| Y | 101 | 113 | 113 | 1 | 1.47 | 185.9 | 112.0 | 152.0 |
| Y | 101 | 113 | 113 | 1 | 1.31 | 114.1 | 80.0  | 156.0 |
| Y | 101 | 113 | 113 | 1 | 1.29 | 139.2 | 116.0 | 152.0 |
| Y | 101 | 113 | 113 | 1 | 1.17 | 124.0 | 96.0  | 152.0 |
| K | 102 | 105 | 104 | 1 | .95  | 393.3 | 496.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | 1.27 | 364.0 | 484.0 | 608.0 |
| K | 102 | 105 | 104 | 1 | 1.21 | 356.3 | 452.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | 1.16 | 399.4 | 472.0 | 608.0 |
| K | 102 | 105 | 104 | 1 | 1.01 | 310.3 | 152.0 | 592.0 |
| K | 102 | 105 | 104 | 1 | .73  | 269.2 | 128.0 | 592.0 |
| K | 102 | 105 | 104 | 1 | .69  | 352.4 | 508.0 | 596.0 |
| K | 102 | 105 | 104 | 1 | 1.12 | 381.5 | 188.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | 1.17 | 398.6 | 500.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | 1.10 | 220.2 | 108.0 | 580.0 |
| K | 102 | 105 | 104 | 1 | 0.84 | 339.5 | 192.0 | 612.0 |
| K | 102 | 105 | 104 | 1 | .89  | 295.5 | 108.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | 1.35 | 431.3 | 464.0 | 580.0 |
| K | 102 | 105 | 104 | 1 | 1.30 | 432.1 | 448.0 | 596.0 |
| K | 102 | 105 | 104 | 1 | 1.25 | 373.7 | 532.0 | 604.0 |
| K | 102 | 105 | 104 | 1 | 1.06 | 364.6 | 484.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | .90  | 220.2 | 88.0  | 584.0 |
| K | 102 | 105 | 104 | 1 | .85  | 400.9 | 484.0 | 596.0 |
| K | 102 | 105 | 104 | 1 | 1.37 | 445.6 | 476.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | 1.34 | 405.3 | 460.0 | 600.0 |
| K | 102 | 105 | 104 | 1 | 1.22 | 403.4 | 488.0 | 588.0 |
| K | 102 | 105 | 104 | 1 | 0.95 | 319.0 | 468.0 | 592.0 |
| L | 110 | 102 | 92  | 1 | .70  | 395.5 | 472.0 | 536.0 |
| L | 110 | 102 | 92  | 1 | 0.87 | 397.9 | 480.0 | 644.0 |
| L | 110 | 102 | 92  | 1 | 0.87 | 379.7 | 488.0 | 552.0 |
| L | 110 | 102 | 92  | 1 | 0.87 | 424.1 | 488.0 | 608.0 |
| L | 110 | 102 | 92  | 1 | 0.74 | 395.4 | 460.0 | 604.0 |
| L | 110 | 102 | 92  | 1 | 1.38 | 302.5 | 464.0 | 628.0 |
| L | 110 | 102 | 92  | 1 | 1.18 | 373.9 | 472.0 | 572.0 |
| L | 110 | 102 | 92  | 1 | 1.10 | 395.7 | 520.0 | 540.0 |
| L | 110 | 102 | 92  | 1 | 0.99 | 402.4 | 512.0 | 600.0 |
| L | 110 | 102 | 92  | 1 | .92  | 395.6 | 492.0 | 580.0 |
| L | 110 | 102 | 92  | 1 | .93  | 304.0 | 500.0 | 580.0 |
| L | 110 | 102 | 92  | 1 | .98  | 428.7 | 500.0 | 568.0 |
| L | 110 | 102 | 92  | 1 | 1.12 | 421.5 | 504.0 | 636.0 |
| L | 110 | 102 | 92  | 1 | .93  | 429.6 | 496.0 | 620.0 |
| L | 110 | 102 | 92  | 1 | .77  | 435.8 | 476.0 | 544.0 |
| L | 110 | 102 | 92  | 1 | 1.03 | 332.1 | 504.0 | 596.0 |
| L | 110 | 102 | 92  | 1 | 1.12 | 371.5 | 508.0 | 540.0 |
| L | 110 | 102 | 92  | 1 | 1.05 | 361.9 | 488.0 | 580.0 |
| L | 110 | 102 | 92  | 1 | 1.04 | 394.3 | 472.0 | 596.0 |
| L | 110 | 102 | 92  | 1 | 1.11 | 353.8 | 464.0 | 616.0 |
| M | 53  | 38  | 68  | 0 | 1.17 | 243.8 | 84.0  | 596.0 |
| M | 53  | 38  | 68  | 0 | 1.91 | 279.4 | 532.0 | 580.0 |
| M | 53  | 38  | 68  | 0 | 2.0  | 205.2 | 84.0  | 560.0 |
| M | 53  | 38  | 68  | 0 | 2.3  | 241.1 | 108.0 | 576.0 |
| M | 53  | 38  | 68  | 0 | 1.91 | 240.0 | 72.0  | 592.0 |

|   |    |    |     |   |      |       |       |       |
|---|----|----|-----|---|------|-------|-------|-------|
| M | 53 | 38 | 68  | 0 | 1.57 | 292.5 | 100.0 | 596.0 |
| M | 53 | 38 | 68  | 0 | 0.89 | 198.3 | 84.0  | 448.0 |
| M | 53 | 38 | 68  | 0 | 1.16 | 184.3 | 104.0 | 140.0 |
| M | 53 | 38 | 68  | 0 | 1.25 | 299.3 | 536.0 | 600.0 |
| M | 53 | 38 | 68  | 0 | 1.17 | 251.9 | 84.0  | 604.0 |
| M | 53 | 38 | 68  | 0 | 1.08 | 209.8 | 96.0  | 544.0 |
| M | 53 | 38 | 68  | 0 | 1.28 | 154.8 | 76.0  | 148.0 |
| M | 53 | 38 | 68  | 0 | 0.83 | 235.3 | 144.0 | 596.0 |
| M | 53 | 38 | 68  | 0 | 1.42 | 366.8 | 588.0 | 608.0 |
| M | 53 | 38 | 68  | 0 | 1.46 | 396.3 | 452.0 | 592.0 |
| M | 53 | 38 | 68  | 0 | 1.49 | 354.6 | 588.0 | 596.0 |
| M | 53 | 38 | 68  | 0 | 1.56 | 377.1 | 540.0 | 604.0 |
| M | 53 | 38 | 68  | 0 | 1.48 | 356.9 | 588.0 | 604.0 |
| M | 53 | 38 | 68  | 0 | 0.86 | 322.6 | 120.0 | 624.0 |
| M | 53 | 38 | 68  | 0 | 1.19 | 322.5 | 80.0  | 604.0 |
| M | 53 | 38 | 68  | 0 | 1.21 | 287.1 | 104.0 | 588.0 |
| M | 53 | 38 | 68  | 0 | 1.12 | 290.5 | 96.0  | 600.0 |
| M | 53 | 38 | 68  | 0 | 1.03 | 165.1 | 120.0 | 596.0 |
| M | 53 | 38 | 68  | 0 | 1.14 | 241.1 | 84.0  | 588.0 |
| N | 91 | 97 | 107 | 1 | .45  | 315.7 | 188.0 | 588.0 |
| N | 91 | 97 | 107 | 1 | .81  | 353.5 | 596.0 | 620.0 |
| N | 91 | 97 | 107 | 1 | .95  | 401.1 | 576.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | .93  | 388.2 | 592.0 | 620.0 |
| N | 91 | 97 | 107 | 1 | .83  | 384.8 | 592.0 | 612.0 |
| N | 91 | 97 | 107 | 1 | .67  | 411.0 | 600.0 | 608.0 |
| N | 91 | 97 | 107 | 1 | .53  | 256.4 | 100.0 | 624.0 |
| N | 91 | 97 | 107 | 1 | .55  | 435.6 | 444.0 | 688.0 |
| N | 91 | 97 | 107 | 1 | .70  | 383.5 | 600.0 | 644.0 |
| N | 91 | 97 | 107 | 1 | .78  | 366.5 | 452.0 | 636.0 |
| N | 91 | 97 | 107 | 1 | .77  | 424.2 | 604.0 | 628.0 |
| N | 91 | 97 | 107 | 1 | .71  | 367.6 | 452.0 | 664.0 |
| N | 91 | 97 | 107 | 1 | .61  | 391.3 | 616.0 | 636.0 |
| N | 91 | 97 | 107 | 1 | .84  | 403.3 | 452.0 | 628.0 |
| N | 91 | 97 | 107 | 1 | 1.07 | 404.1 | 444.0 | 616.0 |
| N | 91 | 97 | 107 | 1 | 1.15 | 396.1 | 448.0 | 648.0 |
| N | 91 | 97 | 107 | 1 | 1.09 | 416.8 | 452.0 | 624.0 |
| N | 91 | 97 | 107 | 1 | 1.07 | 401.3 | 424.0 | 620.0 |
| N | 91 | 97 | 107 | 1 | 1.01 | 341.8 | 428.0 | 652.0 |
| N | 91 | 97 | 107 | 1 | .60  | 345.2 | 116.0 | 648.0 |
| N | 91 | 97 | 107 | 1 | .86  | 406.1 | 260.0 | 664.0 |
| N | 91 | 97 | 107 | 1 | .89  | 405.9 | 464.0 | 628.0 |
| N | 91 | 97 | 107 | 1 | .92  | 404.4 | 424.0 | 660.0 |
| N | 91 | 97 | 107 | 1 | .84  | 404.6 | 204.0 | 684.0 |
| N | 91 | 97 | 107 | 1 | .74  | 413.4 | 484.0 | 636.0 |

## APPENDIX C

EXPIRATION DIRECT DATA SET: MEAN.

