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## PREFACE

These papers were given at the NASA Occupational Medicine and Environmental Health Annual Meeting held at Cambridge, Massachusetts, October 13, 14, and 15, 1970.

Presentations were offered by personnel and consultants directly associated with the NASA programs and by invited authorities and experts in fields which have important relationship to occupational medicine and environmental health.

The conference provided an opportunity to present solutions to problems common to NASA medical installations. The interchange of information and techniques has proven valuable in providing medical care of high professional caliber to NASA personnel.

The effort and time spent in the preparation of the reports enclosed herein, and the interesting and noteworthy discussions presented at the conference by invited specialists in related areas are sincerely appreciated.

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# DYNAMIC EKG STUDY

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I would like to discuss some of the problems and findings we have encountered in the dynamic EKG study program as well as to present some relatively unique although not too uncommon examples. In evaluating the results of these continuous EKG recordings it is important to understand and identify perfectly normal physiological responses from those with potential clinical or prognostic significance. Of course, there is a definite group of responses that are pathological irrespective of whether the subject is active or at rest. However, it quickly became apparent that our overall knowledge regarding normalcy in the dynamic state was far from complete and in some categories virtually non-existant. Many articles have been published of results of continuous long term EKG recordings but invariably with some specific objective such as to clarify unusual chest pain syndromes.

The program began at NASA HQ in October, 1965, when it was decided to select subjects for study by incorporating the procedure as a part of the periodic health examination. Since its beginning approximately 1100 subjects have had over 3000 studies. The procedure was designed to monitor as much of the work day as possible, resulting in a 7 to 7½ hour recording. Each subject kept an activity diary with the only request being to ascend 3 flights of stairs before lunch. Reference to the rate of ascent was carefully avoided. The resulting pulse rate response was studied for degree, duration and recovery rate.

One observation that has been noted is the frequency a subject ascending 3 flights of stairs will produce a pulse rate of 120 beats per minute with the peak duration lasting 10 seconds or less and complete recovery occurring in one to two minutes. The frequency of this response has been so much more than coincidence could account for that it has become a rough guide in estimating one's physical fitness status. Two other prominent and reproducible features considered to be completely physiological are worthy of note. One is the obvious respiratory effect on the pulse rate or sinus arrhythmia producing a 10 BPM variation on the average. This has been confirmed by testing each recorder with a steady signal input to rule out inconstant tape speed as the cause. The second is the effect eating has on the pulse rate.

It is no surprize that a meal increases the pulse rate which it does by an average of 10 BPM usually becoming apparent ½ hour or so after the meal. The surprize came in noting the duration of this response with most subjects taking 2 to 3 hours before the pulse rate returned to the before lunch level.

Three classical patterns of pulse rate responses have been observed with the third type really having two subdivisions. The physical stress of the stairway effort produces a rapid peak of short duration and a prompt return to normal when the exercise is completed. A walking effort produces a plateau effect which is sustained as long as walking continues. The third, the response to non-physical stress stimuli, may produce one of two basic patterns. The first is the absolute pulse rate increase but with a very gradual return to normal rather than the abrupt return of the physical stress type. The second type has been a frequent variant where a frank increase in pulse rate does not occur but instead a marked increase in the variation of the pulse rate due to the breathing effect results with the rate varying as much as 30 to 40 BPM.

The inclusion of this study as a part of the routine periodic health examination may provide another approach to the effort of accomplishing early detection of cardiac abnormalities and offers the advantage of monitoring the subject in his usual environment of a work day. A frequency count has not been attempted but the occurrence of ventricular premature contractions following the noon meal has been quite striking. A dynamic EKG study of one subject showed the occurrence of bigeminy rhythm from multiple ventricular foci approximately ½ hour following his noon meal lasting 8 minutes. The study was repeated two weeks later and demonstrated the exact same phenomena with the exception that the duration was just 2 minutes on the second time. He had absolutely no ectopic beats at any other period of monitoring. The next dynamic study was 3 years later in September, 1969. It failed to show any meal related bigeminy rhythm but did reveal multifocal VPC's occurring sporadically throughout the day. His latest study in August, 1970 shows an apparent overall increase of the ventricular dysrhythmia throughout the day with multifocal bigeminy occurring after a period of physical stress. Perhaps more significant is the occurrence of brief periods of ventricular tachycardia from a non-physical stress situation; specifically, when someone stole a parking place he had been trying to enter.

A retired Air Force officer was first examined on July 14, 1967 presenting a history of recurrent episodes of paroxysmal atrial fibrtllation for which he was treated with quinidine 0.3 gm tablets taking one four times daily. His resting EKG showed a first degree block with a P-R interval of .22 seconds as well as frequent VPC's. His dynamic EKG study showed the presence of premature contractions of atrial, nodal and ventricular origin. His next physical examination with a dynamic EKG study was in July, 1969 showing essentially the same findings except for a suggestion of an increase in frequency of the VPC's. In July, 1970 the dysrhythmia was even more apparent on the resting EKG with the dynamic EKG study showing many multifocal VPC's as well as supraventricular ectopic beats and one period of atrial fibrillation which lasted a measured 5 minutes and 35 seconds. Since these findings seemed to be on the increase and yet without any awareness on the part of the subject, the routine transmittal of findings to his personal physician was backed up by a direct phone call resulting in a revision of the subject's treatment program. He is now due for a repeat study to evaluate the effectiveness of the new regimen.

We have been able to partially follow one subject who has had surgical intervention to enhance his myocardial vascularization. This subject presented a history of a diagnosis of ischemic heart disease having been made in 1964 with the subsequent development of symptomatic exertional angina in October, 1968. A resting EKG in July, 1968 and another in August, 1969 failed to show any significant abnormality or change. However, a dynamic EKG on September 22, 1967 was considered to be marginal while a dynamic study in August, 1969 showed definite ischemic S-T depressions which were associated with anginal chest pains. At this time he was averaging 10 to 12 nitroglycerine tablets a week. In October-November, 1969 he had coronary angiographic studies performed at NIH which showed 90% occlusion of two major coronary arteries with a lesser involvement of the circumflex coronary artery. On January 14, 1970 he underwent a saphenous vein bypass grafting procedure from the ascending aorta to the right and anterior descending coronary arteries with reportedly excellent results. A repeat resting EKG showed a definite loss of T wave amplitude in general and specifically in leads I, V4-5-6. His dynamic EKG on March 18, 1970 showed a persistent tachycardia as well as ischemic type S-T depressions although without symptoms in spite of pulse rates as high as 150. A multistage teadmill test produced a peak pulse rate of 156 again with ischemic S-T depressions without symptoms. He was started on a supervised exercise program to study the effect on the ischemic pattern and to evaluate such a procedure as an adjunct to the revascularization effort. One unexpected event occurred during his first

workout session consisting of an episode of paroxysmal tachycardia lasting 8 seconds and occurring when he was well into the recovery phase from the rope jump exercise. It is considered important for this subject to be aware of his pulse rate responses with much greater attention given to this measurement since he no longer has the anginal warning signal and because this episode of tachyrhythmia occurred without his awareness. It may be added that the rope jump is no longer a part of his exercise protocol.

In summary, the use of the dynamic EKG study as a part of the periodic health examination is considered to be a valuable complement to other forms of stress testing with its ability to detect abnormal responses to non-physical stress stimuli. However, there is still a large grey area in need of clearer definition of significance. It is believed that the statistical correlations of the dynamic EKG findings with the physical examination results will contribute greatly to the reduction of size of this grey area.

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# NORMALLY EXPECTED ABERRATIONS IN THE 8-HOUR DYNAMIC EKG

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At present, the 8-hour dynamic electrocardiogram (DEKG) is a relatively new medical technique. One question asked by those physicians who employ the technique is: what is to be considered normal cardiac behavior in a DEKG record? But how does one go about determining the normal DEKG? It is likely that because of the movement of the patient as he carries the recorder about there is an increase in background noise as well as the creation of artifacts in the record. Also, the DEKG is purposefully recorded as the subject is exposed to the stresses of his daily life. For at least these two reasons it is not logical to expect that what is normal on the resting EKG can be transferred in toto to the interpretation of the dynamic EKG. It therefore appears that new data on the DEKG must be gathered. But from whence should the data arise? What is the population which would yield the picture of normal variability in terms of DEKG diagnostic signs? Is it a population wherein each individual is completely free of any symptomotology of any disease, who particularly has no previous nor present record of cardiovascular disease and who is free of risk factors in cardiac disease? Or is the appropriate normal population for such a study the work force on active duty in an occupational setting? Such a group would contain not only perfectly healthy and especially cardiac heart disease risk free individuals but

also those individuals who display the array of symptoms and disease which usually confront the physician in the usual occupational medical setting. It was decided that both of these populations are of interest as DEKG normative groups.

This study, therefore, attempts to provide a beginning for establishing norms of use in interpreting the DEKG. To do this, the following three questions were posed for a research solution in an empirical setting:

1. In a sample selected because its individuals are free of risk factors relevant to cardiovascular disease (known as the pure sample) what percent of the sample would show (a) no abnormalities on the dynamic EKG, and, (b) what percentages would show what kinds of abnormalities?
2. In the entire sample of subjects used in the study which was drawn from the executive work force at NASA Headquarters, what percent of the individuals were (a) normal on their DEKG, and, (b) what percent manifested what kinds of aberrations on their DEKG's?
3. When on the basis of DEKG's the total sample representative of the NASA executive work force is divided into normal vs. abnormal, on what physical examination medical variables do the two groups differ significantly, and which of the physical examination medical variables correlate with which others within the (a) normal group, and, (b) abnormal group?

Now for the study itself.

From a population of approximately 1,100 subjects a sample was selected on the basis of their records being complete in regard to the requirements of the study. The sample consisted of 362 males between the ages of 33 and 68, who had grades ranging from 12 through 16, and were located at NASA Headquarters in Washington, D. C. Each of the 362 subjects had three MEDICAL RECORD SETS. Each MEDICAL SET contains a Physical Examination Record, and a Dynamic Electrocardiogram (DEKG) reading.

In order to compose a MEDICAL SET, the Physical Examination Record and the DEKG must have been within one year of each other. Each MEDICAL SET was approximately a year apart from another MEDICAL SET. The MEDICAL SETS range from late 1965 to the middle of 1970. Each subject did not necessarily have three consecutive MEDICAL SETS such as one for 1966, 1967, and 1968. MEDICAL SETS represent three different occasions - the earliest occasion, the middle occasion, and the most recent occasion. For instance, one subject may have had MEDICAL SETS for 1966, 1967, and 1970; a second subject may have had them for 1967, 1968, and 1969. Both subjects' MEDICAL SETS are labeled earliest, middle, and most recent regardless of the fact that the 1967 date is the middle occasion MEDICAL SET for the first subject and the earliest occasion MEDICAL SET for the second subject.

In selecting the three MEDICAL SETS for subjects with more than three MEDICAL SETS available, preference was given to the three MEDICAL

SETS with consecutive dates rather than the three MEDICAL SETS with the most recent dates. If there were no three MEDICAL SETS with consecutive dates, the three with the most recent broken dates were selected.

Some subjects had DEKG's which were within a few months of each other but which were grouped with the same Physical Examination Record. In such cases, DEKG's containing aberrant signs were included in the MEDICAL SET for that particular Physical Examination Record.

Missing data on the Physical Examination Records for any of the variables was handled in the following manner:

1. If earliest occasion data were missing, the middle occasion data were recorded.
2. If most recent occasion data were missing, the middle occasion data were recorded.
3. If both the earliest and middle occasion data were missing, the most recent occasion data were repeated twice.
4. If both the middle and most recent occasion data were missing, the earliest occasion data were repeated twice.
5. If middle occasion data were missing, the average of the earliest and most recent occasion data was taken.

Each of the Physical Examination Records contains the following information:

| VARIABLE NAME | HOW RECORDED ON RAW DATA FILE |
|---|---|
| 1. Cholesterol (C). | Actual value in mg.%; Uni-Test method |
| 2. Family History (FH). | Positive (abnormal) only if coronary heart disease in self, mother, father, sister, brother, living or deceased. |
| 3. Smoking (S). | Positive (abnormal) only if examinee smokes cigarettes or inhales pipe or cigars; if he quit a short time before physical, value of following year was recorded if available, otherwise it was recorded as positive; amount smoked was not specified on records all of the time so one could not record varying amounts. |
| 4. Height (Ht). | In inches; all fractions other than 1/2 were rounded off to the nearest whole number. All fractions of 1/2 were rounded off to nearest even number. |
| 5. Weight (Wt). | In pounds; all fractions other than 1/2 were rounded off to the nearest whole number. All fractions of 1/2 were rounded off to the nearest even number. |
| 6. Blood Pressure - systolic (BP's). Blood Pressure - diastolic (BP-d). | Actual value; differences between recumbent, sitting, standing were ignored; where both arms were recorded, value of left arm was |

| VARIABLE NAME | HOW RECORDED ON RAW DATA FILE |
|---|---|
| | taken because when only one arm was recorded it was usually the left arm; if more than one method was recorded (sitting and recumbent) value matching the method of pulse taking was recorded. |
| 7. Resting Electrocardiogram (RECG). | Normal or comment is made by physician. |
| 8. White Blood Cell Count (WBC). | Actual value; Coulter Counter |
| 9. Erythrocyte Sedimentation Rate (ESR). | Actual value in mm/hr; Winthrop Method. |
| 10. Fasting Blood Sugar (FBS). | Actual value in mg.%; fasting. |
| 11. Uric Acid (UA). | Actual value in mg.%; Auto analyzer; no data before early 1966 (Jan. - Feb.); fractions retained. |
| 12. Hemoglobin (Hgb). | Actual value; fractions retained. |
| 13. Pulse (Pl). | Actual value; differences between recumbent, sitting, standing, were ignored; if possible, methods by which BP and Pl were obtained; left arm value was taken where both arms were recorded. |
| 14. Medications and Disease signals (MD). | From comments by physicians on Physical Examination Record. |
| 15. Date of Birth (D.O.B.). | Month, year. |
| 16. Grade (G). | Actual value (12-16). |

Each of the DEKG's was coded by the Fleck Coding List. (Fig. 1). A maximum of four different codings and a minimum of one coding were used to describe a DEKG.

The pure, or completely disease symptom and cardiac risk factor free sample, differed significantly at the 5% confidence level from the non-pure sample in the direction of normality on the following variables: cholesterol, family history, smoking, height, systolic and diastolic blood pressures, erythrocyte sedimentation rate, uric acid, hemoglobin, resting EKG, dynamic EKG, year of birth, degree of overweight, and on medication and disease categories.

RESULTS:

1. Fig. 2 relates the pure sample to the appearance of abnormalities on any of the three occasions when the dynamic EKG was administered.
2. In order to determine the distribution of positive signs on the dynamic EKG in the entire population of 362 subjects on whom three separate dynamic EKG's had been administered at least one year apart, the following normative data were collected. Fig. 3 shows the number and percentage of the total sample of 362 subjects who fell into the normal category by having a Fleck List Code of "00" (no aberration), and the number and percent who had a Fleck List Code other than "00" (presence of an aberration) for at least one of the three



B

dynamic EKG test occasions. As can be seen, there were 184 out of 362 subjects with completely normal dynamic EKG's and 184 out of 362 subjects who had aberrations on their dynamic EKG. Fig. 3 further breaks down the abnormals into specific dynamic EKG diagnostic classifications.

3. Fig. 4 shows the aberrations as indicated by Fleck Code List signs which appeared in total sample.

4. When, on the basis of the dynamic EKG the total sample of 362 subjects was divided into normal vs. abnormal, the two groups differed significantly on the following variables:

| | |
|---|---|
| Cholesterol | Uric Acid |
| Smoking | Resting EKG |
| Systolic Blood Pressure | Year of Birth |
| White Blood Count | Coronary Insufficiency |
| Fasting Blood Sugar | |

It thus appears that the dynamic EKG discriminates between normals and abnormals, for the most part, in terms of traditional risk factors.

When the total sample of 362 subjects was divided into normal vs. abnormal sub-groups, on the basis of their dynamic EKG's, significant positive correlations were obtained between the indicated variables for the normal group:

| | |
|---|---|
| Weight and Height | FBS and ESR |
| Diastolic and Systolic Blood Pressures | UA and Cholesterol |
| WBC and Smoking | UA and Diastolic Blood Pressure |
| ESR and Cholesterol | Hemoglobin and Diastolic Blood Pressure |
| FBS and Systolic Blood Pressure | |

For the abnormal group, significant positive correlations were obtained between the following variables:

| | |
|---|---|
| Weight and Height | Pulse and Smoking |
| Systolic BP and Weight | Pulse and Systolic BP |
| Dystolic BP and Systolic | Pulse and Diastolic BP |
| Dystolic BP and Weight | Pulse and WBC |
| WBC and Smoking | Pulse and Hemoglobin |
| Hemoglobin and WBC | |

Further data will be required and are being collected to construct norms for interpreting DEKG's. It will be necessary to sample other similar and dissimilar occupational groups at the various NASA Centers as well as other occupational groups, such as industrial and military, to provide meaningful norms. Such variable components of the DEKG as different recording equipment, different protocols for administering the DEKG and the different methods of identifying aberrations on the DEKG must be standardized so that more meaningful norms may be determined.

## FIGURE 1

## DYNAMIC EKG CODING SYSTEM

| NUMBER | FINDING |
|---|---|
| 00 | No abnormalities |
| 01-09 | RHYTHM |
| 01 | Tachycardia, sinus, persistent (no rate under 90 BPM) |
| 02 | Tachycardia, paroxysmal |
| 02.1 | Auricular |
| 02.2 | Nodal |
| 03 | Auricular fibrillation |
| 04 | Auricular premature contractions |
| 05 | Nodal premature contractions |
| 06 | Ventricular premature contractions |
| 06.1 | Multifocal PVC's |
| 07 | Ventricular ectopic (not premature) contractions |
| 08.1 | Bradycardia P |
| 08.2 | Bradycardia T (50 or less or under 50) |
| 10-19 | CONDUCTION DEFECTS |
| 10 | First degree block (P-R greater than 0.20 sec.) |
| 11 | Sinus arrhythmia, marked |
| 12 | Wandering pacemaker |
| 13 | Wenckeback's phenomenon (Mobitz 10) |
| 13.1 | Intermittent Wenckeback's |
| 14 | Second degree heart block (Mobitz II) |
| 15 | Complete A-V block |
| 20-29 | OTHER CONDUCTION DEFECTS |
| 20 | Incomplete right bundle branch block (QRS 0.09-0.11) |
| 21 | Complete right bundle branch block |
| 22 | Incomplete left bundle branch block (QRS 0.10-0.11) |
| 23 | Complete left bundle branch block |
| 24 | Wolf-Parkinson-White syndrome |
| 24.1 | Intermittent W-P-W |
| 30-39 | T-WAVE CHANGES |
| 30 | Low amplitude or isoelectric T waves |
| 31 | Notched T waves |
| 32 | Inverted T waves |
| 40-49 | S-T SEGMENT CHANGES |
| 40 | Ischemic |
| 41 | "J" junctional |
| 42 | Early repolarization |
| 43 | Elevated |
| 90-99 | OTHER |

## FIGURE 2

### PURE SAMPLE (40 SUBJECTS) DYNAMIC EKG (DEKG) PATTERNS FOR THREE OCCASIONS

Out of a total of 40 subjects in the PURE SAMPLE, 27 subjects or 67.5 percent have completely normal DEKG's (Fleck List Code of "00" for all three occasions). Thirteen subjects or 32.5 percent have other than "00" Fleck Codes as follows:

| ID Number | 1st Occasion | | |
|---|---|---|---|
| 2007 | Tachycardia (01) | Normal (99) | Wandering Pacemaker (12) |
| 2030 | Notched T (31) | Normal (99) | Normal (99) |
| 2066 | Normal (99) | Normal (99) | Multifocal PVC's (6.1) |
| 2075 | Normal (99) | Normal (99) | Notched T (31) |
| 2076 | Notched T (31) | Notched T (31) | Notched T (31) |
| 2090 | Tachycardia (01) | Tachycardia (01) | Normal (99) |
| 2104 | Notched T (31) | Notched T (31) | Normal (99) |
| 2108 | Notched T (31) | Notched T (31) | Notched T (31) |
| 2109 | Normal (99) | "J" Junctional (41) | Normal (99) |
| 2159 | Atrial PC; Nodal PC; "J" Junctional (04;05;41) | Nodal PC; "J" Junctional (05;41) | "J" Junctional (41) |
| 2166 | Normal (99) | Notched T (31) | Notched T (31) |
| 2177 | Normal (99) | Normal (99) | Low Amplitude T (30) |
| 2182 | Normal (99) | Normal (99) | Ventricular PC (06) |

## FIGURE 3

### DISTRIBUTION OF FLECK LIST CODES IN TOTAL SAMPLE (362 SUBJECTS)

The number and percentage of individuals specified under each heading below manifested the indicated Fleck List Codings at least once for three occasions.

19% (68 subjects) had notched T-waves (31)

17% (62 subjects) had tachycardia, persistent (01)

10% (37 subjects) had ventricular premature contractions (06)

10% (35 subjects) had "J" junctional (41)

8% (30 subjects) had low amplitude T-waves (30)

7% (26 subjects) had inverted T-waves (32)

4% (13 subjects) had nodal premature contractions (05)

4% (13 subjects) had ischemia (40)

2% (7 subjects) had atrial premature contractions (04)

1% (2 subjects) had tachycardia paroxysmal (02.2)

1% (3 subjects) had multifocal premature ventricular contractions (61)

1% (2 subjects) had wandering pacemaker (12)

3% (1 subject) had sinus arrhythmia (11)

49% (178 subjects) had completely normal DEKG's (00) for all three occasions

## FIGURE 4

DYNAMIC EKG LIST

(From Fleck Code List)

| | |
|---|---|
| 01 | Tachycardia, sinus, persistent (no rate under 90 BPM) |
| 02.2 (22) | Tachycardia, paroxysmal, nodal |
| 04 | Atrial premature contractions |
| 05 | Nodal premature contractions |
| 06 | Ventricular premature contractions |
| 06.1 (61) | Multifocal PVC's |
| 11 | Sinus arrhythmia, marked |
| 12 | Wandering pacemaker |
| 30 | Low amplitude or isoelectric T-waves |
| 31 | Notched T-waves |
| 32 | Inverted T-waves |
| 40 | Ischemic |
| 41 | "J" junctional |
| 99 | Normal (a "00" coding on the Fleck Coding List) |
| 00 | No other codings listed |

02.2 and 06.1 on the Fleck Coding List are computer coded as 22 and 61 respectively as indicated by the number in parentheses.

# AN EXERCISE PRESCRIPTION INTERVENTION PROGRAM WITH PERIODIC ERGOMETRIC GRADING

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## INTRODUCTION

Among the functions of the Kelsey-Seybold cardiopulmonary testing laboratory at the NASA Manned Spacecraft Center has been the organization and administration of a program of physical and cardiovascular training for executive personnel utilizing periodic ergometric grading for testing purposes and an individual exercise prescription program for training purposes. This program was offered Manned Spacecraft executive personnel on a basis of existing evidence indicating physical and psychologic benefits from maintenance of an adequate state of physical conditioning and to further test this hypothesis by long-term followup studies. While it has been demonstrated that increases in degree of physical conditioning and maintenance of such can be obtained in population groups of this sort with supervised exercise training three to four times weekly,[1] an individual program based on exercise prescription involving simple types of exercise seemed more practical for the busy executive. The present study tests the feasibility of such a program. The possible benefits are tested by noting concurrent changes in medical status derived from the subject's extensive annual medical examination. The more difficult problem of epidemiologic effects is being studied by long-term followup of this group of subjects.

Initially 243 NASA Manned Spacecraft Center executives entered the program. All were clinically well and free from clinically detectable cardiovascular disease at time of entry. This population group was obt...

* NASA Manned Spacecraft Center and Kelsey-Seybold Clinic

TABLE 1

TABULATION OF POPULATION UNDER STUDY, SELECTION AND ACCEPTANCE OF INVITATION BY GRADE LEVEL

| GRADE LEVEL: | POPULATION UNDER STUDY | SELECTED FOR INVITATION | ACCEPTED INVITATION | % OF SELECTED TO NUMBER INVITED |
|---|---|---|---|---|
| AD | 34 | 33 | 11 | 33 % |
| 16 | 29 | 27 | 12 | 44 % |
| 15 | 284 | 212 | 145 | 68 % |
| 14 | 533 | 169* | 80 | 47 % |
| TOTAL: | 880 | 441 | 248 | 56 % |

Total CSC population at the start of the program was approximately 4, 500.

* The total list of GS14 were not invited at the beginning, but were added later as space became available.

by screening the medical records of NASA employees at the GS-14 Level and above and sending invitations to participate in the program to those whose clinical record revealed no evidence of overt cardiovascular disease. All participants are men. As indicated in Table 1, 441 men were invited to enter the program, 248 accepted the invitation but only 247 have actually participated. This represents approximately 56% of those invited and may well introduce some bias into the study when epidemiologic results are considered since it may well be that those executives least interested in exercising did not accept invitation and vice versa. The program is a continuously on going one and when vacancies have occurred through transfer etc, new subjects are added, so that the number of participants is maintained at 240 to 250. Table 2 illustrates the age distribution of the participants.

## METHODS AND PROCEDURES

The basic plan of the executive physical conditioning program is one of quarterly ergometric testing to determine level of physical training and the prescription of an individual exercise program by the exercise physiologist at the time of testing. The participant then carries out his own individual exercise program and on each subsequent testing reports to the exercise physiologist the degree of which he has been adhering to his prescription. The initial testing evaluated the status of subjects at entry into the program and subsequent tests determine changes which have occurred from a consistent exercise program or lack of a consistent program.

Ergometric testing is done on appointment basis at the subject's convenience. Upon arrival at the cardiopulmonary laboratory the subject is greeted by the exercise physiologist, signs a participants agreement form and

TABLE 2

ACTIVE NASA EXECUTIVES IN THE CARDIOPULMONARY STRESS TESTING PROGRAM

By Age Groups and Executive Grade Levels :

| AGE | GRADE LEVEL | | | | TOTAL |
|---|---|---|---|---|---|
| | 14 | 15 | 16 | AD | |
| 30 years or lower | 2 | 1 | 0 | 0 | 3 |
| 31 to 40 years | 45 | 80 | 2 | 1 | 128 |
| 41 to 50 years | 13 | 70 | 11 | 9 | 103 |
| 51 to 60 years | 4 | 5 | 1 | 1 | 11 |
| 61 years + | 0 | 1 | 0 | 1 | 2 |
| TOTAL: | 64 | 157 | 14 | 12 | 247 |

changes into gym attire. After dressing, height and weight are recorded. A timed vital capacity (FVC) is performed using an Electro-Med 780 Spirometer and a 787 Pulmodigicomp. The values of the FEV 1.0 sec. FVC, PF, FEV 1.0 sec/FVC x 100 are recorded. The attending physician then reviews the health record maintained at the NASA Manned Spacecraft Center Dispensary and attention is given to recent intake of medications, foods or stimulants that might modify the performance and particularly to recent illness or infections. A standard 12-lead electrocardiogram is made and is reviewed by the physician prior to testing. Electrodes for the exercise portion of the test are applied and blood pressure monitoring equipment is placed on the left arm. Electrocardiogram, heart rate, blood pressure and respiratory rate are recorded. The respiratory rate is recorded by impedance pneumography. The subject then stands, and measurement of these parameters are made immediately and after standing one minute.

During the exercise period the subject's electrocardiogram is continuously monitored on a oscilloscope and frequent tracings are taken. The exercise electrodes are fluid column type developed for the Gemini series.[2] The electrodes are filled with Sanborn Redux paste and applied to the skin, which has been decornified with emory cloth (180 grit) in order to achieve an impedance level below 5 kilohms. A bioplar (CM5) ECG lead system with the ground electrode in the RC5 position are used durirg exercise.[3] Blood pressure is measured on demand using a NASA-Gemini piezoelectric crystal microphone and integral amplifier placed directly over the brachial artery under the distal edge of a standard size adult blood pressure cuff. The cuff is inflated by an automatic pump (E&M Instrument model 610). The output of a Gemini blood pressure signal conditioner is displayed with a Clevite Brush model 260 recorder for a range of 0-250 mm Hg.[4]

TABLE 3

## CONTRA-INDICATION TO STRESS TESTING DURING PRE-EXERCISE EVALUATION

1. Reclining heart rate greater than 120 per minute
2. Reclining systolic blood pressure greater than 170 mm Hg.
3. Reclining diastolic blood pressure greater than 110 mm Hg.
4. Reclining respiration rate greater than 40 per minute
5. Significant changes in E. C. G.

The test is started by a signal from the Collins automatic programmer and the participant is instructed to start pedalling the bicycle ergometer at a rate between 60 and 70 revolutions per minute. At the onset of the exercise, the exercise physiologist or physician instructs the subject to keep attendants informed concerning any problems that develop, especially chest pain, arm pain, leg fatigue, light-headedness, nausea, dyspnea, syncope, or anything that might interfere with his testing. If is appears that he might not be able to complete the test, he is requested to signal so that final measurements can be made prior to stopping exercise.

The exercise test is performed with a Morehouse-Collins heart-rate controlled bicycle ergometer.[5] The subject's heart rate is controlled at levels of 100, 120, 140 and 160 beats/minute in steps of 5 minutes. A 23 minute protocol was used in early tests but was later shortened to 20 minutes. Electrocardiogram, blood pressure and respiration rate are recorded at both the peak workload and the end of each step. Collection of the subject's respiratory gases are made at the end of each step for measurement of oxygen consumption. With a noseclip in place the subject breathes into an open system attached to an unidirectional modified Otis-McKerrow valve into a 200 liter Douglas bag. The gases are pumped out of the bag through a drying chamber at a constant rate of 50 cc/minute by a portable sampling pump (Beckman model Y-101) into an infared carbon dioxide analyzer (Beckman model IR-215) and paramagnetic oxygen analyzer (Beckman model E-2) connected in series. The volume of the Douglas bag is measured in a Tissot gasometer, and oxygen consumption, carbon dioxide production and respiratory quoteint are calculated.

Immediately following the 20 minute exercise period the subject rests for five minutes in the supine position. Recordings of electrocardiogram,

TABLE 4

## TERMINATION POINTS ON STRESS TESTING

1. Muscular fatigue or exhaustion
2. Significant rhythm disturbances on E. C. G.
3. Ischemic ST changes
4. Progression of chest discomfort
5. Breathlessness
6. Lightheadedness
7. Pallor or other significant skin changes
8. Failure of heart rate to respond to work
9. Abrupt fall in blood pressure
10. Heart rate greater than predicted for age
11. Systolic B. P. greater than 240
12. Diastolic B. P. greater than 130

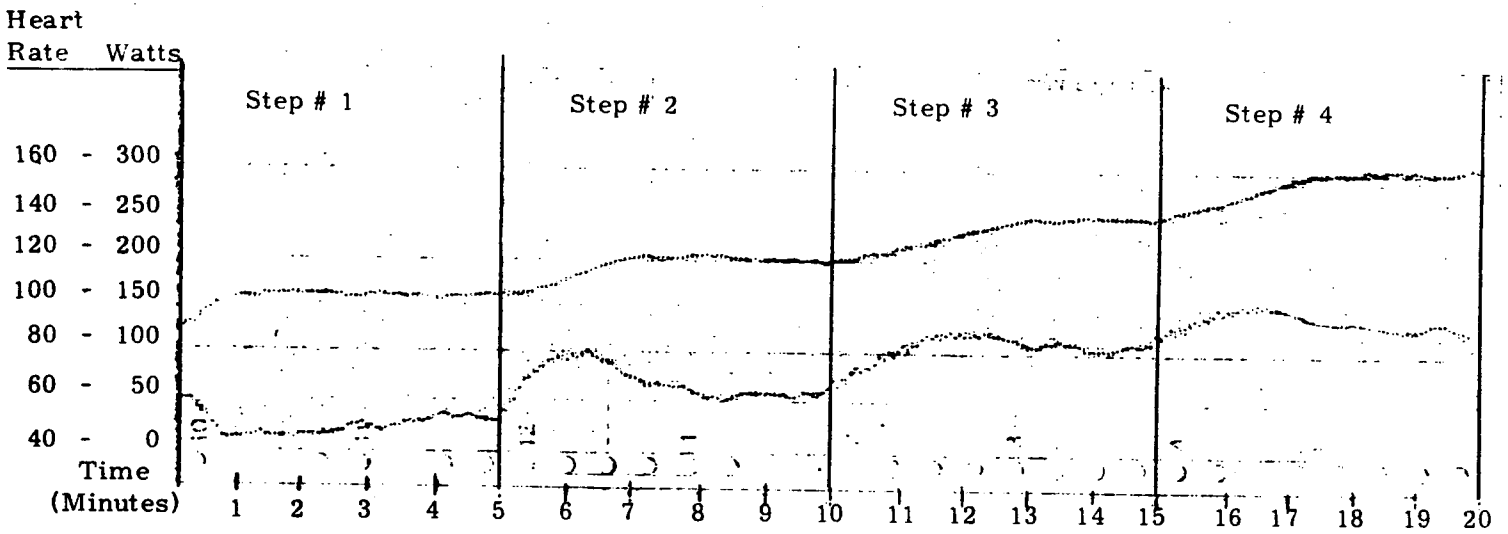
heart rate, blood pressure and respiration rate are made at intervals of two minutes and five minutes post-exercise. At the end of this period the subject is asked to stand quietly and these parameters are again measured both immediately and one minute later. After the subject showers and dresses, the exercise physiologist explains the test results to him and he is advised on a personal exercise program.

Table 3 lists factors from the physician's pre-exercise evaluation of the subject considered as contraindications to proceeding with the exercise test. It was apparent early in the program that in order for the program to be successful and safe, certain guide lines for termination of exercise tests would be required. These are listed in Table 4. Subjects are instructed to stop the test at any time they feel any unusual sort of discomfort, and the attending physician terminates the test at any time he is suspicious of any possible adverse effects. A DC-defibrillator and emergency cardiac resuscitation kit are available at all times, but to date have not been used. Figure 1 illustrates a typical test procedure of the submaximal type, which is the standard procedure done. Subjects under 40 years of age who have successfully completed three standard testing procedures and who have been training for one year are offered the opportunity to perform a maximal type test. In this procedure the exercise level is carried to maximal voluntary effort, which has seemed to approximate maximum pulse rate attainable for age and to approximate maximum oxygen consumption. The maximum response is obtained by programming the ergometer control to a pulse rate of 190 at the end of the standard test. Following the periodic test an exercise prescription is derived after conference with the subject and is recorded on a form for him. Various mo-

FIGURE 1

STRIP CHART RECORDING HEART RATE AND WORK RATE

CHART NO. I




| | | | | |
|---|---|---|---|---|
| Accumulated work units (W. U.) | 215 | 806 | 1735 | 2943 |
| Work units per step | 215 | 591 | 929 | 1208 |
| Watts per step ( $\frac{\text{W. U. x 34}}{300}$ ) | 24 | 67 | 105 | 137 |
| KgM per step ( Watts x 6. 1 ) | 146 | 409 | 641 | 836 |

( 1 vertical line = 1. 6 min )

Preset heart rates ---------- 100 - 120 - 140 - 160

Actual heart rates from ECG at end of steps --------- 104 - 117 - 137 - 160

of exercise are used, but the majority of the subjects seem to prefer running. The level of exercise recommended does not exceed the intensity attained during the laboratory tests as judged by pulse rate. Frequency of training periods recommended has been a minimum of three periods weekly.

Recommendation is based on the individual's response to the exercise test. If no contraindications are present a maximum heart rate of 150 is suggested for the first three months. In the age groups under study this exceeds 70 percent of maximum pulse rates attainable, a level which has been demonstrated to be effective in cardiovascular conditioning. It is recommended that the individual maintain this heart rate for 5 minutes at the end of one month, 10 minutes at the end of two months and 15 minutes at the end of three months. The continuous exercise is preceded by 15 minutes of warming up. A ten minute musculoskeletal warm up consists of flexibility type exercise and a cardiovascular phase of warm up is based on interval training, i.e., run-walk.

The individual is given a card on which to record his exercise. He is encouraged to take his heart rate before he starts exercise, immediately following his longest period of exercise and after two minutes recovery. The pulse is counted for 10 seconds and multiplied by 6. The heart rate in two minutes should be below 120. If it is not he should decrease the intensity of exercise to lower the maximum heart rate. Recommendation on subsequent tests depends on the individual's response to training. A standard recommendation is illustrated in figure 2.

