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PERIOD ANALYSIS OF THE ELECTROENCEPHALOGRAM OF THE BASELINE DATA FOR GEMINI VII

Final Report

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INTRODUCTION

Since the analysis of the electroencephalogram on the Command Pilot of the Gemini VII orbital flight was completed in 1965, it has been of prime interest to make some comparison of the EEG under flight conditions with more normative data.

During the period March 1962 through May 1966 a series of normative electroencephalograms on flight personnel and later on some astronauts was completed at Baylor University College of Medicine under the direction of Dr. Peter Kellaway. Among these was a normative recording of Colonel Frank Borman, a copy of which was sent to this laboratory for the same type of analysis as that used for the orbital flight.

Also in September 1965, Dr. Kellaway and his staff recorded the EEG of Colonel Borman under conditions of simulated flight at the McDonnell Aircraft Corporation in St. Louis, Missouri. These tapes are respectively referred to as "Data Set A" and "Data Set B".

This report presents the Period Analysis of both data sets and makes a comparison between the following three situations.

1. The normal laboratory situation (Houston)
2. The simulated flight condition (St. Louis)
3. The actual orbital flight
4. The Normative Sleep Study

THE NORMAL LABORATORY SITUATION (DATA SET A)

The Recordings

The recordings made on most subjects for the Normative Library (1) did not include electrode placements identical to those used in the Gemini VII orbital flight. However, in the Borman normative recording the same electrode sites were used as in the orbital flight, as follows:

Channel 1

Midline Central Site - 7.8 inches from the external auditory meatus in the coronal plane and 7.9 inches anterior to the inion in the sagittal plane.

Midline Occipital Site 1.6 inches superior to the inion in the mid-sagittal plane.

Channel 2

Left Central Site - 3.1 inches to the left of the midline central site in the coronal plane.

Left Occipital Site - 1.4 inches to the left of the midline occipital site.

The recordings used for the analysis were taken from copies of the original tapes and were monitered on an Offner Dynagraph Type R and reduced by the Period Analysis system into digital information which was further programmed on the general purpose digital computer to provide a weighted total count per second of the EEG. The weighted total count of the EEG was the index used to typify the state of consciousness epochs for the Gemini VII Report (vide-Ref 2)

The Stimulus Field

The normative data contains a highly structured stimulus field divided generally into two parts (Figs. 1-4). Part one was conducted with eyes closed and part two with eyes open with the few exceptions which are indicated in Table I.

Each part contained visual, auditory and mechanical stimuli presented at one cycle per second and also at 12 cycles per second, each different stimulus field being separated from the other by a rest period. Several novelty stimuli were also programmed and three mathematical problems added. Towards the end of the stimulus protocol there were 80 presentations of three one-per-second tones. The fortieth and eightieth presentation differed from the others in that the third tone was separated from the second by two seconds. Following the tone presentations a series of 60 slides were presented, each slide containing six circles one of which was larger than the other five; the odd circle had to be identified verbally. These 60 presentations were programmed in three sets of twenty slides each, the first twenty having a stimulus epoch of 3 seconds, the second twenty slides having a stimulus epoch of two seconds, and the third twenty slides having a stimulus epoch of one second.

Period Analytic Processing

Period analysis of the EEG has been described in detail elsewhere (3, 4), but it is necessary to understand that it yields three basic parameters of major, intermediate, and minor periods. These three periods respectively code the baseline cross of the primary EEG or dominant activity, the peak and valley activity and the very low amplitude inflection point of the signal. The most elegant statistic of period analysis is the count per second of the three periods with the further smoothing step of weighting the major period by 4, the intermediate by 2, and the minor by 1, and producing a three digit total by adding them together. This gives a relatively stable index of the state of consciousness and was used to produce the analysis of the EEG on Colonel Borman during the orbital flight of Gemini VII. We have applied this method to the current study of evaluation of the baseline data.

Results

Table I lists the events in chronological order starting with event #5 as the first active event in the stimulus series. The event is specified in Column 2 and the mode (whether eyes open or closed) is shown in Column 3. Columns 4 and 5 record the time interval in minutes and seconds of the event. This time is the elapsed time from the start of the tape playback and is not necessarily synchronized with the time code on the tape. Column 6 contains the mean weighted total count for the left central occipital lead during the elapsed time of the event. Column 7 shows the same for the midline central occipital lead, and the last six columns are the mean counts of the major, intermediate and minor periods for the elapsed time of the event for both the left and midline recordings. It will be noticed that we have divided some stimulus and rest events into two or three parts. Most rest periods are divided into two parts to enable a comparison of a post event rest period to a pre-event rest period. Events that have been so divided are shown by a repetition of the NASA event number in Column 1 of the table. It will also be noticed that for the most part the subject's eyes are closed until 15.38 minutes when the stimulus field, somewhat modified, is repeated with eyes open. Mode description is underlined where it is not the common mode. At event 56 the tone series is presented and this is followed at events 60 - 119 by the slides.

For analysis purposes we have shown the mean WTC of each group of tones and slides using a one second pre-stimulus epoch and a one second post stimulus epoch to show the changes occurring during stimulus. Figures 1 and 2 show the weighted total counts of each event in chronological sequence with the abscissa showing the classification number of the event corresponding with Table I. The ordinate is in weighted total counts and represents the EEG activity as seen in the left central parietal lead; Figures 3 and 4 show the same information for the midline EEG.

The first observation in the comparison of midline and left EEG leads is the dramatic differences in WTC levels. These differences are due to the higher fast activity factor in the left channel. Both the analysis and the analog recording showed the left central-parietal lead to contain more fast activity than the midline but it is difficult to say whether this was due to incongruent electrode application, to a higher incidence of fine muscle artifact or to a neurophysiological increase of fast activity in the left hemisphere. It is worthy of note that the left parietal-occipital lead in the Gemini VII data also contained faster activity than the midline. Important to the interpretation of this asymmetry of fast activity is the observation that the initial rest period (005) shows a weighted total count of 110 in both channels; thus, both channels show a correspondence in symmetry in the initial resting state.

In the following discussion the figures in parenthesis refer to the event number listed in Table I. The "eyes open" period that follows is slightly higher in the midline than on the left but is within normal variation as is the eyes closed and resting periods that follow. During the instruction the left hemisphere is slightly elevated, but a strong difference occurs when the 1 per second photic stimuli are presented (11). Here the effect is seen dramatically on the left side with the disturbance carried over to the subsequent rest period. This is probably due to muscle artifact produced on that side by an uneven tension caused by clenching the teeth lightly. When asked to make a fist, the right hand was used and it is possible that the same left side tension may account for the higher WTC on this side even in the following rest period (15). It is not until after the mechanical stimulus (16) that the two leads return to a reasonable comparison and from this point onward the comparisons are consistent with expected EEG differences and appear to be relatively free of artifact. Eyes open (26) again shows a sensitivity in the midline (compare with event 6) but is within normal variation and it is not until event 38 that fairly strong differences are seen again. During event 38 and through event 44 the level of activity appears more elevated on the left than the right but the rest period (45) that follows returns the symmetry. It should be noted that the midline responds with dramatic dominance to "eyes open" (51) and is not characteristic of the differences generally found between midline and lateral sites.