### Calibration or Training Set

7 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+  
#

5 Normals (STATE=1)

H  
I  
V  
W  
\*

# EXPIRATION DIRECT DATA SET: MEAN.

## Calibration or Training Set

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM            | VARIABLE      |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|----------------|---------------|
| ID 1     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 33 | 132 290000009 | 32 27902147           | 90 400000000     | 241 700000000    | 5 61005649           | 4365 60000000  | 1041 9352273  |
| FPK      | 33 | 93 57575758   | 13 67257817           | 64 000000000     | 120 000000000    | 2 38009016           | 3088 00000000  | 186 9393939   |
| FMAX     | 33 | 149 57575758  | 22 44859448           | 112 000000000    | 192 000000000    | 3 90779871           | 4936 00000000  | 503 9393939   |
| STATE    | 33 | 0 000000000   | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 00000000     | 0 00000000    |
| ID 2     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 30 | 484 896666667 | 71 43159971           | 342 400000000    | 603 600000000    | 13 04156616          | 14546 90000000 | 5102 47344    |
| FPK      | 30 | 128 800000000 | 41 46822631           | 108 000000000    | 260 000000000    | 7 57102766           | 3864 00000000  | 1719 61379    |
| FMAX     | 30 | 717 333333333 | 523 11779733          | 124 000000000    | 1476 000000000   | 95 50780594          | 21520 00000000 | 273652 22989  |
| STATE    | 30 | 1 000000000   | 0 000000000           | 1 000000000      | 1 000000000      | 0 000000000          | 30 00000000    | 0 00000000    |
| ID 3     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 36 | 347 477777778 | 98 56043284           | 127 600000000    | 497 300000000    | 16 42673881          | 12509 20000000 | 9714 15892    |
| FPK      | 36 | 150 222222222 | 122 48641000          | 72 000000000     | 576 000000000    | 20 41340167          | 5408 00000000  | 15092 92063   |
| FMAX     | 36 | 652 111111111 | 326 07587003          | 152 000000000    | 1372 000000000   | 54 34597834          | 23476 00000000 | 106325 47302  |
| STATE    | 36 | 0 000000000   | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 00000000     | 0 00000000    |
| ID 4     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 24 | 406 25416667  | 60 48871960           | 246 800000000    | 482 000000000    | 12 34720819          | 9750 10000000  | 3658 88520    |
| FPK      | 24 | 148 500000000 | 45 88549074           | 92 000000000     | 260 000000000    | 9 36633658           | 3564 00000000  | 2105 47826    |
| FMAX     | 24 | 432 000000000 | 370 00963560          | 256 000000000    | 1400 000000000   | 75 52790059          | 10368 00000000 | 136907 13043  |
| STATE    | 24 | 1 000000000   | 0 000000000           | 1 000000000      | 1 000000000      | 0 000000000          | 24 00000000    | 0 00000000    |
| ID 5     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 24 | 420 32916667  | 51 46431840           | 298 300000000    | 514 600000000    | 10 50511000          | 10087 90000000 | 2648 576069   |
| FPK      | 24 | 412 500000000 | 249 80079020          | 84 000000000     | 668 000000000    | 50 99037278          | 9900 00000000  | 62400 434783  |
| FMAX     | 24 | 724 000000000 | 47 66550115           | 624 000000000    | 788 000000000    | 9 12967968           | 17376 00000000 | 2272 00000000 |
| STATE    | 24 | 1 000000000   | 0 000000000           | 1 000000000      | 1 000000000      | 0 000000000          | 24 00000000    | 0 00000000    |
| ID 6     |    |               |                       |                  |                  |                      |                |               |
| MPF      | 40 | 391 475000000 | 119 60227197          | 154 100000000    | 625 300000000    | 18 91077964          | 15659 00000000 | 14304 70346   |
| FPK      | 40 | 138 100000000 | 47 58625098           | 60 000000000     | 292 000000000    | 7 52404692           | 5536 00000000  | 2264 45128    |
| FMAX     | 40 | 856 300000000 | 487 98351170          | 172 000000000    | 1452 000000000   | 77 15696788          | 34252 00000000 | 238127 90769  |
| STATE    | 40 | 0 000000000   | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 00000000     | 0 00000000    |

| VARIABLE | DI | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | %ID ERROR<br>OF MEAN | %ID<br>OF     | VARIABLE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|---------------|--------------|
| ID - Q   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 36 | 213 10555556 | 86 25402001           | 95 200000000     | 417 000000000    | 14 37567000          | 7671 800000   | 7439 755968  |
| FPK      | 36 | 161 33333333 | 179 20969362          | 60 000000000     | 600 000000000    | 29 86828227          | 5808 000000   | 32116 114286 |
| FMAX     | 36 | 551 44444444 | 152 56182718          | 104 000000000    | 628 000000000    | 25 42697120          | 19552 000000  | 23275 111111 |
| STATE    | 36 | 0 000000000  | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 000000      | 0 000000     |
| ID - I   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 36 | 281 48611111 | 102 53018274          | 94 600000000     | 414 600000000    | 17 08836379          | 10133 500000  | 10512 438373 |
| FPK      | 36 | 316 88888889 | 246 91395584          | 76 000000000     | 592 000000000    | 41 15232597          | 11408 000000  | 60966 501587 |
| FMAX     | 36 | 541 11111111 | 152 20020232          | 112 000000000    | 616 000000000    | 25 36670039          | 19480 000000  | 23164 901587 |
| STATE    | 36 | 0 000000000  | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 000000      | 0 000000     |
| ID - U   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 23 | 145 09130435 | 44 57346248           | 96 900000000     | 262 000000000    | 9 29420941           | 3337 10000000 | 1986 793557  |
| FPK      | 23 | 95 30434783  | 20 31218797           | 68 000000000     | 172 000000000    | 4 23538397           | 2192 00000000 | 412 584580   |
| FMAX     | 23 | 217 56521739 | 117 78401886          | 100 000000000    | 560 000000000    | 24 55466568          | 5004 00000000 | 13873 075099 |
| STATE    | 23 | 0 000000000  | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 00000000    | 0 000000     |
| ID - V   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 24 | 280 37083333 | 92 52394510           | 132 200000000    | 434 600000000    | 18 88637121          | 6728 900000   | 8560 680417  |
| FPK      | 24 | 300 33333333 | 254 45434658          | 88 000000000     | 628 000000000    | 51 94027600          | 7208 000000   | 64747 014493 |
| FMAX     | 24 | 437 66666667 | 214 76917167          | 144 000000000    | 740 000000000    | 43 83957359          | 11944 000000  | 46125 797101 |
| STATE    | 24 | 1 000000000  | 0 000000000           | 1 000000000      | 1 000000000      | 0 000000000          | 24 000000     | 0 000000     |
| ID - W   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 22 | 303 75454545 | 78 07004625           | 148 900000000    | 475 700000000    | 16 64458979          | 6682 600000   | 6094 93212   |
| FPK      | 22 | 137 81818182 | 48 78293648           | 84 000000000     | 260 000000000    | 10 40055700          | 3032 000000   | 2379 77489   |
| FMAX     | 22 | 485 63636364 | 332 14720567          | 192 000000000    | 1404 000000000   | 70 81402218          | 10684 000000  | 110321 76623 |
| STATE    | 22 | 1 000000000  | 0 000000000           | 1 000000000      | 1 000000000      | 0 000000000          | 22 000000     | 0 000000     |
| ID - X   |    |              |                       |                  |                  |                      |               |              |
| MPF      | 20 | 247 37500000 | 54 14529065           | 141 000000000    | 356 500000000    | 12 10725506          | 4947 500000   | 2931 712500  |
| FPK      | 20 | 118 20000000 | 32 45661071           | 80 000000000     | 196 000000000    | 7 25751879           | 2364 000000   | 1053 431579  |
| FMAX     | 20 | 474 80000000 | 209 32412540          | 120 000000000    | 772 000000000    | 46 80629737          | 9496 000000   | 43816 589474 |
| STATE    | 20 | 0 000000000  | 0 000000000           | 0 000000000      | 0 000000000      | 0 000000000          | 0 000000      | 0 000000     |

Expiration Direct Data Set: Mean

Test Set

7 Abnormals (STATE=0)

M  
C  
D  
G  
S  
B  
E

5 Normals (STATE=1)

K  
L  
F  
Y  
N

## Expiration Direct Data Set: Mean

## Test Set

[illegible]

AD-A184 344

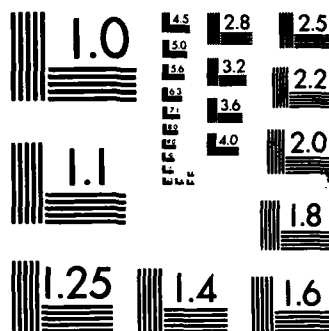
DISCRIMINANT ANALYSIS OF RESPIRATORY SOUNDS OF  
PULMONARY INSUFFICIENT PAT (U) TEXAS A AND M UNIV  
COLLEGE STATION BIOENGINEERING PROGRAM  
C S LESSARD ET AL APR 87 USAFSAM-TR-86-33 F/G 6/

212

UNCLASSIFIED

F/G 6/4

NL



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=K     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 20 | 361.54000000 | 32.56522847           | 288.90000000     | 412.00000000     | 7.28180646           | 7230.800000  | 1060.494105  |
| FPK      | 20 | 401.00000000 | 196.13904842          | 148.00000000     | 596.00000000     | 43.85802453          | 8020.000000  | 38470.526316 |
| FMAX     | 20 | 605.20000000 | 6.63007502            | 592.00000000     | 616.00000000     | 1.48252984           | 12104.000000 | 43.957895    |
| STATE    | 20 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 20.000000    | 0.000000     |
| ID=L     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 20 | 406.78000000 | 23.51500305           | 350.10000000     | 440.60000000     | 5.25811453           | 8135.600000  | 552.9553684  |
| FPK      | 20 | 473.20000000 | 78.50283267           | 152.00000000     | 532.00000000     | 17.55376703          | 9464.000000  | 6162.6947368 |
| FMAX     | 20 | 598.80000000 | 17.41625584           | 560.00000000     | 624.00000000     | 3.89439543           | 11976.000000 | 303.3263158  |
| STATE    | 20 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 20.000000    | 0.000000     |
| ID=M     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 28 | 226.03928571 | 54.01982036           | 117.90000000     | 351.60000000     | 10.20878647          | 6329.100000  | 2918.140992  |
| FPK      | 28 | 122.14285714 | 114.32238830          | 68.00000000      | 576.00000000     | 21.60490062          | 3420.000000  | 13069.608466 |
| FMAX     | 28 | 525.71428571 | 167.30518956          | 116.00000000     | 616.00000000     | 31.61770890          | 14720.000000 | 27991.026455 |
| STATE    | 28 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.000000     |
| ID=N     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 28 | 350.66071429 | 42.73994003           | 258.50000000     | 498.20000000     | 8.07708945           | 9818.500000  | 1826.702474  |
| FPK      | 28 | 336.14285714 | 176.43878684          | 112.00000000     | 608.00000000     | 33.34379654          | 9412.000000  | 31130.645503 |
| FMAX     | 28 | 616.57142857 | 30.74799430           | 564.00000000     | 736.00000000     | 5.81082473           | 17264.000000 | 945.439153   |
| STATE    | 28 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 28.000000    | 0.000000     |
| ID=S     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 27 | 366.53703704 | 142.68821888          | 129.60000000     | 695.60000000     | 27.46036053          | 9896.500000  | 20359.92781  |
| FPK      | 27 | 142.96296296 | 130.02528792          | 56.00000000      | 600.00000000     | 25.02337833          | 3860.000000  | 16906.57550  |
| FMAX     | 27 | 651.55555556 | 423.29452679          | 168.00000000     | 1428.00000000    | 81.46306966          | 17592.000000 | 179178.25641 |
| STATE    | 27 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.000000     |
| ID=Y     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 33 | 253.61515152 | 127.52452980          | 107.60000000     | 523.50000000     | 22.19917122          | 8369.300000  | 16262.505701 |
| FPK      | 33 | 109.09090909 | 34.63051728           | 76.00000000      | 252.00000000     | 6.02839927           | 3600.000000  | 1199.272727  |
| FMAX     | 33 | 371.87878788 | 310.57122347          | 140.00000000     | 1364.00000000    | 54.06351059          | 12272.000000 | 96454.484848 |
| STATE    | 33 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 33.000000    | 0.000000     |

APPENDIX D

INSPIRATION DIRECT DATA SET: MEAN.