## RESULTS

The NASA Manned Space Craft Center Executive Physical Conditioning Program has now been in existance for slightly over two years. Initial

FIGURE 2

TYPICAL EXERCISE PRESCRIPTION

| | |
|---|---|
| **MODE:** | Running |
| **DURATION:** | 30 Minutes |
| **FREQUENCY:** | 3/per week |
| **HEART RATE:** | 10 Minute warm up exercise |
| **COMMENTS:** | 5 Minutes run,walk<br>10-15 Minutes continuous running at heart rate approximately 150 beats per minute. |

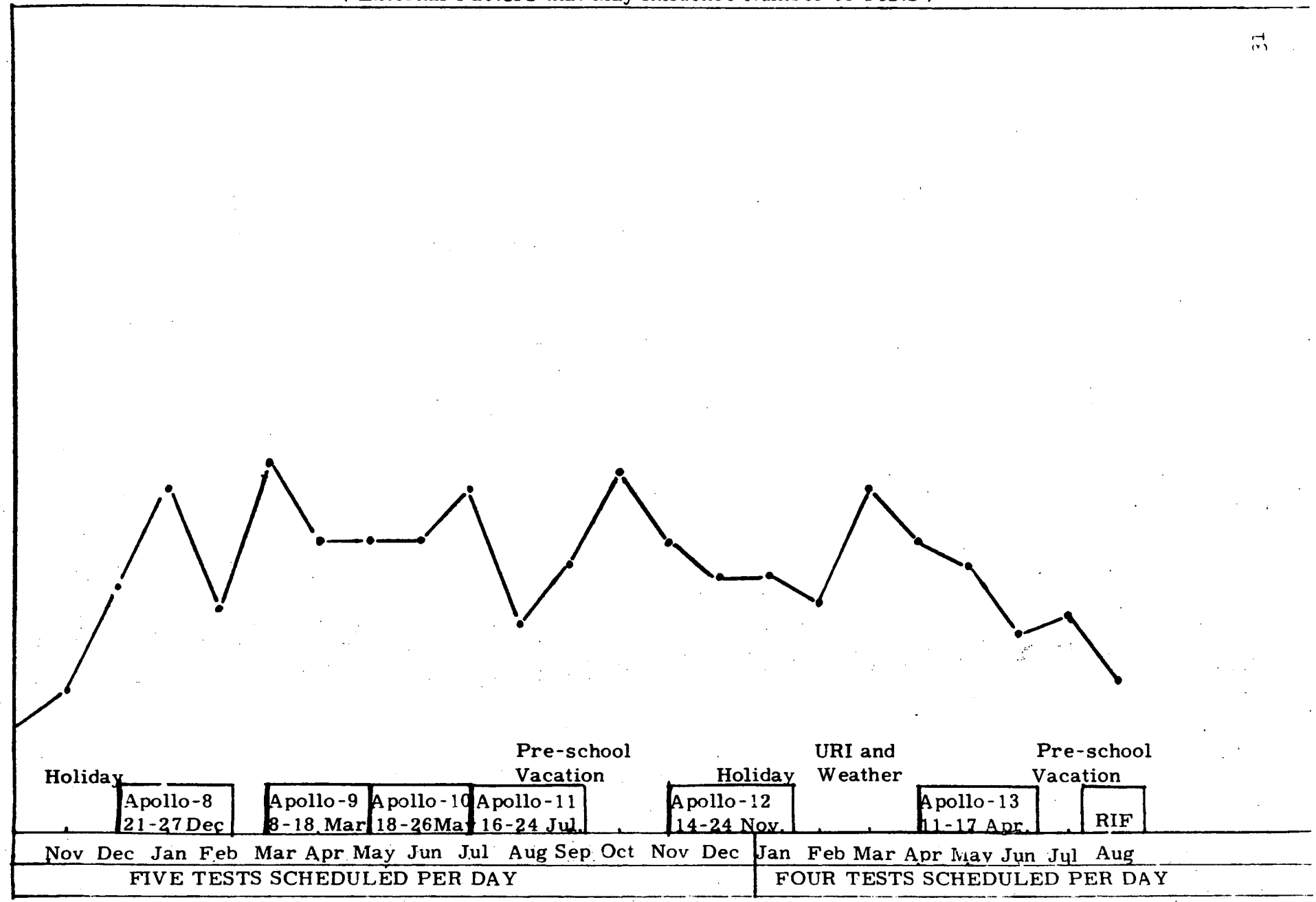
TABLE 5

STRESS TESTS PERFORMED ON NASA EXECUTIVES DURING THE PERIOD
01 November 68 thru 30 April 1970

By month and test number

| DATE of TEST | #1 | #2 | #3 | #4 | (4-M) | #5 | (5-M) | #6 | (6-M) | #7 | (7-M) | Special | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nov. 68 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | |
| Dec. 68 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | |
| Sub-total | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77 | |
| Jan. 69 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 68 | |
| Feb. 69 | 28 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 | |
| Mar. 69 | 39 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 74 | |
| Apr. 69 | 17 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | |
| May 69 | 9 | 42 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | |
| Jun, 69 | 3 | 31 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | |
| Jul. 69 | 4 | 20 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | |
| Aug. 69 | 2 | 8 | 30 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | |
| Sep. 69 | 24 | 7 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 54 | |
| Oct. 69 | 10 | 7 | 20 | 36 | (12) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 73 | (12) |
| Nov. 69 | 7 | 7 | 12 | 32 | (18) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58 | (18) |
| Dec. 69 | 3 | 9 | 15 | 19 | ( 7) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | ( 7) |
| Sub-total | 214 | 224 | 170 | 89 | (37) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 697 | (37) |
| Jan. 70 | 3 | 15 | 9 | 19 | ( 7) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | ( 7) |
| Feb. 70 | 0 | 5 | 4 | 13 | ( 3) | 19 | 0 | 0 | 0 | 0 | 0 | 2 | 43 | ( 3) |
| Mar. 70 | 1 | 3 | 4 | 12 | ( 3) | 26 | ( 4) | 1 | 0 | 0 | 0 | 20 | 67 | ( 7) |
| Apr. 70 | 1 | 6 | 10 | 18 | ( 5) | 16 | ( 4) | 0 | 0 | 0 | 0 | 5 | 56 | ( 9) |
| Sub-total | 5 | 29 | 27 | 62 | (18) | 61 | ( 8) | 1 | 0 | 0 | 0 | 27 | 212 | (26) |
| GRAND TOTAL: | 296 | 253 | 197 | 151 | (55) | 61 | ( 8) | 1 | 0 | 0 | 0 | 27 | 986 | (63) |

FREQUENCY DISTRIBUTION OF TESTS BY MONTH
( External Factors that May Influence Number of Tests )



acceptance was quite good. As mentioned previously, 56% of those invited accepted the invitation to join the program in spite of the fact that no coercion or persuasion of any type was used. It was emphasized that the program was voluntary, that the long-term results of maintenance of good physical conditioning were unknown, and merely that the program was available for those who did wish to participate. Continued participation in the periodic testing portion of the program has also been quite good. Well over 1250 periodic ergometric tests have now been performed. Table 5 illustrates the distribution of ergometric tests by test number performed through April 1970. The number of tests performed monthly on an appointment basis has been influenced by external factors which alter the subject's availability such as holiday and vacation periods, epidemics of respiratory infection and activities associated with manned space craft flights. This is illustrated in Figure 3. The number of subjects withdrawing from the program illustrated in Table 6. It will be noted that there was an overall 22% attrition but a portion of this was from subjects leaving the Manned Space Craft Center. Of those subjects remaining at the Manned Space Craft Center only approximately 18% withdrew from the program. Most withdrawals from the program were in the initial phases (test 1 or test 2). As previously mentioned, all vacancies from withdrawals are filled by other subjects who are on a waiting list to participate.

Participation in the training portion of the program has been considerably more variable. Overall adherance to exercise prescription has been graded on a basis of good, fair, and poor as assessed by the subject's report to the exercise physiologist at each periodic testing. On this basis subjects who have completed at least the first three periodic tests without premature

TABLE 6

PARTICIPANTS WHO WITHDREW FROM PROGRAM BY NUMBER OF TESTS (NUMBER OF PARTICIPANTS 248)
November 1, 1968 thru June 30, 1970

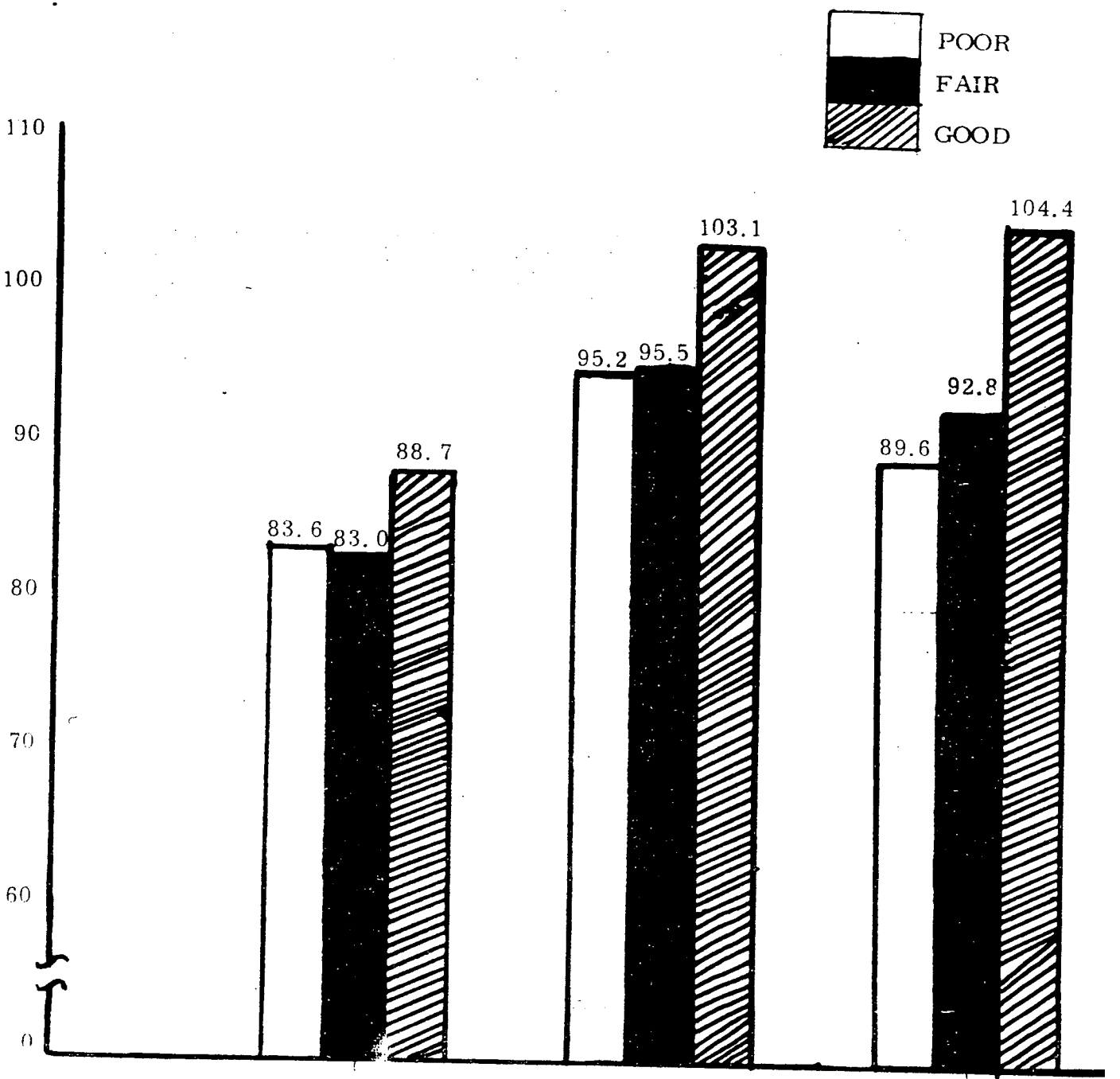
| | TEST# 1 | TEST# 2 | TEST# 3 | TEST# 4 | TEST# 5 | TOTAL |
|---|---|---|---|---|---|---|
| PARTICIPANT STILL AT NASA, MSC. | 18 | 17 | 5 | 3 | 2 | 45 |
| PARTICIPANT NO LONGER AT NASA, MSC. | 5 | 1 | 0 | 1 | 3 | 10 |
| TOTAL WITHDRAWALS | 23 | 18 | 6 | 4 | 5 | 56 (22%) |

test termination (120 subjects) are currently graded good 29 (24%), fair 36 (30%), poor 55 (46%). The overall participation in the individual training portion of the program has also varied from month to month depending on external influences and to some extent the participation by each given individual has varied in the same manner.

The level of physical conditioning obtained is assessed in two ways, firstly, the external work required to reach a pulse rate of 160 during the standard test and secondly the maximum oxygen uptake attainable in those subjects having maximal voluntary effort studies. As illustrated in figure 4, those subjects adhering closely to their exercise prescription program were able to produce a significant average increase of 16% in the work done to reach pulse rate 160. It appears in general that the greatest increment in improvement occurred in the first three months period of participation. While it is too early to assess any possible epidemiologic effect on disease incidence, it is interesting to note that in the first two years no subject has developed either myocardial infarction or angina pectoris. Only one subject has developed a positive ischemic pattern in the exercise and post-exercise electrocardiogram and this has been present only in the sitting position, disappearing in the supine post-exercise electrocardiogram. We are not certain of its significance but the subject is continuing to participate.

In general there have appeared to be other indirect beneficial effects of the program. While psychologic testing has not been done as in some supervised studies,[1] most subjects have reported an increased feeling of well-being when they do exercise and have reported lessening fatigue. Participation in the program has also seemed to increase the individual's attention to other aspects of cardiac hygiene and health maintenance such

FIGURE 4


POOR
FAIR
GOOD
110
100
90
80
70
60
0
AVERAGE WATTS/MIN.
83.6
83.0
88.7
95.2
95.5
103.1
89.6
92.8
104.4

as avoidance of obesity, more sensible living habits and in some cases cession of smoking. Some of these secondary effects may somewhat cloud the effect of exercise as an isolated variable on epidemiology in this particular program.

## DISCUSSION

From the present study it does appear that a nonsupervised individual exercise prescription type of physical training program is feasible for executive population groups. Acceptance and participation in the periodic testing phase has seemed to be excellent. The withdrawal or dropout rate has been quite low in the first two years of the program. In this respect this type of program probably compares favorably with scheduled and supervised types, particularly when subjects are apparently otherwise normal and not cardiac rehabilitation or post-myocardial infarction patients. It would appear that the major difficulty in the unsupervised type of program is in the individual training portion. Motivation factors seem less intense than in supervised, scheduled type programs but, of course, vary markedly between individuals. Lack of understanding and directions is partially obviated by using pulse rate control during the training sessions. The unsupervised program allows more flexibility in mode of exercise but does not supply the facility for exercise inherent in most supervised programs. It does appear, however, that those who adhere to exercise prescriptions as outlined can achieve and maintain a satisfactory degree of conditioning. Furthermore, it is not known with certainty the degree of conditioning necessary to have beneficial effects in forestalling the development of degenerative vascular disease if such effects do indeed exist.[6] It is hoped that long-term results of the present study may make

some minor contribution to this overall problem.

As mentioned previously, the selection of subjects for the present study may have engendered some bias, in that those executives who were most sedentary and least interested in physical exercise simply may not have responded to the invitation to join the program. However, the demonstrated low average level of conditioning on the first ergometric test would seem to indicate that subjects were not, on an average, vigorous exercisers on entering. On the other hand no attempt was made to limit entry into the program to sedentary unconditioned subjects only.

In the present study no attempt has been made to limit or hold constant other variables in order to demonstrate only independent effects of exercise. In fact, subjects have been encouraged to alter other coronary risk factors present and to follow other principles of good preventive cardiology, since the purpose of the present program is primarily a service one to supply the executive with needed testing and advice as he pursues his individual conditioning exercises.

## SUMMARY & CONCLUSIONS

A long-term exercise prescription type of physical conditioning program has been available to executive personnel of the NASA Manned Spacecraft Center for the past two years. Periodic ergometric testing with a heart rate controlled, automatically programmed, bicycle ergometer is used to follow the individual's progress and appropriately alter his exercise prescription from time to time. Such a program appears feasible, and acceptance is excellent, dropout rates small and periodic testing participation good. Adherence to the training portion has been somewhat inconsistent.

Subjects training diligently can maintain satisfactory levels of conditioning but results in this respect seem more variable than those in supervised scheduled programs. Analysis of results of such conditioning is continuously on going.

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N73-17068

# MEDICAL AUTOMATION SYSTEM AT THE MARSHALL SPACE FLIGHT CENTER

James H. Spraul, M.D.
Medical Director
MSFC Medical Center

The long awaited marriage between the technology of the mathematicians in the invention and utilization of the computer and the medical profession has been very slow in its consummation. Many bashful bridegrooms have been found waiting in the wings for a bride who never materialized. A sort of shotgun wedding has occurred between these two at the Marshall Space Flight Center. It is labeled a "shotgun wedding" because necessity was the moving force behind this effort. Faced with a closed population of nearly 6,000 to be examined, cataloged by organization and occupation, and a desire to preserve the health and talents of these highly trained, intelligent, technical people at the NASA Marshall Space Flight Center, the relatively small medical complement was forced to share the computation ability of the very technical engineers it served in order to meet their needs. The very nature of the work done at this Center required a large variation in the types of examinations to be done for the different groups of people who were working with chemicals, lasers, x-ray, isotope sources, toxic fuels, adhesives, and exotic metals. This caused great problems in the scheduling of these people accurately. Since almost 5,000 complete physical examinations per year were performed on this population the tremendous amount of medical data generated was easily foreseen. It became increasingly clear, also, that the problem of keeping



D

# EMPLOYEE NOTIFICATION CARD

DOE, JOHN H. PAYROLL - NO. XXXXX
PM-SAT-G BUILDING NO. 4201

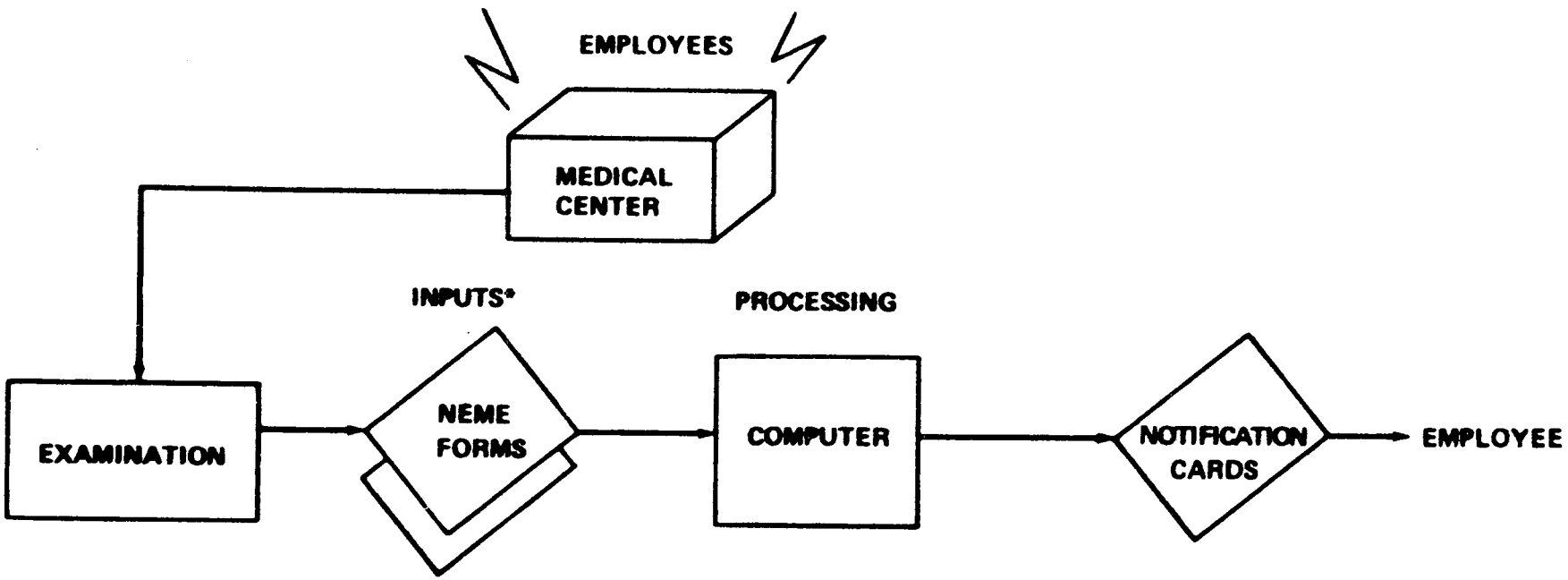
YOU ARE SCHEDULED FOR THE FOLLOWING MEDICAL EXAMINATION/S
PERIODIC AGE OVER 45

REPORT TO THE MEDICAL CENTER, BLDG. 4249 .....
IF YOU WILL NOT MEET THIS APPOINTMENT CALL 453-2390 NOW

Figure 1

up with the scheduling of examinations on the date they were due in the face of additions and deletions from the population, transfers within the population, and changes in job status would require automation. Attempts to handle the scheduling of these examinations manually ended up with long lists of names which were color coded with 4 or 5 different colored check marks, x's, zeros and others. It is easy to imagine what would have happened to a color-blind clerk trying to work with this type of data. It is also easy to see the complexity of trying to manually update this list in the face of job changes, transfers, retirements, etc. The first step in developing a medical automation system, then, was to input to the computer the scheduling master information contained in the old manual lists in computer language rather than in the many colors and symbols and handwritten dates of examination. The programs were, therefore, written and entered into the computer with all the necessary information to divide the population into age groups, organizational groups, and occupational groups (Fig. 1). The type of examination to be done was coded in, and the periodicity, the date of notification for examination, the date of the last actual examination, and the parameters were entered to allow the computer then to enter the date of the next examination. Utilizing this scheduling master, the Medical Center now receives from the computer center a deck of notification cards every two weeks. These cards contain the name, type of examination, and the address of those people due to be examined within that period (Fig. 2).

# I. SYSTEM OVERVIEW




*FORMS - NEME - NASA EMPLOYEE MEDICAL EXAMINATION FORM, CSC - FORM NO. PU -97-67

Figure 2

To update this scheduling master we utilized a single form. Each day all completed charts on examinations, emergency room visits, consultations and follow-ups go to the clerk who enters the medical unique number (a number which only the Medical Center can link with the employee's name), the date of examination, the type of examination, and other data necessary to create the new scheduling master which is always current. From this neme form, cards are punched which are then utilized with the most recent Marshall Center personnel file information to create the scheduling master report (Fig.3). Other data such as an employee cross-reference report, the notification cards, and the new scheduling master are the outputs of this computer effort. It is interesting to note that the response to computer cards is good. Employees receiving these cards consider them to be rather official and react to them without offering the excuses they would normally offer to the telephone caller.

The advantages of this system to the Medical Center are, then:

1. Minimal Medical Center effort in scheduling and notification. We now have a one-line entry on the neme form on each examination performed, and notification cards are automatically sent to us in a pre-printed form. The important thing here is that the computer accurately and on time delivers to us those people's names who need to be examined at the proper time with the proper address.

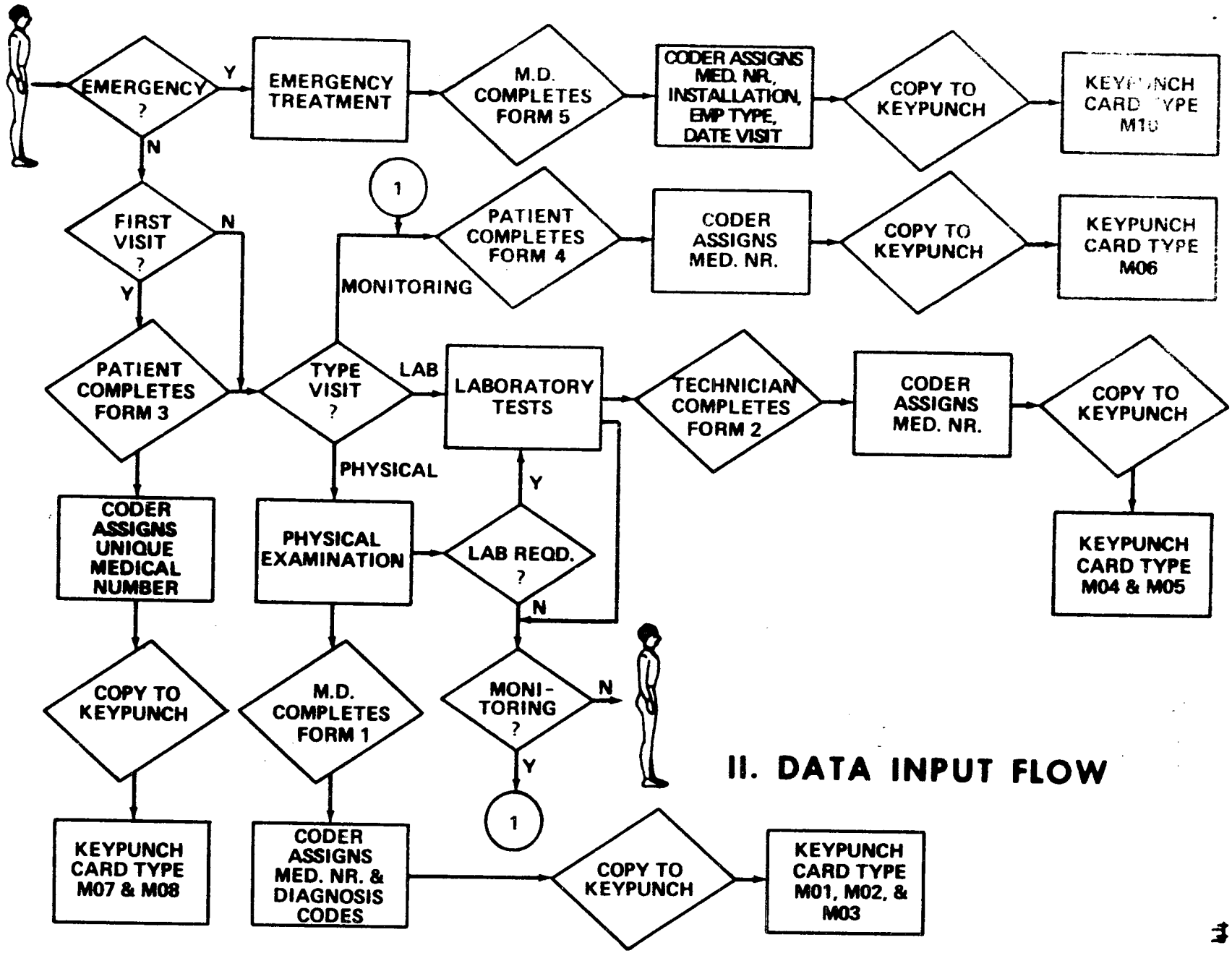

EMERGENCY ?
Y
EMERGENCY TREATMENT
M.D. COMPLETES FORM 5
CODER ASSIGNS MED. NR, INSTALLATION, EMP TYPE, DATE VISIT
COPY TO KEYPUNCH
KEYPUNCH CARD TYPE M10
N
FIRST VISIT ?
N
Y
1
PATIENT COMPLETES FORM 4
CODER ASSIGNS MED. NR.
COPY TO KEYPUNCH
KEYPUNCH CARD TYPE M06
MONITORING
PATIENT COMPLETES FORM 3
TYPE VISIT ?
LAB
LABORATORY TESTS
TECHNICIAN COMPLETES FORM 2
CODER ASSIGNS MED. NR.
COPY TO KEYPUNCH
KEYPUNCH CARD TYPE M04 & M05
PHYSICAL
Y
CODER ASSIGNS UNIQUE MEDICAL NUMBER
PHYSICAL EXAMINATION
LAB REQD. ?
N
COPY TO KEYPUNCH
M.D. COMPLETES FORM 1
MONI-TORING ?
N
Y
1
KEYPUNCH CARD TYPE M07 & M08
CODER ASSIGNS MED. NR. & DIAGNOSIS CODES
COPY TO KEYPUNCH
KEYPUNCH CARD TYPE M01, M02, & M03
II. DATA INPUT FLOW

Figure 3

2. Additions, deletions and changes in job titles, addresses, and other employee status changes are automatically entered in the scheduling master, saving much manual time.

3. Work load determinations are automatic. We can plan our schedule as far ahead as we like since we have a master file that tells us what our work load will be for any given period of 12 months.

4. The Medical Center still controls the day-to-day work load by mailing the cards to those numbers of people that we can handle. We still fill in the exact date we want to see the patient. This is important in working around holidays, vacations and Medical Center obligations in areas other than the examination program.

5. We can see easily just where we are on the schedule. This system has been in effect for three years and appears to be working well.

The natural follow-on to the scheduling master file was, then, a broad medical file. Many times in the past we have felt it necessary to study the results of our examination program to see what the state of health of the Marshall employees really was. It took weeks of work by many people to go through 6,000 or 7,000 charts picking out data and tabulating this data. It was apparent that properly designed physical examination forms and laboratory forms would allow us to directly key punch to the

# IV. OUTPUT CAPABILITIES

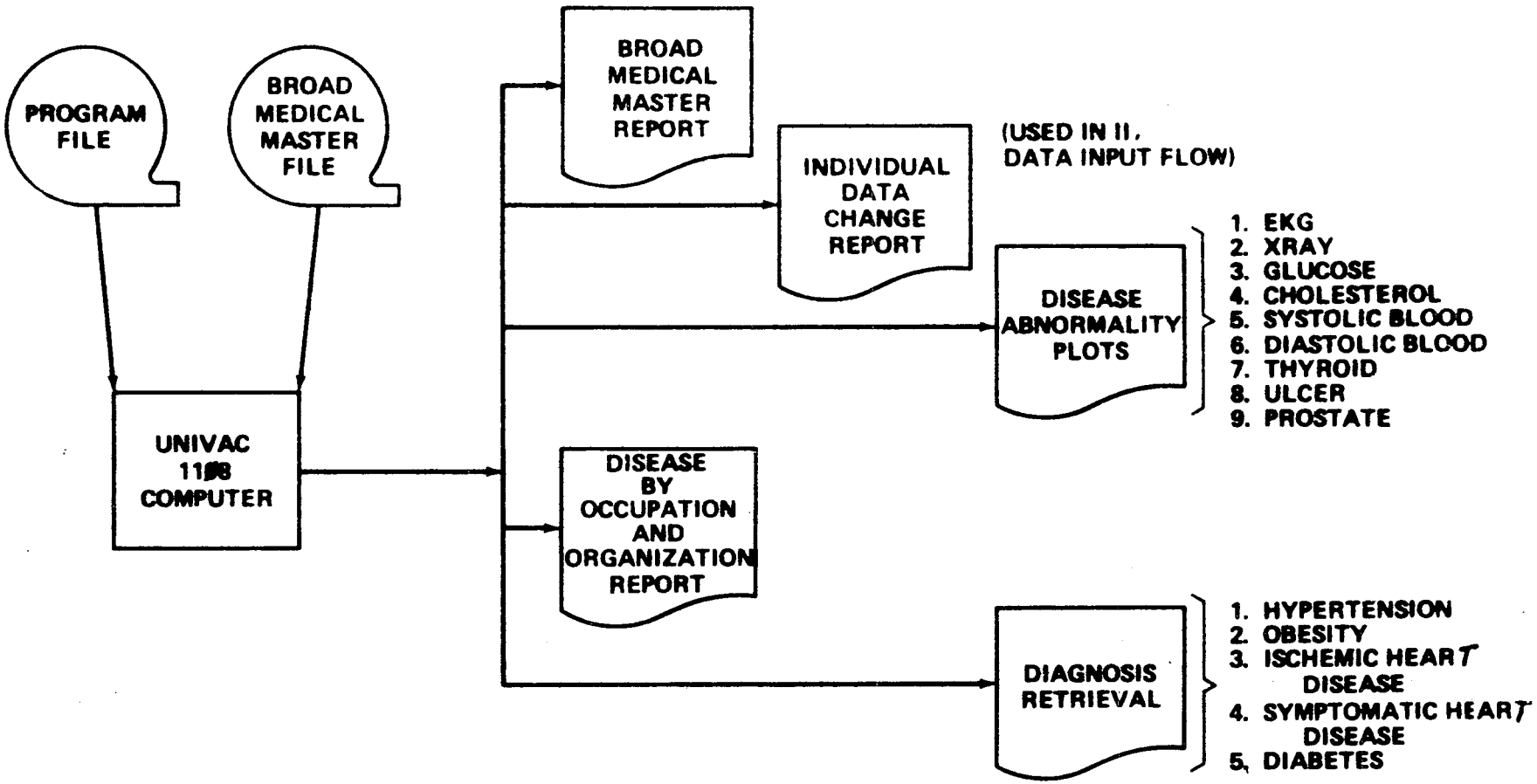


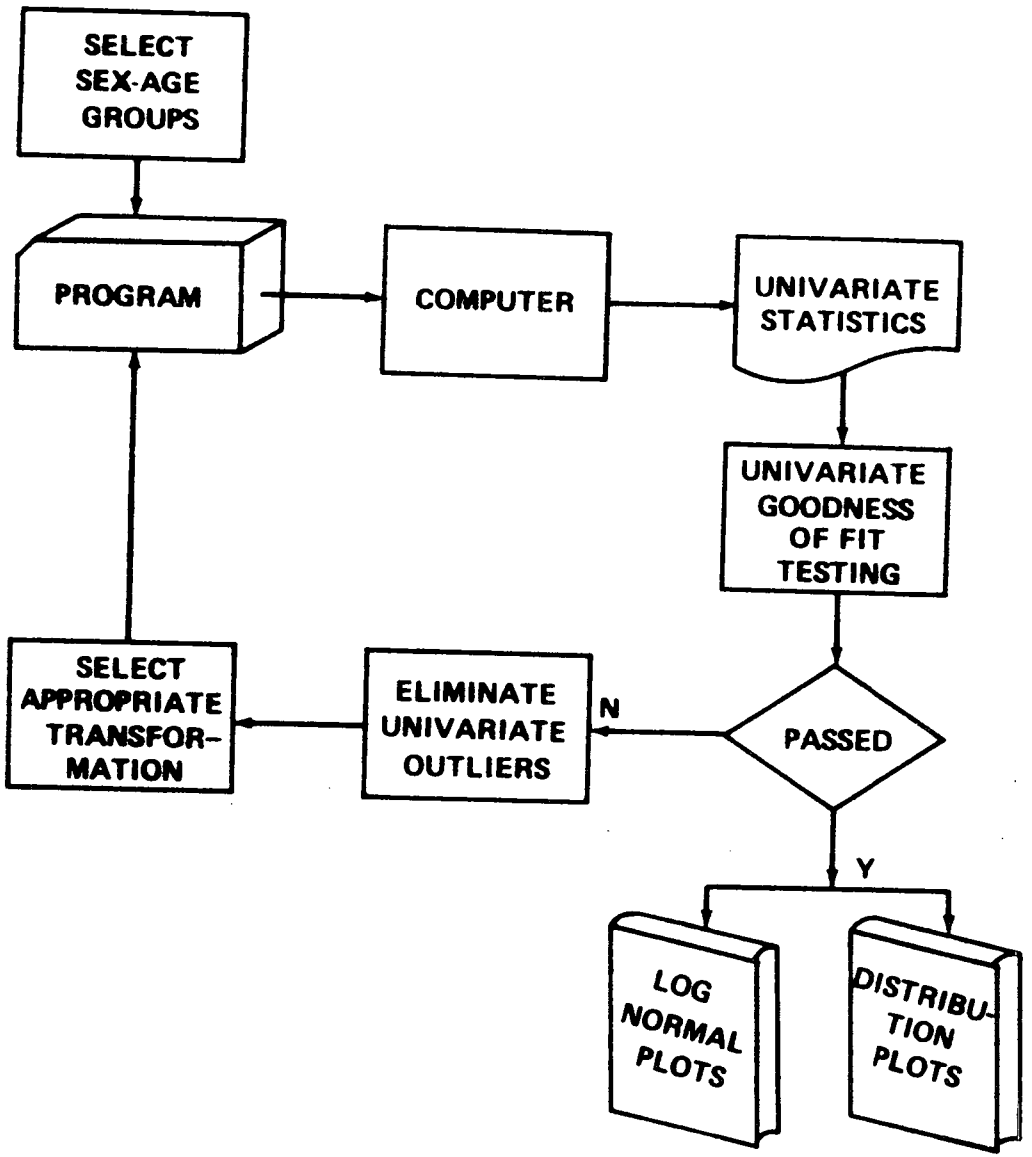

Figure 4

computer all of the data contained in the physical examination. Again utilizing the medical unique numbers to preserve confidentiality, we designed forms that could be copied, deleting the name and all other identification, and placing the unique number on it. To create the broad medical master tape we now copy all lab, x-ray, EKG, history and physical examination forms, and these are key punched directly from our medical forms (Fig. 4). We have then complete medical data on our population, and it is now relatively simple to ask the computer to summarize the data in any form we request by sex, age, occupation, or organization (Fig. 5). The broad medical file is continuously updated. From this broad medical master file requested analyses as to state of health of the Marshall population can now be made, and now that we have 2 or 3 examinations on our employees it will be more and more valuable to us to be able to look at progressive changes in the health status of these employees. The progress of disease can be followed better than ever before. Our efforts to accomplish this follow-on utilizing a mathematical model of health are continuing, and the preliminary results are beginning to be studied.

Many statistical techniques are used in the univariate and multivariate analyses necessary to make meaningful studies in a mathematical model. We see this as a 5-year study, and it is premature to say much about it at this time except to show the progress to date. Fig. 6 shows the flow

# IV. STATISTICAL TECHNIQUES

- UNIVARIATE ANALYSIS




EACH VARIABLE WITHIN EACH SEX AGE GROUP CHECKED FOR NORMALITY USING LOG NORMAL PROBABILITY PAPER

Figure 5

# IV. STATISTICAL TECHNIQUES CONT'D

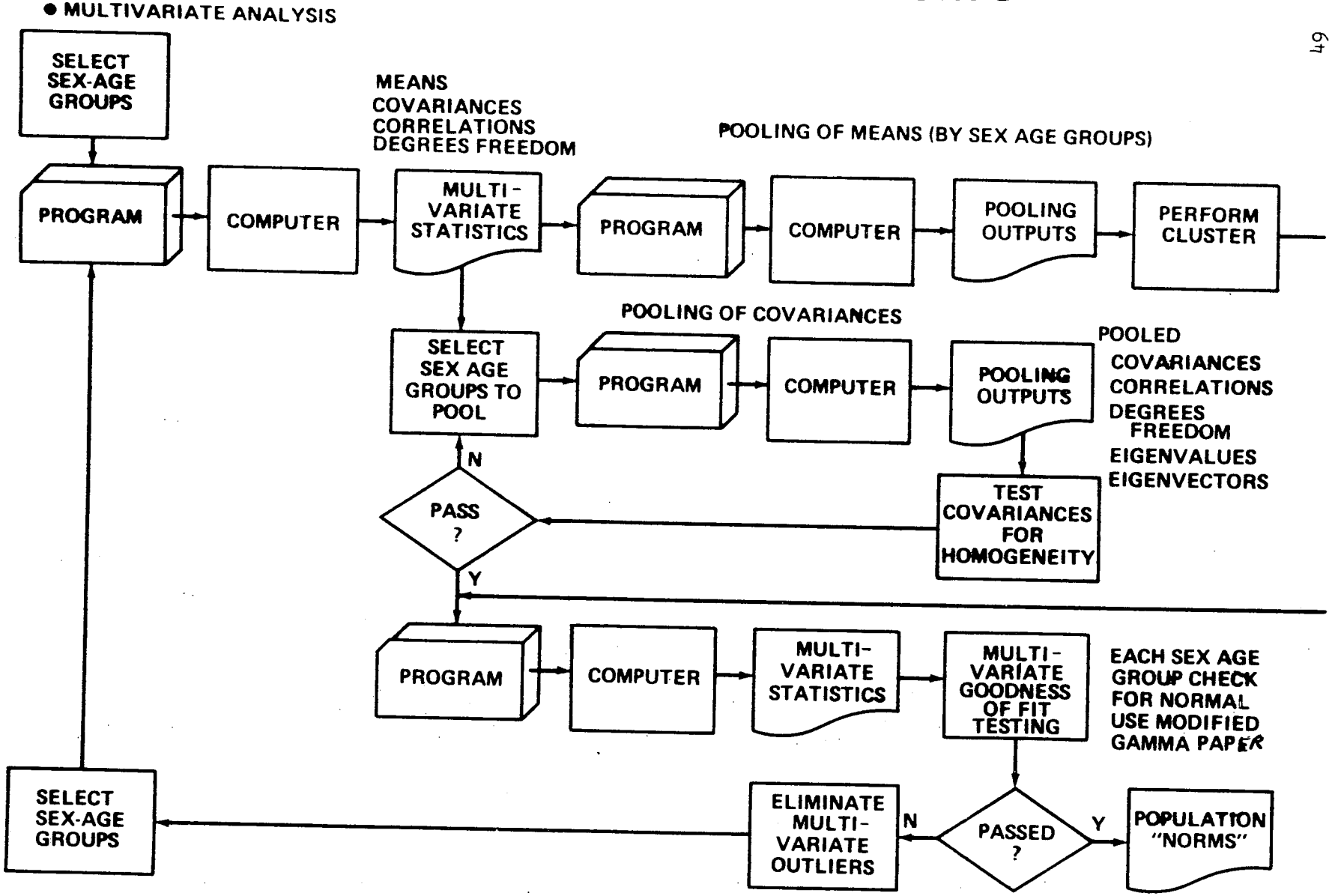



Figure 6

# III. BASIC EXAMINATION CATEGORIES

ALL NASA EMPLOYEES ARE SCHEDULED IN ONE OF THE FOLLOWING CATEGORIES:

PHYSICAL - DIVIDED INTO THREE GROUPS

1. AGE UNDER 31 - 36 MONTH PERIODICITY
2. AGE 31-45-24 MONTH PERIODICITY
3. AGE OVER 45-12 MONTH PERIODICITY

MONITORING

HEARING CONSERVATION } PERIODICITY DETERMINED BY MEDICAL CENTER

EXECUTIVE

SCREENING

Fig. 7

chart on univariate steps at the present, and Fig. 7 shows the flow chart on the multivariate effort at this time. The results of this multivariate study can be described as the plot of a point in space. The location of this point can then be gauged as to its relationship to normal, and drift of this point over a series of several examinations may prove valuable in preclinical detection of heart, kidney, lung or other diseases or disorders. It is to be expected that these disorders would be more amenable to clinical intervention at a preclinical stage than at a more advanced stage.