The Sensory Stimuli

In this study there are presentations of stimuli in three fields:

1. Visual - Flashes (Photic)
2. Sound - Tones (Audio)
3. Tactile - Taps (Mechanical)

The three sensory stimuli are presented in two modes:

1. Eyes Closed
2. Eyes Opened

They are also presented in two patterns:

1. 100 Stimuli at 1 per second
2. 200 Stimuli at 12 per second

The Photic Stimuli

Of these three fields the Photic Stimuli appear to be the most alerting and the 12 per second frequency (20, 32) more arousing than the 1 per second frequency (11, 36). This is true in both modes and for both leads and probably due to the ease with which the primary visual receptor areas may be driven at this frequency. The exception to this is the apparent high arousal of the 1 per second photic on the left (11) during the eyes closed mode. This is probably artifactual and is part of the area in which muscle artifact augments the EEG fast activity giving rise to abnormally high counts and obscuring the true EEG level. In each case of Photic Stimulus, with the exception of Event 11, the response to the flashes shows some accommodation towards the end of the stimulus field, the counts decreasing noticeably after the first half. This is true of both leads and for both modes.

Audio Stimulus

Of the three stimulus fields the audio clicks appear generally the least alerting. An exception to this is event 28 in which the 12 clicks per second stimulus field appears highly arousing. This, however, may be influenced by the fact that the subject is already highly aroused because his eyes were open at event 26 after having been closed throughout the previous mode. It will also be noticed that the subject did not relax during the rest period (27) so that at the onset of the audio stimulus he was still in high arousal, a situation which did not change until the mechanical stimulus field of event 30. As in the photic stimulation there appears to be some accommodation as the WTC's appear to decrease as the stimulus field progresses with the exception of event 22, the 12 per minute stimulus to which increased arousal is seen in the eyes closed mode.

Mechanical Stimuli

The Mechanical Stimuli have an arousal effect second only to the Photic Stimulus but, unlike either the photic or the audio, the effect does not tend to accommodate. Protraction of the stimulus moves the EEG toward greater arousal for the most part. Event 16 is, of course overshadowed with artifact so that this section is not representative of the stimulus effect. It may also be observed that tactile stimulus appears to be less influenced by the mode; that is, opening or closing of the eyes produces less difference in response to tactile stimuli than under either photic or audio stimuli. The mean weighted total counts for each stimulus field in all modes and frequencies show no difference between the photic and mechanical stimuli on the left but the heavy artifact in event 16 creates a distorted figure for the mean value of the mechanical stimuli.*

The total WTC values for $C_3 - O_1$ and the midline are:

Left Central Occipital		Midline Central Occipital	
Photic	144	Photic	137
Mechanical	144*	Mechanical	132
Audio	130	Audio	130

Comparing both channels with the stimulus field we see the same progression in both areas with a slightly higher count on the left than the midline. However, towards the end of the stimulus the midline does not reflect the same degree of arousal as is seen on the left. The decreased index of arousal in the midline as compared to more lateral placements is of importance in the behavioral-state of consciousness interpretation of the neurophysiological state. Decreased activity in the midline potentials may be interpreted as decreased neurophysiological activity in the non-specific pathways and therefore the first evidence of decreasing behavioral levels should be decreased fast activity in the midline as compared to those placements which are fed by classical sensory pathways.

The Novelty Stimuli

Several novelty situations were presented, the most dramatic stimulus being the clenched fist stimulus (13 and 14) which, as we have seen, produced much artifact and elevated the left central-occipital record to such activity that the following events, 15 and 16, were overshadowed by the artifact, a condition not found in the midline.

No further novelty stimuli occurred until after the major stimuli (visual, audio, mechanical) were completed at event 39. Then a series of novel presentations were given. Event 41 was a single flash of light; event 46, a short burst of white noise; and event 54, a single tap. These stimuli, in keeping with the same sensory stimulus as the major program, showed the following responses.

	$C_3 - O_1$	$C_Z - O_Z$
Flash	151	133
Tap	103	110
Noise	108	109

Once again the photic stimulus showed the most arousal and the greatest difference across channels. Noise differentiated the least.

Three oddity problems were presented at events 43, 52, and 58. These problems consisted of a slide presentation of 2 circles and a triangle for 5 seconds. These were presented in different orders and the instructions were to push a button corresponding to the position of the odd geometric figure. The following figures show the stimulus and response W.T.C.'s for both channels.

		$C_3 - O_1$	$C_Z - O_Z$
Oddity # 1	Stimulus	144	155
Oddity # 1	Poststimulus	153	140
Oddity # 2	Stimulus	151	137
Oddity # 2	Poststimulus	156	168
Oddity # 3	Stimulus	188	134
Oddity # 3	Poststimulus	155	141

In Oddity Problem # 1 the left central-occipital responded by increased activity, whereas the midline responded in the opposite direction.

In Oddity Problem #2 the stimulus created increased neuronal activity as shown in the post stimulus figures for both channels, more arousal being seen in the midline.

Oddity #3 reversed the situation found in Oddity #1, the count of 188 suggesting some muscle artifact.

The Mathematical Series

The three mathematical problems, events 48, 49, and 50, are of special interest insofar as they show the same stimulus progression throughout. The active time for problems 48 and 50 are divided into three equal parts and for problem 49 into two equal parts. The progression of response is the same; that is, the first section shows higher elevation of the W.T.C. than do the succeeding sections, suggesting that the succeeding sections reflect comparative relaxation. It will be noticed once again that the left hemisphere is much more elevated than the midline, possibly as a function of the greater activity of the neurons of the visual cortex in this type of stimulus. The tendency for event 49 to be more elevated than the others may be the element of surprise (i.e., the reverse repetition of the problem) or due to the anxiety of a shorter time span for the problem solving.

The Tone Series

Of considerable interest is the series of 80 presentations of three one-per-second tones. For interpretation, we have divided these 80 presentations into four groups of 20 presentations each and the result shows a linear progression of increased arousal in both channels, the left side once again being elevated above the midline (Fig. 5, 6). Over 20 per cent increase is seen in the arousal pattern between the first and the last group and the linearity of the progression is highly suggestive of increasing hypersensitivity to the stimulus or a progressive arousal with the passage of time. The stimulus-poststimulus relationships do not support the hypothesis of increased hypersensitivity to the stimulus; the progressive increase of arousal seen in the prestimulus responses which are often more marked than even the stimulus period itself force us to the interpretation of increasing non-specific arousal unrelated to the specific stimulus event. Considering the undemanding nature of this particular stimulus field which one might expect to decrease level of arousal over a time we must speculate that the subject responded to this series with increasing irritability. If this finding were to remain consistent over a population of subjects, such an undemanding and subjectively trivial tone presentation might be utilized in evaluating tolerance levels for repetitive stimuli in humans.

The Slide Series

The slide series requires a degree of decision by the subject and as a psychomotor task in which the subject is allowed one second less time in three successive presentations, might be expected to increase arousal; the results shown in figures 7 and 8 contradict the hypothesis. The evidence of decreasing arousal is best seen in the progressive decrease of weighted total counts in the prestimulus midline EEG (Fig. 8). The specific stimulus of the slide presentation consistently provokes arousal above the prestimulus level. The poststimulus level consistently shows less arousal than the stimulus event and tends to show less arousal even than the prestimulus. The progressive relaxation of the prestimulus event, the specific and significant arousal to the stimulus and the relaxation of the poststimulus event after the task has been accomplished, all may be interpreted as neurophysiological evidence of well integrated performance. This is an extremely important example of how neurophysiological data may be directly interpreted in terms of behavior-performance. This finding in interpretation allows the hypothesis that neurophysiological data would be predictive of early deterioration of performance. The hypothesis would state that when the above relationships do not hold within a subject population, those subjects not showing the relationships will show poor performance. Further, if the relationships exist initially and then deteriorate into the type of responses seen in the tone series, early deterioration of performance may be expected.