Calibration or Training Set

7 Abnormals (STATE=0)

P

Q

T

U

X

+

#

5 Normals (STATE=1)

H

I

V

W

\*

# INSPIRATION DIRECT DATA SET: MEAN.

## Calibration or Training Set

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=*     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 20 | 139.52000000  | 25.94333096           | 98.80000000      | 196.30000000     | 5.80110516           | 2790.400000  | 673.05642105 |
| FPK      | 20 | 98.00000000   | 13.26649916           | 68.00000000      | 120.00000000     | 2.96647939           | 1960.000000  | 176.00000000 |
| FMAX     | 20 | 156.00000000  | 21.71586856           | 108.00000000     | 204.00000000     | 4.85581583           | 3120.000000  | 471.57894737 |
| STATE    | 20 | 0.00000000    | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.00000000   |
| ID=*     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 39 | 366.87179487  | 34.45553159           | 278.50000000     | 429.30000000     | 5.51730066           | 14308.000000 | 1187.18366   |
| FPK      | 39 | 117.74615385  | 18.46212120           | 92.00000000      | 172.00000000     | 2.95630538           | 4592.100000  | 340.84992    |
| FMAX     | 39 | 594.38461538  | 446.01773716          | 172.00000000     | 1296.00000000    | 71.41999582          | 23064.000000 | 198931.82186 |
| STATE    | 39 | 1.00000000    | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 39.000000    | 0.00000      |
| ID=#     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 21 | 300.14761905  | 87.00586543           | 140.70000000     | 449.50000000     | 18.98623639          | 6303.100000  | 7570.02062   |
| FPK      | 21 | 115.61904762  | 21.46270298           | 80.00000000      | 152.00000000     | 4.68354576           | 2428.000000  | 460.64762    |
| FMAX     | 21 | 636.76190476  | 409.52385825          | 152.00000000     | 1340.00000000    | 89.36543235          | 13372.000000 | 167709.79048 |
| STATE    | 21 | 0.00000000    | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.00000      |
| ID=H     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 18 | 619.09444444  | 51.94969821           | 513.10000000     | 689.20000000     | 12.24466129          | 11143.700000 | 2698.771144  |
| FPK      | 18 | 225.77777778  | 40.58912569           | 172.00000000     | 260.00000000     | 9.56694867           | 4064.000000  | 1647.477124  |
| FMAX     | 18 | 1322.22222222 | 273.43298040          | 260.00000000     | 1472.00000000    | 64.44877155          | 23800.000000 | 74765.594771 |
| STATE    | 18 | 1.00000000    | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 18.000000    | 0.000000     |
| ID=I     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 29 | 542.03793103  | 111.10369807          | 368.30000000     | 828.80000000     | 20.63143879          | 15719.100000 | 12344.03172  |
| FPK      | 29 | 500.68965517  | 239.33734462          | 152.00000000     | 1364.00000000    | 44.44382915          | 14520.000000 | 57282.36453  |
| FMAX     | 29 | 998.89655172  | 319.32589095          | 632.00000000     | 1484.00000000    | 59.29732931          | 28968.000000 | 101969.02463 |
| STATE    | 29 | 1.00000000    | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 29.000000    | 0.00000      |
| ID=P     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 25 | 455.16800000  | 158.40528116          | 255.50000000     | 822.60000000     | 31.68105623          | 11379.200000 | 25092.23310  |
| FPK      | 25 | 199.36000000  | 234.67901483          | 84.00000000      | 1316.00000000    | 46.93580297          | 4984.000000  | 55074.24000  |
| FMAX     | 25 | 964.96000000  | 511.66822584          | 240.00000000     | 1484.00000000    | 102.33364517         | 24124.000000 | 261804.37333 |
| STATE    | 25 | 0.00000000    | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.00000      |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM           | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|---------------|--------------|
| ID=Q     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 37 | 205.61081081 | 89.43860335           | 94.50000000      | 453.00000000     | 14.70361582          | 7607.600000   | 7999.263769  |
| FPK      | 37 | 141.18918919 | 164.04027924          | 56.00000000      | 608.00000000     | 26.96805578          | 5224.000000   | 26909.213213 |
| FMAX     | 37 | 536.21621622 | 182.55457862          | 108.00000000     | 680.00000000     | 30.01178785          | 19840.000000  | 33326.174174 |
| STATE    | 37 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000      | 0.000000     |
| ID=T     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 31 | 259.19032258 | 106.68721371          | 98.70000000      | 419.70000000     | 19.16158924          | 8034.900000   | 11382.161570 |
| FPK      | 31 | 197.41935484 | 180.14378964          | 76.00000000      | 592.00000000     | 32.35477975          | 6120.000000   | 32451.784946 |
| FMAX     | 31 | 603.87096774 | 293.31663687          | 124.00000000     | 1224.00000000    | 52.68122315          | 18720.000000  | 86034.649462 |
| STATE    | 31 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000      | 0.000000     |
| ID=U     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 22 | 154.65454545 | 62.88946257           | 93.80000000      | 350.30000000     | 13.40807847          | 3402.40000000 | 3955.084502  |
| FPK      | 22 | 89.45454545  | 13.72077768           | 52.00000000      | 108.00000000     | 2.92527963           | 1968.00000000 | 188.259740   |
| FMAX     | 22 | 277.63636364 | 277.33880697          | 104.00000000     | 1352.00000000    | 59.12883232          | 6108.00000000 | 76916.813853 |
| STATE    | 22 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.00000000    | 0.000000     |
| ID=V     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 27 | 303.12962963 | 103.89385417          | 157.10000000     | 494.90000000     | 19.99438156          | 8184.500000   | 10793.932934 |
| FPK      | 27 | 262.37037037 | 240.07244870          | 76.00000000      | 644.00000000     | 46.20196429          | 7084.000000   | 57634.780527 |
| FMAX     | 27 | 532.88888889 | 199.77012430          | 156.00000000     | 692.00000000     | 38.44577835          | 14388.000000  | 39908.102564 |
| STATE    | 27 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 27.000000     | 0.000000     |
| ID=W     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 21 | 280.01904762 | 88.57784497           | 134.90000000     | 453.40000000     | 19.32927045          | 5880.40000000 | 7846.034619  |
| FPK      | 21 | 125.71428571 | 36.80372652           | 76.00000000      | 260.00000000     | 8.03123155           | 2640.000000   | 1354.514286  |
| FMAX     | 21 | 423.80952381 | 145.70916891          | 172.00000000     | 660.00000000     | 31.79634743          | 8900.00000000 | 21231.161905 |
| STATE    | 21 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 21.000000     | 0.000000     |
| ID=X     |    |              |                       |                  |                  |                      |               |              |
| MPF      | 25 | 188.77600000 | 63.49351200           | 105.50000000     | 365.80000000     | 12.69870240          | 4719.40000000 | 4031.426067  |
| FPK      | 25 | 105.92000000 | 19.93723485           | 61.00000000      | 164.00000000     | 3.98744697           | 2648.00000000 | 397.493333   |
| FMAX     | 25 | 250.72000000 | 125.70717296          | 136.00000000     | 568.00000000     | 25.14143459          | 6268.00000000 | 15802.293333 |
| STATE    | 25 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.00000000    | 0.000000     |