N73-17069

# PERSONAL BENEFITS OF A HEALTH EVALUATION AND ENHANCEMENT PROGRAM

Fred Heinzelmann, Ph.D.* and Donald C. Durbeck, M.D.*

A study was made of the benefits reported by participants in a health evaluation and enhancement program dealing with physical activity. The program was conducted among employees at NASA Headquarters in Washington, D. C. Program benefits were identified and defined in regard to three major areas: program effects on work; program effects on health; and program effects on habits and behavior. A strong positive and consistent relationship was found between reported benefits in each of these areas and measures of improvement in cardiovascular functioning based on treadmill performance. Significant differences in these measures of improvement were also found between participants who reported program benefits and those persons who did not. These findings provide a meaningful profile of the pattern of benefits generated by this kind of health program.

An association has been found in both experimental and epidemiological studies between physical inactivity and frequency of occurrence of sudden death, myocardial infarction and coronary heart disease.[1,2,3,4] This association has led a number of health professionals to encourage increased physical activity as both a preventive as well as a health enhancing measure.

The present report is based on an organized physical activity program conducted at NASA Headquarters in Washington, D. C. The goals of this program included both disease prevention as well as health enhancement.

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* At the time this study was conducted, the authors were both members of the Heart Disease and Stroke Control Program, Regional Medical Programs, Health Services and Mental Health Administration. Dr. Heinzelmann is now with the National Institute of Law Enforcement and Criminal Justice, Department of Justice. Dr. Durbeck is currently a Fellow in Cardiovascular Disease with the Cleveland Clinic Education Foundation.

## THE NATURE OF THE PROGRAM AND ITS IMPLEMENTATION

The Health Evaluation and Enhancement Program at NASA Headquarters was carried out as a collaborative effort between the NASA Division of Occupational Medicine and the U. S. Public Health Service - Heart Disease and Stroke Control Program. All NASA employees considered eligible for the Program were identified from a payroll listing and included males, age 35-55, with GS pay ratings of 11 or higher, who were directly employed by NASA in the Washington, D.C. area.

These men were notified of the initiation of the NASA-USPHS-Health Evaluation and Enhancement Program by an announcement in the NASA Weekly Bulletin, and by a written invitation to attend a program orientation session. Subject material at the orientation sessions included a general discussion of the Health Program and its objectives; the benefits that could be derived from participation; and the three kinds of physical activity programs available. These programs consisted of: (1) a Stress Lab program involving a circuit of exercise activities such as electronically-paced rowing machines, bicycles, treadmills, etc., (2) a group jogging program and (3) an individual program incorporating an exercise regimen similar to the group jogging program. The participants in all three physical activity programs were expected to exercise for 30 minutes three times a week. The Stress Lab and jogging programs were supervised by physical educators. The individual program was unsupervised.

Volunteers signed up for the Health Program in July 1968, and were asked to provide evidence of consent from their personal physician. Upon receipt of the consent form, each person received a baseline evaluation, consisting of a self-administered medical history and dietary history, chest X-ray, and blood work (CBC with differential, urinalysis, sedimentation rate, two-hour post prandial glucose, fasting cholesterol and triglycerides, uric acid, and creatinine). Anthropometric measurements and a detailed physical examination were also included.

Social-psychological data dealing with the individual's health attitudes, habits and practices were obtained through personal interview and self-administered questionnaires. Special attention was given to the following dimensions: perceived health status and health concern; perceived vulnerability to a heart attack, cancer and stroke, beliefs concerning the specific health actions considered relevant to the prevention of these threats; and behavior patterns dealing with smoking, diet, physical activity, and voluntary medical check-ups. In addition, efforts were made to assess perceived control in regard to illness and health, attitudes toward medical care and medical research, and general attitudes toward heart attacks and physical activity.

Resting EKG, Double Master, and multistage treadmill tests were conducted at the Applied Physiology Laboratory of the Heart Disease and Stroke Control Program at Georgetown University. The treadmill test procedure consisted of a 15-minute exercise phase and a 10-minute post-exercise phase. The exercise phase began with an initial 2-minute

warm-up at 1.5 mph, 0% grade. The speed was then raised to 3 mph. The grade was raised 4% at the end of each 3-minute phase of the test. The subjects were continuously monitored by a bipolar $V_5R$, $V_5L$ lead with a sternal ground.

Upon completion of the baseline evaluation examination, each participant met individually with a study physician to receive an analysis of his examination results, suggestions for risk factor improvement when appropriate, and a more detailed description of each exercise program available. Subjects with positive Double Master tests were excluded from the study. Each participant was entered in the exercise program of his choice, and invited to attend a group orientation session concerning his exercise program. At these sessions, discussion centered around basic exercise physiology, particulars of the program and instructions in taking one's pulse using the carotid artery in the neck. Each participant was checked for accuracy in taking a resting and post-exercise pulse, and was asked to exercise in a heart rate range that was 85% ($\pm$5 beats per minute) of his maximum predicted heart rate, providing he had exceeded that rate during the baseline treadmill test without diagnostic EKG changes. Subjects with positive treadmill tests were given less vigorous programs. Each participant was provided with specific work prescriptions designed to achieve 85% of his maximum predicted heart rate and was told to use his heart rate as his ultimate exercise monitor and goal. Groups of participants were then shown the setting of the exercise program that they had chosen.

## MORE DETAILED DESCRIPTIONS OF THE THREE EXERCISE PROGRAMS

The Stress Lab was developed by NASA Headquarters, Division of Occupational Medicine, and the Bio-Dynamics Corporation. It is a pleasant, well-equipped and convenient place to exercise, located in the sub-basement of one of the NASA office buildings in Washington, D.C. The exercise program is similar to a series of calisthenics done in sequence, arranged in an interval pattern so that each strenuous exercise station is followed by a less strenuous one. Program participants performed the following "circuit" of sequential activities: warm-up, treadmill I, speed bag, bicycle, wall pulley, rope jump, sit-ups, rowing balance beam, treadmill II, medicine ball, and taper off. The treadmill exercises last 3 minutes, the others 90 seconds. After each exercise, the subject took a 15-second immediate post-exercise pulse and recorded this pulse in terms of beats/minute. Prescriptions were written weekly, and were individually tailored so that each subject reached 85% of his maximum predicted heart rate (target heart rate or THR) on the cardiovascular exercises (bicycle, rope jump, rowing, and treadmill II, and 70% of maximum predicted heart rate on the remaining exercises. The subjects were asked to exercise at least three times per week. Each exercise period lasted about 25 minutes. Substitution exercises were provided for make up and travel. The facility was open 8:30 a.m. to 7:30 p.m. each work day and there was no scheduling of activity time.

The jogging program was conducted at the Anacostia Naval Annex, which involved a 10-15 minute drive from NASA Headquarters. Subjects were transported to and from that location twice a day by a combination of government and personal vehicles. Subjects were asked to perform a 3-minute warm-up, and a 2-minute taper off. The jogging program itself consisted of intervals of jogging and walking progressing both in actual time spent jogging and in rate of speed. Subjects took and recorded pulses after the last four jogging periods of the day in a manner similar to that used in the Stress Lab program, and the same heart rate and prescription methods used in the Stress Lab program were used here. Substitutions were provided for make-up periods, weekends and travel.

The individual program was unsupervised, and involved essentially the same exercise program as described for the joggers. However, subjects in this program did have the option of running in place, bench stepping, bicycling, swimming, basketball, and skiing. Each subject was asked to send an exercise record to the study physician weekly. Suggestions and changes were made in the prescription as needed.

A total of 998 men met the eligibility criteria for the Health Program. About one-third of the eligible NASA employees volunteered for the Program and of the 259 men who actually participated, 156 (60%) selected the Stress Lab program, 59 men (22%) selected the jogging program, and 44 men (18%) selected the individual program.

At approximately 12 months after baseline determination, the following parameters were re-assessed: (1) Selected health attitudes and beliefs, (2) cholesterol and triglycerides, (3) cardiovascular and orthopedic history and physical exam, (4) resting EKG and treadmill test, (5) dietary patterns, (6) anthropometric measures, (7) physical activity and smoking patterns and (8) reported program effects in regard to work, health, and health habits and behavior. All participants, regardless of adherence pattern, were strongly urged to take part in the retesting procedure.

The present report will not focus on the physiological effects that were generated as a function of participation in the physical activity programs. These results are discussed in a separate report.[15] However, it is important to indicate that significant changes in measures of cardiovascular functioning were observed. These included improvements in measures of heart rate at a standard workload and the time required to reach a specific heart rate. There were no effects observed in regard to changes in blood lipids. While there were significant changes in skin fold measures, body weight did not change significantly.

Data regarding program attendance are also relevant. While the three exercise programs were not directly comparable, the mean attendance rates were rather similar--averaging about 1.3 days per week. In general, the mean attendance in each of the three programs was about half of that prescribed. During a typical week, about one-half of the participants did not participate at all, about one-fourth exercised one or two days and about one-fourth exercised three or more days.

## PROGRAM EFFECTS ON HEALTH ATTITUDES AND BEHAVIOR

In evaluating a health program, it is important to consider the broad range of effects that may be generated by participation in the program. For example, in addition to the physiological changes that may be produced, it is important to give attention to the effects that program participation may have on health attitudes and behavior. Since previous research has indicated that organized physical activity programs can have significant effects on health attitudes and behavior, special attention was given to a systematic assessment of these variables in the NASA program setting.

After the NASA program had been in operation for about one year (and concurrent with the individual's final medical examination) an assessment was made of program effects on the participants' health attitudes and behavior. A self-administered questionnaire* was used to determine whether or not participants reported any effects or changes in regard to three major content areas:

- Program effects on work
- Program effects on health
- Program effects on habits and behavior

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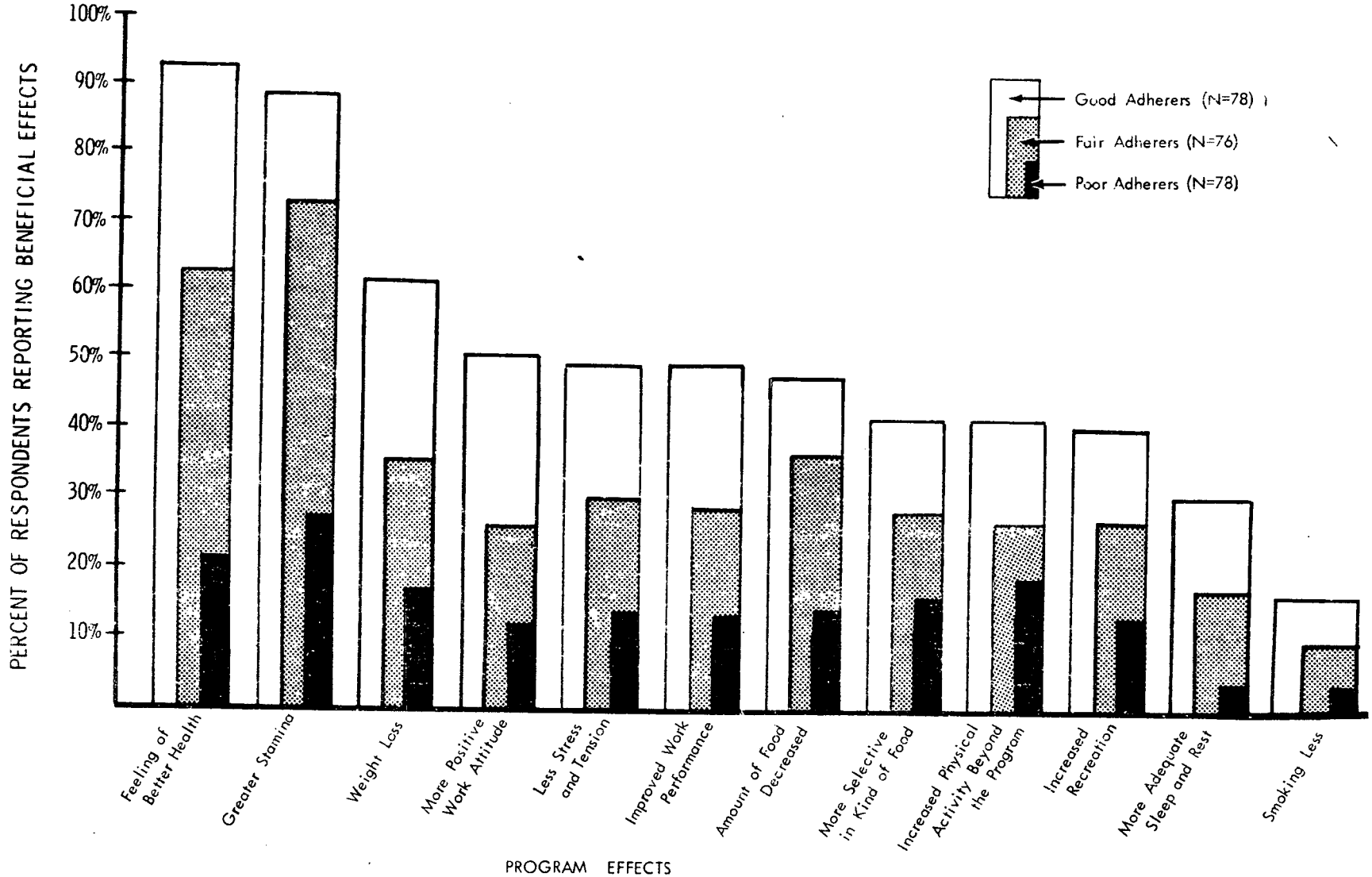
* This questionnaire had been developed, pretested and employed effectively in previous research efforts concerned with this problem area.

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 1. **TOTAL PROGRAM EFFECTS**
**(in relation to adherence)**

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The assessments in these three areas were designed to measure changes of a positive or negative nature which participants felt were specifically due to their participation in the program as well as any other changes that may have occurred which participants did not specifically attribute to the program.

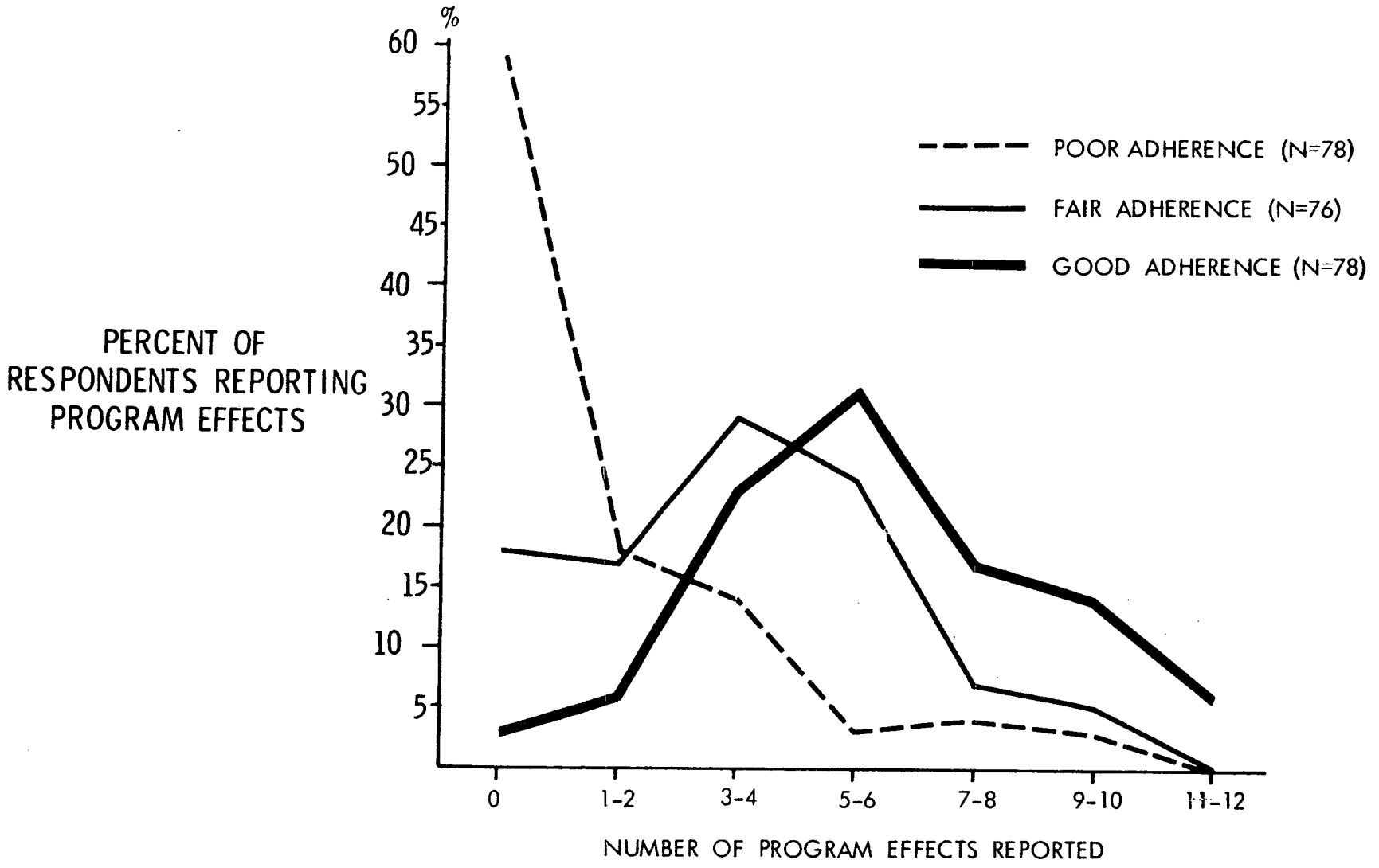
General Findings

- Virtually all of the changes or effects that were reported by participants were judged by them to be due to their participation in the program. In addition, the specific-effects that participants did report as due to the program were viewed as positive or beneficial in nature. Only a very small number of negative effects were reported involving increase in food consumption (4% of the participants) and weight gain (3% of the participants).
- In general, the most prevalent program effects reported were those dealing with feelings of better health and increased stamina. Other effects reported in descending order of frequency concerned weight loss; decrease in amount of food consumed; more positive work attitude; less stress and tension; improved work performance; decrease in the amount of food consumed; more selective in the kind of food consumed; increased physical activity beyond the program; expanded recreational activities; more adequate sleep and rest; and reduction in the amount smoked. (See Figure 1)

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 2. **RELATIVE NUMBER OF PROGRAM EFFECTS REPORTED BY PARTICIPANTS**

(In relation to adherence)

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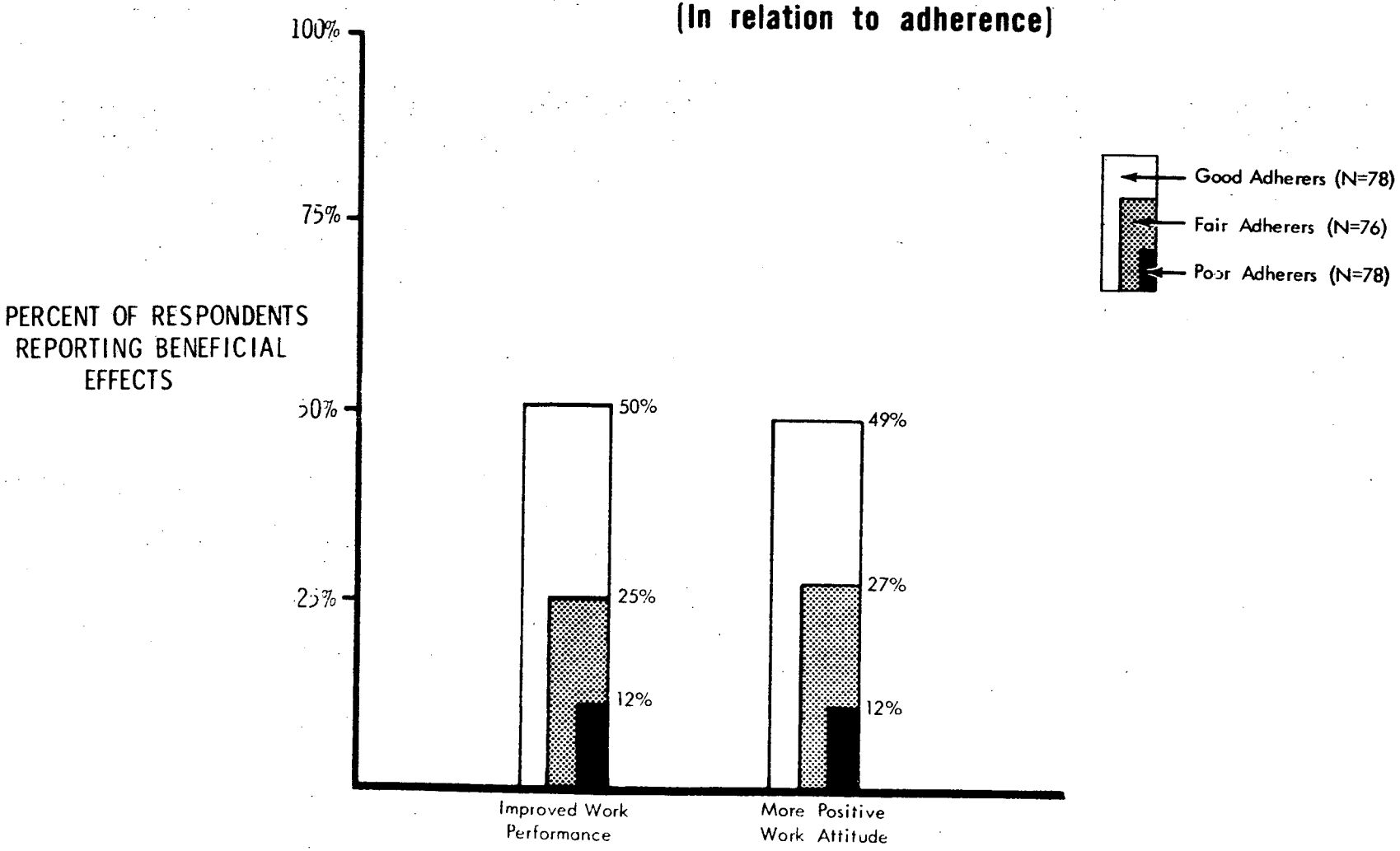
NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 3. **PROGRAM EFFECTS ON WORK**
**(In relation to adherence)**

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- A very strong positive, and consistent relationship was found between program adherence and reported program effects. In each of the three areas--work, health, and behavior--(as well as within each area) effects were reported most often by persons whose adherence level was good and least often by persons whose adherence level was poor.* (See Figure 1 and 2)
- Participants also reported some program effects on the health habits of persons in their social environment--their spouses, family, work colleagues and friends.

It should be emphasized that this general pattern of findings replicates the results obtained in previous research studies of several physical activity programs conducted in community and university settings.[16]

Specific Findings

Participants were asked about program effects in regard to work--both in terms of their work performance and their attitude toward work.

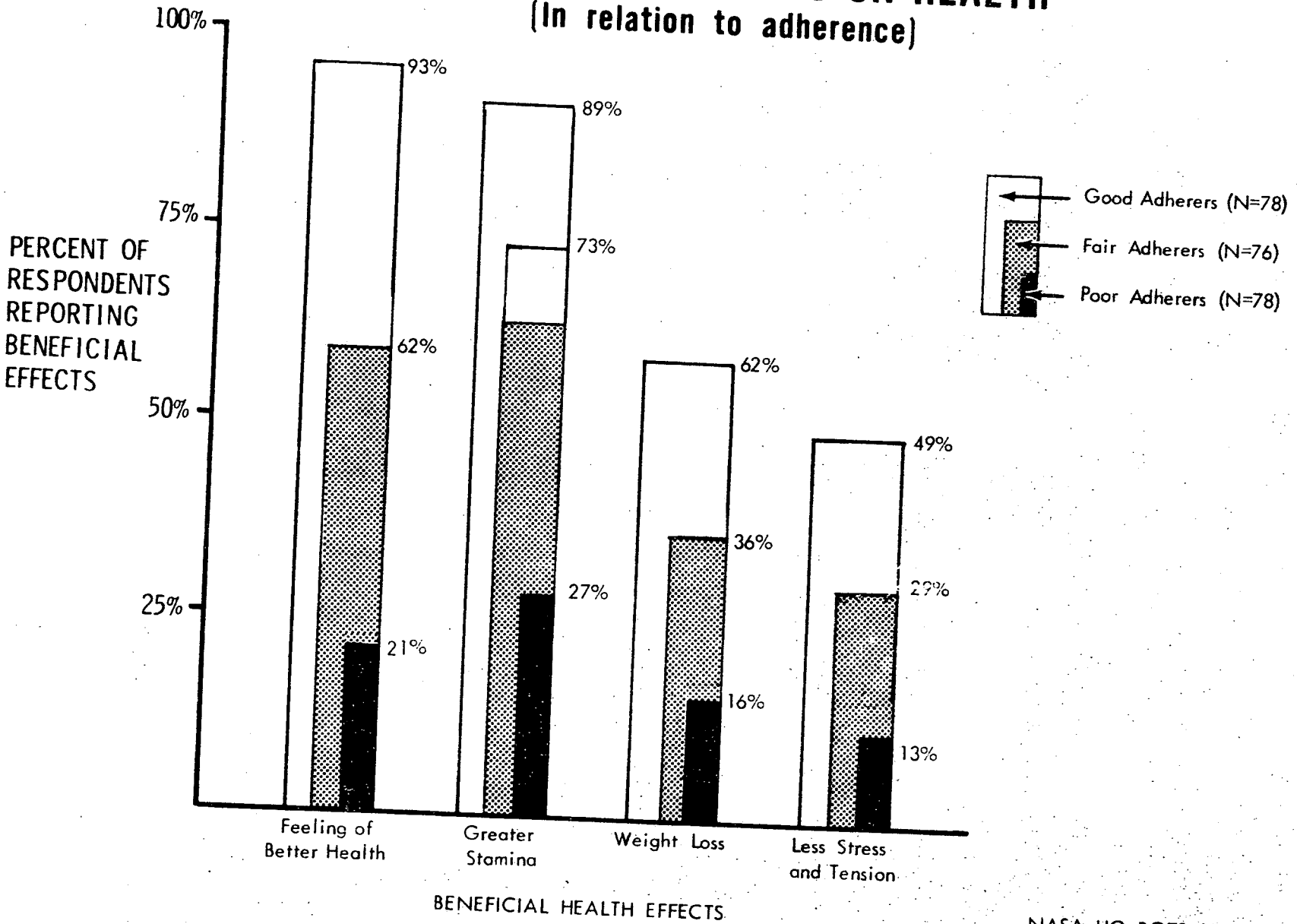
(Figure 3)

The relationship between reported effects and adherence shown in Figure 3 was reflected in the participants' statements indicating that they could work harder both mentally and physically and/or that they enjoyed their work more and found their normal work routine less boring.

* Measures of adherence were based on the average number of days a person participated in the program per week. Three major groupings of adherence were defined--good, fair and poor, corresponding to the upper, middle and lower terciles of the distribution of mean attendance figures for all participants.

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 4. **PROGRAM EFFECTS ON HEALTH**
**(In relation to adherence)**

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Changes or effects that were reported in relation to a person's health are presented in Figure 4. These effects included increased positive feelings about one's health status; increase in the person's level of stamina and energy; weight reduction and a decrease in the level of stress and tension experienced.

(Figure 4)

Typical comments here included statements to the effect that the person felt better and healthier, that he had more stamina and more energy, that his weight had been reduced or was better distributed, and that in general he found things were less stressful and/or that he could handle stress and tension more effectively and with less impact on his life.

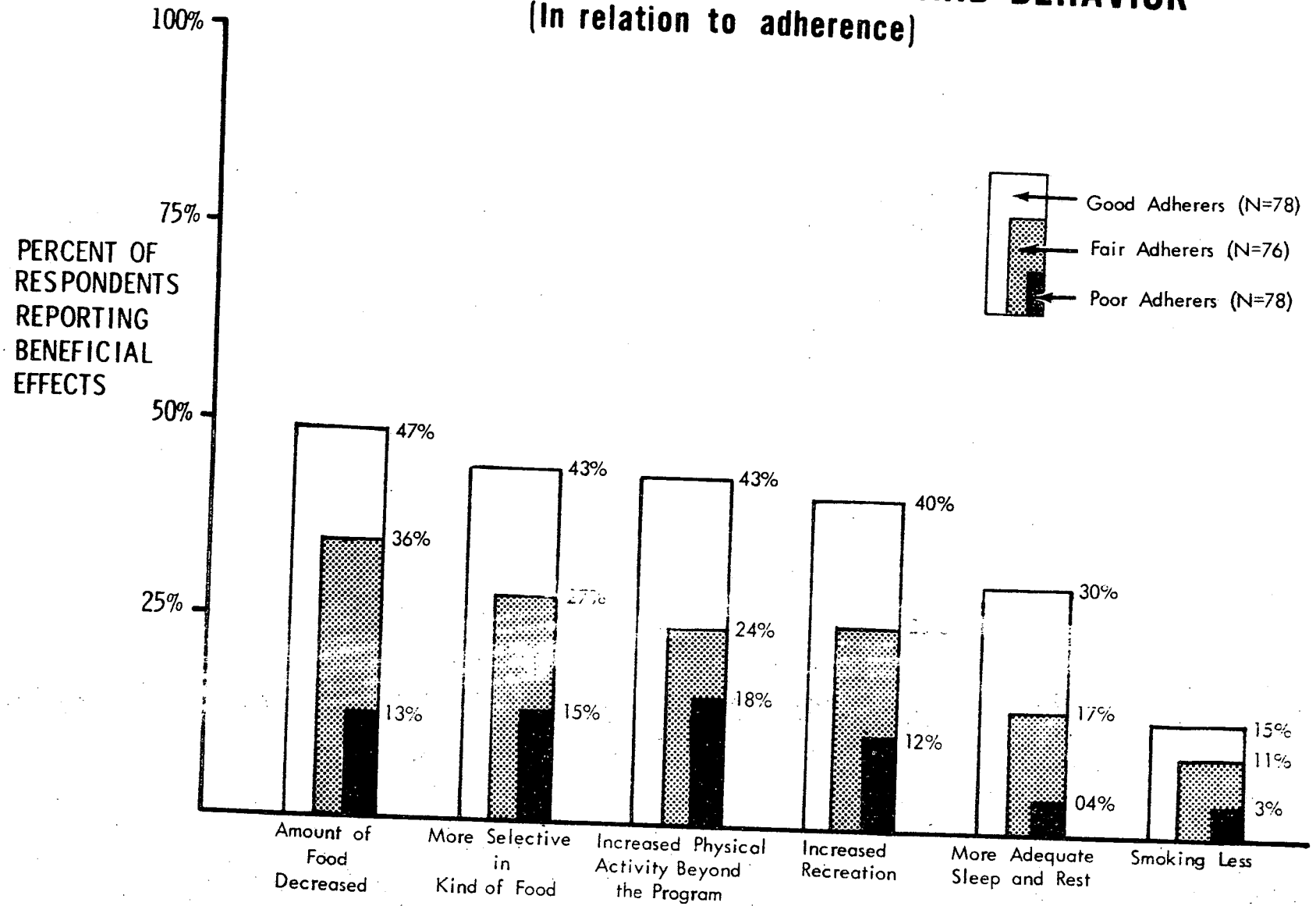
The effects of program participation on habits and behavior are presented in Figure 5. These effects were reported in regard to diet; increased physical activity beyond the program; expanded recreational activities; more adequate sleep and rest; and change in smoking behavior. It should be emphasized here that very few participants indicated that they were eating more now or that they needed more sleep and rest than before.

(Figure 5)

Relative to physical activity, our data suggest that for a number of the program participants, physical activity had become a pervasive habit in terms of their life style. For example, they were now more

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 5. **PROGRAM EFFECTS ON HABITS AND BEHAVIOR**
(In relation to adherence)




BENEFICIAL EFFECTS ON HABITS AND BEHAVIOR

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physically active than before, both within and outside of the program, with many participants reporting that they used stairs rather than elevators and that they often walk rather than ride when the option presents itself. In addition, many participants indicated that their pattern of recreational activities had expanded and that they now were participating more in such activities with their family and friends.

Participants were also asked about program effects on the health habits of other persons in their immediate social environment--their spouse; family; work associates; and friends and neighbors. (See Figure 6 below)

(Figure 6)

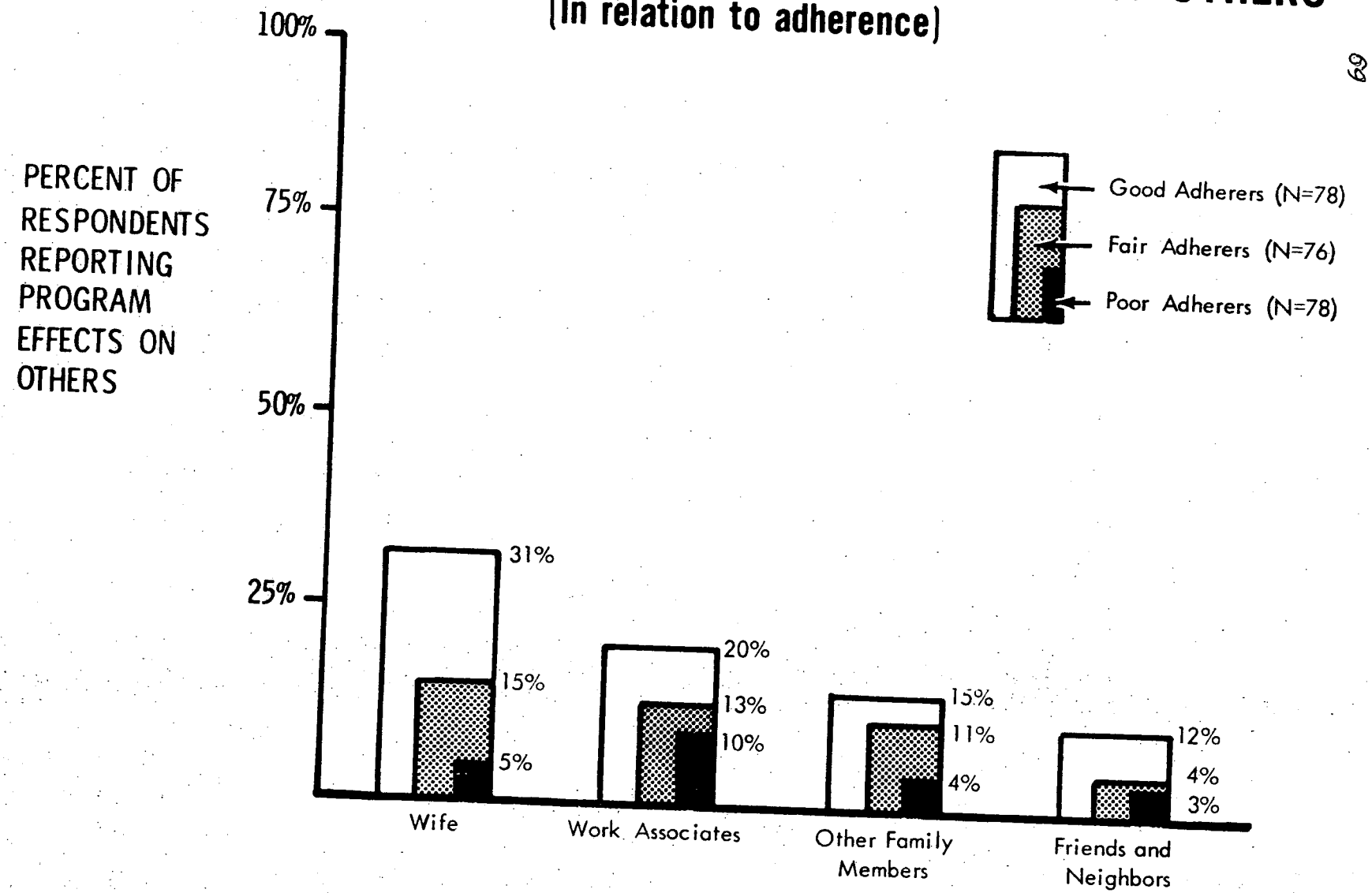
In general, the participant's wife and his work associates were mentioned most often as individuals whose health habits had been influenced by the fact that the individual was participating in the NASA program. Other family members and friends and neighbors were also cited, however. The comments of participants indicate that the influence process here often involved discussion of the program and its effects leading to a heightened interest in and awareness of health matters on the part of others. In addition, no doubt, the individual's participation in the program served as a model and incentive for health behavior change among those persons with whom he related most directly.