SIMULATED FLIGHT RECORDING

On September 16, 1965, Drs. Kellaway and Maulsby monitored and recorded the electroencephalogram on Colonel Borman while he was undergoing simulated flight conditions in an altitude chamber at the McDonnell Aircraft Corporation's installation in St. Louis, Missouri (5). The electrode configuration at this time was identical with that later used in the orbital flight of GT VII in December, 1965 and with the configuration in Colonel Borman's normative library recording.

Since the midline central-occipital recording was unsatisfactory for analysis we have analyzed the left central-occipital recording which will be compared with the left central-occipital recording of the orbital flight analysis. The St. Louis recording ran for approximately fifteen and a half hours and contained no sleep segment. The GT VII recording contained a period of sleep from 14.00 hours to 15.30 hours. To evaluate the comparison of these two recordings only the first 14.00 hours of each tape were utilized.

The weighted total counts of the pre-flight simulation have been plotted as mean values for five minute epochs (Fig. 9) in order to compare the EEG profile of simulation with the profile of the GT VII flight (Fig. 10). A strong family resemblance is seen when these situation are compared, however, some significant differences are seen to exist in the early hours of the profile. The pre-flight EEG activity of the first ten minutes in the GT VII profile, showing a mean value of approximately 170 W.T.C.'s is not seen in the simulation profile. It is the EEG activity of these pre-flight epochs that was taken to characterize the "T_1 state" which we interpreted as reflecting a state of special vigilance. This EEG state recurred during various times in the GT VII flight at points where special vigilance would seem appropriate such as the appearance of the "Delta P" light. The absence in the simulation profile of EEG activity resembling the T_1 activity of the orbital flight is of extreme importance because the major criticism directed at the interpretation of "Special vigilance" has been based upon the probability of eye movement, head movement, etc., artifacts which are probably unique to the bodily movements of an astronaut as he checks out his instrument panel and performs his mission maneuvers. Insofar as the St. Louis simulation approximated the maneuvers of the command pilot of GT VII, it can be concluded that eye movement or bodily movement did not account for the EEG activity of the T_1 state. Other investigators have also interpreted the pre-launch EEG "as relating to strongly focused attention and orienting responses" (6).

The EEG activity of the tenth minute through the fifty-fifth minute of the orbital flight show considerably higher W.T.C.'s than the corresponding time of the simulation; however, the simulation profile approximates these values after some sixty minutes from onset. After three hours, the simulation profile reaches a level of some 234 weighted counts which is a higher level than all but one five minute epoch in the orbital flight thus, the range of values found in both situations is nicely comparable. This high peak in the W.T.C. at three hours and sixteen minutes is a period of heavy muscle artifact with rhythmic slow waves. The trend of the simulation profile shows a W.T.C. around 200 which is maintained rather consistently after the third hour. This same trend appeared in the orbital flight between approximately the fourth and the eighth hour. This finding suggests that the neurophysiological states during these two time spans may have been approximately equivalent.

The eighth through the tenth hour of the GT VII profile show a degree of relaxation similar to those times in the simulation profile when the schedule was interrupted and the command pilot was asked to relax and close his eyes. These points stand out quite clearly in the simulation profile at the following times:

1 hour	45 minutes
7 hours	5 minutes
8 hours	40 minutes
14 hours	45 minutes

NORMATIVE SLEEP STUDY

Figure 11 compares the mean W.T.C.'s for one minutes epochs of the left central-occipital (C_3 - O_1) with the comparable midline placement (C_Z - O_Z). The high frequency asymmetry is clearly seen in the first ten minutes of the recording as a difference of some 60 to 40 W.T.C.'s is noted in the placements. The asymmetry is most marked in the waking state and reduces to a difference of 20-25 W.T.C.'s in the light sleep of the first five minutes and a difference of some 10-15 W.T.C.'s in the deeper sleep of the last 30 minutes. The finding that a significant difference in the W.T.C.'s continues to persist but progressively diminishes in deep sleep is extremely important and strongly suggestive that this asymmetry is of neurophysiological origin and may in itself offer an index to depth of sleep. Because of the potential importance of this finding that frequency <u>symmetry</u> between the midline and lateral placements may progressively increase with depth of sleep, we have undertaken a more rigorous test of this hypothesis.

The normative sleep record was subjected to clinical classifications of sleep stages by the electroencephalographer responsible for the clinical interpretation of the EEG recorded on GT VII, Doctor Robert Maulsby. His classification of the normative sleep for a total of 364 ten second epochs shows a marked preponderance of Stage 4 in agreement with the results of Figure 11. In order to quantitatively determine the degree of symmetry or similarity between the two EEG sites, Professor Bernard Saltzberg has designed a general purpose digital computer program for comparison of period analytic descriptors from each of the two leads. The logic of this comparison program treats the major count, intermediate count, and minor count of each epoch as a three element vector. The vector is of course oriented in three dimensional space as a function of the value of each of the three counts. The vector comparison is made in terms of the Euclidian distance between the vectors. We have taken the clinical classification of Dr. Maulsby to define the samples for each state of consciousness and have determined the mean vector separation characterizing each state for the normative sleep. Results are shown as follows:

STAGE	No. of Samples	Mean Vector Separation
Awake Eyes Closed	28	10.7
Stage 1	30	10.1
Stage 2	70	6.6
Stage 3	60	6.4
Stage 4	176	6.4

The results of the period analytic vector comparison strongly support the initial finding and offer further evidence that state of consciousness may be better identified from similarity-dissimilarity measures of two or more leads in a topological array than from any manipulation of a single channel EEG.

The first slow wave sleep seen in the GT VII profile occurred between the 14th and 16th hours of the flight. The marked disturbance of this GT VII sleep cycle can be seen in the fact that no slow wave sleep comparable to the normative profile occurred except perhaps in the two five minute epochs terminating this cycle. The second slow wave sleep cycle of the orbital flight began at 33 hours and 25 minutes as seen in the midline profile of Figure 12. The progression into slow wave sleep in this cycle of orbital flight resembles the normative profile in that there is a smooth progression to a level of less than 90 W.T.C.'s. The deepest slow wave sleep cycle of the flight between 34 hours 30 minutes and 35 hours reaches a depth of 74 to 76 W.T.C.'s which is significantly deeper than the 82 to 94 of the normative profile. The orbital sleep most closely approximates the normative sleep between the 36th and 37th hours with repeated levels of some 85 to 90 W.T.C.'s.