Inspiration Direct Data Set: Mean

Test Set

7 Abnormals (STATE=0)

M  
C  
D  
G  
S  
B  
E

5 Normals (STATE=1)

K  
L  
F  
Y  
N

# Inspiration Direct Data Set: Mean

## Test Set

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=B     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 17 | 895.76470588  | 103.93119684          | 704.2000000      | 1129.0000000     | 25.20701779          | 15228.000000 | 10801.69368  |
| FPK      | 17 | 740.94117647  | 614.01714864          | 112.0000000      | 1492.0000000     | 148.92103293         | 12596.000000 | 377017.05882 |
| FMAX     | 17 | 1489.41176471 | 10.57744548           | 1464.0000000     | 1496.0000000     | 2.56540735           | 25320.000000 | 111.88235    |
| STATE    | 17 | 0.00000000    | 0.00000000            | 0.0000000        | 0.0000000        | 0.00000000           | 0.000000     | 0.00000      |
| ID=C     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 13 | 414.80000000  | 35.87680309           | 329.3000000      | 455.4000000      | 9.95043486           | 5392.400000  | 1287.145000  |
| FPK      | 13 | 488.61538462  | 185.03942754          | 104.0000000      | 696.0000000      | 51.32070338          | 6352.000000  | 34239.589744 |
| FMAX     | 13 | 673.53846154  | 64.92125408           | 588.0000000      | 788.0000000      | 18.00591619          | 8756.000000  | 4214.769231  |
| STATE    | 13 | 0.00000000    | 0.00000000            | 0.0000000        | 0.0000000        | 0.00000000           | 0.000000     | 0.00000      |
| ID=D     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 19 | 444.64210526  | 130.23281851          | 223.6000000      | 672.0000000      | 29.87745763          | 8448.200000  | 16960.58702  |
| FPK      | 19 | 231.78947368  | 232.74773634          | 100.0000000      | 740.0000000      | 53.39599274          | 4404.000000  | 54171.50877  |
| FMAX     | 19 | 928.00000000  | 481.16525228          | 180.0000000      | 1488.0000000     | 110.38687946         | 17632.000000 | 231520.00000 |
| STATE    | 19 | 0.00000000    | 0.00000000            | 0.0000000        | 0.0000000        | 0.00000000           | 0.000000     | 0.00000      |
| ID=E     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 19 | 374.44210526  | 35.47777576           | 302.5000000      | 430.0000000      | 8.13915996           | 7114.400000  | 1258.672573  |
| FPK      | 19 | 250.31578947  | 185.74207105          | 100.0000000      | 616.0000000      | 42.61215354          | 4756.000000  | 34500.116959 |
| FMAX     | 19 | 682.52631579  | 49.78550483           | 600.0000000      | 748.0000000      | 11.42157813          | 12968.000000 | 2478.596491  |
| STATE    | 19 | 0.00000000    | 0.00000000            | 0.0000000        | 0.0000000        | 0.00000000           | 0.000000     | 0.00000      |
| ID=F     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 28 | 317.27857143  | 100.21188426          | 172.6000000      | 624.7000000      | 18.93826601          | 8883.800000  | 10042.421746 |
| FPK      | 28 | 174.57142857  | 241.48482485          | 100.0000000      | 1028.0000000     | 45.63634228          | 4888.000000  | 58314.920635 |
| FMAX     | 28 | 594.71428571  | 276.14500447          | 172.0000000      | 1228.0000000     | 52.18650054          | 16652.000000 | 76256.063492 |
| STATE    | 28 | 1.00000000    | 0.00000000            | 1.0000000        | 1.0000000        | 0.00000000           | 28.000000    | 0.00000      |
| ID=G     |    |               |                       |                  |                  |                      |              |              |
| MPF      | 17 | 426.62352941  | 50.04241363           | 343.7000000      | 513.2000000      | 12.13706807          | 7252.600000  | 2504.243162  |
| FPK      | 17 | 269.64705882  | 195.38709693          | 100.0000000      | 708.0000000      | 47.38833168          | 4584.000000  | 38176.117647 |
| FMAX     | 17 | 798.58823529  | 110.03582304          | 712.0000000      | 1024.0000000     | 26.68760712          | 13576.000000 | 12107.882353 |
| STATE    | 17 | 0.00000000    | 0.00000000            | 0.0000000        | 0.0000000        | 0.00000000           | 0.000000     | 0.00000      |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=K     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 22 | 358.01363636 | 63.28513927           | 220.20000000     | 445.60000000     | 13.49243703          | 7876.300000  | 4005.008853  |
| FPK      | 22 | 371.81818182 | 166.13237303          | 88.00000000      | 532.00000000     | 35.41954094          | 8180.000000  | 27599.965368 |
| FMAX     | 22 | 598.00000000 | 9.62140471            | 580.00000000     | 612.00000000     | 2.05129038           | 13156.000000 | 92.571429    |
| STATE    | 22 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 22.000000    | 0.000000     |
| ID=L     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 20 | 384.79500000 | 38.62565925           | 302.50000000     | 435.80000000     | 8.63695998           | 7695.900000  | 1491.9415526 |
| FPK      | 20 | 488.00000000 | 17.45972810           | 460.00000000     | 520.00000000     | 3.90411389           | 9760.000000  | 304.8421053  |
| FMAX     | 20 | 587.00000000 | 33.36244343           | 536.00000000     | 644.00000000     | 7.46006914           | 11740.000000 | 1113.0526316 |
| STATE    | 20 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 20.000000    | 0.000000     |
| ID=M     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 24 | 271.51250000 | 68.68549820           | 154.80000000     | 396.30000000     | 14.02036861          | 6516.300000  | 4717.697663  |
| FPK      | 24 | 227.66666667 | 210.93882622          | 72.00000000      | 588.00000000     | 43.05770760          | 5464.000000  | 4495.188406  |
| FMAX     | 24 | 549.33333333 | 129.26368960          | 140.00000000     | 624.00000000     | 26.38584015          | 13184.000000 | 16709.101449 |
| STATE    | 24 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.000000     |
| ID=N     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 25 | 384.89600000 | 38.76268051           | 256.40000000     | 435.60000000     | 7.75253610           | 9622.400000  | 1502.545400  |
| FPK      | 25 | 440.48000000 | 154.66660920          | 100.00000000     | 616.00000000     | 30.93332184          | 11012.000000 | 23921.760000 |
| FMAX     | 25 | 635.68000000 | 23.69022302           | 588.00000000     | 688.00000000     | 4.73804460           | 15892.000000 | 561.226667   |
| STATE    | 25 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 25.000000    | 0.000000     |
| ID=S     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 19 | 414.11052632 | 176.26240821          | 183.60000000     | 785.30000000     | 40.43736973          | 7868.100000  | 31068.43655  |
| FPK      | 19 | 175.15789474 | 186.16398481          | 76.00000000      | 928.00000000     | 42.70894720          | 3328.000000  | 34657.02924  |
| FMAX     | 19 | 692.84210526 | 462.27376006          | 144.00000000     | 1436.00000000    | 106.05287391         | 13164.000000 | 213697.02924 |
| STATE    | 19 | 0.00000000   | 0.00000000            | 0.00000000       | 0.00000000       | 0.00000000           | 0.000000     | 0.000000     |
| ID=Y     |    |              |                       |                  |                  |                      |              |              |
| MPF      | 23 | 214.54347826 | 112.65157396          | 114.10000000     | 481.20000000     | 23.48947694          | 4934.500000  | 12690.377115 |
| FPK      | 23 | 102.08695652 | 12.92605910           | 80.00000000      | 124.00000000     | 2.69526964           | 2348.000000  | 167.083004   |
| FMAX     | 23 | 252.34782609 | 224.36630129          | 124.00000000     | 1224.00000000    | 46.78360785          | 5804.000000  | 50340.237154 |
| STATE    | 23 | 1.00000000   | 0.00000000            | 1.00000000       | 1.00000000       | 0.00000000           | 23.000000    | 0.000000     |

## APPENDIX E

### PFT DIRECT DATA SET.

#### Calibration or Training Set

7 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+  
#

5 Normals (STATE=1)

H  
I  
V  
W  
\*

PFT DIRECT DATA SET.

Calibration or Training Set

| ID | FVC | FEV1 | FEV1P | STATE |
|----|-----|------|-------|-------|
| +  | 72  | 58   | 124   | 0     |
| *  | 99  | 105  | 105   | 1     |
| #  | 70  | 74   | 106   | 0     |
| H  | 114 | 110  | 96    | 1     |
| I  | 112 | 118  | 105   | 1     |
| P  | 73  | 32   | 44    | 0     |
| Q  | 102 | 83   | 81    | 0     |
| T  | 83  | 76   | 91    | 0     |
| U  | 73  | 66   | 90    | 0     |
| V  | 101 | 106  | 104   | 1     |
| W  | 107 | 114  | 106   | 1     |
| X  | 93  | 78   | 85    | 0     |

PFT Direct Data Set.

Test Set

7 Abnormals (STATE=0)

M  
C  
D  
G  
S  
B  
E

5 Normals (STATE=1)

K  
L  
F  
Y  
N

PFT Direct Data Set.

Test Set

| ID | FVC | FEV1 | FEV1P | STATE |
|----|-----|------|-------|-------|
| B  | 82  | 70   | 85    | 0     |
| C  | 77  | 78   | 99    | 0     |
| D  | 102 | 100  | 97    | 0     |
| E  | 90  | 72   | 81    | 0     |
| F  | 146 | 141  | 97    | 1     |
| G  | 78  | 91   | 118   | 0     |
| K  | 102 | 105  | 104   | 1     |
| L  | 110 | 102  | 92    | 1     |
| M  | 53  | 38   | 68    | 0     |
| N  | 91  | 97   | 107   | 1     |
| S  | 92  | 95   | 103   | 0     |
| Y  | 101 | 113  | 113   | 1     |