Attention was also given to the kind of effects the program had on the habits of others. In general, it was found that the habits of others were most directly affected in regard to exercise--leading to increased

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

FIGURE 6. **PROGRAM EFFECTS ON THE HEALTH HABITS OF OTHERS**
(In relation to adherence)



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levels of physical activity and exercise on the part of individuals who had often been quite sedentary. In addition, changes were reported in regard to diet and weight control as well as a greater interest in health matters in general.

Once again we note that the effects of participation in a health program can be pervasive with changes in health interest and action generated among a network of individuals to whom the participant relates.

Participation in a health program may thus generate a dual set of effects:

* The program may serve as a catalyst for change in regard to the participants' broader pattern of health behavior as well as influencing his feelings of health and well being.

* The program may stimulate health behavior change among others with whom individual participants are in most direct contact. This "ripple effect" can serve as a source of diffusion of additional program benefits.

In summary, it is quite evident that participation in a health program can have a number of direct and indirect effects on various forms of health habits and behavior. These effects are usually linked to a change in the person's health orientation indicating greater health interest and awareness. In considering the total benefits of a health program and in evaluating the possible range of effects that may be

produced, it is important to include these consequences as part of the focus of attention. In short, participation in a health program can influence how a person thinks and feels and what he does in regard to various aspects of health including both disease prevention and health enhancement.

## THE RELATIONSHIP BETWEEN REPORTED AND MEASURED PROGRAM BENEFITS

The research methods employed in this study made it possible to analyze the relationship between findings concerning program effects obtained on the basis of self-reports and findings based on observation and measurement. This issue was examined in regard to self-reports concerning perceived level of fitness and perceived effects of the health program - in relation to measures of improved cardiovascular functioning based on treadmill performance. Analyses examining the relationship between these sets of variables are outlined and discussed below.

## THE RELATIONSHIP BETWEEN PERCEIVED LEVEL OF FITNESS AND MEASURES OF FITNESS INVOLVING CARDIOVASCULAR FUNCTION

In order to examine this matter systematically, attention was given to the participants' perceived level of fitness before the program was initiated and their level of fitness determined at that time on the basis of treadmill performance. Fitness was defined here operationally in terms of several measures of cardiovascular functioning.

NASA HEALTH EVALUATION AND ENHANCEMENT PROGRAM

# Table 1. THE RELATIONSHIP BETWEEN PERCEIVED LEVEL OF FITNESS AND MEASURES OF FITNESS INVOLVING CARDIOVASCULAR FUNCTION

| MEASURES OF FITNESS * | PERCEIVED LEVEL OF FITNESS | | | |
|---|---|---|---|---|
| | NOT REALLY FIT AT ALL (N=11) | A LITTLE (N=50) | MODERATELY SO (N=68) | VERY MUCH SO (N=23) |
| Mean time required to reach a heart rate of 140 beats per minute | 7.7 (min.) | 8.1 (min.) | 8.9 (min.) | 9.7 (min.) |
| Mean time required to reach a heart rate of 150 beats per minute | 8.7 (min.) | 9.7 (min.) | 10.4 (min.) | 10.6 (min.) |
| Mean heart rate at 12% grade, 3 mph -- 12 min. into the treadmill test | 162 (bpm) | 159 (bpm) | 154 (bpm) | 152 (bpm) |
| Mean heart rate at 16% grade, 3 mph -- 15 min. into the treadmill test | 175 (bpm) | 170 (bpm) | 167 (bpm) | 165 (bpm) |

* The more time required to reach a specific heart rate -- the more fit the individual is assumed to be.

The lower the heart rate at a given work load (specific grade and time on the treadmill) the more fit the individual is assumed to be.

(Table 1)

Table 1 presents data on the relationship these two sets of variables demonstrating a highly consistent and positive correlation between them. In short, the individual's subjective assessment of his level of fitness corresponded directly to several objective measures of his fitness level based on his treadmill performance. The more fit a person perceived himself to be, the more likely he was to require more time to reach a specific heart rate and the lower his heart rate at a given work load. In other words, participants were able to report on their perceived level of fitness in a manner that corresponded very well to their level of cardiovascular functioning.

## THE RELATIONSHIP BETWEEN REPORTED PROGRAM EFFECTS AND EFFECTS OBSERVED IN CARDIOVASCULAR FUNCTIONING

In order to examine the total pattern of program effects in a complete and meaningful manner, attention was given to the personal health effects reported by the program participants in relation to the effects observed in their cardiovascular functioning based on treadmill performance. In general a highly consistent and positve relationship was observed between these "subjective" and "objective" measures of program effects. In addition, significant differences in the measures of improvement in cardiovascular functioning were found between participants who reported health effects and those participants who did not.

# able 2. DIFFERENCES IN MEAN CHANGES OBSERVED IN STRESS TEST PARAMETERS BETWEEN GROUP REPORTING A SPECIFIC PROGRAM EFFECT AND GROUP REPORTING NO EFFECT

| DIFFERENCES IN MEAN CHANGE IN STRESS TEST PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| SPECIFIC PROGRAM EFFECTS REPORTED | DURATION OF STRESS TEST (Min.) | TIME TO REACH HR OF 140 bpm (Min.) | TIME TO REACH HR OF 150 bpm (Min.) | HEART RATE AT 12 MIN. (bpm) | HEART RATE AT 15 MIN. (bpm) | MAXIMUM HEART RATE (bpm) |
| Feelings of better health | 1.4** | 1.36** | 1.15** | 6.8** | 6.1** | 6.5** |
| Greater stamina | .9** | 1.31** | .90** | 5.9** | 6.3** | 6.9** |
| Greater health interest & awareness | 1.2** | 2.01** | 2.12** | 8.6** | 8.6** | 10.1** |
| Less stress and tension | 1.1** | 1.67** | 1.16** | 7.3** | 6.6** | 7.6** |
| Weight reduction | 1.0** | 1.44* | 1.08** | 7.2** | 8.5** | 7.8** |
| More positive work attitude | .8* | 1.73** | 1.44** | 6.8** | 6.2** | 6.2** |
| Improved work performance | .3 | .60 | .81* | 2.4 | 4.3* | 3.3 |
| Amount of food decreased | .7* | 1.02** | .63 | 2.4 | 3.0 | 3.5* |
| More selective in kind of food | .8* | .47 | .23 | .3 | 2.1 | 2.5 |
| More adequate sleep & rest | .6 | .92* | 1.01* | 3.5 | 2.4 | 3.1 |
| Increased physical activity beyond the Program | .9** | .57 | .90* | .2 | .1 | 2.3 |
| Increased recreation | .9* | .57 | .63 | .6 | .9 | 3.3 |
| Smoking less | .7 | .17 | .55 | .7 | .0 | 2.5 |

* Indicates a significant difference at the .05 level of confidence between Group reporting an effect & Group reporting no effect due to Program.

** Indicates a significant difference at the .01 level of confidence between Group reporting an effect & Group reporting no effect due to Program.

Specifically, after the program had been in operation for one year, attention was given to the program effects reported by participants and the levels of improvement noted in measures of their cardiovascular functioning. Differences in an individual's treadmill performance based on measures obtained before the program began and the same treadmill test one year later were used to determine levels of improvement.

Each of the 13 areas in which participants could report program effects was examined in relation to changes in the cardiovascular parameters assessed on the basis of treadmill performance. For each area in which an effect could have been reported, participants who reported a program effect were separated from participants who reported no effect in that area. These two groups were then compared in relation to the improvement noted in their cardiovascular functioning based on treadmill performance. The latter included mean changes in 6 parameters that were assessed through physical stress testing of the cardiovascular system.

(Table 2)

Table 2 indicates that a highly consistent pattern of differences was found in the mean changes in stress test parameters between persons who reported a program effect in a particular area and those persons who did not. This was particularly true for the program effects reported in relation to feelings of better health, greater stamina,

# Table 3. NUMBER OF PROGRAM EFFECTS REPORTED AND MEAN CHANGES OBSERVED IN STRESS TEST PARAMETERS

| MEAN CHANGE IN STRESS TEST PARAMETERS | NUMBER OF PROGRAM EFFECTS REPORTED * | | | |
|---|---|---|---|---|
| | NO EFFECTS (N=66) | ONE EFFECT (N=39) | TWO EFFECTS (N=99) | THREE EFFECTS (N=15) |
| Duration of Stress Test | 1.0 (min.) | 1.8 (min.) | 2.1 (min.) | 3.3 (min.) |
| Time required to reach heart rate of 140 beats per minute | 1.8 (min.) | 2.6 (min.) | 3.4 (min.) | 4.3 (min.) |
| Time required to reach heart rate of 150 beats per minute | 2.3 (min.) | 2.6 (min.) | 3.3 (min.) | 5.1 (min.) |
| Heart rate at 12 minutes | -12.6 (bpm) | -21.1 (bpm) | -20.2 (bpm) | -28.1 (bpm) |
| Heart rate at 15 minutes | -12.1 (bpm) | -22.7 (bpm) | -20.8 (bpm) | -25.4 (bpm) |
| Maximum Heart Rate | -12.5 (bpm) | -22.4 (bpm) | -20.6 (bpm) | -26.4 (bpm) |

* The effects examined here involved feelings of better health; greater stamina; and increases in health interest and awareness. A respondent could report effects in any one or all of these areas.

greater health interest and awareness, less stress and tension, weight reduction, and a more positive work attitude. In each of these areas, persons who reported a program effect were found to have improved their cardiovascular functioning at a level significantly different from those persons who had reported no program effect in that area.

While some differences were also observed in relation to some of the other program effects reported, these differences were less consistent in relation to the improvements observed in each of the six cardiovascular parameters measured.

Since certain program effects that participants reported were highly correlated with each other (e.g., feelings of better health, greater stamina, and greater health interest and awareness) attention was given to the number of effects that were reported by participants and the improvement noted in their cardiovascular functioning based on changes in stress test parameters.

(Table 3)

Table 3 presents a summary of the findings here. It is evident that there is a highly consistent and positive relationship between the number of effects reported and the improvement observed in cardiovascular functioning based on changes in the stress test parameters. In general, a direct relationship can be observed between these two sets of variables. The increment of change in heart rate is minimal, however, between the groups of participants reporting one and two effects in this area.

In summary, the results of the analyses in this area indicate that:

*Self-reports concerning perceived level of fitness corresponded very well with measures of fitness involving cardiovascular functioning.

*A strong positive and consistent relationship was found between reported program benefits and measures of improvement in cardiovascular functioning based on treadmill performance. In addition, significant differences in measures of cardiovascular improvement were found between participants who reported program benefits and those who did not.

These findings establish a meaningful profile of the pattern of effects generated by this kind of health program. The findings also support the credibility and value of self-reports provided by participants in a health program. The results obtained suggest that improvements in cardiovascular and physiological functioning can influence a person's thoughts and feelings about his state of health and well being as well as his pattern of health attitudes and behavior.

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N73-17070

SYNOPSIS OF 45-MINUTE TALK PRESENTED
BY MICHAEL A. PAGLIUSO
NASA Headquarters, Office of Facilities

## FACILITIES ENGINEERING IN NASA

Purpose of the presentation was to give an overview of NASA facilities outlining some of the more interesting and unique aspects of engineering and facilities associated with the space program.

Outlined some of the policies under which the Office of Facilities conducts its business.

Facilities engineering as a staff function embraces:

- facilities planning and programming
    - master planning
- plant engineering or day-to-day operations and maintenance
- establishment of design criteria, and the carrying out of or monitorship of design and/or construction
- surveillance of our NASA industrial base and equipment
- carrying out staff real estate functions
- in addition:
    - propellants/pressurants
    - DOD Facilities Coordination
    - representing NASA on a multitude of committees and panels which involve facilities matters
    - environment quality control

Followed by 30 minutes of slides totalling 36 in number that highlighted NASA facilities that included structures, buildings, equipment and space hardware and achievements.

M. A. Pagliuso also touched upon the "hot" subject of the day - Environmental Quality Control, and the role played by the Office of Facilities in this highly controversial subject.

CLOSING REMARKS

In looking back a little over a decade since Explorer I to Apollo 11 (moon landing and safe return), the key to our success has been the ability to conduct the required -

Research

Development

Testing

as needed by our programs.

Our well endowed facilities were and are today the very roots of national readiness and that these same type of facilities only -

- Larger
- More complex
- More costly

must form the base for future space progress. To explore the unknown and to test the uncertain and untried.

We as professionals must more fully appreciate this and the value of space.

We must take a leading role in seeing that others understand the importance of technological and scientific progress to our national needs.

We, as facilities engineers in NASA, are most fortunate to be so close to a significant element of our technological and scientific progress

and

we appreciate this opportunity to share a bit of it with you.

N73-17071

# HAZARDS FROM HIGH-INTENSITY LAMPS AND ARCS

By David H. Sliney*

## INTRODUCTION

The principal occupational health problem generally associated with high-intensity arc lamps results from exposure of the eye and skin to ultraviolet radiation. Occasionally, the chorioretinal burns are of concern. In general one can say that the eye is more susceptible than the skin to injury from high-intensity optical radiation sources whether ultraviolet, visible or infrared. Until recently it was felt that no chorioretinal burns would occur from exposure to visible light in industrial operations (Kuhns, 1950). However, recent developments in technology have shown that some high-intensity optical radiation sources which have output parameters greatly different from those encountered in the natural environment may present a serious chorioretinal burn hazard.

## HIGH-INTENSITY SOURCES ENCOUNTERED AT NASA

Besides the many lasers reported last year, one frequently encounters sources of continuous optical radiation, such as solar simulators, quartz-iodide-tungsten lamps, gas discharge tubes, electric welding units, and sources of pulsed optical radiation, such as flash lamps used in laser research and photochemical investigation. These sources may be of concern when adequate protective measures are not being taken. At Kennedy Space Flight Center 20-kW xenon short-arc searchlights which each have a luminous intensity above one billion candlepower have been used during launchings.

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* Laser-Microwave Division, US Army Environmental Hygiene Agency.

ULTRAVIOLET RADIATION

Although only limited standards exist for the exposure of the skin and eye to ultraviolet radiation, several research studies and other references permit analysis of the ultraviolet exposure risk to "black" lights and arc lamps

a. Ocular Hazard. It is generally agreed that ultraviolet light does not present a chorioretinal burn hazard. The ocular media do not transmit a significant amount of radiant energy in the ultraviolet (Kinsey, 1948; Boettner and Wolter, 1962). However, the absorption of ultraviolet in the cornea and conjunctiva does result in photokeratitis. Experiments by Cogan and Kinsey indicated that the peak response for photokeratitis is at 288 nm and that radiation having wavelengths greater than 310 nm do not appear to produce photokeratitis (or at least one can say that such radiation has less than 1/100th times the effectiveness of energy incident upon the cornea at the 310 nm wavelength)(Cogan and Kinsey, 1946). Cogan and Kinsey reported an integrated dose (radiant exposure) of 0.015 $j/cm^2$ was required to produce photokeratitis in rabbits' eyes at the 288 nm line. More recent investigations by Pitts (Pitts, et al, 1969) indicate a slightly lower threshold for photokeratitis in the rabbit, as shown in figure 1. Pitts, et al and previous investigations generally reported that the human eye was approximately twice as sensitive to ultraviolet than the rabbit eye, but the spectral sensitivity was essentially the same.

The action curve for the production of photokeratitis in the primate eye is shown in figure 2 and is believed to be reasonably close to the

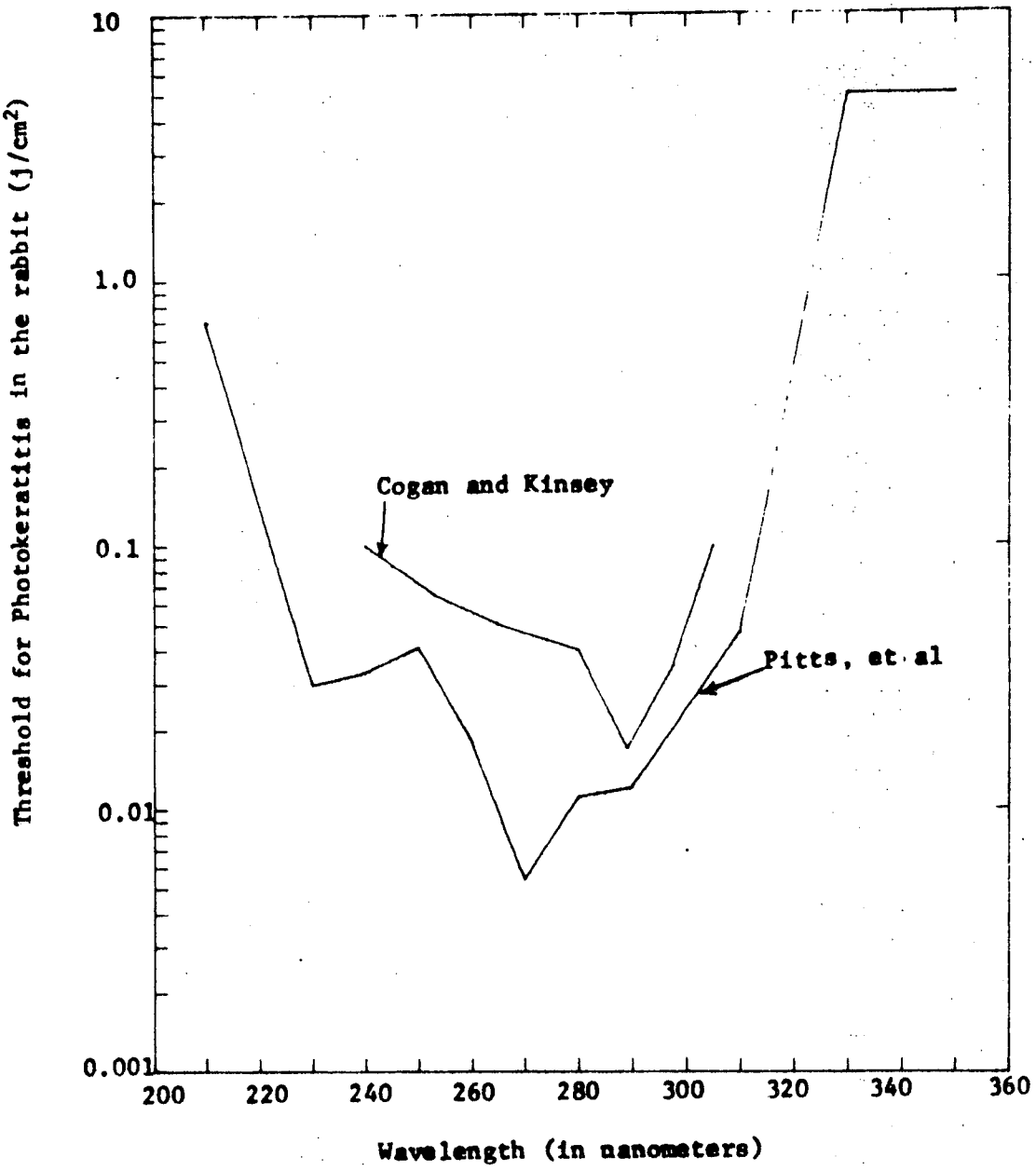


Figure 1. Threshold for Photokeratitis in the Rabbit Eye

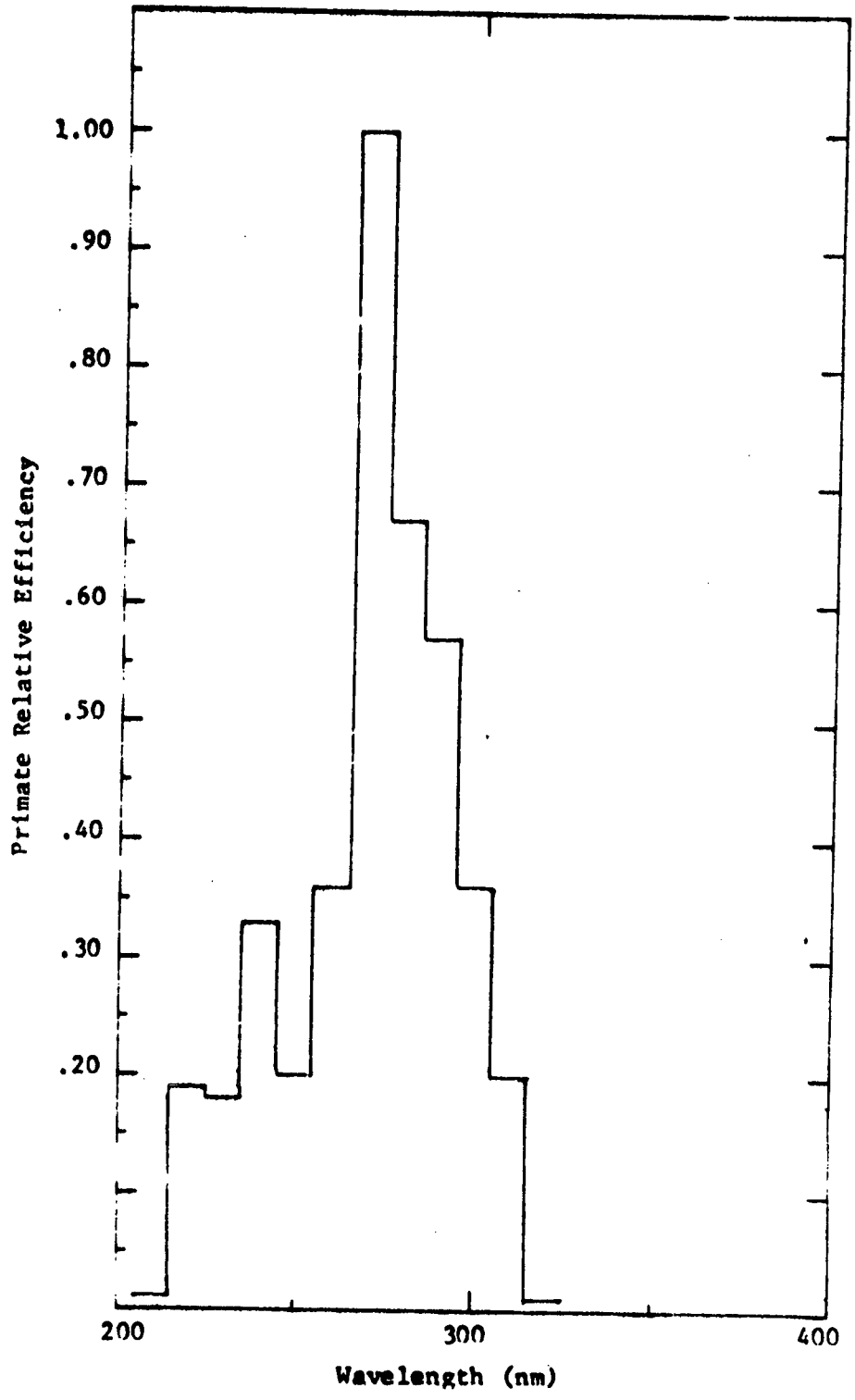


Figure 2 Relative Spectral Efficiency for Photokeratitis in Primates

action spectrum for the human eye (Pitts, et al, 1970). The minimum threshold dose cited for the human eye (at 270 nm) is given by Pitts, et al as 5 mj/cm$^2$. Defining the hazardous level as half this value, 2.5 mj/cm$^2$, the maximum permissible exposure may be computed in the following way: The spectrum $H(\lambda)$ of, for example, a black light (figure 3) may be numerically integrated with the action curve $S(\lambda)$ for photokeratitis to yield an effective irradiance weighted to the ultraviolet action spectrum to determine if the black light could produce photokeratitis in the normal human eye by using the following formula:

$$H' = \sum_{200}^{320} H(\lambda)\ S(\lambda)\ \Delta\ \lambda$$

where:

$H'$ = effective illuminator irradiance referenced to the 270 nm wavelength in W/cm$^2$ (i.e., the irradiance of a monochromatic source at 270 nm producing the same biological effect upon the eye as the illuminator)

$H(\lambda)$ = spectral irradiance of black light (figure 3) in W/cm$^2$.nm

$S(\lambda)$ = relative spectral sensitivity of the eye (figure 2)

The effective normalized irradiance obtained using the spectral irradiance in figure 3 was $3.3 \times 10^{-8}$ W/cm$^2$. If we multiply this irradiance by 28,800 seconds (number of seconds in eight hours), we obtain an integrated dose of $9.5 \times 10^{-4}$ j/cm$^2$ which is a factor of 2.8 below the threshold value of $2.5 \times 10^{-3}$ j/cm$^2$.

b. Skin Hazard. The minimal erythemal dose for ultraviolet erythema is strongly wavelength dependent (resembling the sensitivity curve for photokeratitis) The action spectrum generally is believed to have two peaks at 260 and 300 nm (Giese, 1964; Blum, 1954; Urbach, 1969). The minimal

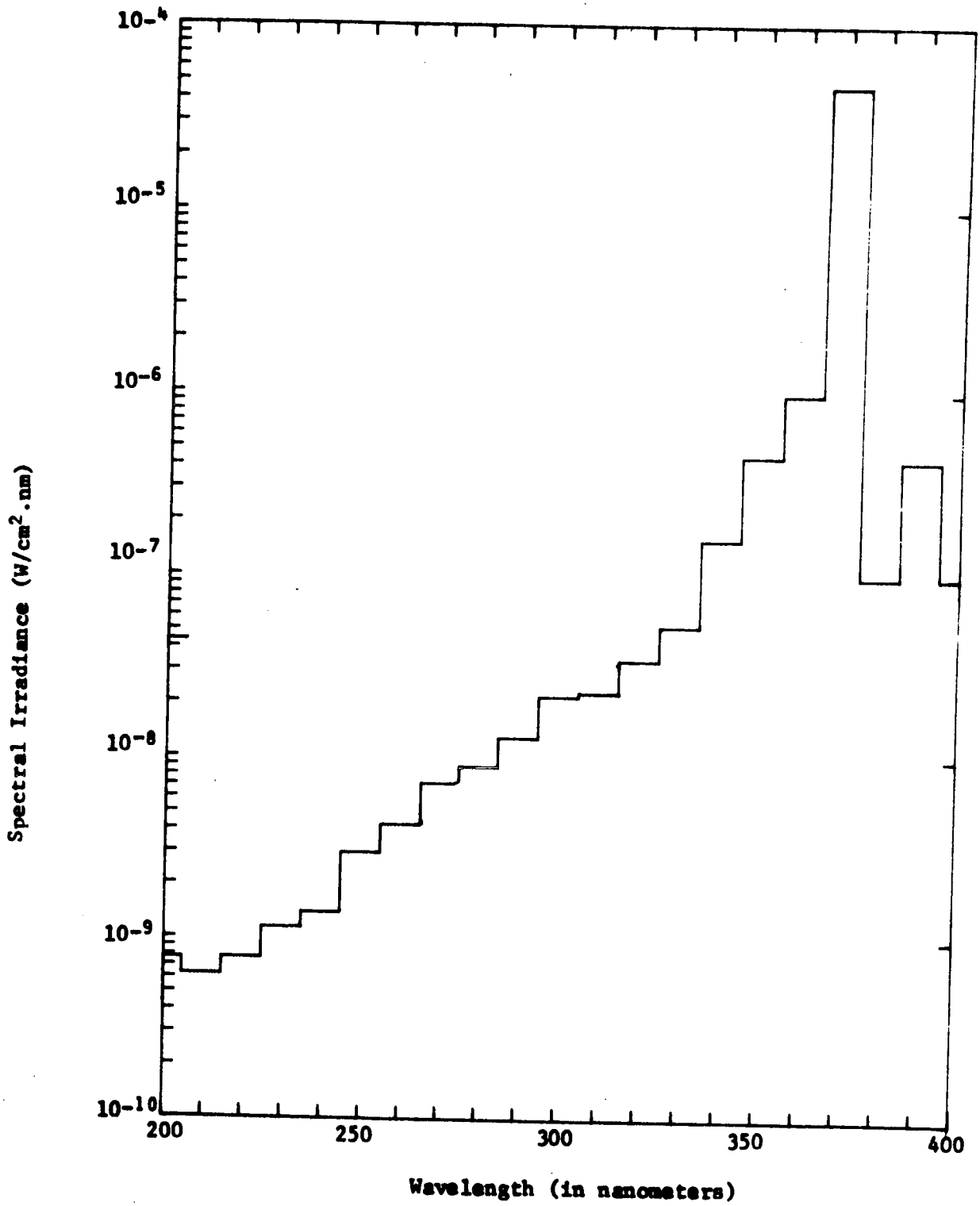


Figure 3. Spectral Irradiance of Zyglo Black Lamp at 20 cm from Lamp Face with Filter

erythemal dose at 300 nm is on the order of $10^{-2}$ j/cm$^2$. The AMA Council on Physical Medicine (1948) recommended a maximum exposure dose at 296.7 nm of 0.3 μW/cm$^2$ for eight hours or 8 x $10^{-3}$ j/cm$^2$.

CHORIORETINAL BURNS

The potential for receiving a chorioretinal burn depends upon the wavelength distribution of the source, the brightness (radiance) of the source, the exposure duration, and the size of the retinal image of an observer. The first three parameters are generally known, or can be obtained from manufacturers' data, or can be measured by several types of instruments. The latter parameter, retinal image size, depends upon the viewing situation of the exposed individual and some knowledge of the application and operational situation is required to obtain this.

Retinal injury due to radiant energy was discussed at length long before the advent of the laser. Much data are available relating to eclipse blindness and results of viewing the sun. There are many reports of accidentally and experimentally produced retinal injury produced by intense man-made radiant sources, such as electric arcs and the nuclear fireball. Results of injury to the human eye and to the eye of experimental animals (generally the rabbit) provide an extensive literature. Effects of viewing the sun, particularly during an eclipse, have been reported throughout history. As early as 1867, Czerny produced experimental lesions in the rabbit (Walker, 1916), and several later

investigators used experimental animals to investigate such ocular damage. It was not until 1916 that a truly comprehensive study, both quantitative as well as qualitative, was published. This study, by Verhoeff and Bell (1916) of the Massachusetts Eye and Ear Infirmary, described the role played by ultraviolet, visible, and infrared radiation, in producing various ocular effects, and remains a classic in this field. A companion paper to the above was an extensive review, by Walker (1916), of the literature dating back to the Ancients -- with 428 references. The review covered reports of eclipse blindness, observation of lightning bolts at close range, and experiences of 19th century scientists who first worked with high-intensity arc lamps. The review also covered the experimental work of Czerny, Deutschman and Herzog. More recent reviews of the subject may be found in Duke-Elker (1954) and articles by Cogan (1950), Kutscher (1946a and 1946b), Newell (1964), and Bartleson (1968).

Verhoeff and Bell (1916) concluded that man-made sources of radiant energy would not be expected to present a retinal hazard in normal use. Only a few cases have been reported of injury following ocular exposure to arcs produced from electrical short circuits, welding arcs, sunlamps, and arc lamps. This record could change with the recent development of higher radiance sources. Reports of ocular injury from such sources are discussed by Dias (1965); Turtz (1948); Wurdemann (1936); Jofe (1936); and Walker (1916). The development of the xenon-arc photocoagulator by Meyer-Schwickerath (1954, 1960) showed the beneficial clinical applications of the arc lamp in ophthalmology and led to the laser photocoagulator.

A large variety of optical radiation sources have been evaluted for potential ocular hazards by the US Army Environmental Hygiene Agency. Figure 4 shows the dramatic range of retinal irradiances produced by some of these sources as well as some commonly encountered light sources for comparison. The retinal image size is of concern since the threshold for thermal injury varies with image size even when the exposure time is extremely short and heat conduction in the retina and choroid does not occur during the duration of exposure. The threshold for a 0.1-second exposure (duration of the blink reflex) is also shown in figure 4. As an example of the importance of the retinal image size, consider an individual viewing an electric welding arc without eye protection at a distance of 200 feet. The image size would be approximately 20 μ as is shown in figure 4. However, if the welder struck the arc within a foot of his eye without eye protection, not only would he receive "welder's flash," he might also receive a retinal burn since the image size could be on the order of 1 mm. The influence of retinal image size also explains why an individual momentarily viewing the sun with the unaided eye would normally not receive retinal injury: whereas if he were to observe the sun even momentarily through a binocular or telescope, which increasesthe image size, the results are well known.

NON-THERMAL EFFECTS UPON THE RETINA

Recently, a number of investigators have been studying the effects of retinal exposures in the largely unexplored region of retinal irradiances between $10^{-4}$ to 1.0 W/cm$^2$. For instance, Noell, et al (1966), Gorn and Kuwabara (1967), Friedman and Kuwabara (1967), and Kuwabara and Gorn (1968)

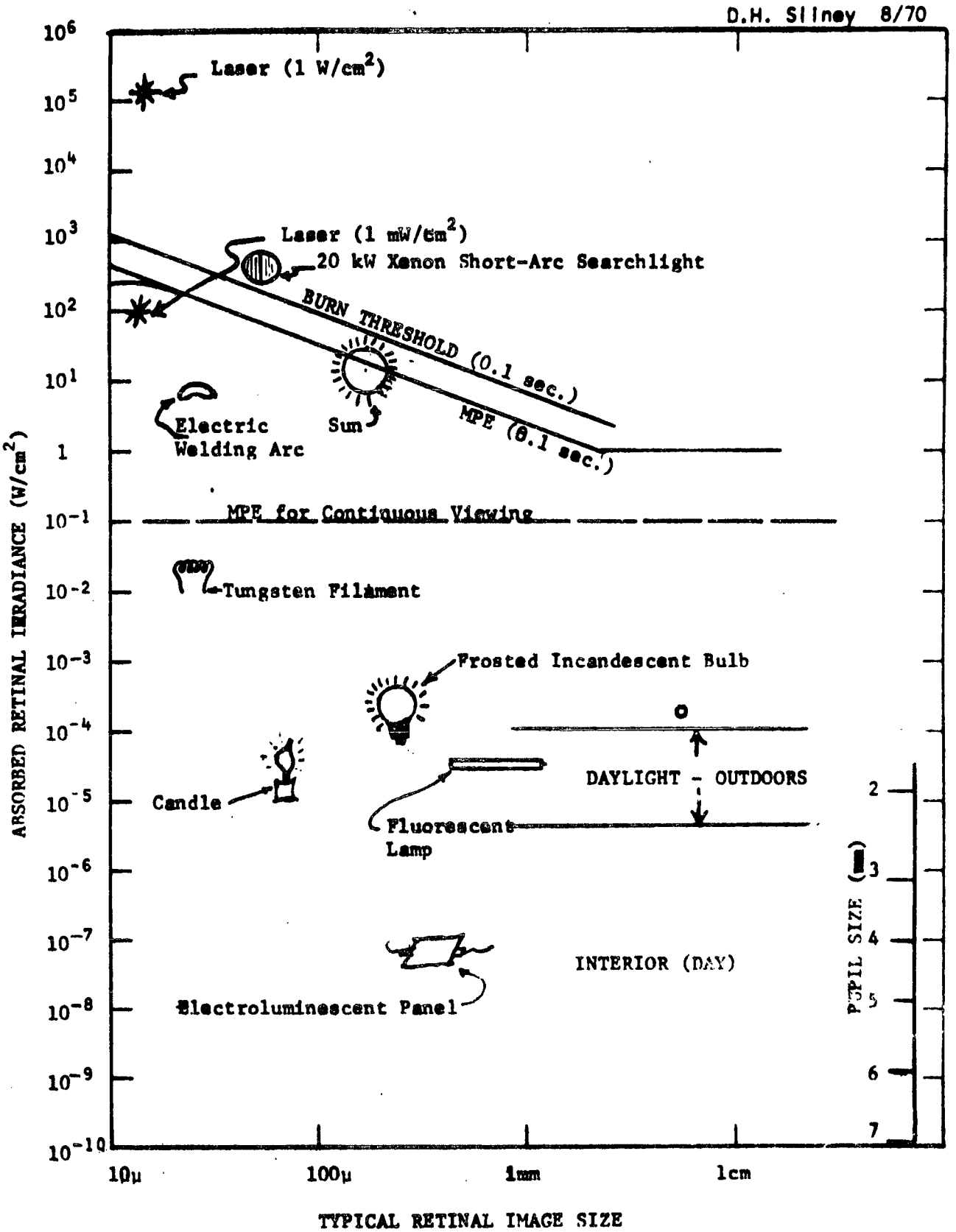


Figure 4. Approximate retinal irradiances from viewing common optical radiation sources.

have reported findings of retinal injury in rats after long-term exposure to ordinary fluorescent lights (note irradiance given in figure 4). Sperling (1968, 1970) has reported a shift in retinal sensitivity to monochromatic light sources in trained monkeys after exposure to retinal irradiances slightly above $10^{-4}$ W/cm$^2$.

CONCLUSIONS

In summary most optical radiation sources may be evaluated for potential health hazards with a reasonable degree of accuracy. While it is true that there exists a largely unexplored region of biological effects vs. retinal irradiances between levels associated with normal daylight illumination and levels which produce retinal burns, this is not a serious problem. The retina would normally not be exposed to such levels since the normal photophobic reflex would limit such exposures to a duration less than the blink reflex. A possible exception would be exposure of the retina to near-infrared radiation which would not evoke a photophobic response. Infrared sources which would produce such retinal irradiances do not exist in nature without a correspondingly high percentage of visible radiation. A few man-made sources have been produced which employ filters to eliminate the visible component and thereby present a serious hazard problem. I have not discussed the potential hazards of infrared cataracts. This subject is not well documented, although one general source of information does exist (Duke-Elder, 1954). Biological research is still needed to fill in the gap of information which exists for exposure to near-infrared radiation, high-intensity monochromatic light sources, and high-intensity flash lamps which are repetitively pulsed.