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TEXAS RESEARCH INSTITUTE OF MENTAL SCIENCES

National Aeronautics and Space Administration
Tape #501B - Frank Borman

NASA EVENT NUMBER	EVENT		MODE	FROM	TO	WTC		MAJ		INT		MIN	
				Inclusive		L	M	L	M	L	M	L	M
5	Rest		E.C.	05.15	05.22	107	110	12	12	16	16	29	31
5	Rest		E.C.	05.23	05.30	110	107	12	11	16	17	32	30
6	Open Eyes		E.O.	05.32	05.39	131	135	12	12	23	23	39	40
7	Close Eyes		E.C.	05.44	05.47	108	103	11	11	16	15	31	28
8	Rest		E.C.	05.51	06.00	112	109	12	11	17	17	33	31
9	Instructions 1		E.C.	06.03	06.19	117	113	12	11	18	17	34	33
9	Instructions 2		E.C.	06.20	06.36	121	117	12	12	19	19	35	33
9	Instructions 3		E.C.	06.37	06.53	133	125	13	12	22	21	38	35
10	Rest - Post Instructions		E.C.	06.57	07.01	107	110	12	12	15	16	32	29
10	Rest - Pre Photic		E.C.	07.02	07.06	111	109	11	11	17	17	33	31
11	Photic 1/sec. 1		E.C.	07.12	07.44	129	125	12	12	21	21	37	33
11	Photic 1/sec. 2	100 flashes	E.C.	07.45	08.17	136	120	13	11	23	22	39	35
11	Photic 1/sec. 3		E.C.	08.18	08.50	158	123	14	12	28	21	45	34
12	Rest - Post Photic		E.C.	08.56	09.02	183	135	17	12	33	24	49	37
12	Rest - Pre Fist		E.C.	09.03	09.09	153	116	14	12	26	18	45	32
13	Clench Fist		E.C.	09.11	09.17	209	170	20	15	39	32	50	45
14	Release Fist		E.C.	09.20	09.24	195	149	19	14	34	26	49	39
15	Rest		E.C.	09.26	09.30	149	120	13	12	26	19	44	34
15	Rest		E.C.	09.31	09.35	184	126	18	12	31	21	50	36
16	Mechanical Stimulus 1	100 taps	E.C.	09.40	10.12	178	128	17	12	31	22	48	36
16	Mechanical Stimulus 2	at	E.C.	10.13	10.45	172	128	16	12	31	22	47	36
16	Mechanical Stimulus 3	1/sec.	E.C.	10.46	11.18	146	133	13	13	26	22	42	36
17	Rest		E.C.	11.24	11.30	112	112	12	12	16	16	32	32
17	Rest		E.C.	11.31	11.37	123	125	12	13	19	20	36	34
18	Audio Stimulus 1	100 clicks	E.C.	11.40	12.14	124	129	12	12	20	22	34	36
18	Audio Stimulus 2	at	E.C.	12.15	12.48	123	121	12	12	20	20	35	34
18	Audio Stimulus 3	1/sec.	E.C.	12.49	13.22	123	120	12	12	19	20	34	34
19	Rest		E.C.	13.27	13.33	116	121	11	12	18	20	35	33
19	Rest		E.C.	13.34	13.40	123	122	12	12	21	20	33	34
20	Photic Stimulus 1	200 flashes	E.C.	13.43	13.50	150	139	15	13	25	25	39	36
20	Photic Stimulus 2	at 12/sec.	E.C.	13.51	13.58	128	122	13	12	21	20	36	33

Table I.

NASA EVENT NUMBER	EVENT		MODE	FROM Inclusive	TO	WTC L	WTC M	MAJ L	MAJ M	INT L	INT M	MIN L	MIN M
21	Rest		E.C.	14.02	14.10	128	121	12	12	21	20	35	34
21	Rest		E.C.	14.11	14.19	108	111	11	11	16	18	32	31
22	Audio Stimulation 1	200 clicks	E.C.	14.22	14.29	122	117	13	12	20	18	32	32
22	Audio Stimulation 2	at 12/sec.	E.C.	14.30	14.37	130	128	13	12	21	22	38	37
23	Rest		E.C.	14.40	14.48	128	127	12	12	20	22	38	37
23	Rest		E.C.	14.49	14.57	120	121	12	12	18	18	35	36
24	Mechanical Stimulus 1	200 taps	E.C.	14.59	15.06	128	133	12	13	20	22	39	37
24	Mechanical Stimulus 2	at 12/sec.	E.C.	15.07	15.14	144	135	14	13	25	23	40	38
25	Rest		E.C.	15.18	15.26	143	142	14	14	24	24	40	40
25	Rest		E.C.	15.27	15.35	128	131	12	12	20	21	41	41
26	Eyes Open		E.O.	15.38	15.42	158	164	12	14	31	31	47	47
27	Rest		E.O.	15.44	15.50	141	153	13	14	24	27	39	42
28	Audio Stimulation 1	200 clicks	E.O.	15.53	16.00	149	156	14	15	26	27	42	43
28	Audio Stimulation 2	at 12/sec.	E.O.	16.01	16.08	138	146	13	13	23	26	43	42
29	Rest		E.O.	16.12	16.20	151	148	14	14	26	27	44	40
29	Rest		E.O.	16.21	16.29	148	144	14	13	26	25	41	40
30	Mechanical Stimulus 1	200 taps	E.O.	16.32	16.39	129	130	12	13	22	21	39	37
30	Mechanical Stimulus 2	at 12/sec.	E.O.	16.40	16.47	127	125	11	12	21	21	39	36
31	Rest		E.O.	16.50	16.58	143	142	13	13	25	26	40	39
31	Rest		E.O.	16.59	17.07	136	137	13	14	23	23	39	38
32	Photic Stimulation 1	200 flashes	E.O.	17.10	17.17	162	158	15	14	30	29	44	46
32	Photic Stimulation 2	at 12/sec.	E.O.	17.18	17.25	145	145	13	14	25	24	43	39
33	Rest		E.O.	17.30	17.37	136	131	12	12	23	23	40	37
33	Rest		E.O.	17.38	17.45	138	131	13	13	23	23	40	35
34	Audio Stimulation 1	100 clicks	E.O.	17.49	18.22	132	129	12	12	24	23	39	36
34	Audio Stimulation 2	at	E.O.	18.23	18.56	139	135	13	12	24	24	40	38
34	Audio Stimulation 3	1/sec.	E.O.	18.57	19.30	123	121	12	12	20	20	37	35
35	Rest		E.O.	19.34	19.40	117	111	11	11	19	18	36	33
35	Rest		E.O.	19.41	19.47	129	127	12	11	21	23	37	37
36	Photic Stimulation 1	100 flashes	E.O.	19.50	20.23	152	152	14	13	27	28	43	43
36	Photic Stimulation 2	at	E.O.	20.24	20.57	141	144	13	13	24	25	40	41
36	Photic Stimulation 3	1/sec.	E.O.	20.58	21.31	141	140	13	13	24	24	40	41
37	Rest		E.O.	21.35	21.41	147	148	12	13	27	27	45	44
37	Rest		E.O.	21.42	21.48	147	149	14	14	25	27	42	42
38	Mechanical Stimulus 1	100 taps	E.O.	21.51	22.24	141	138	13	12	24	24	42	40
38	Mechanical Stimulus 2	at	E.O.	21.25	22.58	126	127	12	12	21	22	38	37
38	Mechanical Stimulus 3	1/sec.	E.O.	22.59	23.32	150	142	14	13	26	25	43	40

Table I (continued)