APPENDIX F

EXPIRATION REGRESSION ANALYSIS DATA

14 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+

M  
C  
D  
G  
S  
B  
E

10 Normals (STATE=1)

H  
I  
V  
W  
\*  
K  
L  
F  
Y  
N

# EXPIRATION REGRESSION ANALYSIS DATA.

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM            | VARIANCE     |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|----------------|--------------|
| ID=+     |    |               |                       |                  |                  |                      |                |              |
| FVC      | 33 | 72.00000000   | 0.00000000            | 72.00000000      | 72.00000000      | 0.00000000           | 2376.00000000  | 0.00000000   |
| FEV1     | 33 | 58.00000000   | 0.00000000            | 58.00000000      | 58.00000000      | 0.00000000           | 1914.00000000  | 0.00000000   |
| FEV1P    | 33 | 124.00000000  | 0.00000000            | 124.00000000     | 124.00000000     | 0.00000000           | 4092.00000000  | 0.00000000   |
| MPF      | 33 | 132.29090909  | 32.27902147           | 90.40000000      | 241.70000000     | 5.61905639           | 4365.60000000  | 1041.9352273 |
| FPK      | 33 | 93.57575758   | 13.67257817           | 64.00000000      | 120.00000000     | 2.38009036           | 3088.00000000  | 186.9393939  |
| FMAX     | 33 | 149.57575758  | 22.44859448           | 112.00000000     | 192.00000000     | 3.90779871           | 4936.00000000  | 503.9393939  |
| ID=+     |    |               |                       |                  |                  |                      |                |              |
| FVC      | 30 | 99.00000000   | 0.00000000            | 99.00000000      | 99.00000000      | 0.00000000           | 2970.00000000  | 0.00000000   |
| FEV1     | 30 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 3150.00000000  | 0.00000000   |
| FEV1P    | 30 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 3150.00000000  | 0.00000000   |
| MPF      | 30 | 484.89666667  | 71.43159971           | 342.40000000     | 603.60000000     | 13.04156616          | 14546.90000000 | 5102.47344   |
| FPK      | 30 | 128.80000000  | 41.46822631           | 108.00000000     | 260.00000000     | 7.57102766           | 3864.00000000  | 1719.61379   |
| FMAX     | 30 | 717.33333333  | 523.11779733          | 124.00000000     | 1476.00000000    | 95.50780594          | 21520.00000000 | 273652.22989 |
| ID=#     |    |               |                       |                  |                  |                      |                |              |
| FVC      | 36 | 70.00000000   | 0.00000000            | 70.00000000      | 70.00000000      | 0.00000000           | 2520.00000000  | 0.00000000   |
| FEV1     | 36 | 74.00000000   | 0.00000000            | 74.00000000      | 74.00000000      | 0.00000000           | 2664.00000000  | 0.00000000   |
| FEV1P    | 36 | 106.00000000  | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 3816.00000000  | 0.00000000   |
| MPF      | 36 | 347.47777778  | 98.56043284           | 127.60000000     | 497.30000000     | 16.42673881          | 12509.20000000 | 9714.15892   |
| FPK      | 36 | 150.22222222  | 122.48641000          | 72.00000000      | 576.00000000     | 20.41440167          | 5408.00000000  | 15002.92063  |
| FMAX     | 36 | 652.11111111  | 326.07587003          | 152.00000000     | 1372.00000000    | 54.34597834          | 23476.00000000 | 106325.47302 |
| ID=B     |    |               |                       |                  |                  |                      |                |              |
| FVC      | 25 | 82.00000000   | 0.00000000            | 82.00000000      | 82.00000000      | 0.00000000           | 2050.00000000  | 0.00000000   |
| FEV1     | 25 | 70.00000000   | 0.00000000            | 70.00000000      | 70.00000000      | 0.00000000           | 1750.00000000  | 0.00000000   |
| FEV1P    | 25 | 85.00000000   | 0.00000000            | 85.00000000      | 85.00000000      | 0.00000000           | 2125.00000000  | 0.00000000   |
| MPF      | 25 | 629.44400000  | 133.61529067          | 278.90000000     | 799.80000000     | 26.72305813          | 15736.10000000 | 17853.04590  |
| FPK      | 25 | 286.40000000  | 229.82602116          | 108.00000000     | 956.00000000     | 45.96520423          | 7160.00000000  | 52820.00000  |
| FMAX     | 25 | 1216.48000000 | 321.87848639          | 604.00000000     | 1488.00000000    | 64.37569728          | 30412.00000000 | 103605.76000 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=C     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 22 | 77.00000000  | 0.00000000            | 77.00000000      | 77.00000000      | 0.00000000           | 1694.000000  | 0.000000     |
| FEV1     | 22 | 78.00000000  | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1716.000000  | 0.000000     |
| FEV1P    | 22 | 99.00000000  | 0.00000000            | 99.00000000      | 99.00000000      | 0.00000000           | 2178.000000  | 0.000000     |
| MPF      | 22 | 408.67727273 | 69.62449577           | 217.60000000     | 476.90000000     | 14.84399237          | 8990.900000  | 4847.570411  |
| FPK      | 22 | 472.00000000 | 171.12290209          | 76.00000000      | 608.00000000     | 36.48352531          | 10384.000000 | 29283.047619 |
| FMAX     | 22 | 620.72727273 | 18.00048099           | 584.00000000     | 684.00000000     | 3.83771544           | 13656.000000 | 324.017316   |
| ID=D     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 16 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 1632.000000  | 0.000000     |
| FEV1     | 16 | 100.00000000 | 0.00000000            | 100.00000000     | 100.00000000     | 0.00000000           | 1600.000000  | 0.000000     |
| FEV1P    | 16 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 1552.000000  | 0.000000     |
| MPF      | 16 | 353.86250000 | 82.81757362           | 236.20000000     | 495.60000000     | 20.70439340          | 5661.800000  | 6858.75050   |
| FPK      | 16 | 217.75000000 | 53.42596123           | 100.00000000     | 212.00000000     | 13.35649031          | 3484.000000  | 2854.33333   |
| FMAX     | 16 | 855.75000000 | 354.62496622          | 392.00000000     | 1360.000000      | 88.65624156          | 13692.000000 | 125758.86667 |
| ID=E     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 26 | 90.00000000  | 0.00000000            | 90.00000000      | 90.00000000      | 0.00000000           | 2340.000000  | 0.000000     |
| FEV1     | 26 | 72.00000000  | 0.00000000            | 72.00000000      | 72.00000000      | 0.00000000           | 1872.000000  | 0.000000     |
| FEV1P    | 26 | 81.00000000  | 0.00000000            | 81.00000000      | 81.00000000      | 0.00000000           | 2106.000000  | 0.000000     |
| MPF      | 26 | 271.19615385 | 97.50866825           | 129.50000000     | 558.70000000     | 19.12302316          | 7051.100000  | 9507.940385  |
| FPK      | 26 | 195.84615385 | 174.22185679          | 68.00000000      | 676.00000000     | 34.16771721          | 5092.000000  | 30353.255385 |
| FMAX     | 26 | 510.30769231 | 200.68418358          | 128.00000000     | 724.00000000     | 39.35740647          | 13268.000000 | 40274.141538 |
| ID=F     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 30 | 146.00000000 | 0.00000000            | 146.00000000     | 146.00000000     | 0.00000000           | 4380.000000  | 0.000000     |
| FEV1     | 30 | 141.00000000 | 0.00000000            | 141.00000000     | 141.00000000     | 0.00000000           | 4230.000000  | 0.000000     |
| FEV1P    | 30 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 2910.000000  | 0.000000     |
| MPF      | 30 | 185.28666667 | 29.73376965           | 129.40000000     | 246.10000000     | 5.42861879           | 5558.600000  | 884.097057   |
| FPK      | 30 | 121.33333333 | 30.14142908           | 80.00000000      | 176.00000000     | 5.50304687           | 3640.000000  | 908.505747   |
| FMAX     | 30 | 360.93333333 | 178.93688607          | 148.00000000     | 632.00000000     | 32.66925629          | 10828.000000 | 32018.409195 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=G     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 21 | 91.00000000  | 0.00000000            | 91.00000000      | 91.00000000      | 0.00000000           | 1911.000000  | 0.000000     |
| FEV1     | 21 | 78.00000000  | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1638.000000  | 0.000000     |
| FEV1P    | 21 | 118.00000000 | 0.00000000            | 118.00000000     | 118.00000000     | 0.00000000           | 2478.000000  | 0.000000     |
| MPF      | 21 | 291.13333333 | 77.16794239           | 117.70000000     | 405.20000000     | 16.83942558          | 6113.800000  | 5954.891333  |
| FPK      | 21 | 163.61904762 | 44.71965585           | 80.00000000      | 224.00000000     | 9.75862895           | 3436.000000  | 1999.847619  |
| FMAX     | 21 | 595.23809524 | 232.48782866          | 124.00000000     | 788.00000000     | 50.73300348          | 12500.000000 | 54050.590476 |
| ID=H     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 24 | 114.00000000 | 0.00000000            | 114.00000000     | 114.00000000     | 0.00000000           | 2736.000000  | 0.000000     |
| FEV1     | 24 | 110.00000000 | 0.00000000            | 110.00000000     | 110.00000000     | 0.00000000           | 2640.000000  | 0.000000     |
| FEV1P    | 24 | 96.00000000  | 0.00000000            | 96.00000000      | 96.00000000      | 0.00000000           | 2304.000000  | 0.000000     |
| MPF      | 24 | 406.25416667 | 60.48871960           | 246.80000000     | 482.00000000     | 12.34720819          | 9750.100000  | 3658.88520   |
| FPK      | 24 | 148.50000000 | 45.88549074           | 92.00000000      | 260.00000000     | 9.36633658           | 3564.000000  | 2105.47826   |
| FMAX     | 24 | 432.00000000 | 370.00963560          | 256.00000000     | 1400.00000000    | 75.52790059          | 10368.000000 | 136907.13043 |
| ID=I     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 24 | 112.00000000 | 0.00000000            | 112.00000000     | 112.00000000     | 0.00000000           | 2688.000000  | 0.000000     |
| FEV1     | 24 | 118.00000000 | 0.00000000            | 118.00000000     | 118.00000000     | 0.00000000           | 2832.000000  | 0.000000     |
| FEV1P    | 24 | 105.00000000 | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 2520.000000  | 0.000000     |
| MPF      | 24 | 420.32916667 | 51.46431840           | 298.30000000     | 514.60000000     | 10.50511000          | 10087.900000 | 2648.576069  |
| FPK      | 24 | 412.50000000 | 249.80079020          | 84.00000000      | 668.00000000     | 50.99037278          | 9900.000000  | 62400.434783 |
| FMAX     | 24 | 724.00000000 | 47.66550115           | 624.00000000     | 788.00000000     | 9.72567968           | 17376.000000 | 2272.000000  |
| ID=K     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 20 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 2040.000000  | 0.000000     |
| FEV1     | 20 | 105.00000000 | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 2100.000000  | 0.000000     |
| FEV1P    | 20 | 104.00000000 | 0.00000000            | 104.00000000     | 104.00000000     | 0.00000000           | 2080.000000  | 0.000000     |
| MPF      | 20 | 361.54000000 | 32.56522847           | 288.90000000     | 412.00000000     | 7.28180646           | 7230.800000  | 1060.494105  |
| FPK      | 20 | 401.00000000 | 196.13904842          | 148.00000000     | 596.00000000     | 43.85802453          | 8020.000000  | 38470.526316 |
| FMAX     | 20 | 605.20000000 | 6.63007502            | 592.00000000     | 616.00000000     | 1.48252984           | 12104.000000 | 43.957895    |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=L     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 20 | 110.00000000 | 0.00000000            | 110.00000000     | 110.00000000     | 0.00000000           | 2200.000000  | 0.00000000   |
| FEV1     | 20 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 2040.000000  | 0.00000000   |
| FEV1P    | 20 | 92.00000000  | 0.00000000            | 92.00000000      | 92.00000000      | 0.00000000           | 1840.000000  | 0.00000000   |
| MPF      | 20 | 406.78000000 | 23.51500305           | 350.10000000     | 440.60000000     | 5.25811453           | 8135.600000  | 552.9553684  |
| FPK      | 20 | 473.20000000 | 78.50283267           | 152.00000000     | 532.00000000     | 17.55376703          | 9464.000000  | 6162.6947368 |
| FMAX     | 20 | 598.80000000 | 17.41626584           | 560.00000000     | 624.00000000     | 3.89439543           | 11976.000000 | 303.3263158  |
| ID=M     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 28 | 53.00000000  | 0.00000000            | 53.00000000      | 53.00000000      | 0.00000000           | 1484.000000  | 0.00000000   |
| FEV1     | 28 | 38.00000000  | 0.00000000            | 38.00000000      | 38.00000000      | 0.00000000           | 1064.000000  | 0.00000000   |
| FEV1P    | 28 | 68.00000000  | 0.00000000            | 68.00000000      | 68.00000000      | 0.00000000           | 1904.000000  | 0.00000000   |
| MPF      | 28 | 226.03928571 | 54.01982036           | 117.90000000     | 351.60000000     | 10.20878647          | 6329.100000  | 2918.140992  |
| FPK      | 28 | 122.14285714 | 114.32238830          | 68.00000000      | 576.00000000     | 21.60490062          | 3420.000000  | 13069.608466 |
| FMAX     | 28 | 525.71428571 | 167.30518956          | 116.00000000     | 616.00000000     | 31.61770890          | 14720.000000 | 27991.026455 |
| ID=N     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 28 | 91.00000000  | 0.00000000            | 91.00000000      | 91.00000000      | 0.00000000           | 2548.000000  | 0.00000000   |
| FEV1     | 28 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 2716.000000  | 0.00000000   |
| FEV1P    | 28 | 107.00000000 | 0.00000000            | 107.00000000     | 107.00000000     | 0.00000000           | 2996.000000  | 0.00000000   |
| MPF      | 28 | 350.66071429 | 42.73994003           | 258.50000000     | 498.20000000     | 8.07708945           | 9818.500000  | 1826.702474  |
| FPK      | 28 | 336.14285714 | 176.43878684          | 112.00000000     | 608.00000000     | 33.34379654          | 9412.000000  | 31130.645503 |
| FMAX     | 28 | 616.57142857 | 30.74799430           | 564.00000000     | 736.00000000     | 5.81082473           | 17264.000000 | 945.439153   |
| ID=P     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 40 | 73.00000000  | 0.00000000            | 73.00000000      | 73.00000000      | 0.00000000           | 2920.000000  | 0.00000000   |
| FEV1     | 40 | 32.00000000  | 0.00000000            | 32.00000000      | 32.00000000      | 0.00000000           | 1280.000000  | 0.00000000   |
| FEV1P    | 40 | 44.00000000  | 0.00000000            | 44.00000000      | 44.00000000      | 0.00000000           | 1760.000000  | 0.00000000   |
| MPF      | 40 | 391.47500000 | 119.60227197          | 154.10000000     | 625.30000000     | 18.91077964          | 15659.000000 | 14304.70346  |
| FPK      | 40 | 138.40000000 | 47.58625098           | 60.00000000      | 292.00000000     | 7.52404692           | 5536.000000  | 2264.45128   |
| FMAX     | 40 | 856.30000000 | 487.98351170          | 172.00000000     | 1452.00000000    | 77.15696788          | 34252.000000 | 238127.90769 |