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N73-17072

# THE VALUE OF CONTINUED FOLLOWUP IN A PREVENTIVE MEDICINE PROGRAM

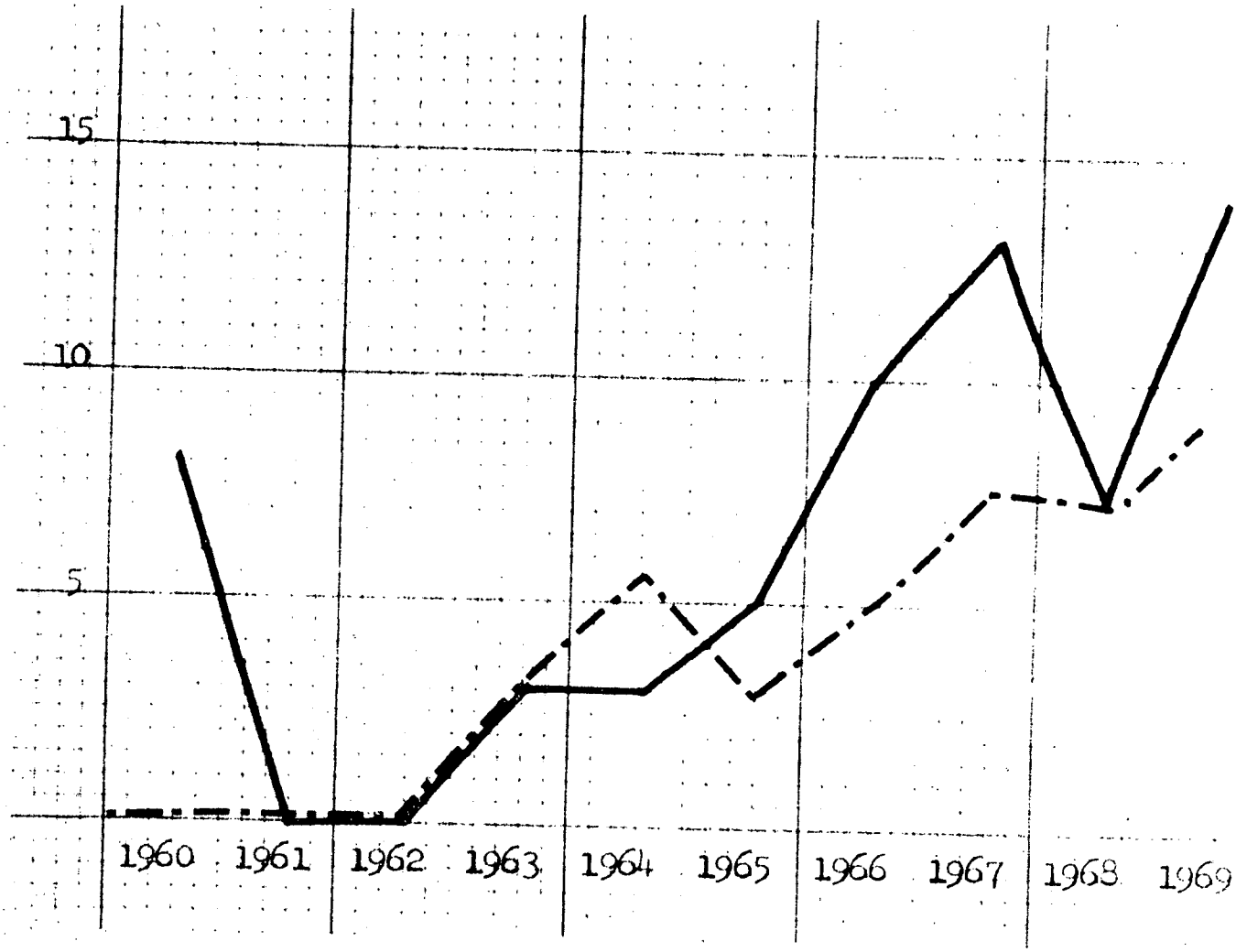
Carlos Villafana, M. D., and Jean Mockbee

The prevalence of heart disease at the NASA Goddard Space Flight Center is between 2 and 5%. This compares favorably with the prevalence in the general population which is from 12 to 25%.[1] However, during the past five years, while a fairly ambitious employee preventive medicine program has been in effect at the Center, the cardiovascular disease mortality rate has increased from five to fourteen per 10,000, and deaths from other diseases have increased from three to nine per 10,000 (Figure 1). The upward trend has been almost constant (only in 1968 was there a drop in the cardiovascular disease death rate) and has involved a population which has experienced no appreciable increase in age. In addition, in the past four years, temporary disability episodes (causing job time loss of five days or more) have increased from 30 to 65 per 10,000 for cardiovascular disease, and from 99 to 189 per 10,000 for other chronic diseases (Figure 2).

Clearly, the preventive measures which have been instituted thus far have not been wholly successful and the Goddard medical facility, for the past two years, has engaged in various program modifications in the hope of reducing employee mortality and disability rates. One of the measures taken has been a continued followup of medical conditions detected.

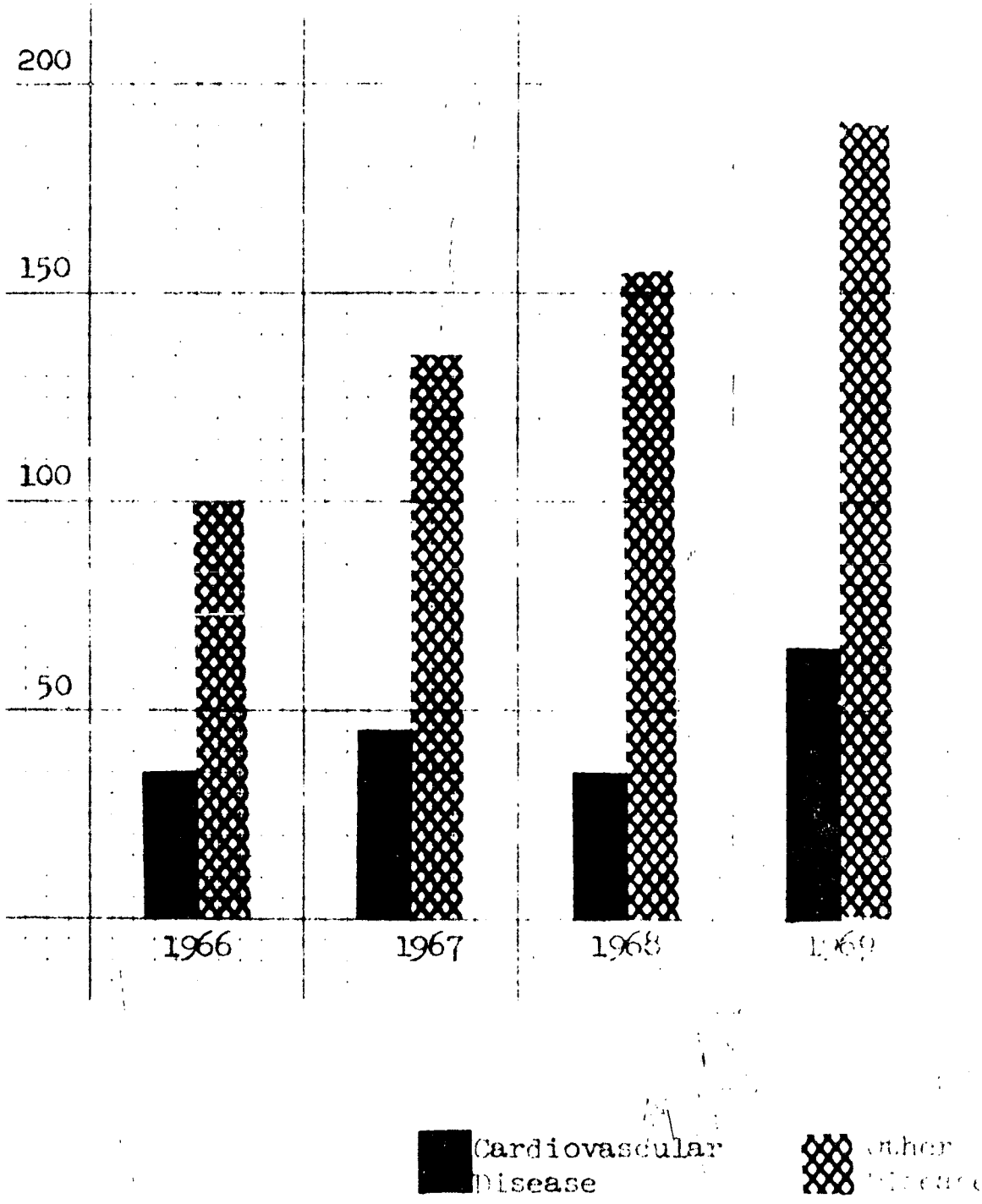
NASA Goddard Space Flight Center
Employee Mortalities
1960-1969

Rate Per 10,000



NASA Goddard Space Flight Center
Major Disability Episodes
1966-1969

Rate Per 10,000



This is basically different from the more traditional approach taken by many physicians working in an organizational environment such as NASA, where it is felt that the responsibility to the employee patient ends with the detection of a potentially disabling disease, that the patient is forewarned at the time of examination, and from that point onward the burden is transferred to him and to the outside medical community, to which he must turn for further assistance. In proceeding beyond detection, we want to insure that the conditions revealed in the course of preventive activities are brought under control. In this paper we propose to present the results of the followup programs for employees with confirmed hypertension and hypercholesterolemia which are two of the primary, if not the most important, contributors to the development of cardiovascular disease. We hope it will bring a clearer understanding of the role that continued followup has as an essential element of any preventive medicine program.

METHODS

Hypertension followup is accomplished by a series of visits to the medical facility at specific intervals. An employee in whom hypertension is suspected is requested to return on three successive days for repeat blood pressure checks. Blood pressure is taken after a ten minute rest period in three different positions: sitting, standing,

and recumbent. The criteria used for hypertension are: systolic pressure of 150 or greater or diastolic pressure of 94 or greater. At the end of this period the patients in whom the condition is confirmed are referred to the private medical community for treatment. They are then requested to return to the NASA facility at daily, weekly, or monthly intervals, until the adequacy of the control measures has been established.

If an employee's blood pressure continues to be uncontrolled on followup visits, he is returned to his private physician for further management. The objective is to insure adequate control of his blood pressure.

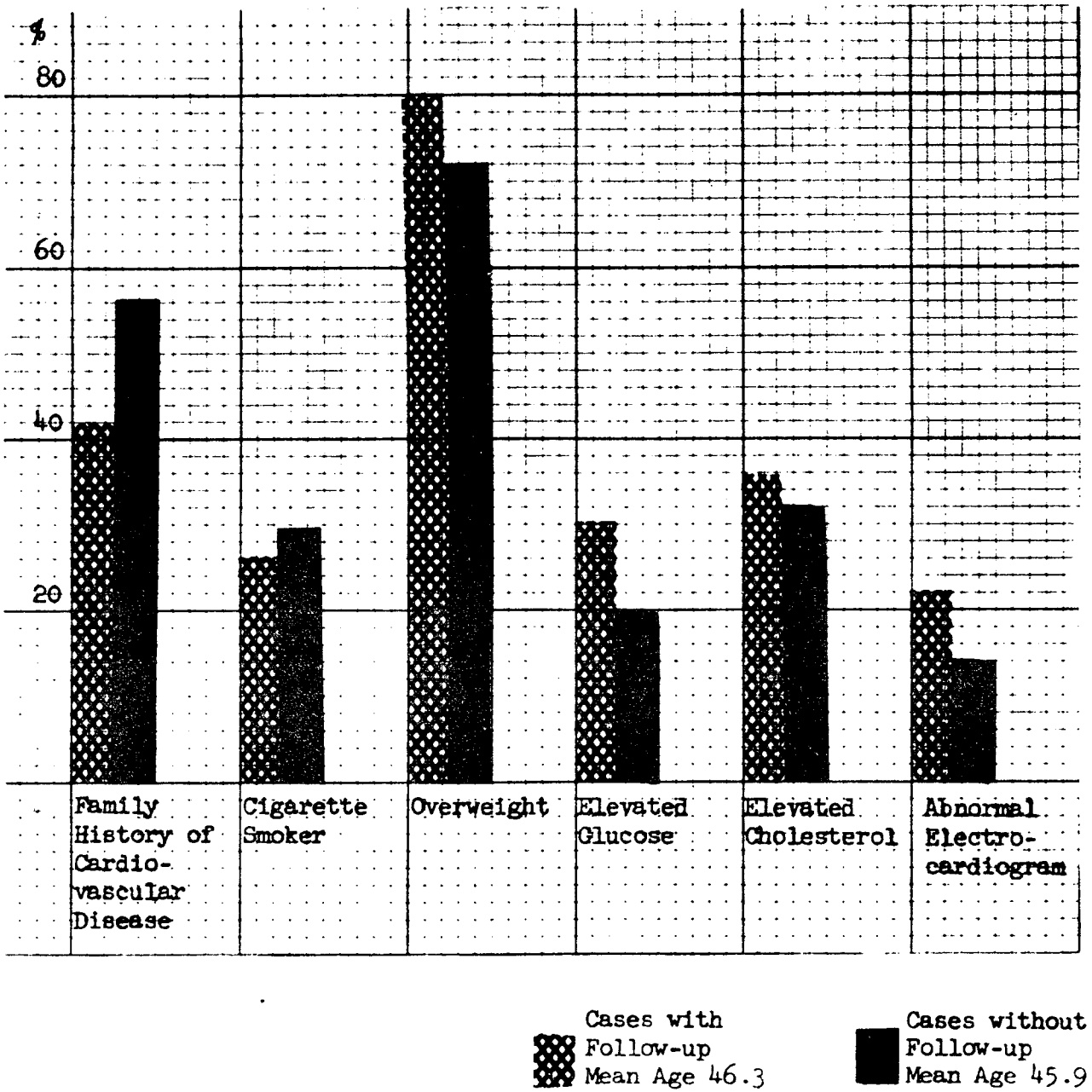
Cholesterol followup is accomplished by a series of visits to the medical facility for repeat cholesterol measurements, at three month intervals. The blood samples are collected after fasting for eight hours. An employee with a cholesterol value, at the time of examination, of 250 mg% or greater, is counselled about diet and placed on a followup roster, and his name is not removed until his cholesterol drops below 250 mg%. If cholesterol is 300 mg% or above and persists at that level despite dieting attempts to control it, the patient is then referred to his private physician for further studies to determine his lipid patterns and the possibility of medication.

Cholesterol, unlike hypertension, is controlled mainly by diet. Since the employee-patient receives no medication, the emphasis is on his own self-control in readjusting a lifetime eating habit. Unfortunately, information obtained through routine questionnnaires at Goddard reveal that the average cholesterol content of the diet of an employee with confirmed hypercholesterolemia does not appear to be excessive, or differ noticeably from employees with no cholesterol problem. These food quantities may be biased, however, in that years of repeat examinations and counselling, even without explicit cholesterol followup, might have already caused some alteration in the diet pattern.

## RESULTS

In a thirty month period from January, 1968, to June, 1970, 1,719 male employees were examined at the Goddard medical facility. Their occupations, ages, and socioeconomic backgrounds were as widely diversified as the findings from their examinations, and generally were representative of the total NASA population. Two hundred and one cases of hypertension (11.7% of the total population) were detected. Projecting this to the population remaining to be examined, it is likely that the total for the installation would be 348 cases.

## Prevalence of Coronary Risk Factors in 215 Male Employees with Confirmed Hypertension



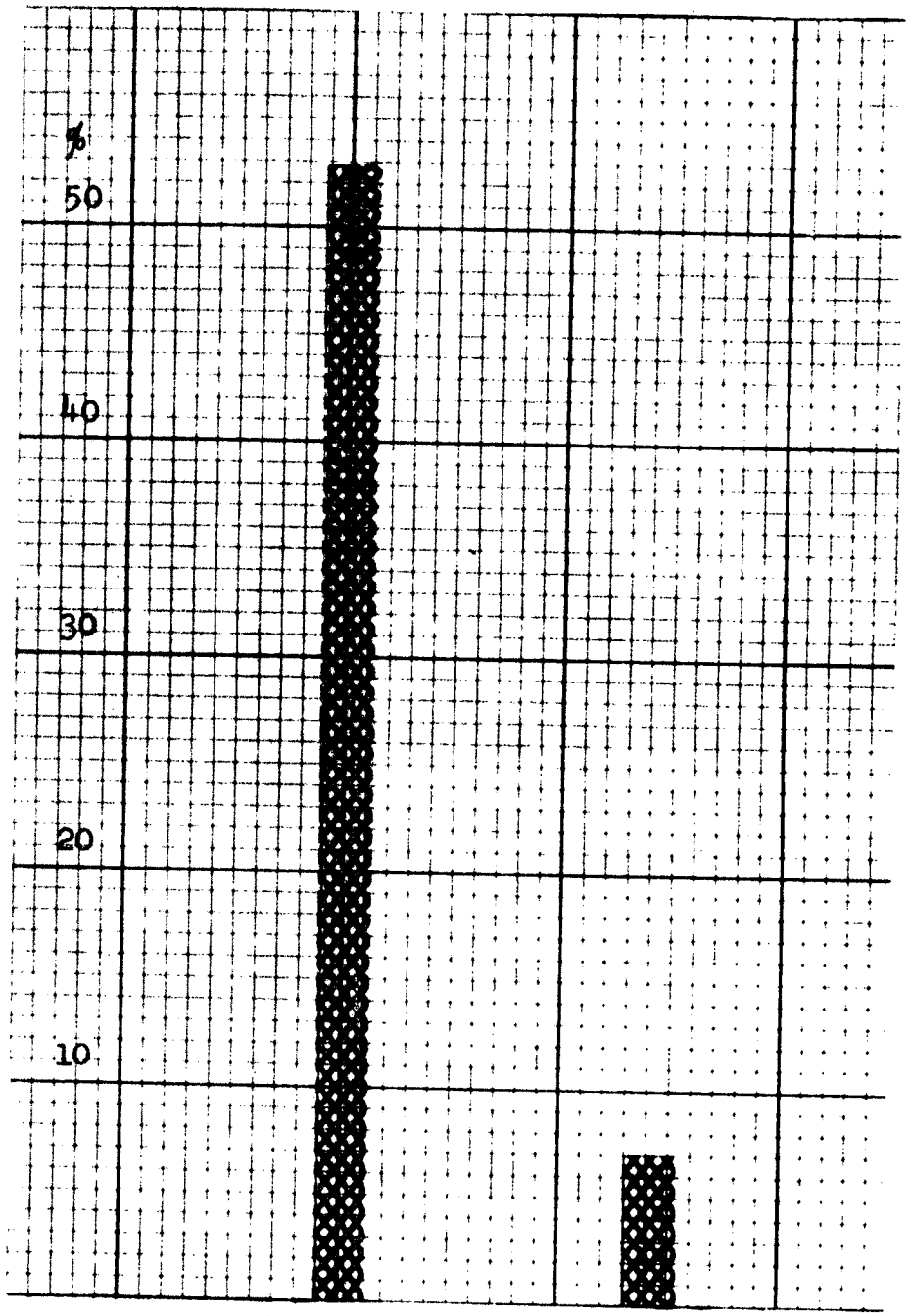
A group of 184 confirmed hypertensive employees received followup at the Goddard clinic for a thirty month period. Another group of 31 employees with confirmed hypertension received no followup. The status of their conditions was evaluated at the end of the study period.

Among the 184 employees that were followed-up for hypertension, there were significant quantities of additional coronary risk factors, such as family history, smoking, and elevated cholesterol, the most universal factor being overweight, which was present in 80% of the patients (Figure 3). The sample of 31 employees with confirmed hypertension, but who had no followup in the clinic, showed a comparable prevalence in these factors. Both groups are comparable in age, occupation, salary level, and education.

Of the 184 followup cases, 98 or 53%, were considered to have adequate therapeutic control. This was significantly higher than in the group with no followup in which only 7% of the patients were found to be controlled(Figure 4).

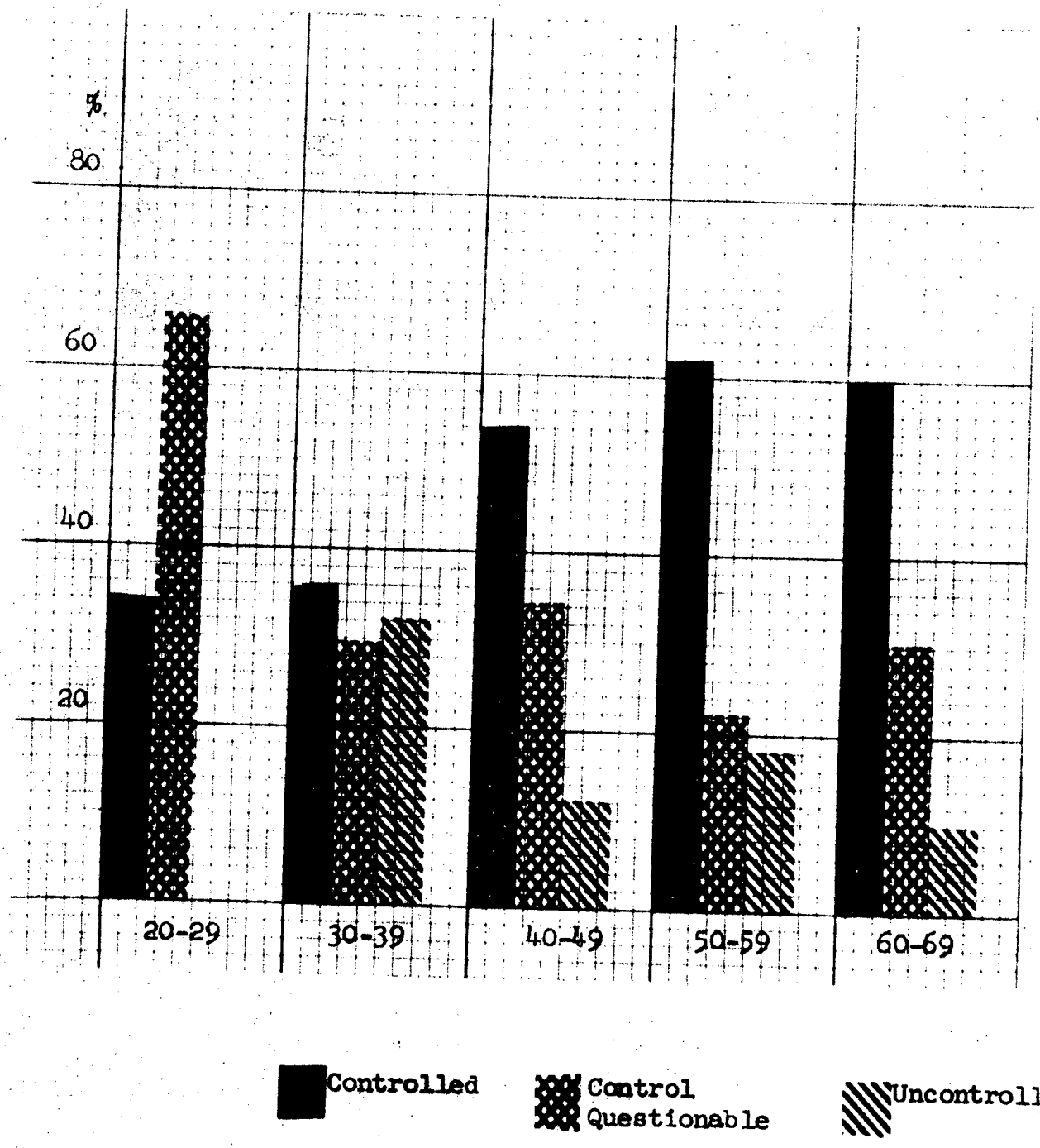
In occupation and educational background there was no significant difference between the controlled and the uncontrolled hypertensive patients. By ten year age groups, there did seem to be an upward trend in control among older employees (Figure 5). This may be due to generally greater concern for health with increasing age, but also to

**Confirmed Hypertension**
**Percentage with Adequate Control**

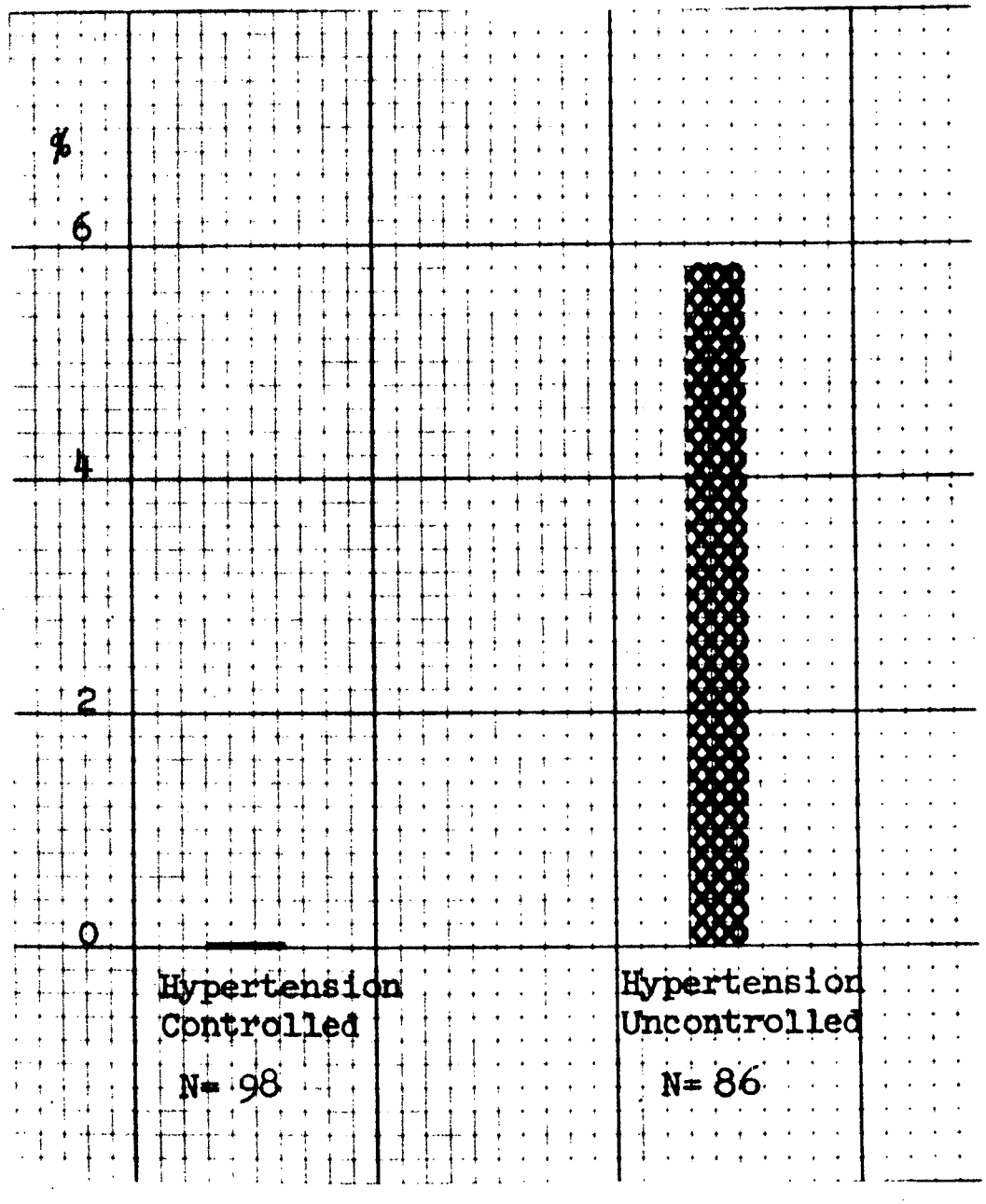



| Cases Followed-up | Cases Not Followed-up |
|---|---|
| N= 184 | N= 31 |
| Mean Age 46.3 | Mean Age 45.9 |

184 Male Employees with Confirmed Hypertension
Degree of Control, by Age Group



Confirmed Hypertension
Percentage of Population Per Year Lost
Through Cardiovascular Disease Deaths
and Disability Retirements
Period 1-1-68 to 4-30-70

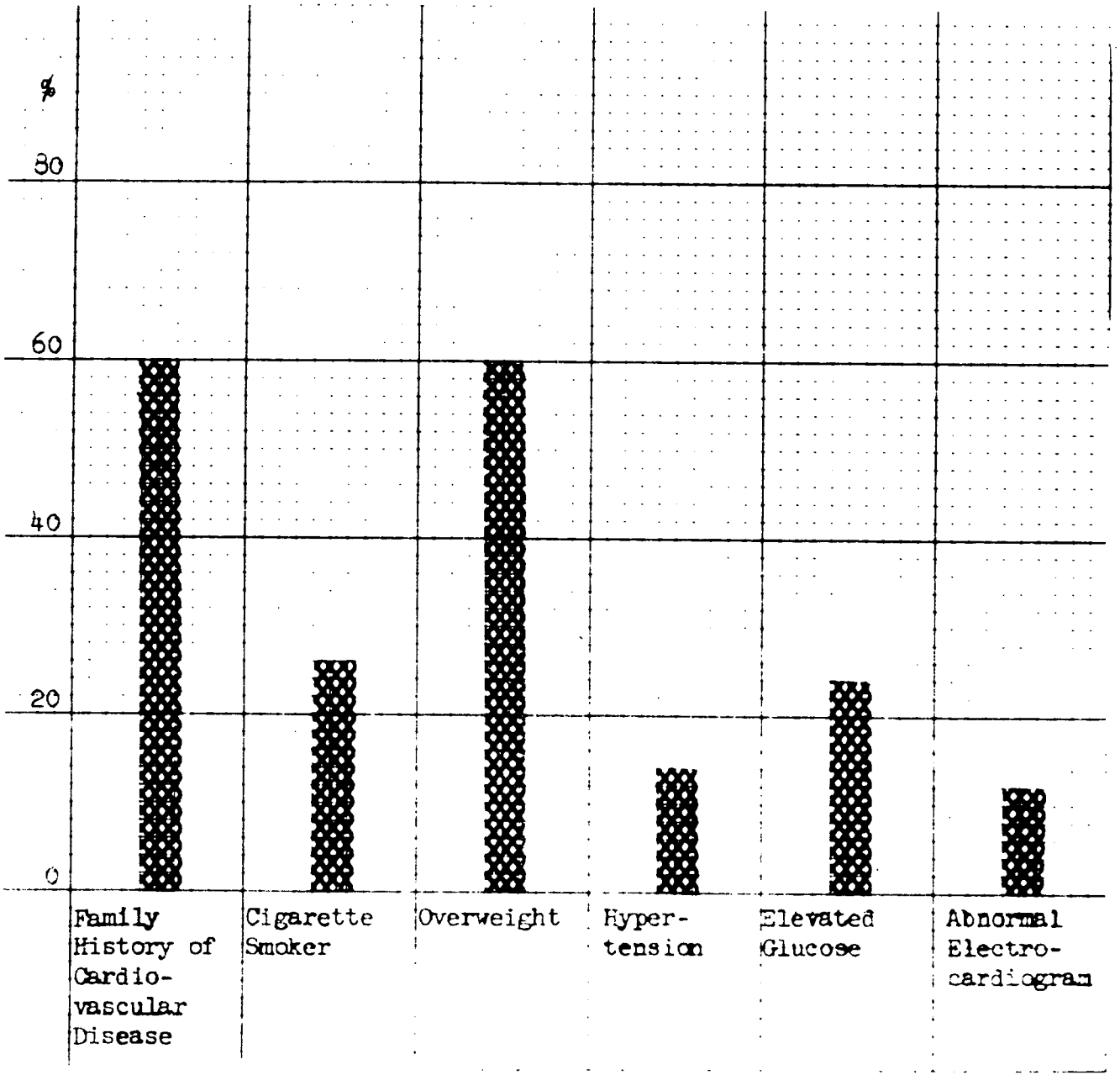


the fact that some of the employees in the controlled group, by age 50 had already experienced acute cardiovascular disease episodes, and control of hypertension was thus intensified. This suggests that we should place more emphasis in our followup program on the younger hypertensive employees.

Hypertension followup is now a routine element of the Goddard preventive medicine program. The significance of good hypertension control is perhaps most dramatically demonstrated in Figure 6. Although the numbers are far too small to present conclusive evidence, in records of employee cardiovascular disease mortalities and disability retirements over a 28 month period, personnel loss was 5.8% per year among employees in whom hypertension was uncontrolled, compared to 0% among employees in whom hypertension was adequately controlled. This is in agreement with recent Veterans Administration studies[2] which have shown that control of mild hypertension will result in less cardiovascular episodes. The Framingham study,[3] where systolic blood pressure was found to be as important as diastolic blood pressure as a risk factor, confirms these findings.

Hypercholesterolemia, defined in our study as the presence of a cholesterol level of 250 mg% or greater, is found in 28% of the Goddard male employees. Four hundred and seventy-nine cases have been detected thus far. Projecting this to the total population, it is possible that 879 cases may be present at the installation.

Prevalence of Coronary Risk Factors
in 283 Male Employees with Confirmed Hypercholesterolemia



The prevalence of additional coronary risk factors among employees with hypercholesterolemia is considerably less than among employees with hypertension (Figure 7). The most universal factors here are family history of cardiovascular disease, and overweight.

Of the 272 confirmed cases, 125 (46%) were considered to have adequate control, 88 (32%) were questionably controlled, and 59 (22%) were found to be uncontrolled. By occupation and educational level (as in employees with confirmed hypertension) there was no significant difference between employees who were controlled and those who were uncontrolled.

By ten year age groups, there appears to be a downward trend in the ability to control cholesterol, among older employees (Figure 8). This is precisely opposite to the pattern established among hypertensive employees, where control was found to be greater in the older age groups. In other words, prevalence of hypercholesterolemia is less in older age groups, but those having it are more difficult to control. Younger age groups may be more responsive to educational efforts.

283 Male Employees with Confirmed Hypercholesterolemia
Degree of Control, by Age Group

DISCUSSION

Hypertension patients average 4.2 visits to the medical facility per year for blood pressure measurements alone, with a range from one to fifty-five visits per employee. In 1969, there were 638 visits to the Goddard facility, each consuming five to eight minutes of nursing time, or the equivalent of two man years per year. Many of the visits are at the request of the employee's private physician, but most are the result of the medical facility's concern for their patients, and some are, of course, initiated by the patients themselves.

We find that the initial complete workup for hypertension on new cases is not usually performed by the private physician. On the

basis of the recent hypertension poll conducted by Modern Medicine, this is not surprising.[4] Patients are frequently placed on medication for blood pressure control without further testing. Whether a prevention clinic should extend its capabilities to provide this kind of evaluation is open to question. However, we share the responsibility for the health maintenance of these patients with the private physician. Therefore, if the initial workup is not done privately, then it should be done by the clinic.

Blood pressure monitoring alone does not constitute an adequate followup for a hypertensive patient. Examining the eye grounds and testing the urine for albumin as well as the blood urea nitrogen, are additional measures. Therefore, our followup measures are incomplete.

Generally, it is felt that hypertension as a disease is not fully understood by the patients, or adequately explained by the private medical community. Often the employees are unaware that the medications they are taking may or may not be adequate and each case must be evaluated independently until the right medication dosage is established. They rarely understand that they will probably be on this medication for the remainder of their lives, and to interrupt treatment for a week or a month may place them in a risk category.

For economic reasons, an employee may not wish to spend the money for his medicine, or, if his private physician is on vacation, may not be able immediately to renew his prescription. For whatever the reason, an individual's blood pressure wavers from day to day and week to week, and only through a schedule of routine monitoring, as a minimal followup, may dangerous changes be detected. If this monitoring is not performed properly by the private community, then it becomes an additional, but necessary burden to the preventive clinic.

Cholesterol monitoring is difficult to achieve when left to the outside medical community. Since the patient feels no ill effects from the condition, he is less likely to spend the money and time for repeated visits to his private physician. Similarly, the private physician, viewing a patient in apparent good health is less likely to devote as much attention to him as to his patients with verified illness symptoms. Consequently, the condition goes unchecked, and each year the cholesterol deposits increase until they become a very real threat in the development of cardiovascular disease. It does appear from the Framingham Studies that the risk is increased as the cholesterol increases, even when the individual has values below 250 mg%.

The limitations of time and medical resources pose a very real

problem in the selection of appropriate preventive medicine activities, and the employee candidates who will be the recipients of the services. The folly of placing total reliance on detection mechanisms has been proven to the satisfaction of the Goddard medical staff and it has turned more and more to increased diagnostic and supportive care. If we are going to operate a truly preventive medicine program, then an adequate followup mechanism has to be instituted. Otherwise, many early symptoms and conditions will continue to be ignored and go untreated until they develop to a stage beyond control, and to a point where they cause not only potential physical impairment, but a threat to life itself.

Continuous followup is one way in which the contribution of occupational health clinics to the total health care of the people who work in a community would be more productive. It relieves the private physician of an excessive burden in his office, allowing him more time for actual treatment of medical conditions. The combination of treatment by the private physician and followup by the employee health clinic thus insures a high quality of care and correction or improvement of the medical conditions prevalent in the population.

The question of resources allocation to services rendered assumes major importance here. If resources are to remain the same, then it is mandatory that we look at each service performed and modify,

increase, decrease, or eliminate it altogether after a careful evaluation. This should be particularly applicable to the periodic examination which involves, in many instances, a great waste of time repeating year after year nonproductive procedures. A restructuring of the physical examination is in order so that the scope and contents of the examinations are strictly based on the health risks and needs of individual employees. This would eliminate a complete examination for everyone as a requirement. More careful selection of employee candidates who would be the recipients of services is also important.

## SUMMARY

We have presented some evidence to support the view that continued followup of conditions detected should be an integral part of the preventive medicine program. It should compete equally for resource allocations with the other preventive services offered in the total program. It is one of the many contributions of the preventive medicine program to the total health care of the individual employee and his community.

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## COMMENTS BY ARCHIE A. HOFFMAN, M.D.

Gentlemen, it is my privilege to make a few remarks concerning this stimulating work done at the Goddard Space Flight Center. Dr. Villafana elucidates the problems in an occupational medicine program that overlap into the private practice of medicine. This study shows how occupational medicine can strengthen apparent weak points of private practice.

Dr. Villafana has had a good deal of success in the follow-up of the GSFC population with stigmata of cardiovascular disease. He has aggressively monitored the employees involved, contacted the private physicians, reported on their control measures and suggested stronger therapy as needed. This paper reveals the difficulty in evaluating the ambulatory patient with suggestive evidence of hypertension and hypertensive heart disease. The status of casual blood pressures remains to be clarified in many instances.