NASA EVENT NUMBER	EVENT	MODE	FROM Inclusive	TO	WTC L	WTC M	MAJ L	MAJ M	INT L	INT M	MIN L	MIN M
39	Rest	E.O.	23.35	23.46	133	128	13	12	22	22	39	37
39	Rest	E.O.	23.47	24.05	147	135	14	12	26	24	40	37
40	Instructions 1 Oddity	E.O.	24.08	24.19	136	133	11	12	25	24	41	39
40	Instructions 2 Symbols	E.O.	24.20	24.31	151	135	13	11	28	26	43	39
40	Instructions 3	E.O.	24.32	24.43	143	132	12	12	27	24	42	39
41	Novel Stimulus - Single Flash	E.O.	24.48	24.52	151	133	14	12	26	24	42	39
42	Rest	E.O.	24.55	24.59	155	137	14	12	28	26	42	39
43	Oddity Problem #1 Stimulus	E.O.	25.02	25.02	144	155	10	12	29	30	46	47
43	Oddity Problem #1 Response	E.O.	25.03	25.06	153	140	10	13	30	26	42	37
44	Instructions 1 Pre Mental	E.O.	25.10	25.19	151	136	13	12	28	25	43	39
44	Instructions 2 Calculations	E.O.	25.20	25.29	139	128	11	10	26	26	43	39
45	Rest	E.O.	25.34	25.38	115	111	11	11	18	18	36	32
46	Novel Stimulus - Loud white noise	E.O.	25.42	25.46	108	109	11	11	15	17	35	33
47	Rest	E.C.	25.52	25.58	111	102	12	11	17	16	31	29
48	Mathematical Problem 1 - 21 X 45	E.O.	26.03	26.19	158	146	14	13	30	27	44	42
48	Mathematical Problem 2	E.O.	26.20	26.36	136	124	12	11	23	22	40	36
48	Mathematical Problem 3	E.O.	26.37	26.53	125	123	12	12	21	20	37	37
49	Mathematical Problem 1 - 45 X 21	E.C.	26.57	27.05	165	145	15	12	30	27	46	43
49	Mathematical Problem 2	E.C.	27.06	27.14	140	117	12	11	24	19	42	35
50	Mathematical Problem 1 - 12 X 45	E.C.	27.17	27.27	159	133	14	11	28	23	46	41
50	Mathematical Problem 2	E.C.	27.28	27.38	131	117	13	11	21	18	37	35
50	Mathematical Problem 3	E.C.	27.39	27.49	118	111	12	11	18	16	35	32
51	Eyes Open	E.O.	27.53	27.57	115	146	13	12	30	28	44	41
52	Oddity Problem #2 Stimulus	E.O.	27.59	27.59	151	137	11	10	30	28	47	41
52	Oddity Problem #2 Response	E.O.	28.03	28.03	156	168	13	16	29	32	46	40
53	Instructions - Tone Series 1	E.O.	28.09	28.21	141	135	12	11	26	26	41	39
53	Instructions - Tone Series 2	E.O.	28.22	28.34	136	132	11	11	25	24	41	39
54	Novel Stimulus - Single tap	E.C.	28.40	28.45	103	110	11	12	15	16	30	32
55	Rest	E.C.	28.48	28.52	105	104	11	11	16	16	30	29

Table I (continued)

TONE SERIES

This series of 80 stimulus presentations were divided into four groups of twenty presentations each. Each stimulus was a series of three tones one second apart except for presentations 40 and 80 where the last tone was delayed for two seconds. For analysis purposes, each stimulus epoch was preceded by a one second pre-stimulus epoch and followed by a one second post stimulus epoch. The following figures are the means for each group:

NASA EVENT NUMBER	EVENT	MODE	FROM (Inclusive)	TO (Inclusive)	WTC L	WTC M	MAJ L	MAJ M	INT L	INT M	MIN L	MIN M
56	Tone Series - Group 1											
	Pre-stimulus Epoch	E.C.	28.56	30.57	105	103	11	11	15	15	32	30
	Stimulus Epoch (3 seconds)	E.C.			110	110	11	11	16	17	33	32
	Post-stimulus Epoch	E.C.			110	106	11	11	17	16	34	30
56	Tone Series - Group 2											
	Pre-stimulus Epoch	E.C.	31.00	33.02	120	113	13	11	18	17	34	32
	Stimulus Epoch (3 seconds)	E.C.			116	113	11	11	18	18	36	33
	Post-stimulus Epoch	E.C.			116	119	10	12	20	20	37	34
56	Tone Series - Group 3											
	Pre-stimulus Epoch	E.C.	33.04	35.06	125	120	12	12	19	20	38	34
	Stimulus Epoch (3 seconds)	E.C.			125	120	12	11	20	20	38	35
	Post-stimulus Epoch	E.C.			117	115	10	12	20	18	38	33
56	Tone Series - Group 4											
	Pre-stimulus Epoch	E.C.	35.08	37.11	130	127	13	12	21	21	39	37
	Stimulus Epoch (3 seconds)	E.C.			134	122	12	12	22	21	40	37
	Post-stimulus Epoch	E.C.			128	126	11	12	22	21	41	37
57	Eyes Open	E.O.	37.21	37.27	165	132	15	12	30	23	46	36
58	Oddity Problem #3 Stimulus	E.O.	37.31	37.31	188	134	18	8	36	29	52	44
58	Oddity Problem #3 Response	E.O.	37.32	37.35	155	141	13	12	29	26	44	40
59	Instructions 1	E.O.	37.41	37.57	165	156	15	14	30	29	46	41
59	Instructions 2	E.O.	37.58	38.14	192	187	18	18	36	34	49	46

Table I (continued)

SLIDE SERIES

This series is presented in three sections. Section One presents a three second stimulus; Section Two presents a two second stimulus; and Section Three presents a one second stimulus. Each stimulus is preceded by a one second pre-stimulus epoch and followed by a one second post-stimulus epoch. The figures are means for each group (20 presentations of the event).

NASA EVENT NUMBER	EVENT	MODE	FROM (Inclusive)	TO (Inclusive)	WTC L	WTC M	MAJ L	MAJ M	INT L	INT M	MIN L	MIN M
60-79	Slide Series - Group 1											
	Pre-stimulus Epoch	E.O.	38.20	41.02	158	147	14	13	29	27	43	40
	Stimulus Epoch (3 seconds)	E.O.			163	160	14	13	31	31	46	46
	Post-stimulus Epoch	E.O.			150	142	14	12	27	26	42	41
80-99	Slide Series - Group 2											
	Pre-stimulus Epoch	E.O.	41.11	43.28	140	145	12	14	25	25	41	39
	Stimulus Epoch (2 seconds)	E.O.			168	152	15	14	32	31	46	45
	Post-stimulus Epoch	E.O.			142	140	13	13	25	25	41	38
100-119	Slide Series O Group 3											
	Pre-stimulus Epoch	E.O.	43.31	45.25	147	143	13	13	27	26	42	41
	Stimulus Epoch (1 second)	E.O.			162	158	14	13	30	31	45	44
	Post-stimulus Epoch	E.O.			140	140	12	12	26	25	41	41

Table I (continued)

LEGENDS

Figure 1. The weighted total count levels for stimuli 5 through 39 from the normative library recording on Colonel Borman (left central-occipital). Legends for Figures 1 through 4 are also shown.

Figure 2. The weighted total count levels for stimuli 40 through 119 from the normative library recording on Colonel Borman (left central-occipital).