| VARIABLE | N | MEAN | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM | VARIANCE |
|----------|---|------|-----------------------|------------------|------------------|----------------------|-----|----------|
|----------|---|------|-----------------------|------------------|------------------|----------------------|-----|----------|

|       |    |              |              |              |              |             |              |              |
|-------|----|--------------|--------------|--------------|--------------|-------------|--------------|--------------|
| ID=Q  |    |              |              |              |              |             |              |              |
| FVC   | 36 | 102.00000000 | 0.00000000   | 102.00000000 | 102.00000000 | 0.00000000  | 3672.000000  | 0.000000     |
| FEV1  | 36 | 83.00000000  | 0.00000000   | 83.00000000  | 83.00000000  | 0.00000000  | 2988.000000  | 0.000000     |
| FEV1P | 36 | 81.00000000  | 0.00000000   | 81.00000000  | 81.00000000  | 0.00000000  | 2916.000000  | 0.000000     |
| MPF   | 36 | 213.10555556 | 86.25402001  | 95.20000000  | 417.00000000 | 14.37567000 | 7671.800000  | 7439.755968  |
| FPK   | 36 | 161.33333333 | 179.20969362 | 60.00000000  | 600.00000000 | 29.86828227 | 5808.000000  | 32116.114286 |
| FMAX  | 36 | 551.44444444 | 152.56182718 | 104.00000000 | 628.00000000 | 25.42697120 | 19852.000000 | 23275.111111 |

|       |    |              |              |              |               |             |              |              |
|-------|----|--------------|--------------|--------------|---------------|-------------|--------------|--------------|
| ID=S  |    |              |              |              |               |             |              |              |
| FVC   | 27 | 92.00000000  | 0.00000000   | 92.00000000  | 92.00000000   | 0.00000000  | 2484.000000  | 0.000000     |
| FEV1  | 27 | 95.00000000  | 0.00000000   | 95.00000000  | 95.00000000   | 0.00000000  | 2565.000000  | 0.000000     |
| FEV1P | 27 | 103.00000000 | 0.00000000   | 103.00000000 | 103.00000000  | 0.00000000  | 2781.000000  | 0.000000     |
| MPF   | 27 | 366.53703704 | 142.68821888 | 129.60000000 | 695.60000000  | 27.46036053 | 9896.500000  | 20359.92781  |
| FPK   | 27 | 142.96296296 | 130.02528792 | 56.00000000  | 600.00000000  | 25.02337833 | 3860.000000  | 16906.57550  |
| FMAX  | 27 | 651.55555556 | 423.29452679 | 168.00000000 | 1428.00000000 | 81.46306966 | 17592.000000 | 179178.25641 |

|       |    |              |              |              |              |             |              |              |
|-------|----|--------------|--------------|--------------|--------------|-------------|--------------|--------------|
| ID=T  |    |              |              |              |              |             |              |              |
| FVC   | 36 | 83.00000000  | 0.00000000   | 83.00000000  | 83.00000000  | 0.00000000  | 2988.000000  | 0.000000     |
| FEV1  | 36 | 76.00000000  | 0.00000000   | 76.00000000  | 76.00000000  | 0.00000000  | 2736.000000  | 0.000000     |
| FEV1P | 36 | 91.00000000  | 0.00000000   | 91.00000000  | 91.00000000  | 0.00000000  | 3276.000000  | 0.000000     |
| MPF   | 36 | 281.48611111 | 102.53018274 | 94.60000000  | 414.60000000 | 17.08836379 | 10133.500000 | 10512.438373 |
| FPK   | 36 | 316.88888889 | 246.91395584 | 76.00000000  | 592.00000000 | 41.15232597 | 11408.000000 | 60966.501587 |
| FMAX  | 36 | 541.11111111 | 152.20020232 | 112.00000000 | 616.00000000 | 25.36670039 | 19480.000000 | 23164.901587 |

|       |    |              |              |              |              |             |             |              |
|-------|----|--------------|--------------|--------------|--------------|-------------|-------------|--------------|
| ID=U  |    |              |              |              |              |             |             |              |
| FVC   | 23 | 73.00000000  | 0.00000000   | 73.00000000  | 73.00000000  | 0.00000000  | 1679.000000 | 0.000000     |
| FEV1  | 23 | 66.00000000  | 0.00000000   | 66.00000000  | 66.00000000  | 0.00000000  | 1518.000000 | 0.000000     |
| FEV1P | 23 | 90.00000000  | 0.00000000   | 90.00000000  | 90.00000000  | 0.00000000  | 2070.000000 | 0.000000     |
| MPF   | 23 | 145.09130435 | 44.57346248  | 96.90000000  | 262.00000000 | 9.29420941  | 3337.100000 | 1986.793557  |
| FPK   | 23 | 95.30434783  | 20.31218797  | 68.00000000  | 172.00000000 | 4.23538397  | 2192.000000 | 412.584980   |
| FMAX  | 23 | 217.56521739 | 117.78401886 | 100.00000000 | 560.00000000 | 24.55966568 | 5004.000000 | 13873.075099 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=V     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 24 | 101.00000000 | 0.00000000            | 101.00000000     | 101.00000000     | 0.00000000           | 2424.000000  | 0.000000     |
| FEV1     | 24 | 106.00000000 | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 2544.000000  | 0.000000     |
| FEVIP    | 24 | 104.00000000 | 0.00000000            | 104.00000000     | 104.00000000     | 0.00000000           | 2496.000000  | 0.000000     |
| MPF      | 24 | 280.37083333 | 92.52394510           | 132.20000000     | 434.60000000     | 18.88637121          | 6728.900000  | 8560.680417  |
| FPK      | 24 | 300.33333333 | 254.45434658          | 88.00000000      | 628.00000000     | 51.94027600          | 7208.000000  | 64747.014493 |
| FMAX     | 24 | 497.66666667 | 214.76917167          | 144.00000000     | 740.00000000     | 43.83957359          | 11944.000000 | 46125.797101 |
| ID=W     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 22 | 107.00000000 | 0.00000000            | 107.00000000     | 107.00000000     | 0.00000000           | 2354.000000  | 0.000000     |
| FEV1     | 22 | 114.00000000 | 0.00000000            | 114.00000000     | 114.00000000     | 0.00000000           | 2508.000000  | 0.000000     |
| FEVIP    | 22 | 106.00000000 | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 2332.000000  | 0.000000     |
| MPF      | 22 | 303.75454545 | 78.07004625           | 148.90000000     | 475.70000000     | 16.64458979          | 6682.600000  | 6094.93212   |
| FPK      | 22 | 137.81818182 | 48.78293648           | 84.00000000      | 260.00000000     | 10.40055700          | 3032.000000  | 2379.77489   |
| FMAX     | 22 | 485.63636364 | 332.14720567          | 192.00000000     | 1404.00000000    | 70.81402218          | 10684.000000 | 110321.76623 |
| ID=X     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 20 | 93.00000000  | 0.00000000            | 93.00000000      | 93.00000000      | 0.00000000           | 1860.000000  | 0.000000     |
| FEV1     | 20 | 78.00000000  | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1560.000000  | 0.000000     |
| FEVIP    | 20 | 85.00000000  | 0.00000000            | 85.00000000      | 85.00000000      | 0.00000000           | 1700.000000  | 0.000000     |
| MPF      | 20 | 247.37500000 | 54.14529065           | 141.00000000     | 356.50000000     | 12.10725506          | 4947.500000  | 2931.712500  |
| FPK      | 20 | 118.20000000 | 32.45661071           | 80.00000000      | 196.00000000     | 7.25751879           | 2364.000000  | 1053.431579  |
| FMAX     | 20 | 474.80000000 | 209.32412540          | 120.00000000     | 772.00000000     | 46.80629737          | 9496.000000  | 43816.589474 |
| ID=Y     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 33 | 101.00000000 | 0.00000000            | 101.00000000     | 101.00000000     | 0.00000000           | 3333.000000  | 0.000000     |
| FEV1     | 33 | 113.00000000 | 0.00000000            | 113.00000000     | 113.00000000     | 0.00000000           | 3729.000000  | 0.000000     |
| FEVIP    | 33 | 113.00000000 | 0.00000000            | 113.00000000     | 113.00000000     | 0.00000000           | 3729.000000  | 0.000000     |
| MPF      | 33 | 253.61515152 | 127.52452980          | 107.60000000     | 523.50000000     | 22.19917122          | 8369.300000  | 16262.505701 |
| FPK      | 33 | 109.09090909 | 34.63051728           | 76.00000000      | 252.00000000     | 6.02839927           | 3600.000000  | 1199.272727  |
| FMAX     | 33 | 371.87878788 | 310.57122347          | 140.00000000     | 1364.00000000    | 54.06351059          | 12272.000000 | 96454.484848 |