Once it has been determined that hypertension is present by either serial blood pressure readings in the physician's office or by a.m. and P.M. recordings at home, the examinee ideally should be hospitalized for study. This is an important step since, depending on source quoted, 5% to 20% of hypertensives have a form of curable hypertension. In addition to required cardiac radiology, blood studies inclusive of serum electrolytes, electrocardiographic and/or vectorcardiographic studies, a careful cardiac ausculation is in order. Dr. Harvey has demonstrated the value of detecting an atrial gallop which is more

likely to be a constant finding with persistent elevation of blood pressure. It is too late to wait until a left ventricular strain pattern appears on the electrocardiogram to treat hypertension. Other studies recommended are at least a two hour period of automatic blood pressure recording with the examinee in a quiet darkened room, retinal photography, renal function, renogram, intravenous pyelography, exclusion of coarctation of the aorta, pheochromocytoma, primary aldosternoism. In the consideration of renovascular hypertension, renal arteries should be visualized and Dr. Brollman's renal artery plasma bioassay may be in order. Such a study will indicate whether treatment is indicated. I stress the importance of using the ophthalmoscope and taking retinal photographs for both diagnosis and progress.

I feel that a sustained diastolic pressure of 95 mm Hg or more with abnormal eye ground findings warrants treatment. With a mild elevation of diastolic pressure, an adequate response may be obtained with weight loss, sodium restriction and a supervised exercise program. If the examinee can get a dog, walking it several times a day will be helpful to both. The use of a diuretic as the sole drug should be saved for those who do not have enough intelligence or are too lazy to take a low sodium diet. Dr. Fries has pointed out the value of the spouse taking the blood pressure in the home so that the physician can evaluate prescribed therapy. All antihypertensive drugs are potentially dangerous. If a drug cocktail is deemed necessary, I prefer to begin with a combination of chlorthiazide and alpha-methyl dopa. After adequate titration, other drugs may be added or substituted.

Hypertensive heart disease and ischemic heart disease are both shown in this paper. Both have different pathophysiologic processes and when combined may act synergestically. Dr. Townsend has covered most adequately the biochemical lipid alterations that are found in ischemic heart disease. Dr. Frederickson in his first papers required a 14 hour fast for study of blood lipids. I have found people who have an elevated serum cholesterol at an 8 hour posprandial period (e.g. 280 mg) but showed a level of 210 mg at the end of 12 hours. I personally will not draw blood to examine the lipids unless the examinee had a 12 to 14 hour fast.

In summary, I am not satisfied with the handling of the reported 10 to $12\frac{1}{2}$ million cases of heart disease in our population at the minimum. Some individual physicians do a splendid job in this area, but it seems that the only method to reach all those in potential danger is through the public health approach. Dr. Villafana's report seems to be a beacon in the right direction.

N73-17023

# Laboratory Aspects Of Blood Lipids

Frank M. Townsend, M.D.

The term lipid embraces a wide variety of compounds that are grouped together by virtue of similar solubility properties in the so-called "fat solvents" which include ether, chloroform, benzene, carbon tetrachloride, etc. They are a heterogeneous group which includes the sterols, vitamin A, E and K, bile pigments, waxes, carotenoid and related dietary pigments, as well as the triglycerides, phosphatides, and free fatty acids (1).

Only some of the above conglomerate of compounds are commonly referred to in clinical medicine. These are the triglycerides, cholesterol, a member of the steroid group, and the lipoproteins and chylomicrons.

Cholesterol is one of the most mysterious substances found in the tissues of animals. It is present in all cells and apparently has some function in the maintaining of the structure and permeability of the cells (2). Cholesterol is an alcohol and is capable of forming esters with fatty acids. These cholesterol esters are found in the plasma, constituting two-thirds of the cholesterol there. They are formed chiefly in the liver.

The structure of cholesterol is complex. However, the biosynthesis can be accomplished with very simple precursors. Acetate radicals, chiefly in the form of Acetylcoenzyme A are all the body requires as starting material. Consequently, many amino acids, carbohydrates, and fatty acids when supplied in excess of other metabolic needs can contribute to the cholesterol pool. The liver is the main site of synthesis, but the skin, adrenals, gonads, intestines and even the aorta can carry out the biosynthesis (1). It is estimated that the liver can produce 1.5 grams per day and the other tissues 0.5 grams.

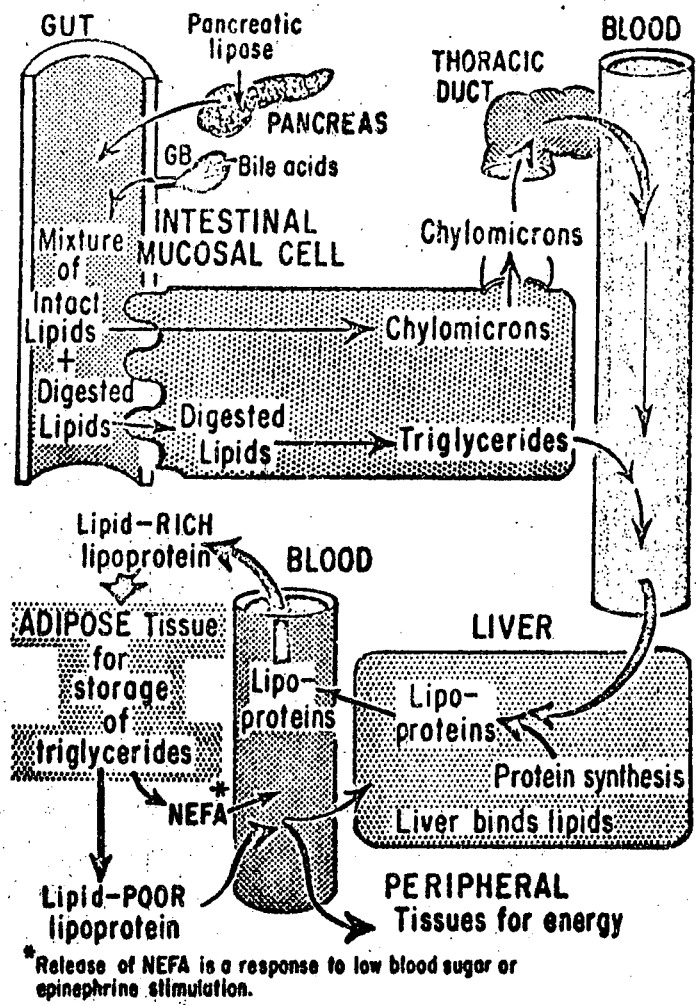
As stated by Dryer (1) the total cholesterol produced from acetate or other sources is almost two or three times the amount consumed in the typical American diet. "Attempts to lower serum cholesterol by reducing the dietary cholesterol have not, in the long run, been successful unless the total caloric intake was reduced at the same time period. This is presumably a result of increased biosynthesis from an excessive energy intake. It is possible to lower the serum cholesterol by diets low in preformed cholesterol if the amount of fat and simple sugars (hexoses and disaccharides) is also curtailed. Oriental peoples, whose diets meet these standards, typically show cholesterol levels some 100 to 150 mg./100 ml. less than their American counterparts. If the Orientals switch to a typical Western diet, the level of cholesterol in their serum rises to typical American levels."

There is unquestionably a statistically significant relationship between high serum cholesterol levels and the incidence of coronary disease. Thus it would appear desirable to maintain low or at least normal levels of cholesterol in the serum. At one time, diets high in polyunsaturated fatty acids were very popular, since it seemed that these substances tended to lower the serum cholesterol level. However, this idea has been attacked on the basis that the level was lowered by driving the cholesterol from the serum into the solid tissues, including the vascular system. Therefore, this procedure may not be without harmful results. It would probably be simpler to restrict caloric intake or burn excess calories by more vigorous physical exercise or work (1).

The liver appears to be the principal site of cholesterol esterfication. In the past great store was set on the relationship between the two forms, but in recent years this has not been the case since the relationship of cholesterol to cholesterol esters is substantially unchanged, except in severe liver disease.

Triglycerides (neutral fats) are esters of fatty acids. They can be readily hydrolyzed by strong alkalis or acids. The lipases of the serum, pancreatic juice and intesti hydrolyze triglycerides. Under normal conditions this hydrolysis results in the production of one or more free fatty acids and mono and diglycerides.

Triglycerides are formed from ingested lipids in the intestinal mucosal cells and enter the portal blood and are transported to the liver. Here they become incorporated into the lipoproteins (see below) and are transported to the adipose tissue for storage. As needed in response to a low blood sugar or as a result of epinephrine stimulation the adipose fat is released from the adipose tissue as non esterfied fatty acids (NEFA or free fatty acids FFA). combined with albumin. Some of this is used for energy and some goes to the liver where it may be reformed into triglycerides. It is thus apparent that the triglycerides are intimately associated with the body lipoproteins.




Factors involved in lipid transport in the body. The liver is central in the formation of lipid-rich lipoproteins, which carry triglycerides to the adipose tissue for storage. NEFA are released as needed to furnish available energy elsewhere. The lymphatic system cooperates in the absorption process.

Figure 1.

Tietz,N.W.,Fundementals of Clin. Chem.,W.B. Saunders,Philadelphia 1970

Virtually all of the plasma lipids exist in the form of complexes in combination with specific proteins, as is the case of the NEFA noted above. These are called lipoproteins. They represent a mechanism by which lipids are kept in aqueous solution in the plasma and can be transferred across cell membranes. They are large molecules containing along with the proteins phospholipids (glycerophosphatides), cholesterol, cholesterol esters, triglycerides and even small amounts of NEFA.

How such large molecules as the lipoproteins (some with a molecular weight of several million) can be soluble in water can best be explained by the existence of the hydrophilic portions of the molecules such as the proteins and phospholipids, being on the outside in contact with the water in the plasma, while the hydrophobic triglycerides, cholesterol, and cholesterol esters are on the inside, sheltered from contact with water molecules in the plasma.

The lipoproteins can be separated into smaller groups by electrophoresis or ultracentrifugation. The latter produces more significant results, but the technique is limited by its expense. The electrophoretic method is now in wide use in clinical laboratories.

The ultracentrifuge technique involves the mixing of an aliquot of serum sample with salt solutions of such density as to cause flotation of low density lipoproteins in an ultracentrifigal field. This mixture is centrifuged at high speed for at least 15 hours. The top layer is then removed and subjected to analytical ultracentrifugation for 30 minutes. During this interval six photographic exposures are made. Analysis of the film and appropriate calculations yield the concentration of the lipoprotein fraction.

Lipoproteins are classified as being low density if they show flotation in a salt solution of density 1.063. Those that float in salt solution with densities between 1.063 and 1.210 are called high densitylipoproteins (HDL).

The low density fraction (LDF) is further subdivided on their flotation rate in Svedberg flotation units (Sf). The subgroup 0-12 is the heaviest of the low density fraction and is found in the plasma of all people. Another group, Sf 12-20, was found by Gofman in increased concentration in persons susceptible to atherosclerosis and myocardial infarction. More recently the Sf 12-20 has been included in a broader group called Sf 12-400. This broad group represents basic low density lipoproteins in which variable amounts of triglycerides have become attached.

The following table from Hoffman (2) gives data on these groups. At one extreme is albumin which carries most of the free fatty acids (NEFA) in the plasma (1 percent lipid, 99 percent protein) and at the other extreme chylomicrons (99 percent lipid, chiefly triglyceride and 1 percent protein).

PERCENTAGE COMPOSITION OF LIPOPROTEINS IN NORMAL POSTABSORPTIVE PLASMA

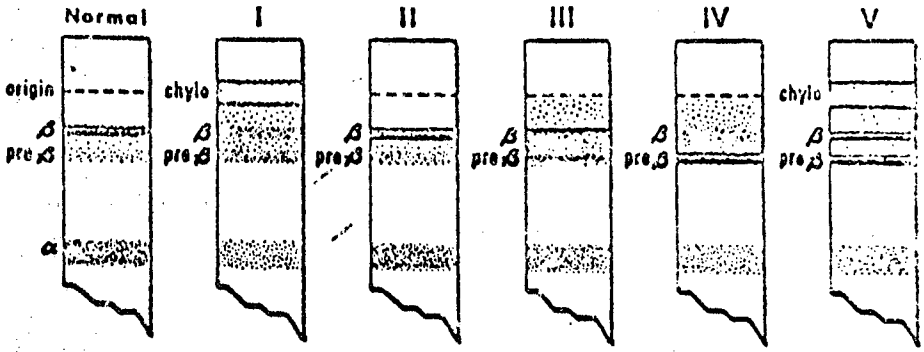
| FRACTION | Sf | AV. CONC., MG/100 ML | ELECTROPHORETIC ZONE | PROTEIN | FREE CHOLESTEROL | CHOLESTEROL ESTER | PHOSPHOLIPID | TRIGLYCERIDE | FFA |
|---|---|---|---|---|---|---|---|---|---|
| Chylomicrons | | 0-10 | $\alpha$ | 1 | 1 | 3 | 8 | 87 | — |
| Low-density (LDF) | | | | | | | | | |
| D<1.006 | 20-400 | 120 | $\beta$ | 7 | 7 | 14 | 19 | 52 | 1 |
| D 1.006-1.019 | 12-20 | 40 | $\beta$ | 11 | 10 | 29 | 23 | 26 | 1 |
| D 1.019-1.063 | 0-12 | 280 | $\beta$ | 21 | 9 | 37 | 22 | 10 | 1 |
| High-density (HDL) | | | | | | | | | |
| D 1.063-1.125 | | 40 | $\alpha_1$ | 33 | 6 | 21 | 29 | 11 | — |
| D 1.125-1.21 | | 240 | $\alpha_1$ | 57 | 4 | 11 | 20 | 6 | 2 |
| Albumin-FFA | | 4,000 | — | 99 | | | | | 1 |

Hoffman, W.S., The Biochemistry of Clinical Medicine, Year Book Pub, Chicago, 1970 Figure 2.

The low density fractions (LDF) have a mobility of beta globulins on electrophoresis and are called beta lipoproteins. The high density lipoproteins migrate further with the alpha globulins and are called alpha lipoproteins.

Of the beta lipoproteins, the Sf 0-12 is normally the largest fraction and contains the largest part of the total cholesterol. From the table it is seen that 129 mg. of the total 216 mg./100 ml. is accounted for by the Sf 0-12 fraction or 60%.

In 1965 Fredrickson and Levy (3) introduced a system of partial phenotyping of familial hyperlipoproteinemia because knowledge of abnormal plasma concentrations of cholesterol and triglycerides was often considered inadequate for specific diagnosis. The system was based on five major lipoprotein patterns as defined by paper electrophoresis. In the past six years they have studied more than 2500 hyperlipemic patients. They have developed highly specific and apparently effective diet and drug regimens for each of the five types. A summary of this work and the current concept of treatment of each type is presented in the following table:




| Features | Type I | Type II | Type III | Type IV | Type V |
|---|---|---|---|---|---|
| Incidence | Very rare | Common | Relatively uncommon | Common | Uncommon |
| Appearance of plasma | Cream layer over clear infranate on standing | Clear | Clear, cloudy or milky | Slightly turbid to cloudy, unchanged with standing | Cream layer over turbid infranate on standing |
| Cholesterol | Normal or elevated | Elevated | Elevated | Normal or elevated | Elevated |
| Triglyceride | Markedly elevated | Normal | Usually elevated | Elevated | Elevated to markedly elevated |
| Clinical presentation | Lipemia retinalis, eruptive xanthomas, hepatosplenomegaly, abdominal pain | Xanthelasma, tendon and tuberous xanthomas, juvenile corneal arcus, accelerated atherosclerosis | Xanthoma planum; eruptive, tuberous and tendon xanthomas; accelerated atherosclerosis of coronary and peripheral vessels | Accelerated coronary vessel disease, abnormal glucose tolerance, hyperuricemia | Lipemia retinalis, eruptive xanthomas, hepatosplenomegaly, abdominal pain, hyperglycemia, hyperuricemia |
| Origin; possible mechanism | Genetic recessive; deficiency in lipoprotein lipase | When genetic, dominant, sporadic; decreased catabolism of beta-lipoprotein | When genetic, recessive; sporadic? | When genetic, dominant, sporadic; excessive endogenous glyceride synthesis or deficient glyceride clearance? | Probably genetic sporadic |
| Age of detection | Early childhood | Early childhood (in severe cases) | Adulthood (over age 20) | Adulthood | Early adulthood |
| Conditions to be excluded | Dysgammaglobulinemia, diabetes, pancreatitis? | Dietary cholesterol excess, porphyria, myxedema, myeloma, nephrosis, obstructive liver disease | Myxedema, dysgammaglobulinemia | Diabetes, glycogen storage disease, nephrotic syndrome, pregnancy, Werner's syndrome | Myeloma and macroglobulinemia, insulin-dependent diabetes mellitus, nephrosis, alcoholism, pancreatitis |

Fig. 3 (Ref 5)

## Therapy of Hyperlipoproteinemia

| Type | Diet | Drug of Choice |
|---|---|---|
| I | 1. Restriction of fat to about 25 gm per day<br>2. Supplementation with medium chain-length triglycerides | None effective at present |
| II | 1. Low-cholesterol diet (less than 300 mg per day)<br>2. Increased intake of polyunsaturated fats | 1. Cholestyramine, 16 to 32 gm per day<br>2. D-Thyroxine<br>3. Nicotinic acid |
| III | 1. Reduction to ideal body weight<br>2. Balanced diet (40 percent of calories fat, 40 percent carbohydrate)<br>3. Low-cholesterol diet (less than 300 mg per day) | 1. Clofibrate, 2 gm per day<br>2. D-Thyroxine<br>3. Nicotinic acid |
| IV | 1. Reduction to ideal body weight<br>2. Increased intake of polyunsaturated fats<br>3. Modest restriction of carbohydrates | 1. Clofibrate, 2 gm per day<br>2. Nicotinic acid, 3 to 6 gm per day |
| V | 1. Reduction to ideal body weight<br>2. Increased intake of protein<br>3. Reduction of fat to less than 70 gm per day<br>4. Restriction of carbohydrates when possible | 1. Nicotinic acid, 3 to 6 gm per day<br>2. Clofibrate |

Fig 3a (Ref. 5)

Another approach to the classification of the hyperlipemias is presented in figure 4:

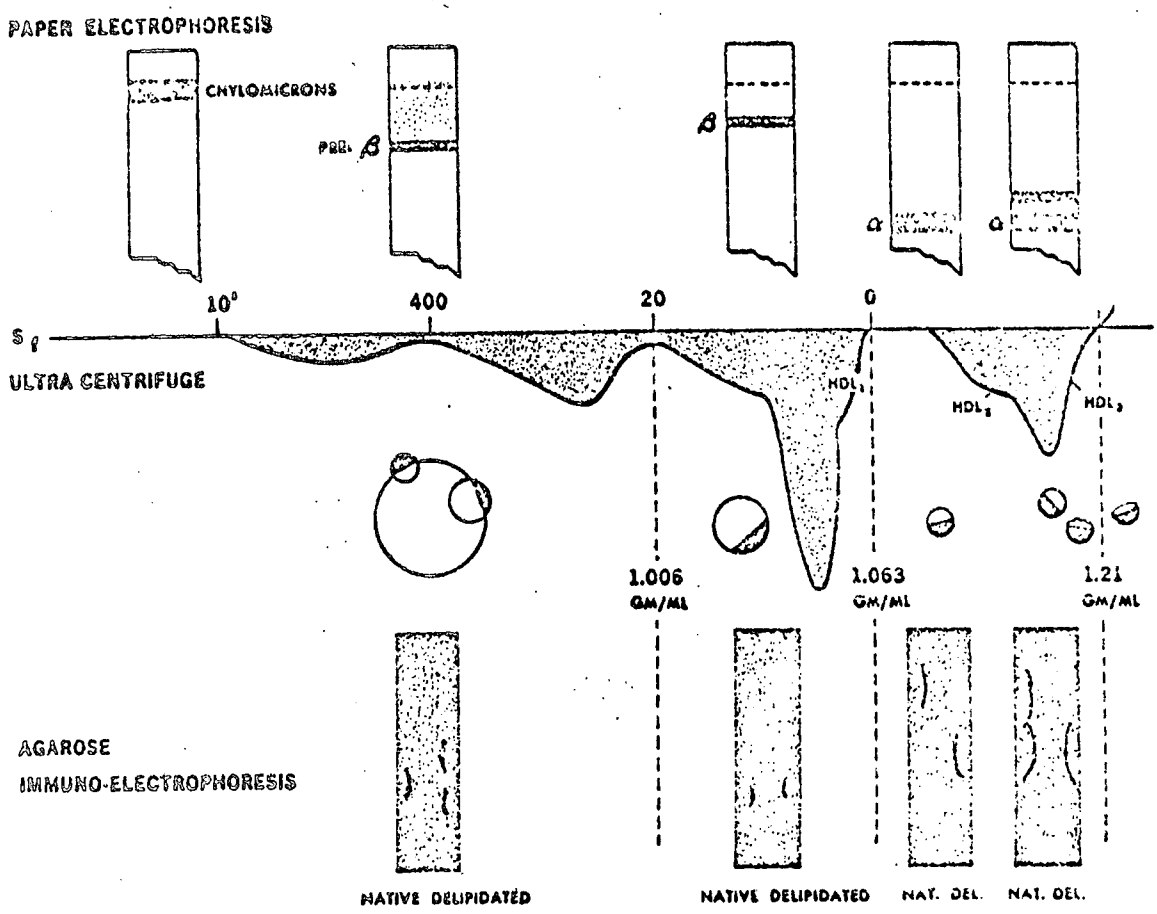
(After Kahlke, W.: Otsch. Med. Wscht., 91:26, 1966.)

| | Essential Hypertriglyceridemia | | | Familial Hypercholesterolemia | |
|---|---|---|---|---|---|
| | fat-induced form<br>Type I | carbohydrate-induced form<br>Type IV | caloric (fat and carbohydrate) induced form<br>Type V | without accompanying triglyceridemia<br>(Type II) | with accompanying triglyceridemia<br>(Type III) |
| Serum | opalescent turbid | clear or turbid | opalescent turbid | clear | clear or turbid |
| Cholesterol | slightly elevated | normal or slightly elevated | slightly elevated | elevated | elevated |
| *Triglycerides | significantly elevated | elevated | elevated | normal | elevated |
| β–Lipoproteins | normal | normal | normal | increased | increased |
| α–2 Lipoproteins (pre–β–lipoproteins) | normal | increased | increased | normal | increased |
| Glucose tolerance | normal | 90% Plus abnormal | Almost 100% abnormal | normal | Approx. 90% abnormal |

*Normal Range 30-135 mg/dl (12 hour fasting)

Figure 4.

A comparison of the patterns on paper electrophoresis, the ultracentrifuge and agarose immuno-electrophoresis is shown in figure 5:




*Schematic Representation of the Major Portions of the Lipoprotein Spectrum as Defined by Paper Electrophoresis, the Ultracentrifuge and by Immunoelectrophoresis Using Antiserums Reacting with Both α and β Lipoproteins.*

Figure 5.

Fredrickson, D.S., Levy, R.I. & Lees, R.S., N.E. Jour. Med. 276:34, 1967.

Roberts et al (4) reviewed the five types of hyperlipoproteinemia from the standpoint of the morbid anatomy. Atherosclerosis of the coronary arteries and aorta is definitely accelerated and extensive in patients with type 2, 3 and 4 and possibly type 5. The peripheral arteries may be excessively atheromatous in type 3 also. The plaques of the coronary arteries of types 2 and 4 contain calcific deposits, pultaceous material and cholesterol clefts. In type 3 the plaques may consist predominantly of foam cells without calcific deposits or cholesterol clefts. Therapy in patients with types 2 and 4 has not proved nearly as effective as that for the patients with type 3 where the response may be dramatic (5). It is reasoned that plaques formed mainly of foam cells as seen in type 3 would be expected to disappear on good therapy, whereas those plaques containing calcium and cholesterol clefts as seen in types 2 and 4 would not be expected to be reversible lesions.

Hepatomegaly and splenomegaly may occur in any patient with hypertriglyceremia and therefore, may occur in types 1, 3, 4 or 5. Foam cells may also occur in the bone marrow and lymph nodes of any patient with hypertriglyceremia. There is nothing distinctive or characteristic of the tissue foam cells occurring in patients with hypertriglyceremia. Hepatic, splenic and marrow foam cells observed in many other conditions, including Niemann-Pick disease, Wolman's disease, generalized gangliosidosis and congenital amaurotic idiocy are similar to those seen in hypertriglyceremia. The number of foam cells seen in the liver, spleen, lymph nodes, and bone marrow with hyperproteinemia probably correlates with the degree of hypertriglyceridemia, although not enough anatomic data is presently available to be certain.

From the foregoing, it seems apparent that each patient suspected of hyperlipemia should have a serum cholesterol and triglyceride determination. If either or both of these are elevated, a lipoprotein electrophoresis is in order to determine the possible phenotype. As can be seen from the electrophoretic patterns, the presence of excessive chylomicrons can be determined in this fashion.

Both cholesterol and triglyceride determinations should be done only in a laboratory equipped and staffed to perform accurate tests. There are scores of procedures for cholesterol determinations and in general there is fairly good comparison of results from one laboratory to another. The determinations of triglycerides is not as frequently accomplished as cholesterol in all laboratories. Triglycerides are often determined by measuring glycerol after its liberation from fatty acids by saponification (6). Since glycerol is also a structural unit of phospholipids that would interfere with the determination of triglycerides the phospholipids must be removed before triglycerides can be analyzed. This separation is made by means of absorption chromatography commonly using silicic acid or zeolite. Another good procedure is to separate the triglycerides by chromatography. Still another good method is based on determination of fatty acids liberated by hydrolysis of triglycerides either by direct titration with alkali or by photometry of the colored fatty acid hydroximate-ferric iron complex that may be chemically produced. The latter procedure usually involves a series of approximations that might better be avoided.

The separation of triglycerides by thin layer chromatography (TLC) or column chromatography are used in some laboratories. The common method in use is to remove the phospholipids by extracting with zeolite and eliminate glucose with copper-lime treatment and saponification of the glycerol and oxidation to formaldehyde and measurement by fluorescence at 405 mu. This procedure can be automated to accomplish 20 determinations an hour using auto analyzer equipment (7). Dade, Harleco, Boehringer-Mannheim and Wood Scientific offer kits for triglyceride determinations. (See table I)

COMPARISON OF TRIGLYCERIDE METHODOLOGIES

TABLE I

| | DADE (8) | HARLECO (9) | BOEHRINGER MANNHEIM (10-11) | WOOD SCIENTIFIC (12) | TURNER (METHOD) (13) |
|---|---|---|---|---|---|
| COST PER TUBE | .77 | 1.30 | 1.69 | .81 | Make own reagents |
| TOTAL NO OF TUBES PER SET | 75 | 30 | 25 | 40 | - |
| SAMPLE SIZE, ml | less than 0.2 | 0.5 | 0.4 | 0.5 | 0.05 |
| WAVELENGTH | VISIBLE RANGE COLORIMETRIC AND FLUOROMETRIC | VISIBLE RANGE COLORIMETRIC | U.V. | VISIBLE RANGE COLORIMETRIC | VISIBLE RANGE FLUOROMETRIC |
| METHODOLOGY USED | MODIFIED ROYER AND KO | MODIFIED FLETCHER | MODIFIED EGGSTEIN AND KREVTZ | CARLSON AND WADSTROM | MODIFIED FLETCHER (PHILLIPS) |
| MINIMUM NO OF TUBES PER FIVE DUPLICATE UNKNOWNS | 13 | 13 | 22 | 13 | 17 |
| Solid additions | 0 | 13 | 0 | 13 | 17 |
| Centrifugings | 0 | 1 | 1 | 0 | 2 |
| Shakings (15 sec) | 26 (6.5 min) | 78 (39 min) | 68 (17 min) | 78 (39 min) | 17 (4 min) |
| Incubating, waiting and cooling times | (40 min) | (57 min) | (51 min) | (7 [illegible]) | (49 min) |
| Readings (1 min) | 12 (12 min) | 12 (12 min) | 44 (44 min) | 12 (12 min) | 16 (16 min) |
| Evaporations (10 min) | 0 | 0 | 0 | 3 (30 min) | 0 |
| Filtrations (2 min) | 0 | 0 | 0 | 13 (26 min) | 0 |
| Aspirating off (30 sec) | 0 | 0 | 0 | 13 (6.5 min) | 0 |
| Total Time | 1 hour 29 min | 2 hours 12 min | 2 hrs 18 min | 3 hrs 3[illegible] min | 2 hrs 9 min |
| Actual Working Time | 49 min | 1 hr 10 min | 1 hr 24 min | 1 hr 5[illegible] min | 1 hr 10 min |
| NO OF REAGENTS TO BE PREPARED | 4 | 2 | 4 | 2 | ALL |
| EXTRA REAGENTS TO BE SUPPLIED BY USER | ISOPROPYL ALC, CHLOROFORM, SULFURIC ACID, | ISOPROPYL ALCOHOL | ALCOHOLIC KOH MAGNESIUM SULFATE | CHLOROFORM PETROLEUM ETHER | ALL |
| REFRIGERATION NEEDED | NO | YES | YES | | YES |

One ml. of serum is usually sufficient. It should be fresh and from a patient fasting preferably for 15 hours. If it is to be shipped some laboratories prefer freezing the sample, but others do not consider this necessary if the shipping time of the fresh specimen is not too prolonged. If the blood is collected in vacutainers the use of glycerol free vacutainers is recommended. Special vacutainers are prepared by the Becton-Dickinson Company for this purpose.

From the foregoing, it should be apparent that triglyceride measurement should not be undertaken without a careful consideration of the problems inherent in this technique.

## Summary

At present it is considered that patients suspected of hyperlipemia should have both a total cholesterol and triglyceride determination. If either or both of these are elevated, lipoprotein electrophoresis should be carried out to attempt to calssify the type of hyperlipemia. Only on the basis of such classification can there be a reasonably rational approach to treatment.

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# PROGRAMMED MULTIPHASIC HEALTH TESTING*

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Wilson and Junger in their book on "Principals and Practice of Screening for Disease" divide prevention of disease into two phases. The first of these is the abolishment of disease and the second is the early detection of disease processes (1). It is believed possible to abolish disease by protecting the individual and even whole populations from attack even before the challenge has been made. While this goal may apply to acute illness such as most infectious disease, it certainly does not, on a long-term or permanent basis, apply to chronic illnesses such as coronary heart disease or to the neoplastic diseases. It therefore becomes important to discover various medical conditions as early in their course as possible and to retard or "cure" them.

However, the fact that we cannot abolish disease does not prevent government policy from implying that we can indeed do so. For example, the report of the National Program to Conquer Heart Disease, Cancer and Stroke published in 1964 (2), contains the statement by President Johnson in charging the DeBakey Commission: "Unless we do better, two thirds of all Americans now living will suffer or die from cancer, heart disease, or stroke. I expect you to do something about it." It is perhaps unfortunate that 100% of us will eventually develop some disease from which we will die and even presidential edicts cannot change this simple fact of life. In order to postpone death, at least among relatively younger individuals, it is therefore believed appropriate to uncover the disease state as early as possible; therefore, early detection becomes important.

With regard to early detection, consideration is almost immediately directed toward the area of preventive medicine as distinct from therapeutic or curative medicine, and most physicians unfortunately have this very precise division of medical practice clearly in mind. In the case of any patient who is well at a given point in time, we are practicing preventive medicine. For example, a particular patient is well until he suddenly sustains his acute myocardial infarction or experiences his stroke or until his cancer was detected. At this point, the physician's approach changes from preventive to therapeutic in orientation.

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*This work was supported by research grant NGR 22-007-203 from the Division of Occupational Medicine and Environmental Health, NASA.

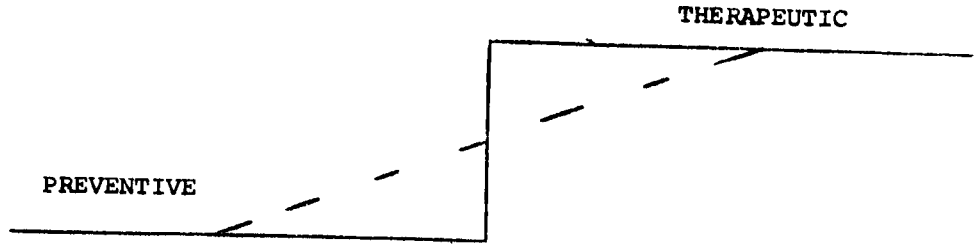


Figure 1. Transition from Preventive to Therapeutic Medicine.

This situation is illustrated by the schematic diagram of Figure 1 which shows the transition from preventive to therapeutic medicine occurring as a step function at a given point in time. Certainly, one cannot argue against the existence of such a step function in considering an acute infectious process such as a pulmonary or urinary tract infection; however, in the case of chronic or degenerative disease, there is, in fact, no step function and the curve looks more like the dashed line with the time course being years or even decades rather than hours or days.

Using coronary heart disease as an example, this is well demonstrated by the data of White, Edwards, and Dry (3). In this study, 600 hearts were examined at autopsy and the degree of coronary atherosclerosis was graded on a scale of 1, representing minimal sclerosis, to 4, implying complete occlusion. Maximal atherosclerosis occurred in individuals approximately 55 years of age, even though most significant coronary episodes occur somewhat beyond this age. Coronary atherosclerosis is seen to develop, at least from these results, during the ages of 35 to 55. In interpreting such data, however, it is necessary to realize that the hearts included in the study were taken from different individuals, and that the investigation was not longitudinal in nature. The implications are nevertheless valid, and the progressive nature of degenerative cardiovascular disease has been clearly demonstrated.

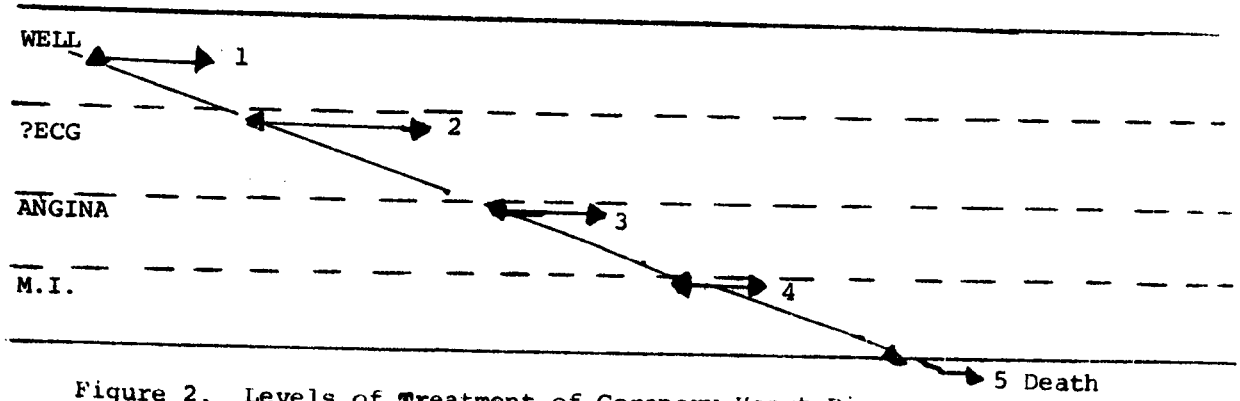


Figure 2. Levels of Treatment of Coronary Heart Disease

The physician is then faced with a dilemma as regards his basic approach toward the treatment of coronary heart disease. In order to consider this problem, hypothetical "therapeutic levels" as regards coronary heart disease have been illustrated schematically in Figure 2, which is, of course, a vast oversimplication of complex, almost individualistic, disease patterns which present themselves in different patients. With this limitation in mind, it is possible to discuss alternate approaches to treatment.

In the case of 42% of all deaths from coronary heart disease, this diagnosis cannot presently be made during the life of the patient (4). Stage 5 of Figure 2 (death) is, therefore, not an unusual level for the physician to first diagnose cardiovascular disease. The onset of myocardial infarction (Stage 4) is likewise not a satisfactory moment for initial diagnosis. Although the mortality from myocardial infarction is only about 40% (5), half of all survivors are likely to be dead within eight years following recovery from their initial attack (Singer, R.B., unpublished data). Stage 3 (angina pectoris) is, once again, an inappropriate level at which to initiate adequate medical treatment, since about 50% of angina patients will be dead within 5 to 7 years after this diagnosis is first established (6-7). Even the questionable or ischemic electro-cardiogram (Stage 2) is associated with an abbreviated life expectancy. For example, the ischemic post-exercise electrocardiogram carries with it a mortality several times greater than expected (8).

## COSTS OF SCREENING TESTS

With the example of Figure 2 in mind, it therefore becomes useful to consider the desirability of detecting disease at an earlier stage than would normally be encountered using the vehicles provided by conventional medical practice. Neglecting for the moment all benefits of a social nature which might be derived from the early detection of disease processes, one can consider only the economic benefits which could result from health screening. The economic goal of early detection is hopefully less morbidity, less hospitalization, less expense in caring for seriously ill patients and less absence from income-producing employment. So that there may be less expense involved in the care of ill people if one detects disease at an early stage.

Contrasted with these cost savings are the costs of screening procedures themselves. We should also realize that uncovering cases can result in costs of long-term management which must be contrasted with costs of treating acute illness. Uncovering a case of diabetes mellitus, for example, can result in

a requirement for twenty, thirty, or more years of constant and often fairly intensive medical management. We must also compare costs and value, here considering the rationale of screening for diseases which might be quite prevalent in the population. As an example, virtually the entire population of Ethopia suffers from tuberculosis, rendering screening for this disease entirely impractical and of essentially no value.

As we know, however, costs of health screening can be reduced through the use of technicians in lieu of highly trained personnel, such as physicians and nurses and thru the application of automated techniques. As an example of the need for improved automation in health screening methodology, consider for a moment the problems encountered in taking an electrocardiogram fourty or fifty years ago. In order to have his cardiogram taken, the patient would first roll up his trousers and shirt sleeves. His extremities would then be immersed in salt water solution, into which were also placed electrical conductive leads. These wires would then be directed to a primitive electrical amplifier circuit. A technician would stand at the instrument and turn various dials for from five to ten minutes or until he was able to find a connection which resulted in minimal electrical noise. While the patient remained essentially motionless, a small strip of electrocardiograph record was recorded. This same process was then repeated for all of the different lead configurations. Think for a moment how impractical screening electrocardiography would be if such complex and exacting adjustments were required in modern cardiologic practice.