Figure 3. The weighted total count levels for stimuli 5 through 39 from the normative library recording on Colonel Borman (midline central-occipital).

Figure 4. The weighted total count levels for stimuli 40 through 119 from the normative library recording on Colonel Borman (midline central-occipital).

Figure 5. Normative library recording - Colonel Borman - Details of the 80 tone series presented in 4 groups of 20 sets showing the weighted total count levels of the one second pre-stimulus epochs, the three second stimulus epochs, and the one second post stimulus epochs (left central-occipital).

Figure 6. Normative library recording – Colonel Borman – Details of the 80 tone series presented in 4 groups of 20 sets showing the weighted total count levels of the one second pre-stimulus epochs, the three second stimulus epochs, and the one second stimulus epochs (midline central-occipital).

Figure 7. Normative library recording – Colonel Borman – Details of the slide series presented in three sets of 20 stimuli, showing the weighted total count levels of the one second pre- and post stimulus epochs and the three, two, and one second stimulus epochs respectively (left central-occipital).

Figure 8. Normative library recording – Colonel Borman – Details of the slide series presented in three sets of 20 stimuli, showing the weighted total count levels of the one second pre- and post stimulus epochs and the three, two, and one second stimulus epochs respectively (midline central-occipital).

Figure 9. The weighted total count profile of the EEG recording on Colonel Borman during the first fourteen hours of the simulated flight conditions recorded in St. Louis, Mo. (left central-occipital).

Figure 10. The weighted total count profile of the first fourteen hours of the EEG recording on Colonel Borman during the orbital flight of Gemini VII (left central-occipital).

Figure 11. Comparison of the central-occipital with the midline central-occipital sites showing the mean weighted total counts for the first hour of the normative sleep recording on Colonel Borman.

Figure 12. The midline central-occipital recording of the EEG on Colonel Borman during the orbital flight of Gemini VII showing the sleep section from 33:00 hours to 40:00 hours.