APPENDIX G

INSPIRATION REGRESSION ANALYSIS DATA

14 Abnormals (STATE=0)

P  
Q  
T  
U  
X  
+  
  
M  
C  
D  
G  
S  
B  
E

10 Normals (STATE=1)

H  
I  
V  
W  
\*  
K  
L  
F  
Y  
N

# INSPIRATION REGRESSION ANALYSIS DATA.

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=*     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 20 | 72.00000000   | 0.00000000            | 72.00000000      | 72.00000000      | 0.00000000           | 1440.000000  | 0.00000000   |
| FEV1     | 20 | 58.00000000   | 0.00000000            | 58.00000000      | 58.00000000      | 0.00000000           | 1160.000000  | 0.00000000   |
| FEVIP    | 20 | 124.00000000  | 0.00000000            | 124.00000000     | 124.00000000     | 0.00000000           | 2480.000000  | 0.00000000   |
| MPF      | 20 | 139.52000000  | 25.94333096           | 98.80000000      | 196.30000000     | 5.80110516           | 2790.400000  | 673.05642105 |
| FPK      | 20 | 98.00000000   | 13.26649916           | 68.00000000      | 120.00000000     | 2.96647939           | 1960.000000  | 176.00000000 |
| FMAX     | 20 | 156.00000000  | 21.71586856           | 108.00000000     | 204.00000000     | 4.85581583           | 3120.000000  | 471.57894737 |
| ID=*     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 39 | 99.00000000   | 0.00000000            | 99.00000000      | 99.00000000      | 0.00000000           | 3861.000000  | 0.00000000   |
| FEV1     | 39 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 4095.000000  | 0.00000000   |
| FEVIP    | 39 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 4095.000000  | 0.00000000   |
| MPF      | 39 | 366.87179487  | 34.45553159           | 278.50000000     | 429.30000000     | 5.51730066           | 14308.000000 | 1187.18366   |
| FPK      | 39 | 117.74615385  | 18.46212120           | 92.00000000      | 172.00000000     | 2.95630538           | 4592.100000  | 340.84992    |
| FMAX     | 39 | 591.38461538  | 446.01773716          | 172.00000000     | 1296.00000000    | 71.41999682          | 23064.000000 | 198931.82186 |
| ID=#     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 21 | 70.00000000   | 0.00000000            | 70.00000000      | 70.00000000      | 0.00000000           | 1470.000000  | 0.00000000   |
| FEV1     | 21 | 74.00000000   | 0.00000000            | 74.00000000      | 74.00000000      | 0.00000000           | 1554.000000  | 0.00000000   |
| FEVIP    | 21 | 106.00000000  | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 2226.000000  | 0.00000000   |
| MPF      | 21 | 300.14761905  | 87.00586543           | 140.70000000     | 449.50000000     | 18.98623639          | 6303.100000  | 7570.02062   |
| FPK      | 21 | 115.61904762  | 21.46270298           | 80.00000000      | 152.00000000     | 4.68354576           | 2428.000000  | 460.64762    |
| FMAX     | 21 | 636.76190476  | 409.52385825          | 152.00000000     | 1340.00000000    | 89.36543235          | 13372.000000 | 167709.79048 |
| ID=B     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 17 | 82.00000000   | 0.00000000            | 82.00000000      | 82.00000000      | 0.00000000           | 1394.000000  | 0.00000000   |
| FEV1     | 17 | 70.00000000   | 0.00000000            | 70.00000000      | 70.00000000      | 0.00000000           | 1190.000000  | 0.00000000   |
| FEVIP    | 17 | 85.00000000   | 0.00000000            | 85.00000000      | 85.00000000      | 0.00000000           | 1445.000000  | 0.00000000   |
| MPF      | 17 | 895.76470588  | 103.93119684          | 704.20000000     | 1129.00000000    | 25.20701779          | 15228.000000 | 10801.69368  |
| FPK      | 17 | 740.94117647  | 614.01714864          | 112.00000000     | 1492.00000000    | 148.92103293         | 12596.000000 | 377017.05882 |
| FMAX     | 17 | 1489.41176471 | 10.57744548           | 1464.00000000    | 1496.00000000    | 2.56540735           | 25320.000000 | 111.88235    |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=C     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 13 | 77.00000000  | 0.00000000            | 77.00000000      | 77.00000000      | 0.00000000           | 1001.0000000 | 0.0000000    |
| FEV1     | 13 | 78.00000000  | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1014.0000000 | 0.0000000    |
| FEV1P    | 13 | 99.00000000  | 0.00000000            | 99.00000000      | 99.00000000      | 0.00000000           | 1287.0000000 | 0.0000000    |
| MPF      | 13 | 414.80000000 | 35.87680309           | 329.30000000     | 455.40000000     | 9.95043486           | 5392.4000000 | 1287.1450000 |
| FPK      | 13 | 488.61538462 | 185.03942754          | 104.00000000     | 696.00000000     | 51.32070338          | 6352.0000000 | 34239.589744 |
| FMAX     | 13 | 673.53846154 | 64.92125408           | 588.00000000     | 788.00000000     | 18.00591619          | 8756.0000000 | 4214.769231  |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM           | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|---------------|--------------|
| ID=D     |    |              |                       |                  |                  |                      |               |              |
| FVC      | 19 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 1938.0000000  | 0.0000000    |
| FEV1     | 19 | 100.00000000 | 0.00000000            | 100.00000000     | 100.00000000     | 0.00000000           | 1900.0000000  | 0.0000000    |
| FEV1P    | 19 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 1843.0000000  | 0.0000000    |
| MPF      | 19 | 444.64210526 | 130.23281851          | 223.60000000     | 672.00000000     | 29.87745763          | 8448.2000000  | 16960.58702  |
| FPK      | 19 | 231.78947368 | 232.74773634          | 100.00000000     | 740.00000000     | 53.39599274          | 4404.0000000  | 54171.50877  |
| FMAX     | 19 | 928.00000000 | 481.16525228          | 180.00000000     | 1488.00000000    | 110.38687946         | 17632.0000000 | 231520.00000 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM           | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|---------------|--------------|
| ID=E     |    |              |                       |                  |                  |                      |               |              |
| FVC      | 19 | 90.00000000  | 0.00000000            | 90.00000000      | 90.00000000      | 0.00000000           | 1710.0000000  | 0.0000000    |
| FEV1     | 19 | 72.00000000  | 0.00000000            | 72.00000000      | 72.00000000      | 0.00000000           | 1368.0000000  | 0.0000000    |
| FEV1P    | 19 | 81.00000000  | 0.00000000            | 81.00000000      | 81.00000000      | 0.00000000           | 1539.0000000  | 0.0000000    |
| MPF      | 19 | 374.44210526 | 35.47777576           | 302.50000000     | 430.00000000     | 8.13915996           | 7114.4000000  | 1258.672573  |
| FPK      | 19 | 250.31578947 | 185.74207105          | 100.00000000     | 616.00000000     | 42.61215354          | 4756.0000000  | 34500.116959 |
| FMAX     | 19 | 682.52631579 | 49.78550483           | 600.00000000     | 748.00000000     | 11.42157813          | 12968.0000000 | 2478.596491  |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM           | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|---------------|--------------|
| ID=F     |    |              |                       |                  |                  |                      |               |              |
| FVC      | 28 | 146.00000000 | 0.00000000            | 146.00000000     | 146.00000000     | 0.00000000           | 4088.0000000  | 0.0000000    |
| FEV1     | 28 | 141.00000000 | 0.00000000            | 141.00000000     | 141.00000000     | 0.00000000           | 3948.0000000  | 0.0000000    |
| FEV1P    | 28 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 2716.0000000  | 0.0000000    |
| MPF      | 28 | 317.27857143 | 100.21188426          | 172.60000000     | 624.70000000     | 18.93826601          | 8883.8000000  | 10042.421746 |
| FPK      | 28 | 174.57142857 | 241.48482485          | 100.00000000     | 1028.00000000    | 45.63634228          | 4888.0000000  | 58314.920635 |
| FMAX     | 28 | 594.71428571 | 276.14500447          | 172.00000000     | 1228.00000000    | 52.18650054          | 16652.0000000 | 76256.063492 |