## THE VALIDITY OF HEALTH SCREENING PROCEDURES

During the past twenty years, various criteria have evolved for purposes of evaluating health screening procedures. In addition to possible benefits derived from the procedure, another criteria has been the validity of the particular test in terms of its capacity to correctly detect disease processes. Validity really implies the ability of the procedure to separate those patients who have the particular condition from those who do not, thereby correctly identifying both positives and negatives. The ability of a test is to classify as positive those persons with the disease is called sensitivity and as negatives those persons without the disease is called specificity. The following general equations can be used to determine validity (9):

$$\text{SENSITIVITY} = \frac{\text{Diseased Persons with a Positive Test}}{\text{All Persons in the Population with the Disease}}$$

$$\text{SPECIFICITY} = \frac{\text{Non-Diseased Persons with a Negative Test}}{\text{All Persons in the Population without the Disease}}$$

In designing a particular screening test, a primary concern is the attainment of high values of both sensitivity and specificity. In reality, one is actually forced into some form of compromise in that a screening "threshold" which is low enough to pick up virtually all true positives will, at the same time, result in the indication of a relatively large percentage of false positives as well. It is therefore necessary to set arbitrary limits for allowable false negative determinations so that the test is suitable for purposes of routine screening for disease.

Depending upon the screening procedure, sensitivities can range from 40% (or less) to perhaps 99% with specificities which must certainly exceed 70-75% in order to make the test practical on a large-scale basis. One usually attempts in most cases to set limits such that the specificity is at least 90% so as to render the test truely useful.

Over the past twenty years, principles of validity testing have been applied to various chemical laboratory tests, electrocardiography, radiographic interpretation, cervical cytology, pulmonary function monitoring and certain other health screening tests.

In addition to sensitivity ($S_e$) it is possible to define the term non-specificity ($N_S$) as being:

$$N_S = \frac{\text{Non-Diseased Persons with a Positive Test}}{\text{All Persons in the Population without the Disease}}$$

and the incidence ($I_X$) as:

$$I_X = \frac{\text{Persons with the Disease}}{\text{All Persons Tested}}$$

On this basis, Sunderman (10) has performed the following calculations:

| INCIDENCE OF "X" DISEASE, $I_X$ | PROBABILITY OF "X" DISEASE WHEN $T_X$ IS POSITIVE, $P(X/T_X)$ |
|---|---|
| $I_X$ | $\frac{S_e \cdot I_X}{N_S(1-I_X) + S_e \cdot I_X}$ |
| 20% | 0.83 |
| 2% | 0.29 |

In other words, the probability of having a disease when the screening test is positive is very definitely related to the incidence of that disease. This concept can be extended in that it is also possible to calculate the percentage of healthy subjects who would have 0, 1, 2, ....5 abnormal test results in multi-test health screening profiles, assuming 95% tolerence limits. In this case, the probability that a healthy subject will have at least one abnormal result is dependent upon the number of different independent tests, y, such that $P = 1 - (.95)^y$. A table of results as provided by Sunderman (10) is indicated in Figure 3.

From Figure 3 it is evident that a perfectly healthy individual subjected to a twelve test screening profile would stand about a 50% chance of having no abnormal results, a 34% chance of having one abnormal result and a 12% chance of having two or more abnormal results. Using the 22 channel analyzer soon to be available from Dow Corning, the healthy subject would stand greater than a two in three chance of having at least two abnormal test results. In considering these data, it would appear that we must also consider the statistical problem which lies in the difficulty in separating normal from abnormal values.

## SEPARATION OF NORMAL FROM ABNORMAL VALUES

It has been mentioned previously, with regard to validity testing, that it is rarely possible to separate any population into those who are clearly "well" and those who are "sick". As a result, one is, in many cases, dealing with test values which lies somewhere between those which are normal and those which are abnormal -- in the so-called "gray", or borderline, area. One is therefore faced with the difficult problem of distinguishing one patient who has the disease from another who does not.

Individuals having "normal" values can, in most cases, be separated from those who have high abnormal values. So-called "borderline cases" lie imtermediate between the two. We can say that the borderline problem creates significant difficulty for the physician in his approach to patient management. The physician does not feel -- and logically so -- that these patients should be treated as if they were diseased. Neither does he feel comfortable in dismissing them as normals. The result is that he often finds himself performing repeated, time-consuming, and frequently costly additional tests -- all too often resulting in exactly the same finding; namely, that the patient's tests label him as being borderline -- neither "well" nor diseased.

Figure 3

PERCENTAGES OF HEALTHY SUBJECTS WITH 0,1,2,...5
ABNORMAL RESULTS IN MULTI-TEST PROFILES
(Normal Limits = 95th Percentiles)

| No. of Tests in Each Profile | No. of Abnormal Results in Each Profile | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| 5 | 77.4 | 20.4 | 2.1 | 0.1 | | |
| 6 | 73.5 | 23.2 | 3.0 | 0.2 | | |
| 7 | 69.8 | 25.7 | 4.1 | 0.4 | | |
| 8 | 66.3 | 27.9 | 5.1 | 0.5 | | |
| 9 | 63.0 | 29.9 | 6.3 | 0.8 | | |
| 10 | 59.9 | 31.5 | 7.5 | 1.0 | 0.1 | |
| 11 | 56.9 | 32.9 | 8.7 | 1.4 | 0.1 | |
| 12 | 54.0 | 34.1 | 9.9 | 1.7 | 0.2 | |
| 13 | 51.3 | 35.1 | 11.1 | 2.1 | 0.3 | |
| 14 | 48.8 | 35.9 | 12.3 | 2.6 | 0.4 | |
| 15 | 46.3 | 36.6 | 13.5 | 3.1 | 0.5 | 0.1 |
| 16 | 44.0 | 37.1 | 14.6 | 3.6 | 0.6 | 0.1 |
| 17 | 41.8 | 37.4 | 15.8 | 4.1 | 0.8 | 0.1 |
| 18 | 39.7 | 37.6 | 16.8 | 4.7 | 0.9 | 0.1 |
| 19 | 37.7 | 37.7 | 17.9 | 5.3 | 1.1 | 0.2 |
| 20 | 35.8 | 37.7 | 18.9 | 6.0 | 1.3 | 0.2 |
| 21 | 34.1 | 37.6 | 19.8 | 6.6 | 1.6 | 0.3 |
| 22 | 32.4 | 37.5 | 20.7 | 7.3 | 1.8 | 0.3 |

*DOW CORNING ANALYZER

With regard to the chronic diseases, it is believed that one is on relatively safe grounds in postponing decision on borderline values. For example, in diabetes testing, it has been demonstrated that the inter-clinic variation in providing a positive diagnosis of diabetes mellitus can range from a low of about 1% to a high of over 4% of the patient population (11). In this case, the diagnosis of diabetes would depend not upon the absolute glucose value and not upon the particular physician performing the evaluation, but rather upon fairly arbitrary diagnostic criteria. For example, an individual having a post-prandial blood sugar between 109 and 127 mg. percent has approximately equal likelihood of being labeled as diabetic and non-diabetic (11). This should not imply that the physician withhold advice of a strictly preventive nature, such as the control of obesity or the recommendation of a proper diet, in any patient having a borderline glucose determination. This same statement should apply to sound preventive medicine in the face of other borderline determinations as well.

In reviewing the results of automated multiphasic health testing procedures conducted on basically healthy populations, the physician must keep these matters clearly in mind. As we have seen, some abnormal results are actually only variants of normal, while other abnormal values signal potential dangerous disease and are of key importance in initiating suitable therapeutic action if one is to have any hope of promoting "cure." But how is the physician to sort out the "wheat from the chaff?" In considering this problem the most important factor would appear to be the cost of positive tests from health screening procedures.

In one approach to this problem, Collen et al have calculated the cost to identify a clinically important test result in an automated multiphasic screening program (12). When over fourty thousand multiphasic examinations were analyzed, the most costly procedure was found to be the detection of breast cancer, listed as being $408 per positive mammogram, even when limited to women over the age of 47. The least expensive was hearing impairment ($1.55 per positive audiogram). All other tests ranged between these extremes, usually varying with age and sex of the examinee. These costs were critically related to a multiphasic laboratory load of 500 patients per week. The results showed how the prevalence of an abnormal test depended upon the specific population examined, especially as related to its age-sex composition.

Although the above study was very thorough to the extent that it was conducted, a number of factors were not satisfactorily considered in the investigation. These factors were the following:

1) Although mentioned by the authors, it was not sufficiently emphasized that a doubling of cost per test would result from a halving of volume. Since most health screeing facilities would operate at less than half the quoted volume, this would at least double the cost.
2) The costs do not reflect research, development and equipment expenses, all of which were largely provided under government grants.
3) Many of those patients noted to have positive test results already knew of their disease; i.e. poor hearing, vision tests, etc.
4) The costs do not reflect the expense per true positive, but only per positive test. In their paper, Collen et al (12) note that the cost per true positive test for breast cancer was actually about $2,000, not $408, because only one in every five of these women were subsequently noted to have positive breast biopsies.
5) In the case of false positive tests, significant expense was often required to rule-out the presence of disease.
6) It was not determined how much additional cost was required to treat the true positive cases at an earlier stage than would have been required via conventional medical detection channels.
7) Most importantly, it is not clear how effective was the clinical result of early detection; namely, how much healthier was the patient and/or how much longer did he live?

## RISK EVALUATION

The matter of actual cost versus benefit of health screening promotes serious consideration and this is not easily resolved. The problem becomes even more complex when one thinks about appropriating funds for conducting periodic multiphasic screening of employees of large industrial groups or governmental agencies. I think that an indication of one possible approach to this problem was presented at this conference last year by Gen. Hoffman, who indicated that occupation could be added to the criteria of age and sex in considering what tests to do on which employees at what time interval (13).

In considering chronic disease and its detection one concept in health care that has received far too little attention has been the probability of disease states. In other words, the disease being screened for in a given individual should in some way be related to the likehood of the disease in that individual rather than in the population as a whole. For example, there would be little justification for performing tonometry measurements in young adults; yet, such a determination in persons over 40 years of age is indicated as part of comprehensive health care. Similarily, mass screening for congenital heart disease, while a sound medical practice in school children, cannot be justified as part of the evaluation of adult patients. One approach to this problem has been avocated by Sadusk and Robbins who suggest that the evaluation of any patient should be dictated by mortality figures for individuals of the same age and sex (14). In planning any battery of health screening tests, it is therefore most important to consider likelihood of the diseases being screened for. One problem with such data is that they reflect only mortality figures -- not morbidity -- and one fails to appreciate the overall health implications of certain diseases such as degenerative arthritis, glaucoma and diabetes mellitus. Nevertheless, such data do comprise a valuable starting point from which to diverge toward the designation of specific health screening procedures.

## PRESENT STUDY

With the above considerations in mind, it was believed feasible to extend the concept of risk factor analysis to the screening of basically-well individuals. Several years ago, the Lahey Clinic Foundation developed an initial automated medical history questionnaire for use in the screening of most patients coming to the clinic for medical evaluation. Under the supervision of the author and with the advice and cooperation of many physicians on the Lahey Clinic staff, the original questionnaire was extensively modified over a period of almost two years during which the questionnaire was completed by approximately 25,000 patients. The fourth version was designed for mark-scanning input and includes in excess of 500 specific questions.

Following automated processing of the completed questionnaire, a computer printout is produced. This printout is inserted into the chart for each new patient between two other forms, one of which is utilized for recording information relating to the present illness -- if any, and the other for the insertion of findings on physical examination. In addition to open-ended type data, almost all of the information relates to the patient's general medical history, family and social history and review of systems.

In the present study, patient answers to all medical history questions provided by between 1,000 and 2,000 patients are being correlated with laboratory results for 22 different laboratory biochemical determinations. This project was initiated only three months ago. However we would anticipate data of the form shown in Figure 4, which depecits results of another study and indicates white blood cell count on the second day in a Coronary Care Unit tabulated as a function of recovery from myocardial infarction. As a result, it may be possible to suggest to the physician planning health testing profiles exactly which tests should be conducted on a particular patient and which abnormal results are, on the basis of the patient's own medical history, likely to be of clinical importance. Completion date for the present investigation is scheduled for June 30, 1971 and it is hoped that the results will be available for presentation at next year's meeting.

CORONARY CARE UNIT

OCTOBER 1, 1969

CELL PERCENT BASED ON COLUMN SUM

CONTINGENCY TABLE NO. 16

VAR 16 WHITE BLOOD CT. 2

| VAR 120 RECOVERY | 20000+ OVER | 15000-19999 | 12000-14999 | 10000-11999 | 8000-9999 | 6000-7999 | 4000-5999 | 2000-3999 | UNDER 2000 | TOTAL | PERCENT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UNEVENTFUL | 28.6 | 56.2 | 56.7 | 58.6 | 83.3 | 87.8 | 88.2 | | | | |
| | 2 | 9 | 17 | 17 | 40 | 36 | 15 | | | 136 | 72.3 |
| EVENTFUL | 71.4 | 43.7 | 43.3 | 41.4 | 16.7 | 12.2 | 11.8 | | | | |
| | 5 | 7 | 13 | 12 | 8 | 5 | 2 | | | 52 | 27.7 |
| TOTAL | 7 | 16 | 30 | 29 | 48 | 41 | 17 | | | 188 | |
| PERCENT | 3.7 | 8.5 | 16.0 | 15.4 | 25.5 | 21.8 | 9.0 | | | | 100.0 |
| MEAN | 1.71 | 1.44 | 1.43 | 1.41 | 1.17 | 1.12 | 1.12 | | | | 1.28 |
| SD | 0.49 | 0.51 | 0.50 | 0.50 | 0.38 | 0.33 | 0.33 | | | | 0.45 |

CHISQUARE STATISTIC = 25.130** WITH 8 DEGREES OF FREEDOM (SIGNIFICANT AT THE 0.002 LEVEL)

NO. OF MISSING UNITS = 115

Figure 4.

White Blood Cell Count as a Function of Recovery

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N73-17075

# CONTROL OF NITROGEN DIOXIDE IN STACK EMISSION BY REACTION WITH AMMONIA

By Allen J. Metzler and Edward F. Stevenson
Lewis Research Center

A unique combustor test facility was developed for an advanced combustor research program. This facility utilized an oxidant-rich hydrazine-nitrogen tetroxide rocket as a gas generator to simulate high enthalpy inlet flow conditions to the combustor (reference 1). Propellant flow rate was high, 100 pounds per second, and the exhaust was pumped to the atmosphere through a high stack. The exhaust emissions contained sufficient $NO_2$ from even 5-second test runs to form large reddish-brown clouds which dispersed slowly, and potentially could drift and settle over nearby populous areas. Although the concentration in the drifting cloud was low, concern over possible health hazard to the adjoining communities required that the nitrogen dioxide level in the exhaust emissions be reduced essentially to zero and that the gases emitted from the stack be colorless.

Nitrogen dioxide is a brown gas that is intensely colored so that even low concentrations are readily visible. Furthermore, visibility is increased as the optical path length is increased. Therefore, in order to render stack emissions which contain $NO_2$ colorless, removal of the oxide must be essentially complete and must be accomplished within the confines of the exhaust system.

Prolonged or repeated exposure to low concentrations of nitrogen dioxide can be a health hazard to healthy individuals and can be a severe hazard to those with respiratory problems. The degree of the hazard would

be dependent upon not only the concentration and time of exposure, but also on the health of the individual exposed to the $NO_2$. Thus, to eliminate all possibility of hazard to the surrounding populace, the continuance of the research program was dependent upon the removal of the $NO_2$ from the stack gases. As an added precaution to protect against accident, no tests could be run unless the wind would carry the exhaust emissions away from the nearby populated areas.

Chemically, $NO_2$ acts as an acid and oxidizer which suggests possible removal by either acid-base reaction or by combustion reaction processes. Prior concern with the problem suggested removal by sodium hydroxide absorption or by consumption in a fuel-rich natural gas-air burner (reference 2,3). Sodium hydroxide absorption scrubbing as well as exhaust gas burners are impractical removal schemes for use with rocket test facility exhaust systems because of the extensive and expensive reactors which would be required to insure the almost complete removal of $NO_2$ gas from such a high volume flow rate system.

An acid-base gas-phase reaction system which utilized anhydrous ammonia as the reactant to remove the $NO_2$ was ultimately selected for a gas treatment system on the basis of its effectiveness in removing $NO_2$ from rocket exhaust emissions and because of its practicality for use in a high-volume system. The effectiveness in removing $NO_2$ was demonstrated by only limited testing and was not optimized. However, the $NO_2$ level in the exhaust emissions was so reduced that the resulting cloud was completely white.

# SCALE MODEL OF TEST FACILITY AND FLOW SYSTEM

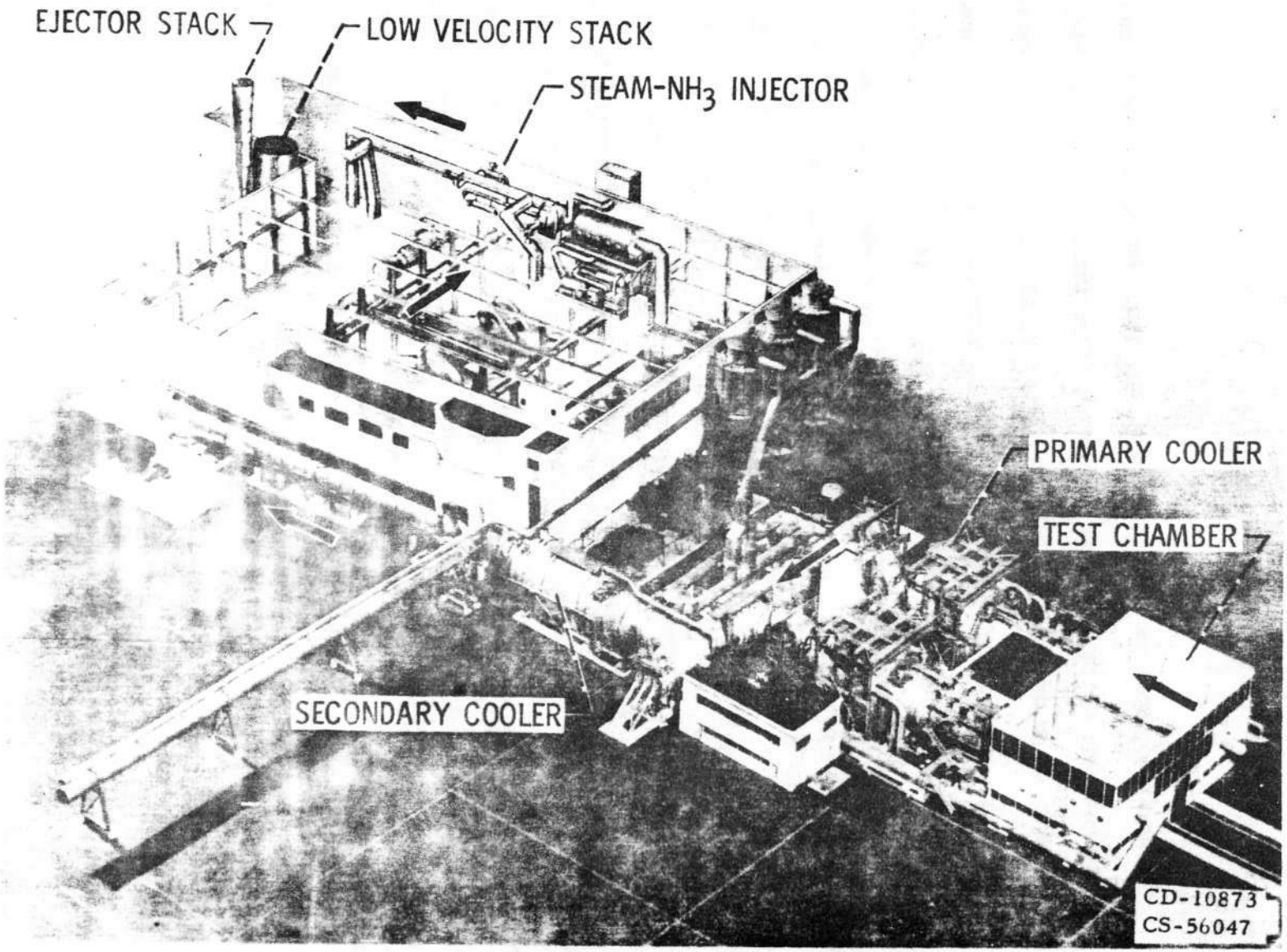



FIG. 1

Preliminary analyses indicated the importance of reaction time and ammonia concentration on the removal efficiency of the system and suggested a system design to optimize the $NO_2$-$NH_3$ reaction through extended reaction-contact time and high ammonia concentration and yet emit no visible or hazardous stack gases.

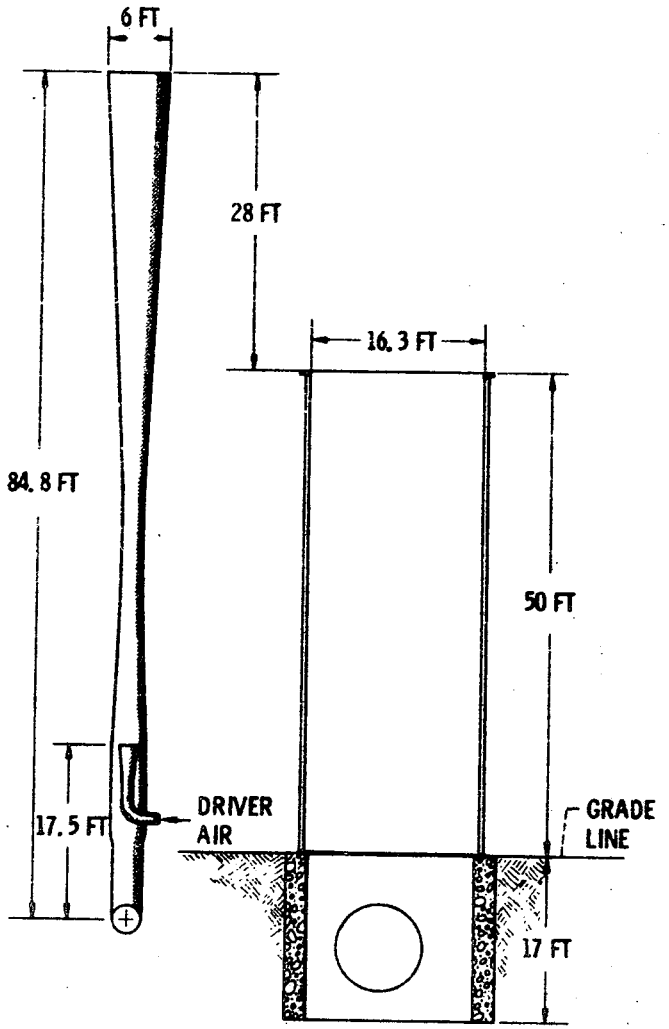
The purpose of this publication is to document the development and performance of a practical system for the removal of $NO_2$ gas from research facility exhaust gases so that this information might serve as timely guidance to others in the R&D community faced with similar problems. This work was conducted at the Lewis Research Center, Cleveland, Ohio.

## POLLUTION PROBLEM SOURCE

Test Installation.--A combustor test facility consisting of a 20K thrust rocket and a direct-connected combustor was installed in the test chamber of an altitude system for a combustor test program (reference 1). The test chamber was pumped with six stages of rotating machinery, and an air ejector served as a seventh stage when required. Figure 1 is a photograph of a scale model of the dual-chamber test facility to schematically and geometrically illustrate the flow system. The grid scale of the figure is equal to 100-feet per division.

The rocket exhaust flow traversed about 1000-feet of large diameter piping between the exhaust stack and the test chamber. This resulted in a time lag of about 8 seconds between the time of rocket engine firing and the first evidence of brown coloration in the ejector stack exhaust. Flow rate time-averaging undoubtedly occurred during this period, but the extent of it is not known.

# COMPARISON OF EJECTOR STACK AND LOW VELOCITY STACK GEOMETRIES




CS-56051

FIG. 2

For the combustor tests, the 14-foot diameter test chamber was evacuated to 3 psia. Total gas loading at the test chamber consisted of 103 pounds per second of exhaust flow plus ten to fifteen pounds per second of purge air-flow which was added to prevent recirculation of propellant vapors in the test chamber. Downstream of the cooler an additional flow of air was introduced to prevent compressor surge. In-leakage through seals and fittings was estimated to be near 30 pounds of air per second so that the total mass flow rate passing through the 13-foot diameter ducting and the pumping equipment to enter the exhaust stacks was about 150 pounds per second. This is equivalent to a duct velocity of about 100-feet per second upstream of the compressors. Six stages of rotating machinery compressed the gas to near-atmospheric pressure. Downstream of the compressors the exhaust flow was diverted to either of two exhaust stacks (Figure 2). One stack was a low-velocity chimney 17-feet in diameter and 50-feet high which was acoustically baffled internally for sound suppression. The other, which was used for most of the test program, was an ejector stack which used compressed air as the driver gas. It was 78-feet high and had an exit diameter of 6-feet. The ejector air flow was 65 pounds per second, so that the total ejector stack flow rate was about 215 pounds per second. This resulted in an exit velocity of 105 feet per second which added an additional effective stack height due to exit gas velocity of 127-feet as calculated according to reference 4. Total effective stack height for the ejector then would be near 200-feet as compared with the 50-foot height of the low velocity exhaust stack.

# AIR DISPERSION OF $NO_2$ EMITTED FROM THE EJECTOR STACK

| | CONCENTRATION OF $NO_2$ AT STACK EXIT PLANE, PPM | |
|---|---|---|
| | 4900 | 9000 |
| STACK EXIT VELOCITY, FT/SEC | 80 | 104 |
| EFFECTIVE STACK HEIGHT, FT | 137 | 205 |
| WIND VELOCITY, FT/SEC | 10 | 16 |
| GROUND CONCENTRATION, PPM | 5 | 9 |
| DISTANCE FROM STACK, FT | 1365 | 2050 |

CS-56052
TABLE I

Ejector stack emission during preliminary rocket firings was dark brown and appeared to be heavy with $NO_2$. Gas samples taken from the core flow at the top of the stack indicated an $NO_2$ concentration of near 4500 ppm even when the rocket was operating at a low thrust level. The follow-on combustor had not yet been installed during these preliminary tests. Extrapolation of this analysis to the 20K thrust level, however, indicated a possible concentration of $NO_2$ in the stack effluent of near 9000 to 10,000 ppm, but the combustor installation was expected to markedly reduce this concentration.

The stack emission of $NO_2$ was dispersed in the atmosphere and no ground effects were noted. However, safety and air pollution control considerations required that an estimate be made of the maximum ground level concentration which might be expected assuming atmospheric dispersion with very moderate wind conditions (reference 4). The assumptions made and pertinent results of these calculations are listed in Table 1. Thus, even for high concentrations of $NO_2$ in the gases emitted from the ejector stack, normal atmospheric dispersion with a mild wind would disperse and dilute the emission sufficiently so that the concentration at ground level touch-down would be well below the short term dangerous limits of 100-150 ppm (reference 5). Conditions of temperature inversion would, of course, inhibit dispersion and increase the severity of the problem.

The local laboratory standards for air quality required that the $NO_2$ concentration of the stack emission be sufficiently reduced to render the

# THEORETICAL EXHAUST GAS COMPOSITION FOR $N_2H_4$-$N_2O_4$ ROCKET WITH EQUILIBRIUM OR FROZEN NOZZLE EXPANSION

$A_e/A^* = 5.3$, $P_c = 300$ PSIA, O/F = 3.0

| COMPONENT | EQUILIBRIUM | | FROZEN | |
|---|---|---|---|---|
| | MOL % | LB/LB PROP | MOL % | LB/LB PROP |
| $H_2O$ | 0.38946 | 0.28103 | 0.37221 | 0.27096 |
| $N_2$ | .39792 | .44651 | .38394 | .43464 |
| NO | .00065 | .00078 | .02155 | .02613 |
| $NO_2$ | .00000 | .00000 | .00007 | .00013 |
| $O_2$ | .21187 | .27156 | .19379 | .25058 |
| OH | .00010 | .00007 | .02214 | .01522 |
| H | ------- | ------- | .00058 | .00002 |
| $H_2$ | ------- | ------- | .00252 | .00021 |
| O | ------- | ------- | .00321 | .00208 |

CS-56049

TABLE II

effluent colorless. Therefore, effort was directed to first determine the source and quantity of the $NO_2$ which was entering the exhaust gases. The second approach toward solving the pollution problem was directed toward the development of an effective and simple system to remove the $NO_2$ from the exhaust mixture before it was pumped to the atmosphere.

$NO_2$ Problem Source.--The combustor test facility consisted of a 20K thrust level rocket and combustor in a direct-connect series installation. The rocket burned hydrazine-nitrogen tetroxide at an oxidant-fuel ratio (O/F) equal to 3 with a propellant flow rate of 100 pounds per second. Combustor fuel flow ranged from zero to that required for chemical stoichiometry. The rocket exhaust composition predicted by thermodynamic calculations (reference 6) is shown in Table 11 for the assumptions of equilibrium and frozen nozzle expansion. The actual nozzle process was probably somewhere between the two cases.

These data indicate that in the absence of other possible removal mechanisms, $NO_2$ was released to the exhaust system at a rate somewhere between 0.12 to about 4 pounds per second. Including the system air dilution effects, this corresponded to a maximum concentration of about 10,000 ppm at the exit of the ejector stack. For the case of combustion in the connected combustor, appreciably less $NO_2$ would be expected to be released. Similarly, the assumption of equilibrium nozzle expansion rather than frozen would reduce the predicted level of $NO_2$ by a factor of near 30 so that the probably concentration of $NO_2$ in the 2 stack gases was expected to be well below 10,000 ppm.

Post-run analysis of rocket propellant flow records indicated that as much as 18 pounds of unreacted $NO_2$ entered the rocket chamber in 0.25 seconds before the hydrazine flow was initiated. This is equivalent to a transient unreacted $NO_2$ flow rate of 72 pounds per second. Thus, system thermodynamics, start transients, and rocket combustion inefficiency all contributed to the $NO_2$ in the exhaust gases. Except for the starting flow, much of this could be consumed in fuel-rich regions of the connected combustor. The $NO_2$ release from the start transient was, therefore, considered to be the more severe problem source since there were no mechanisms to remove it.

Stack Emission Density.--Gases which contain even a low concentration of $NO_2$ appear colored when viewed against light backgrounds. The opacity, or apparent density, and color of a cloud containing $NO_2$ is partially dependent upon the angle of illumination and the effective optical path length, or cloud depth, for light absorption. A concentration of 0.25 ppm in the Los Angeles atmosphere appears light brown against a light sky (reference 7). As deduced from references 5 and 8 an equilibrium mixture of $N_2O_4$ and $NO_2$ may be qualitatively characterized as being orange with 22% $NO_2$, red-brown with 28%, and dark chocolate brown with 48%. These color descriptions, however, were probably based upon laboratory observations of relatively small containers. Since the apparent color density or opacity of $NO_2$ vapors is a direct function of the product of the concentration (ppm) and the optical absorption path length (feet), the density may be quantitatively described in terms of ppm-ft. units. A cloud 100-feet thick with

a concentration of 100 ppm would thus have the same optical density as one only 10-feet thick but with a concentration of 1000 ppm. Hibbard (reference 9) has estimated a light brown cloud to have a density of near $10^4$ ppm-ft. The visible detection limit for $NO_2$ is nominally accepted as about 50 to 100 ppm, but the path length or cloud depth is not specified. Using Hibbard's estimate it may be concluded that this visible limit probably assumes a path length of at least several feet under ideal conditions.

From these considerations two basic facts are apparent. First, non-colored stack emissions require essentially complete removal of the $NO_2$. Secondly, the concentration of residual $NO_2$ in stack gas emissions cannot be determined by "eyeballing" the apparent color density but requires analytical instrumentation. Rugged, automatic instrumentation for on-line analysis was not available for these tests, although an instrument suitable for $NO_2$ concentrations ranging from 0.1 to 15,000 ppm is described in reference 10. For most of these tests the stack gases were bottle sampled at the exhaust stack at a point just upstream of the ejector nozzle. The bottle samples withdrawn were subsequently analyzed for $NO_2$ and $NH_3$ content by wet analytical methods.

## NITROGEN DIOXIDE REMOVAL

Removal by Chemical Reaction.--Nitrogen dioxide is water soluble to form nitric acid, but it is not an anhydride of nitric acid. The absorption can be simply expressed by the reactions

$$\begin{aligned} H_2O + 2NO_2 &= HNO_3 + HNO_2 \\ HNO_2 + NO_2 &= HNO_3 + NO \end{aligned} \qquad (1)$$

The absorption is not rapid and does not result in complete removal of the $NO_2$. Complete removal is favored by the neutralization of the acid products.

Nitrogen dioxide is also a strong oxidizer and is readily burned with an excess of fuel.

A third mechanism for the removal of $NO_2$ is suggested by references 11 and 12. At temperatures below 200°C the main reaction product between anhydrous ammonia and $NO_2$ is $NH_4NO_3$. At low pressures, at least 99% of the product is formed according to

$$2NO_2 + 2NH_3 = NH_4NO_3 + N_2 + H_2O \qquad (2)$$

with only traces of ammonium nitrite being formed, and this may originate from the reaction between the $NO_2$ and the water product of the reaction.

These reactions with nitrogen dioxide suggested various schemes for the removal of $NO_2$ from stack gases. Combustion systems, however, appeared to be too cumbersome, expensive, and impractical for a large volume system. An absorption tower, too, had to be large and of high efficiency to ensure effectively complete removal of $NO_2$ from a comparatively dilute gas mixture. Early small scale rocket tests (reference 13) failed to satisfactorily solve the problem of removal of the $NO_2$ from the exhaust gases using either combustion or sodium hydroxide absorption schemes.

The ammonia-$NO_2$ reaction was first investigated in a small scale bench-top experiment to qualitatively evaluate a removal system which would be based upon the use of anhydrous $NH_3$ as the prime agent. $NO_2$ and

$NH_3$ were passed into a glass tube to mix and react according to equation (2) to form $NH_4NO_3$. The experiment was repeated with moisture added as an additional reactant to satisfy equation set 1. These bench tests indicated essentially instantaneous reaction, as evidenced by the immediate formation of a white smoke at the point of reactant mixing in both the wet and dry reactions. Both reaction systems seemed to be equally effective, but the smoke of the dry reaction appeared to have a slight tinge of gray.

Reaction rate data of references 11 and 12 was used in an attempt to estimate the reaction time required to remove $NO_2$ by reaction with anhydrous $NH_3$ according to Equation (2). Depending upon the particular assumptions which were made for reactant concentrations and end conditions, the reaction time calculated ranged from 0.4 seconds to an hour or longer. It was obvious, however, that to optimize the rate and completion of the reaction, ammonia should be in excess. Also, in order to remove all, or most, of the $NO_2$ reaction time should be as long as possible.

Ammonia Reactor System.--An ammonia reactor was designed and built on the basis of the above principles. For design purposes it was assumed that the average weight flow of $NO_2$ in the facility exhaust gases would not exceed 5.7 pounds per second and the exhaust system total mass flow rate at the point of the $NH_3$ addition would not exceed 150 pounds per second. Liquid $NH_3$ was to be injected at a rate of 5 pounds per second (max) to insure an excess of reactant, assuming a mole for mole reaction. The ammonia was to be vaporized by the addition of 3.5 pounds per second of high pressure steam to provide the necessary heat of vaporization to the

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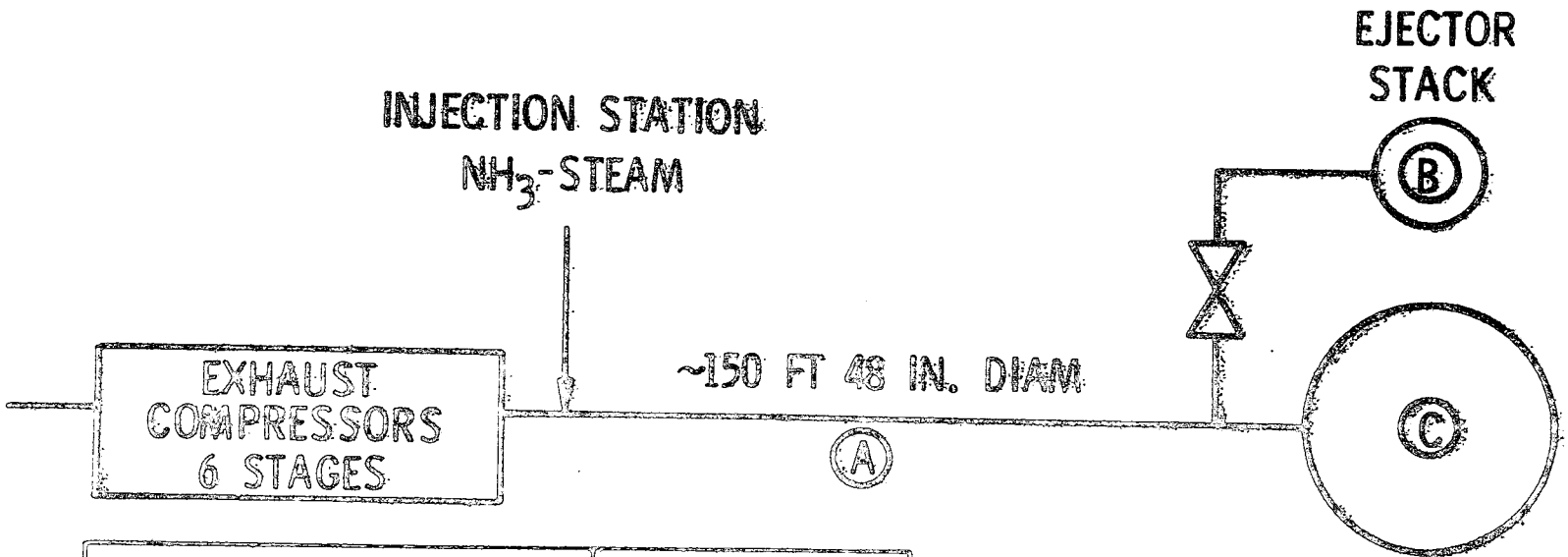
# AMMONIA REACTOR SYSTEM VELOCITY AND RESIDENCE TIME




| | LOCATION | | |
|---|---|---|---|
| | A | B | C |
| MASS FLOW RATE, PPS | 150 | 215 | 150 |
| VELOCITY, FPS | 190 | 360 | 10 |
| RESIDENCE TIME, SEC | 0.8 | 0.2 | 6.7 |

CS-56050

FIG. 3

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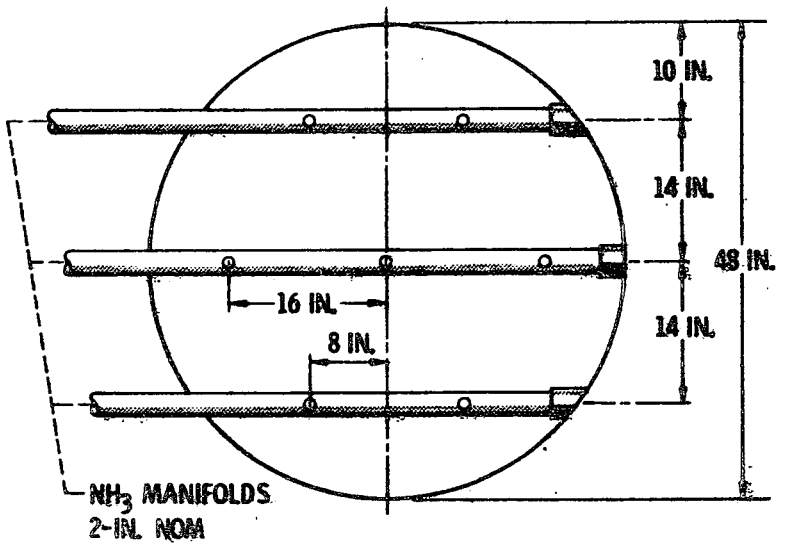
liquid reactant. Ejector air flow rate was assumed to be 65 pounds per second. Duct sizing, velocity, and residence time for the various sections of the reactor are indicated in Figure 3 for these flow rate conditions. Reactor pressures were assumed to be near atmospheric.