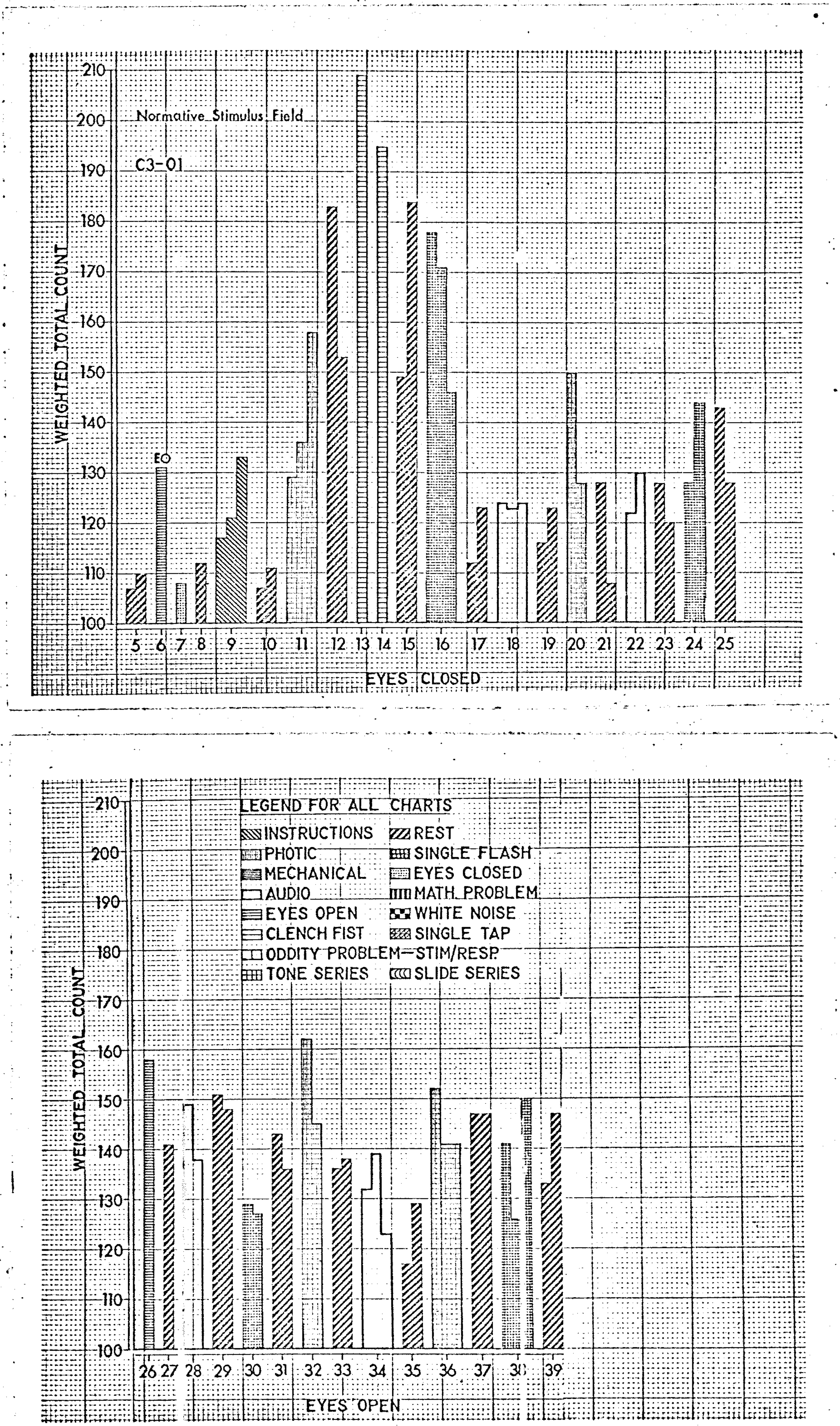
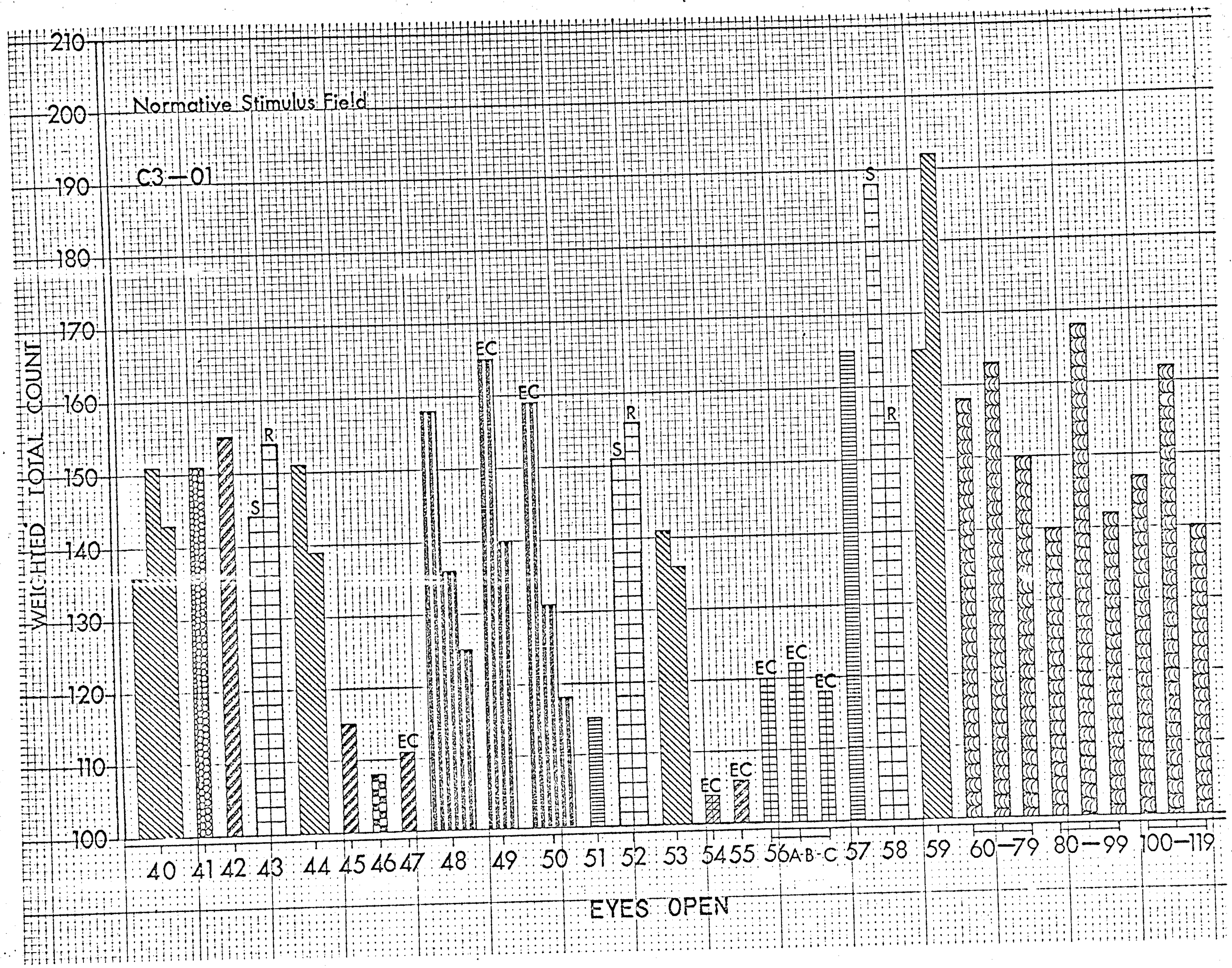
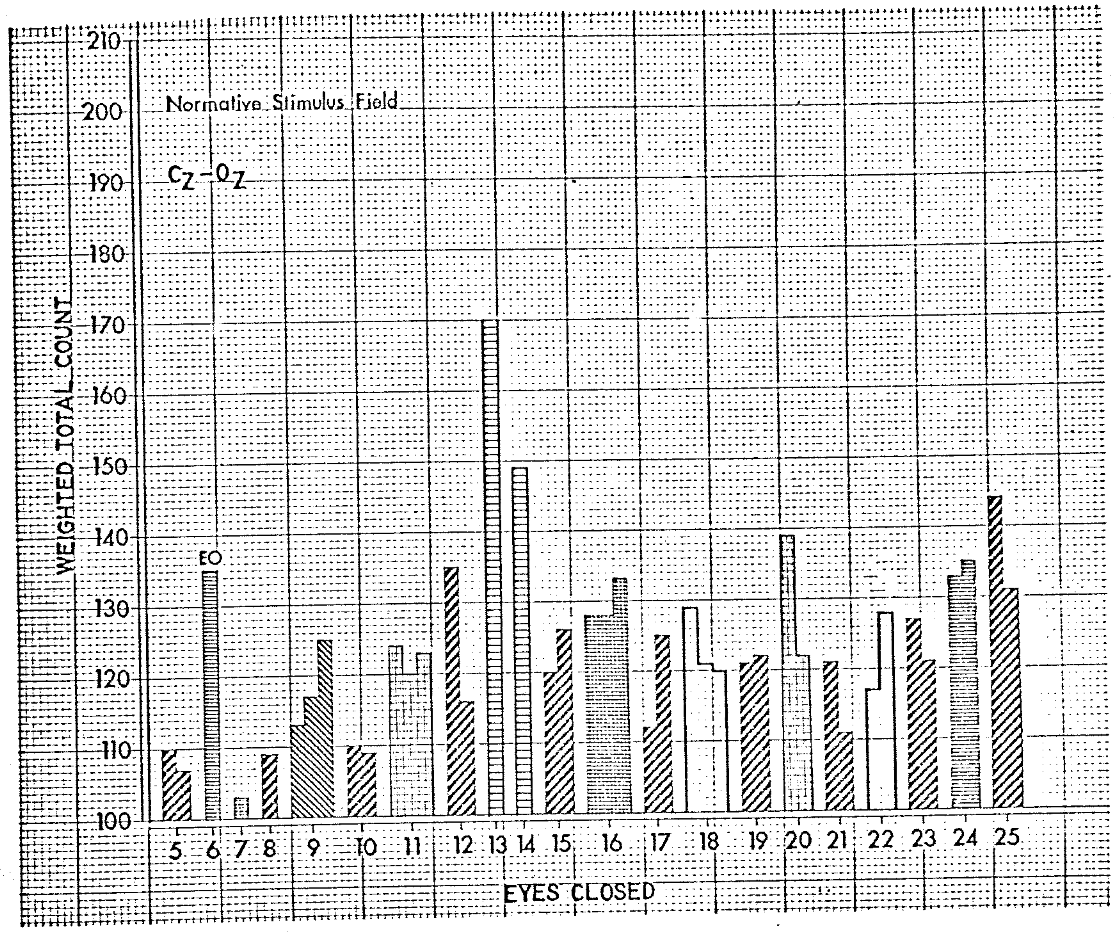

Normative Stimulus Field
C3-01
WEIGHTED TOTAL COUNT
210
200
190
180
170
160
150
140
130
120
110
100
EO
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
EYES CLOSED
LEGEND FOR ALL CHARTS
INSTRUCTIONS
REST
PHOTIC
SINGLE FLASH
MECHANICAL
EYES CLOSED
AUDIO
MATH PROBLEM
EYES OPEN
WHITE NOISE
CLENCH FIST
SINGLE TAP
ODDITY PROBLEM—STIM/RESP.
TONE SERIES
SLIDE SERIES
WEIGHTED TOTAL COUNT
26 27 28 29 30 31 32 33 34 35 36 37 38 39
EYES OPEN