| VARIABLE | N  | MEAN          | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|---------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=G     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 17 | 78.00000000   | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1326.000000  | 0.000000     |
| FEV1     | 17 | 91.00000000   | 0.00000000            | 91.00000000      | 91.00000000      | 0.00000000           | 1547.000000  | 0.000000     |
| FEV1P    | 17 | 118.00000000  | 0.00000000            | 118.00000000     | 118.00000000     | 0.00000000           | 2006.000000  | 0.000000     |
| MPF      | 17 | 426.62352941  | 50.04241363           | 343.70000000     | 513.20000000     | 12.13706807          | 7252.600000  | 2504.243162  |
| FPK      | 17 | 269.64705882  | 195.38709693          | 100.00000000     | 708.00000000     | 47.38833168          | 4584.000000  | 38176.117647 |
| FMAX     | 17 | 798.58823529  | 110.03582304          | 712.00000000     | 1024.00000000    | 26.68760712          | 13576.000000 | 12107.882353 |
| ID=H     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 18 | 114.00000000  | 0.00000000            | 114.00000000     | 114.00000000     | 0.00000000           | 2052.000000  | 0.000000     |
| FEV1     | 18 | 110.00000000  | 0.00000000            | 110.00000000     | 110.00000000     | 0.00000000           | 1980.000000  | 0.000000     |
| FEV1P    | 18 | 96.00000000   | 0.00000000            | 96.00000000      | 96.00000000      | 0.00000000           | 1728.000000  | 0.000000     |
| MPF      | 18 | 619.09444444  | 51.94969821           | 513.10000000     | 689.20000000     | 12.24466129          | 11143.700000 | 2698.771144  |
| FPK      | 18 | 225.77777778  | 40.58912569           | 172.00000000     | 260.00000000     | 9.56694867           | 4064.000000  | 1647.477124  |
| FMAX     | 18 | 1322.22222222 | 273.43298040          | 260.00000000     | 1472.00000000    | 64.44877155          | 23800.000000 | 74765.594771 |
| ID=I     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 29 | 112.00000000  | 0.00000000            | 112.00000000     | 112.00000000     | 0.00000000           | 3248.000000  | 0.000000     |
| FEV1     | 29 | 118.00000000  | 0.00000000            | 118.00000000     | 118.00000000     | 0.00000000           | 3422.000000  | 0.000000     |
| FEV1P    | 29 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 3045.000000  | 0.000000     |
| MPF      | 29 | 542.03793103  | 111.10369807          | 368.30000000     | 828.80000000     | 20.63143879          | 15719.100000 | 12344.03172  |
| FPK      | 29 | 500.68965517  | 239.33734462          | 152.00000000     | 1364.00000000    | 44.44382915          | 14520.000000 | 57282.36453  |
| FMAX     | 29 | 998.89655172  | 319.32589095          | 632.00000000     | 1484.00000000    | 59.29732931          | 28968.000000 | 101969.02463 |
| ID=K     |    |               |                       |                  |                  |                      |              |              |
| FVC      | 22 | 102.00000000  | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 2244.000000  | 0.000000     |
| FEV1     | 22 | 105.00000000  | 0.00000000            | 105.00000000     | 105.00000000     | 0.00000000           | 2310.000000  | 0.000000     |
| FEV1P    | 22 | 104.00000000  | 0.00000000            | 104.00000000     | 104.00000000     | 0.00000000           | 2288.000000  | 0.000000     |
| MPF      | 22 | 358.01363636  | 63.28513927           | 220.20000000     | 445.60000000     | 13.49243703          | 7876.300000  | 4005.008853  |
| FPK      | 22 | 371.81818182  | 166.13237303          | 88.00000000      | 532.00000000     | 35.41954094          | 8180.000000  | 27599.965368 |
| FMAX     | 22 | 598.00000000  | 9.62140471            | 580.00000000     | 612.00000000     | 2.05129038           | 13156.000000 | 92.571429    |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=L     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 20 | 110.00000000 | 0.00000000            | 110.00000000     | 110.00000000     | 0.00000000           | 2200.000000  | 0.00000000   |
| FEV1     | 20 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 2040.000000  | 0.00000000   |
| FEV1P    | 20 | 92.00000000  | 0.00000000            | 92.00000000      | 92.00000000      | 0.00000000           | 1840.000000  | 0.00000000   |
| MPF      | 20 | 384.79500000 | 38.62565925           | 302.50000000     | 435.80000000     | 8.63695998           | 7695.900000  | 1491.9415526 |
| FPK      | 20 | 488.00000000 | 17.45972810           | 460.00000000     | 520.00000000     | 3.90411389           | 9760.000000  | 304.8421053  |
| FMAX     | 20 | 587.00000000 | 33.36244343           | 536.00000000     | 644.00000000     | 7.46006914           | 11740.000000 | 1113.0526316 |
| ID=M     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 24 | 53.00000000  | 0.00000000            | 53.00000000      | 53.00000000      | 0.00000000           | 1272.000000  | 0.00000000   |
| FEV1     | 24 | 38.00000000  | 0.00000000            | 38.00000000      | 38.00000000      | 0.00000000           | 912.000000   | 0.00000000   |
| FEV1P    | 24 | 68.00000000  | 0.00000000            | 68.00000000      | 68.00000000      | 0.00000000           | 1632.000000  | 0.00000000   |
| MPF      | 24 | 271.51250000 | 68.68549820           | 154.80000000     | 396.30000000     | 14.02036861          | 6516.300000  | 4717.697663  |
| FPK      | 24 | 227.66666667 | 210.93882622          | 72.00000000      | 588.00000000     | 43.05770760          | 5464.000000  | 44495.188406 |
| FMAX     | 24 | 549.33333333 | 129.26368960          | 140.00000000     | 624.00000000     | 26.38584015          | 13184.000000 | 16709.101449 |
| ID=N     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 25 | 91.00000000  | 0.00000000            | 91.00000000      | 91.00000000      | 0.00000000           | 2275.000000  | 0.00000000   |
| FEV1     | 25 | 97.00000000  | 0.00000000            | 97.00000000      | 97.00000000      | 0.00000000           | 2425.000000  | 0.00000000   |
| FEV1P    | 25 | 107.00000000 | 0.00000000            | 107.00000000     | 107.00000000     | 0.00000000           | 2675.000000  | 0.00000000   |
| MPF      | 25 | 384.89600000 | 38.76268051           | 256.40000000     | 435.60000000     | 7.75253610           | 9622.400000  | 1502.545400  |
| FPK      | 25 | 440.48000000 | 154.66660920          | 100.00000000     | 616.00000000     | 30.93332184          | 11012.000000 | 23921.760000 |
| FMAX     | 25 | 635.68000000 | 23.69022302           | 588.00000000     | 688.00000000     | 4.73804460           | 15892.000000 | 561.226667   |
| ID=P     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 25 | 73.00000000  | 0.00000000            | 73.00000000      | 73.00000000      | 0.00000000           | 1825.000000  | 0.00000000   |
| FEV1     | 25 | 32.00000000  | 0.00000000            | 32.00000000      | 32.00000000      | 0.00000000           | 800.000000   | 0.00000000   |
| FEV1P    | 25 | 44.00000000  | 0.00000000            | 44.00000000      | 44.00000000      | 0.00000000           | 1100.000000  | 0.00000000   |
| MPF      | 25 | 455.16800000 | 158.40528116          | 255.50000000     | 822.60000000     | 31.68105623          | 11379.200000 | 25092.23310  |
| FPK      | 25 | 199.36000000 | 234.67901483          | 84.00000000      | 1316.00000000    | 46.93580297          | 4984.000000  | 55074.24000  |
| FMAX     | 25 | 964.96000000 | 511.66822584          | 240.00000000     | 1484.00000000    | 102.33364517         | 24124.000000 | 261804.37333 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=Q     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 37 | 102.00000000 | 0.00000000            | 102.00000000     | 102.00000000     | 0.00000000           | 3774.000000  | 0.000000     |
| FEV1     | 37 | 83.00000000  | 0.00000000            | 83.00000000      | 83.00000000      | 0.00000000           | 3071.000000  | 0.000000     |
| FEVIP    | 37 | 81.00000000  | 0.00000000            | 81.00000000      | 81.00000000      | 0.00000000           | 2997.000000  | 0.000000     |
| MPF      | 37 | 205.61081081 | 89.43860335           | 94.50000000      | 453.00000000     | 14.70361582          | 7607.600000  | 7999.263769  |
| FPK      | 37 | 141.18918919 | 164.04027924          | 56.00000000      | 608.00000000     | 26.96805578          | 5224.000000  | 26909.213213 |
| FMAX     | 37 | 536.21621622 | 182.55457862          | 108.00000000     | 680.00000000     | 30.01178785          | 19840.000000 | 33326.174174 |
| ID=S     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 19 | 92.00000000  | 0.00000000            | 92.00000000      | 92.00000000      | 0.00000000           | 1748.000000  | 0.000000     |
| FEV1     | 19 | 95.00000000  | 0.00000000            | 95.00000000      | 95.00000000      | 0.00000000           | 1805.000000  | 0.000000     |
| FEVIP    | 19 | 103.00000000 | 0.00000000            | 103.00000000     | 103.00000000     | 0.00000000           | 1957.000000  | 0.000000     |
| MPF      | 19 | 414.11052632 | 176.26240821          | 183.60000000     | 785.30000000     | 40.43736973          | 7868.100000  | 31068.43655  |
| FPK      | 19 | 175.15789474 | 186.16398481          | 76.00000000      | 928.00000000     | 42.70894720          | 3328.000000  | 34657.02924  |
| FMAX     | 19 | 692.84210526 | 462.27376006          | 141.00000000     | 1436.00000000    | 106.05287391         | 13164.000000 | 213697.02924 |
| ID=T     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 31 | 83.00000000  | 0.00000000            | 83.00000000      | 83.00000000      | 0.00000000           | 2573.000000  | 0.000000     |
| FEV1     | 31 | 76.00000000  | 0.00000000            | 76.00000000      | 76.00000000      | 0.00000000           | 2356.000000  | 0.000000     |
| FEVIP    | 31 | 91.00000000  | 0.00000000            | 91.00000000      | 91.00000000      | 0.00000000           | 2821.000000  | 0.000000     |
| MPF      | 31 | 259.19032258 | 106.68721371          | 98.70000000      | 419.70000000     | 19.16158924          | 8034.900000  | 11382.161570 |
| FPK      | 31 | 197.41935484 | 180.14378964          | 76.00000000      | 592.00000000     | 32.35477975          | 6120.000000  | 32451.784946 |
| FMAX     | 31 | 603.87096774 | 293.31663687          | 124.00000000     | 1224.00000000    | 52.68122315          | 18720.000000 | 86034.649462 |
| ID=U     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 22 | 73.00000000  | 0.00000000            | 73.00000000      | 73.00000000      | 0.00000000           | 1606.000000  | 0.000000     |
| FEV1     | 22 | 66.00000000  | 0.00000000            | 66.00000000      | 66.00000000      | 0.00000000           | 1452.000000  | 0.000000     |
| FEVIP    | 22 | 90.00000000  | 0.00000000            | 90.00000000      | 90.00000000      | 0.00000000           | 1980.000000  | 0.000000     |
| MPF      | 22 | 154.65454545 | 62.88946257           | 93.80000000      | 350.30000000     | 13.40807847          | 3402.400000  | 3955.084502  |
| FPK      | 22 | 89.45454545  | 13.7207768            | 52.00000000      | 108.00000000     | 2.92527963           | 1968.000000  | 188.259740   |
| FMAX     | 22 | 277.63636364 | 277.3380697           | 104.00000000     | 1352.00000000    | 59.12883232          | 6108.000000  | 76916.813853 |

| VARIABLE | N  | MEAN         | STANDARD<br>DEVIATION | MINIMUM<br>VALUE | MAXIMUM<br>VALUE | STD ERROR<br>OF MEAN | SUM          | VARIANCE     |
|----------|----|--------------|-----------------------|------------------|------------------|----------------------|--------------|--------------|
| ID=V     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 27 | 101.00000000 | 0.00000000            | 101.00000000     | 101.00000000     | 0.00000000           | 2727.000000  | 0.000000     |
| FEV1     | 27 | 106.00000000 | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 2862.000000  | 0.000000     |
| FEVIP    | 27 | 104.00000000 | 0.00000000            | 104.00000000     | 104.00000000     | 0.00000000           | 2808.000000  | 0.000000     |
| MPF      | 27 | 303.12962963 | 103.89385417          | 157.10000000     | 494.90000000     | 19.99438156          | 8184.500000  | 10793.932934 |
| FPK      | 27 | 262.37037037 | 240.07244870          | 76.00000000      | 644.00000000     | 46.20196429          | 7084.000000  | 57634.780627 |
| FMAX     | 27 | 532.88888889 | 199.77012430          | 156.00000000     | 692.00000000     | 38.44577835          | 14388.000000 | 39908.102564 |
| ID=W     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 21 | 107.00000000 | 0.00000000            | 107.00000000     | 107.00000000     | 0.00000000           | 2247.000000  | 0.000000     |
| FEV1     | 21 | 114.00000000 | 0.00000000            | 114.00000000     | 114.00000000     | 0.00000000           | 2394.000000  | 0.000000     |
| FEVIP    | 21 | 106.00000000 | 0.00000000            | 106.00000000     | 106.00000000     | 0.00000000           | 2226.000000  | 0.000000     |
| MPF      | 21 | 280.01904762 | 88.57784497           | 134.90000000     | 453.40000000     | 19.32927045          | 5880.400000  | 7846.034619  |
| FPK      | 21 | 125.71428571 | 36.80372652           | 76.00000000      | 260.00000000     | 8.03123155           | 2640.000000  | 1354.514286  |
| FMAX     | 21 | 423.80952381 | 145.70916891          | 172.00000000     | 660.00000000     | 31.79634743          | 8900.000000  | 21231.161905 |
| ID=X     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 25 | 93.00000000  | 0.00000000            | 93.00000000      | 93.00000000      | 0.00000000           | 2325.000000  | 0.000000     |
| FEV1     | 25 | 78.00000000  | 0.00000000            | 78.00000000      | 78.00000000      | 0.00000000           | 1950.000000  | 0.000000     |
| FEVIP    | 25 | 85.00000000  | 0.00000000            | 85.00000000      | 85.00000000      | 0.00000000           | 2125.000000  | 0.000000     |
| MPF      | 25 | 188.77600000 | 63.49351200           | 105.50000000     | 365.80000000     | 12.69870240          | 4719.400000  | 4031.426067  |
| FPK      | 25 | 105.92000000 | 19.93723485           | 64.00000000      | 164.00000000     | 3.98744697           | 2648.000000  | 397.493333   |
| FMAX     | 25 | 250.72000000 | 125.70717296          | 136.00000000     | 568.00000000     | 25.14143459          | 6268.000000  | 15802.293333 |
| ID=Y     |    |              |                       |                  |                  |                      |              |              |
| FVC      | 23 | 101.00000000 | 0.00000000            | 101.00000000     | 101.00000000     | 0.00000000           | 2323.000000  | 0.000000     |
| FEV1     | 23 | 113.00000000 | 0.00000000            | 113.00000000     | 113.00000000     | 0.00000000           | 2599.000000  | 0.000000     |
| FEVIP    | 23 | 113.00000000 | 0.00000000            | 113.00000000     | 113.00000000     | 0.00000000           | 2599.000000  | 0.000000     |
| MPF      | 23 | 214.54347826 | 112.65157396          | 114.10000000     | 481.20000000     | 23.48947694          | 4934.500000  | 12690.377115 |
| FPK      | 23 | 102.08695652 | 12.92605910           | 80.00000000      | 124.00000000     | 2.69526964           | 2348.000000  | 167.083004   |
| FMAX     | 23 | 252.34782609 | 224.36630129          | 124.00000000     | 1224.00000000    | 46.78360785          | 5804.000000  | 50340.237154 |

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