The ammonia reaction time, or residence time, within the ducting for the two possible exhaust paths indicated in Figure 3 was 1 second using the ejector leg or 7.5 seconds if the low velocity exhaust stack were used. This time would be the total time available for reaction within the confines of the ducting for the case of ammonia injection in the 48-inch diameter pipe near the exit of the last stage of the rotating machinery. In comparison with the reaction time requirement of previous calculation, it appeared that even the 7.5 second time period might be marginal, especially if the ammonia vaporization and mixing processes were not rapid. Nevertheless the ejector stack path was selected as the initial approach since it provided most protection, by virtue of effective stack height, to adjacent ground areas in the case of ammonia system malfunction.

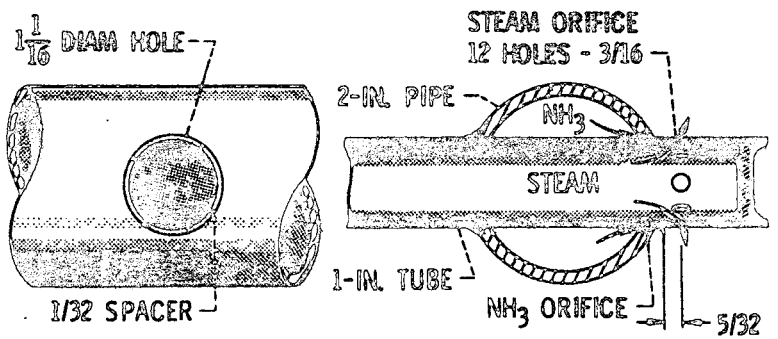
Injection of ammonia upstream of the rotating compressors was rejected. The low pressures in the upstream ducting would reduce the reaction rate, ammonia distribution would be more difficult since the duct sizes were larger, and the free ammonia would probably be detrimental to the brass and aluminum seals of the equipment. More importantly, it was feared that deposition of $NH_4NO_3$ in some areas of the ducting might create a latent explosive hazard since it could combine with hydrocarbon depositions present from jet engine testing.

# AMMONIA-STEAM INJECTOR

## DISTRIBUTION OF INJECTION LOCATIONS




## DETAIL OF INJECTOR CONSTRUCTION




CS-56053
FIG. 4

At the reactor injection station, ammonia and steam were injected at 7 points in a plane across the exhaust duct as shown in Figure 4. The exhaust duct at this point was a nominal 48-inch diameter duct. The ammonia manifolds were three 2-inch pipes spaced on 14-inch centers and mounted cross-flow. At each of the 7 injection locations, the manifold was drilled and fitted with a steam line as shown in the detail of Figure 4. Ammonia flow was concentric with the steam line and normal to the flow of the steam jets issuing therefrom in order to ensure the evaporation of the liquid ammonia. This injector design was utilized for all of the tests.

The ammonia injection system was manually controlled by an operator viewing the stack emission. Seconds prior to rocket firing the steam supply solenoid was opened. Ammonia flow was simultaneously initiated. Initial ammonia flow rate was scheduled to insure maximum flow at a time coincident with the arrival of the initial $NO_2$ flow. Five seconds after the rocket fired the full flow of 5 pounds per second of ammonia was injected into the exhaust ducting. Subsequently the ammonia flow rate was manually adjusted on a demand basis as judged by the coloration of the ejector stack emission. The ammonia flow rate was adjusted to maintain the emission as white as possible with the minimum ammonia flow rate.

When this removal system was used, the $NO_2$ remaining in the stack gases was reduced markedly, but the treatment was not complete. The steam and finely divided nitrates suspended in the gases gave the cloud a billowy appearance, but it was still colored. The cloud was colored light brown to grayish brown depending in part on the lighting conditions existing. The cloud dispersed only slowly and tended to drift with the wind as a slowly enlarging mass. Observation of the stack emission determined that most of the coloration, and hence incomplete treatment, occurred during the

initial period. Reprogramming of lead time, flow rate, and other variables was ineffective in altering either the initial or overall treatment effectiveness as judged by the color of the stack gases. These results suggested: (1) the flow rate of the $NO_2$ during the initial time period was in excess of the neutralization capacity of the ammonia flow rate; and/or (2) the available reaction time within the confines of the ducting was inadequate for the $NH_3$-$NO_2$ reaction to go to completion before the dilution by the ejector air and the atmosphere effectively stopped the reaction. Gas samples taken from the flow up-stream of the ejector confirmed the presence of an excess of ammonia.

Although the concentration of free $NO_2$ in the stack gases was reduced by the treatment, it was still too high to meet the air pollution objectives of only white emission from the exhaust stack.

Only a few runs were made prior to the end of the combustor test program in which the low velocity stack was used instead of the ejector. For these runs, the rocket propellant flow and ammonia system flow conditions were the same as were used for previous tests. Exhaust gas treatment time was increased by a factor of about 7, however, over that available with the ejector stack. Apparently complete treatment of the exhaust gases was obtained as evidenced by the white, uncolored cloud which was emitted at the exit of the stack. Even the flow from the start transient which was only very poorly treated in earlier runs was more completely reacted. The large volume and low velocity in the stack chamber seemed to act as a surge chamber to time-integrate the ammonia treatment. By eliminating the dilution

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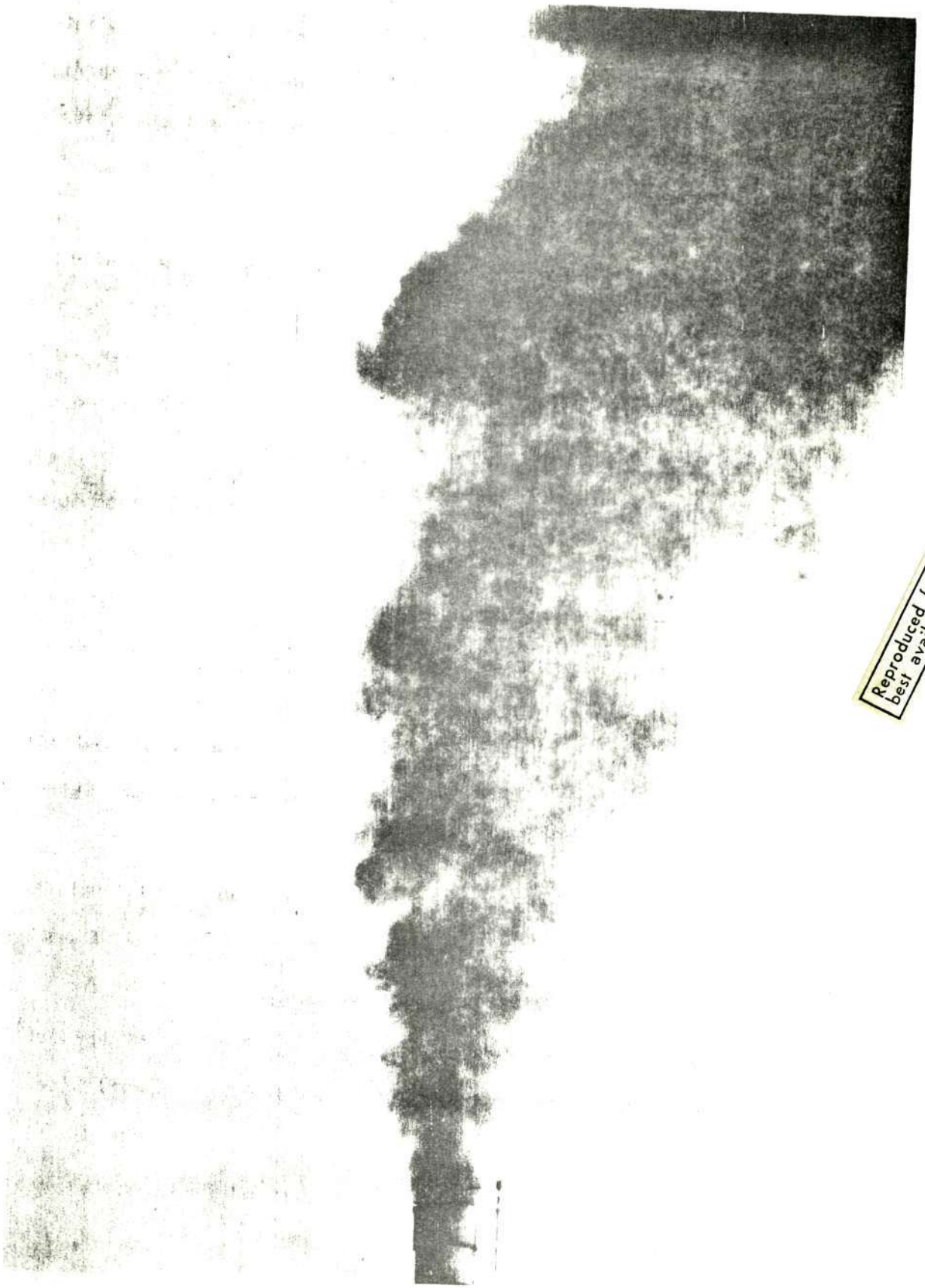




FIG. 5

effect of the ejector air and increasing the available reaction and contact time, the reaction between the ammonia and nitrogen dioxide was sufficiently optimized to permit it to approach completion. Following these tests no ammonia odor was detected at ground level within a radius of about 1/4-mile downwind of the stack even though an ammonia excess was present in the emitted gas mixture. The treatment of the gases using the ammonia injection system described in Figure 4 was effective in removing $NO_2$ from the rocket exhaust gases so that the stack emission would meet the local air pollution requirement. Figure 5 clearly illustrates the change in exhaust coloration which was obtained as a result of ammonia treatment.

The effectiveness of long reaction time for the $NH_3$-$NO_2$ reaction was also demonstrated in a non-pumped atmospheric rocket test facility. The basic facility is shown in Figure 6. With no afterburning of the rocket exhaust, the 20K rocket previously described was fired into the large volume atmospheric exhaust collector system shown in the figure. Ammonia was sprayed through a spray station at a point upstream of the muffler at a rate of about 5 pounds per second. The resulting exhaust was white and showed no evidence of free $NO_2$.

Treatment System Improvements.--These results have suggested treatment system modifications to improve the effectiveness and economy of removing $NO_2$ gases from stack gas emissions. The immediate requirement for this particular development was a system to remove $NO_2$ from the exhaust of research rocket tests. These firings were of 20-seconds duration and

# ATMOSPHERIC TEST FACILITY

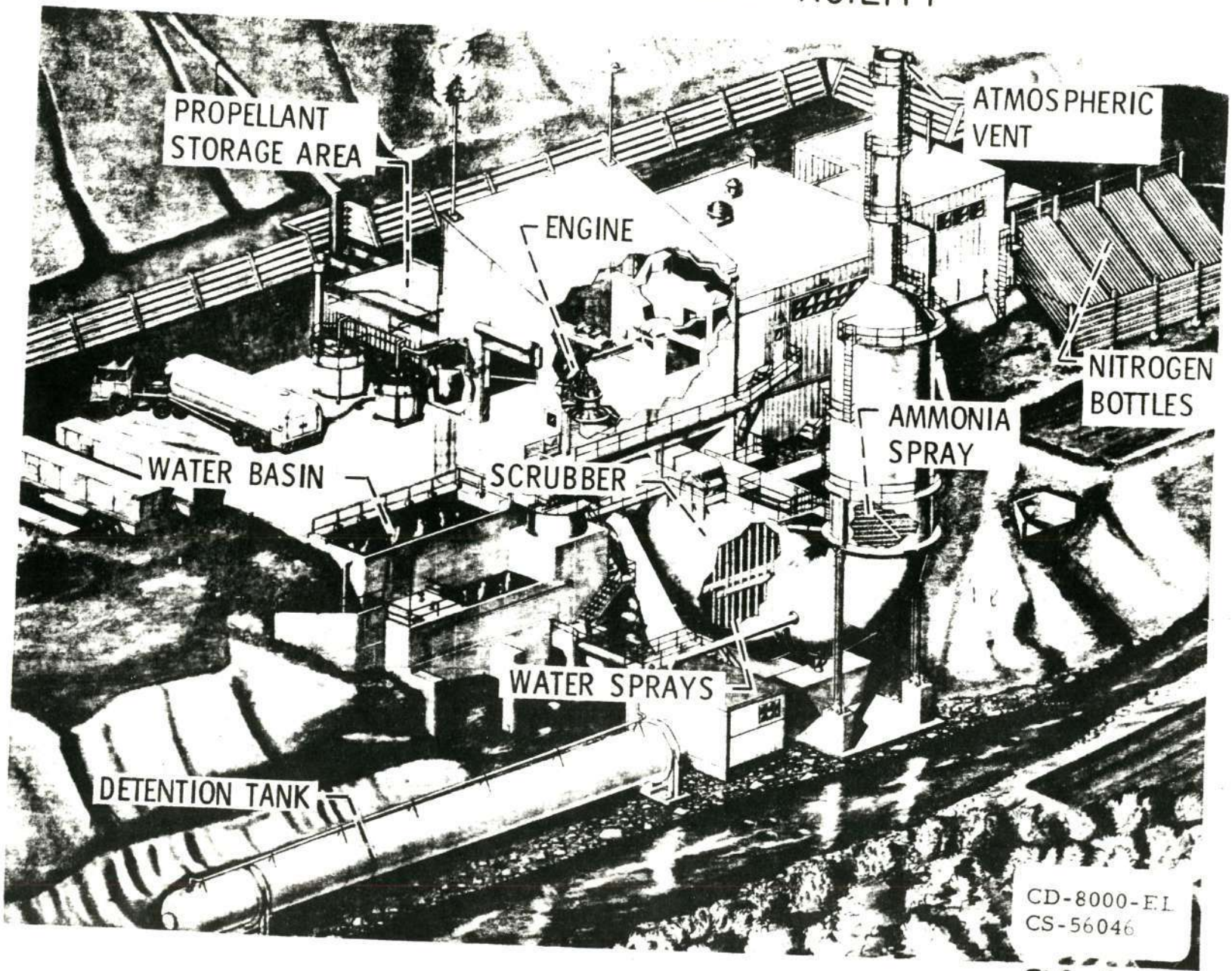


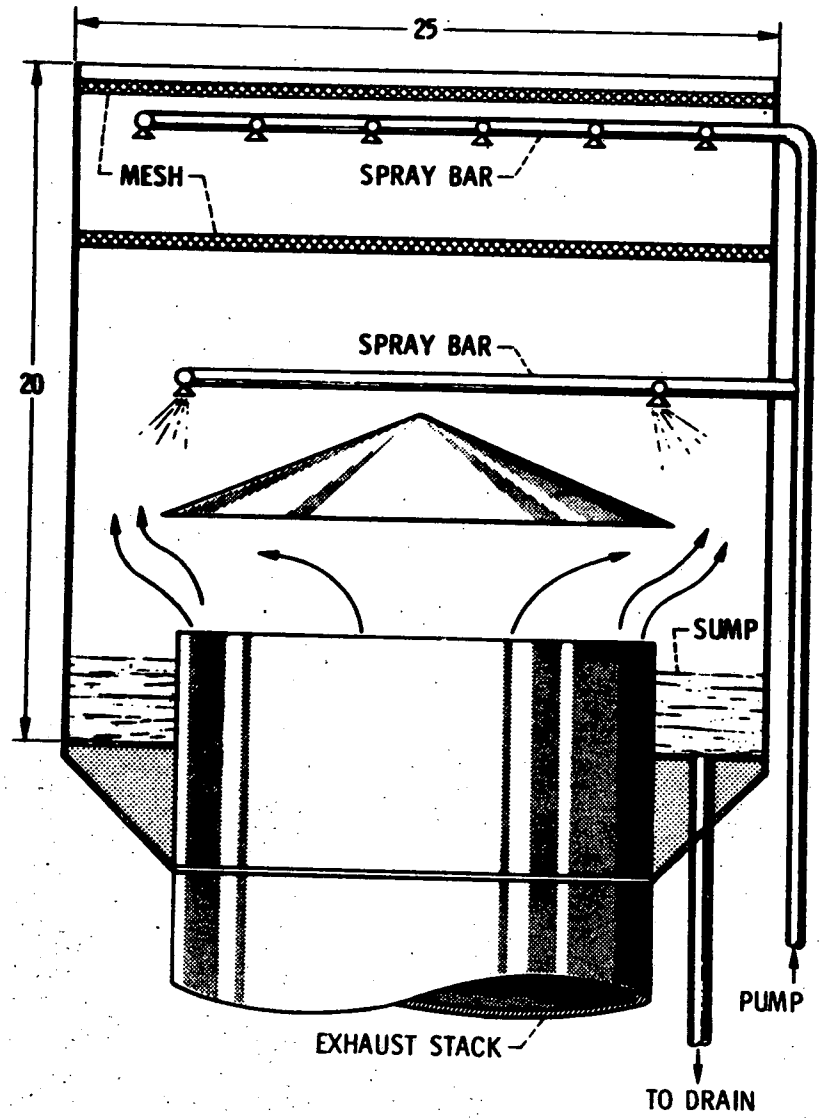

FIG. 6

averaged only one or two per day. Therefore, for such test periods the very dense white cloud containing dispersed nitrate would not be expected to be troublesome and the excess $NH_3$ useage would not be an economic problem. By recovering and using the excess ammonia, however, the efficiency and economics of this system might make it attractive for the treatment of some industrial waste gases.

A long term emission of even a white cloud of nitrates and free $NH_3$ would be as unacceptable as brown $NO_2$ emissions with respect to ultimate air pollution concern. In order to alleviate such situations, the addition of a water scrubber system to a long contact-time stack system has been proposed as a system improvement. With no compromise to the basic $NH_3$-$NO_2$ reaction system, scrubbers of various designs might be used. One is indicated in Figure 7 which would be compatible with the low velocity stack system used in these tests. The scrubber would remove the finely divided solid salts as well as the free $NH_3$ in excess. Stack gases would be non-polluting and probably would not be visible. The basic scrubber design involves the use of a high-contact area water curtain or absorption tower to remove both the solids and free $NH_3$. The water would be collected in a sump and be recirculated. The ammonia thus recovered would be effective in scrubbing any remaining unreacted $NO_2$ or acid from the gas stream. Ammonia would be conserved, but more importantly, the scrubber would act as a large ammonia reservoir, or reaction surge tank, with the capability of absorbing large quantities of $NO_2$ which might otherwise be untreated as a result of either failure of the primary treatment system or sudden surge

# EXHAUST STACK SCRUBBER SYSTEM






CS-56054
FIG. 7

of the $NO_2$ source. The scrubber would be the safety valve to the emission control system and utilize, as an integral part of the treatment system, the ammonia excess which would otherwise go unrecovered.

## CONCLUDING REMARKS

The removal of $NO_2$ from stack emissions is a problem in the research community as well as in industry. Figure 8 shows the geographical relationship of the exhaust stack to the adjacent population concentration. The impetus of improved air quality has put increased emphasis on requirements for improved treatment of all types and quantities of atmospheric emissions. The high degree of visibility of the $NO_2$ and its contribution to the problem of smog in large urban areas makes the emission of $NO_2$ containing stack gases particularly vulnerable to criticism. The high degree of visibility of the $NO_2$ also makes the removal problem severe since "clean" emission in the case of $NO_2$ means completely free of $NO_2$ for all practical purposes. Partial removal of the offending $NO_2$ from gases is only little better than no removal.

The system for removal of nitrogen dioxide which was developed and reported herein, was a first approach to a problem, and was not economically refined. The system was effective, however, and stack gases were uncolored and met air pollution requirements. Improvements appear to be possible which would not only make treatment more effective for the research type of requirement, but might also make the system effective and economically attractive for some industrial pollution abatement requirements.

# GEOGRAPHIC RELATIONSHIP OF STACK TO ADJACENT POPULATION CONCENTRATIONS



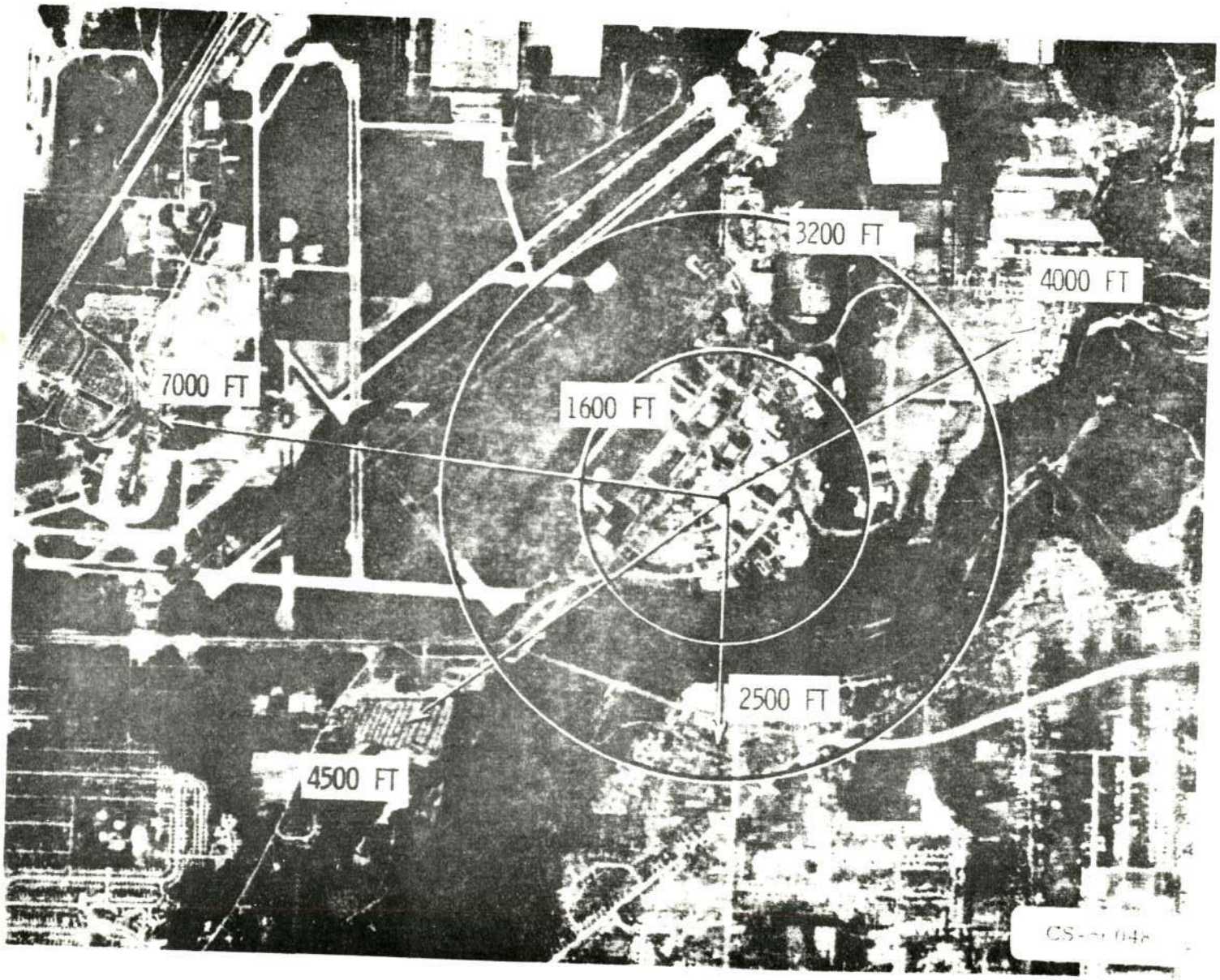



FIG. 8

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N73-17076

# FLIGHT CREW HEALTH MAINTENANCE

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Time will not permit the giving of a detailed report of our health maintenance program. However, one or two aspects of the results of this program would be of interest to all, since the basic principles of our preventive health maintenance are practiced by many of you and are applicable to any employee group or the population as a whole. The end results, if applied to the general population, would probably be different in that we are dealing with a highly selective group. We anticipate that our experience will improve over the next decade or two as a greater proportion of our flights crews are composed of those both selected and maintained under our current program. Although TWA has been operating for over forty years, pre-employment and sporadic periodic crew physical examinations were done by a multitude of fee-for-service and part time physicians until 1948. Since that time knowledge in this field has grown significantly and the analysis of TWA's own accumulated medical records and experience led to the formulation of the selective standards and maintenance principles now being used. TWA currently employs over 4,500 flight deck crew personnel. This is over twice the number employed just ten years ago. Consequently, five years ago the bulk of our crews were 35 to 50 years of age with the mean age at about 42; today the large peak is in the early 30's with the mean age at 38 years, as can be seen on figure 1. Despite this large influx of young pilots almost half of our pilots were hired prior to the establishment of our current standards. The philosophy that prevailed 30 to 40 years ago in the early days of aviation was to hire the rugged individualists. The dynamic, hot rodder, athletic type daredevil was thought to be the type to withstand the rigors of early flying, which was described as a young man's game.

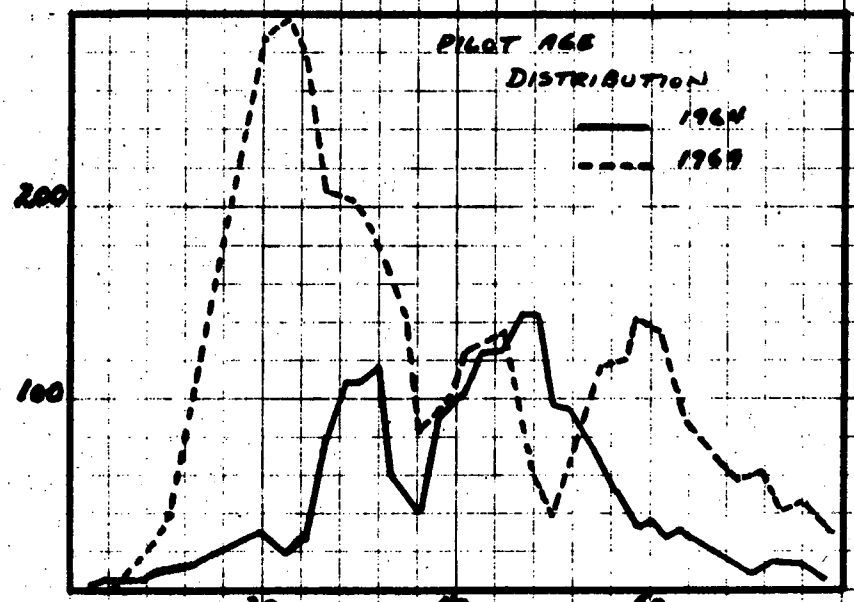


FIG. 1

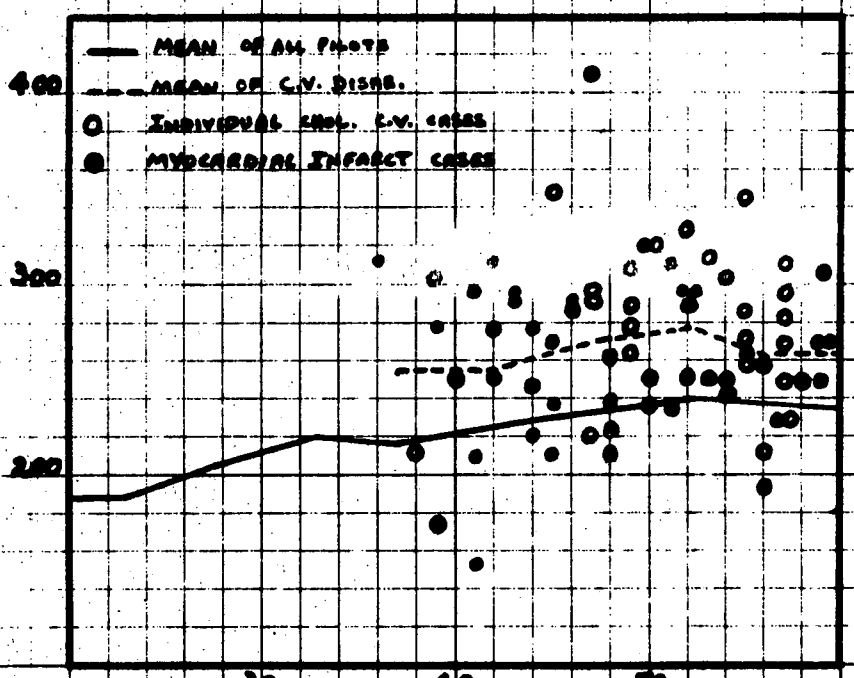


FIG. 2

MEAN CHOLESTEROL LEVELS
BY AGE GROUP

Today, we readily recognize this type as having the coronary profile. Today our philosophy of what makes a good reliable airline pilot has changed significantly. We know airline aviation is not just a young man's game. Consequently, we now select the candidate who we think will most likely be able to maintain at least minimal FAA medical standards to age 60. To allow for the deterioration attributed to aging, we must obviously start with candidates who are not borderline at the time of hire. This has resulted in a very high rejection rate (15-20%) of currently physically fit active experienced military pilots. In addition to general physical fitness the major items stessed are, emotional maturity, weight, blood pressure, cholesterol, glucose tolerance, and family health history.

The question still to be answered is whether it is possible to significantly alter the prognosis of the coronary prone individual, for instance, by preventive therapy. As you all know, there are several studies underway around the country that will ultimately establish whether this is possible. This is, of course, what we are attempting to do. Although our data to date has not all been analyzed yet, there are indications that are favorable. The pilot's loss of license insurance companies have said that the incidence of loss is much lower among pilots employed by airlines with full time preventive medical programs than those in airlines without full time medical departments.

TWA's preventive medicine program for pilots incorporates comprehens health status monitoring and counselling. In addition to his regular FAA physical examination, the pilot is given a complete company examination

at least once a year. At this time, the company flight surgeon can discuss the importance of diet, weight control, and regular exercise on an individual basis. Early minor undesirable trends in the physical findings are identified and the pilot counselled accordingly. The pilot is likewise re-evaluated and counselled when indicated after each major illness or injury that may occur between the annual examinations. They are likewise encouraged to consult us regarding any medication prescribed by their family doctor even for minor illnesses. Another opportunity for group counselling occurs at the time of the pilot's recurrent ground school training when one of our staff lectures on high altitude physiology and general health measures. For a variety of reasons, in the earlier days, pilots tended to avoid company medical departments largely out of fear of being grounded. Today, on the whole, we now emjoy a very friendly relationship. We have proven repeatedly that we can help perpetuate their careers especially when we have been brought in on the problem early. The company, likewise, has come to recognize the value of such programs and has given the medical department complete independence in operation. The secret of the good relationship lies in good up to date medical practices and complete impartiality.

Cardiovascular disease continues to be the number one disabling disease among pilots as it is of the general population although the incidence is much lower for reasons discussed previously. Total serum cholesterol has proven to be the most reliable indicator for predicting atherosclerotic risk. Although other lipid fractions have shown definite correlation, they have not proven to be any better indicators.

For the purpose of this discussion, I took a random sampling from the records of 800 pilots (20 for each year of age). Figure 2 shows the mean cholesterol level of this group during the period from 1961-1970 represented by the bold solid line. The bulk of the individual levels fell generally 20-30 mg. on either side of the mean. The circles concentrated largely on the upper right quadrant represent the cholesterol levels of pilots grounded because of cardiovascular disease during the 10 year period. The solid circles are those with myocardial infarction. The vast majority of these disabled pilots had prior cholesterol levels well above the mean of the pilot group. The dotted line is the mean cholesterol level of the disabled group. Of the 77 cases of disabling cardiovascular disease, 42 were myocardial infarctions. Many of these had manifestations of arterial disease prior to their grounding and/or infarction. Ten of these died immediately, with their first infarct. Ten more of the 77 have died since from their 1st, 2nd, or 3rd myocardial infarct or cerebral vascular accidents. Several of the younger survivors are actively employed in ground type jobs such as ground school instructors in flight training. It may be of interest to note that the mean blood pressure of the 2,500 newly hired pilots in the past six years was 127/74, whereas the mean for the 77 disabled pilots was 149/92. Although some studies such as Framingham have not shown overweight to be a significant risk factor separate from cholesterol and blood pressure, 83% of our disabled group were on an average 24 pounds overweight using Metropolitan Life Insurance Company maximum for a large frame as a standard.

We have noted, as others have, that there is a very high correlation between hypertension and overweight. We have hopes and reasons to believe that diet, weight control, and exercise will significantly alter our pilots' future mortality rates during their flying career.

N73-17077

# OCCUPATIONAL MEDICAL TRENDS IN THE '70's FROM INDUSTRIAL VIEW

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The Boeing Company

Most industries will look at the 1970's as the beginning of increased action by many agencies for the control of the working environment. The revised Walsh-Healey Act will give greatly added emphasis on noise control and hearing conservation. The proposed Occupational Health and Safety Act will concentrate on the work environment and determine what are acceptable exposure levels at the work site. This Act will be very much concerned with standards and what types of standards can be established. Governmental legislation on air, water, and solid pollution have had and will have an effect on the work environment, for the trend grows as to how the community environment affects the worker and his health.

Most industrial managers are beginning to accept that more than the 8-hour work environment affects the health of his employee as well as his absenteeism and production records. The importance of chronic disease is being recognized as is an increased awareness of the mental health and attitude of the worker.

The largest industries with some established medical departments will not be heavily impacted immediately by the new Occupational Health Acts except as they affect the production capability of small sub-contractors being relied upon for parts. It will be on the small plants that the control effects of these Acts will impact, and it will be up to the leadership of the larger industries to aid in establishing environmental control measures and services for them.

In this period the use of computers for environmental health control will play a great part. Well thought out programs of environmental health examinations and record-keeping methods will aid in evaluating the environment and its longer term effect upon workers. The computer will be used for physical examination programs of all types. The present multiphasic screening-type exams and programs will need to be modified and evaluated for occupational health use. Some programs now in use have good promise that by using multiphasic techniques they can cut down on the demands of the physician's time. They make full use of technicians and para-medical personnel in order to conserve the time and short supply of physicians trained in Occupational and Preventive Medicine. These computers have the ability to analyze the results of the examinations in light of the environment exposure factors to help evaluate the employee's health status. The computer programs will be able to indicate which employees can qualify for various positions that may have potentially hazardous environments and also indicate when more detailed medical study is needed as health changes occur.

It is now possible to record the industrial radiation exposure from film badges into a computer program so that the accumulation is fully recorded. By this means, any employee who exceeds the prescribed weekly, monthly, or yearly dose can be reported quickly to the Medical Department by the computer so that he can be removed from further exposure. This method also is very useful in complying with the regulations of providing the annual exposure record of every employee under such a program.

These computer programs in general are an effort to save the physician's time so that he can use them more fully in preventive programs and in actual dealing with patients. In industry the trend will continue to expand to make maximum use of technicians to perform basic tests that are now thought to be conducted only by physicians. The role of the occupational nurse must be expanded so that she is more thoroughly trained in the broader areas of Occupational and Preventive Medicine as well as act as a first line medical person in our Mental Health Programs in industry. The Medex-type person now being trained in the various medical schools can have great application in the field of Occupational Medicine and will be utilized by industry in this next decade. The thoughts of using Medex assistants coupled with a closed circuit TV system for physician supervision opens many interesting ways to provide service to multiple small industrial plants.

The Occupational Medicine Programs in industry during the '70's will not be considered by itself but will be broadened to include more questions of health insurance plans and disability insurance. These programs do play a part in the overall health of the workers and influence how the worker can continue on the job. The Occupational Medicine staffs are the ones who have the training and the experience to be able to deal with insurance companies on disability and disability programs and especially in establishing good rehabilitation programs to return the employee to work. The Occupational Physician must enter into health care insurance plans to be able to blend the in-plant treatment programs to complement the out-plant medical treatment.

Indeed industry will become more concerned with the community health programs for they realize that from the local communities will come their employees of the future. Thus, the community with good health facilities to fulfill the needs will indeed eventually produce better and healthier employees and applicants. The hiring procedures with regard to health will need to undergo quite a bit of re-doing for many of our medical placement and restriction programs are creating an undo burden upon the employee or applicant without really producing any evidence of saving of further injury or disability for that person. Too many of these placement programs are not medically sound and work an economic disadvantage to the person as well as to the industry.

Included in the overall awareness of community health of course will come the problem of alcoholism and mental health. These two areas play such an important part in the employee work force and if good health programs are not available for them the loss to industry is in the billions of dollars. Here again, the occupational physician must be the leader in establishing constructive programs both in the community and in-plant. The question of the use of drugs in our population today will have to undergo some close study as it applies to industry for the facts today are not very clear as to what the actual effects are upon the work force at the site of employment.

With all of these health programs it is not to be construed that industry is ready to provide the so-called "cradle to grave-type of care" but they do recognize that the health of the worker involves more than the period of his work shift. So much of what happens to the health of the employee and his family away from work plays a great part on his ability to produce that it can no longer be ignored. Neither can industry feel that each part of the medical care for an employee can be handled by different groups either in-plant or in a community. There must be a coordinating health group to try to bring these programs together. It is the Occupational Medicine staffs within industry upon whose shoulders a great deal of this will fall and who actually stand at the present time and for the next decade to be in the best position to make constructive efforts in the health care programs. The occupational physician in industry needs to look at the '70's as a challenge and a great opportunity to serve the worker and his community.

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