Figure 1

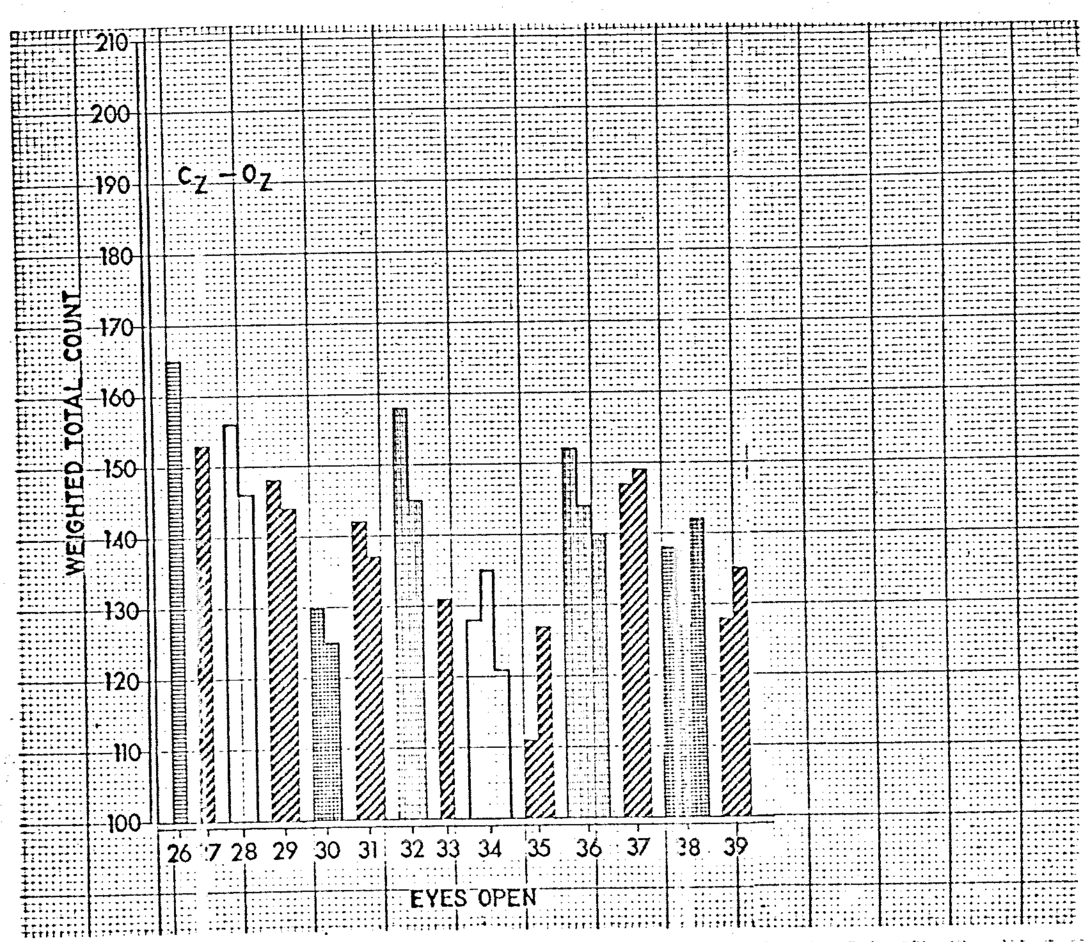


Normative Stimulus Field
C3—01
WEIGHTED TOTAL COUNT
210
200
190
180
170
160
150
140
130
120
110
100
S
R
EC
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56A·B·C 57 58 59 60—79 80—99 100—119
EYES OPEN

Figure 2



Normative Stimulus Field
$C_Z - O_Z$
WEIGHTED TOTAL COUNT
210
200
190
180
170
160
150
140
130
120
110
100
EO
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
EYES CLOSED



$C_Z - O_Z$
WEIGHTED TOTAL COUNT
210
200
190
180
170
160
150
140
130
120
110
100
26 27 28 29 30 31 32 33 34 35 36 37 38 39
EYES OPEN

Figure 3

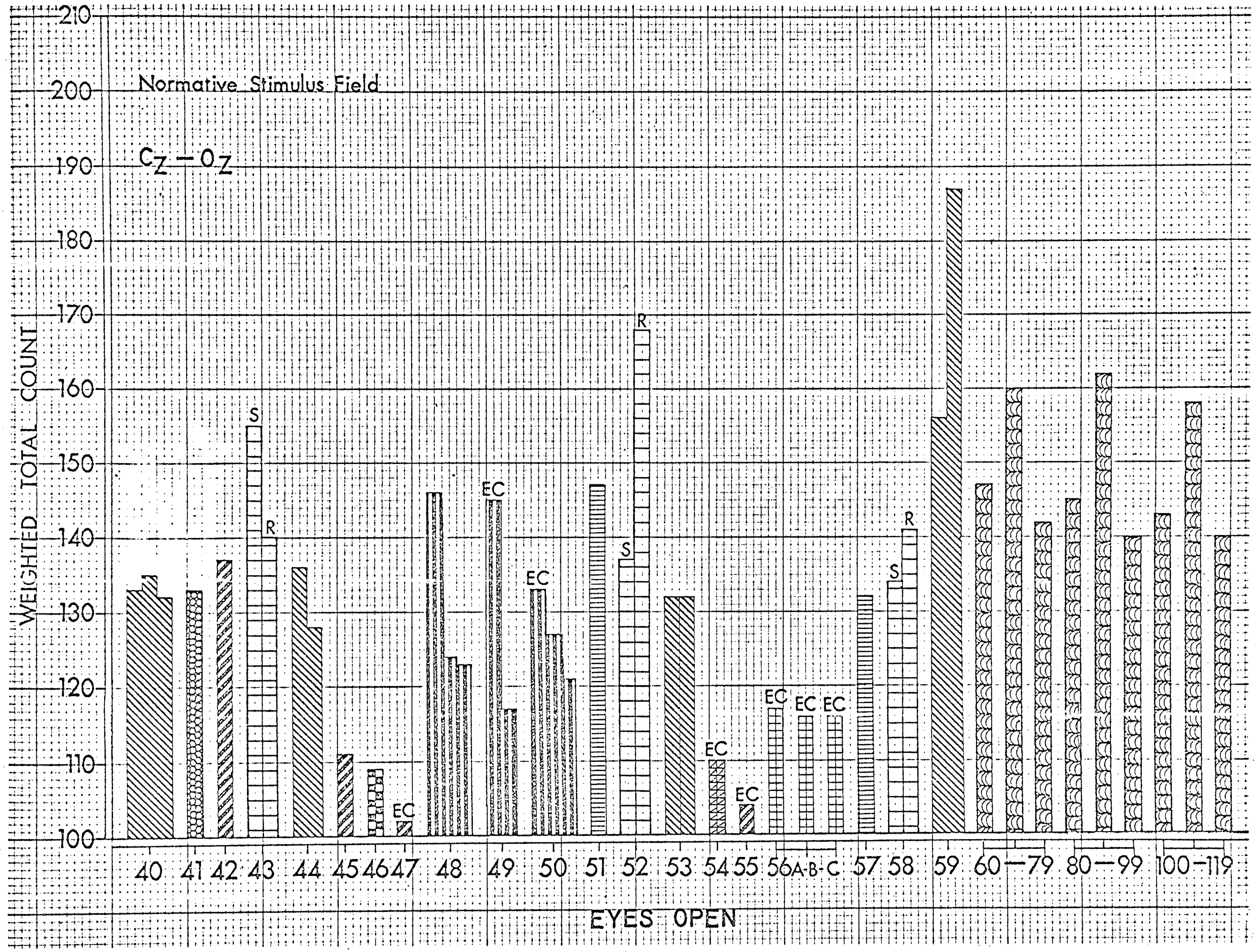

Normative Stimulus Field
$C_Z - O_Z$
WEIGHTED TOTAL COUNT
210
200
190
180
170
160
150
140
130
120
110
100
S
R
EC
40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56A-B-C 57 58 59 60—79 80—99 100—119
EYES OPEN

Figure 4

NO. 341-10 DIETZGEN GRAPH PAPER, 10 X 10 PER INCH
EUGENE DIETZGEN CO. MADE IN U. S. A.

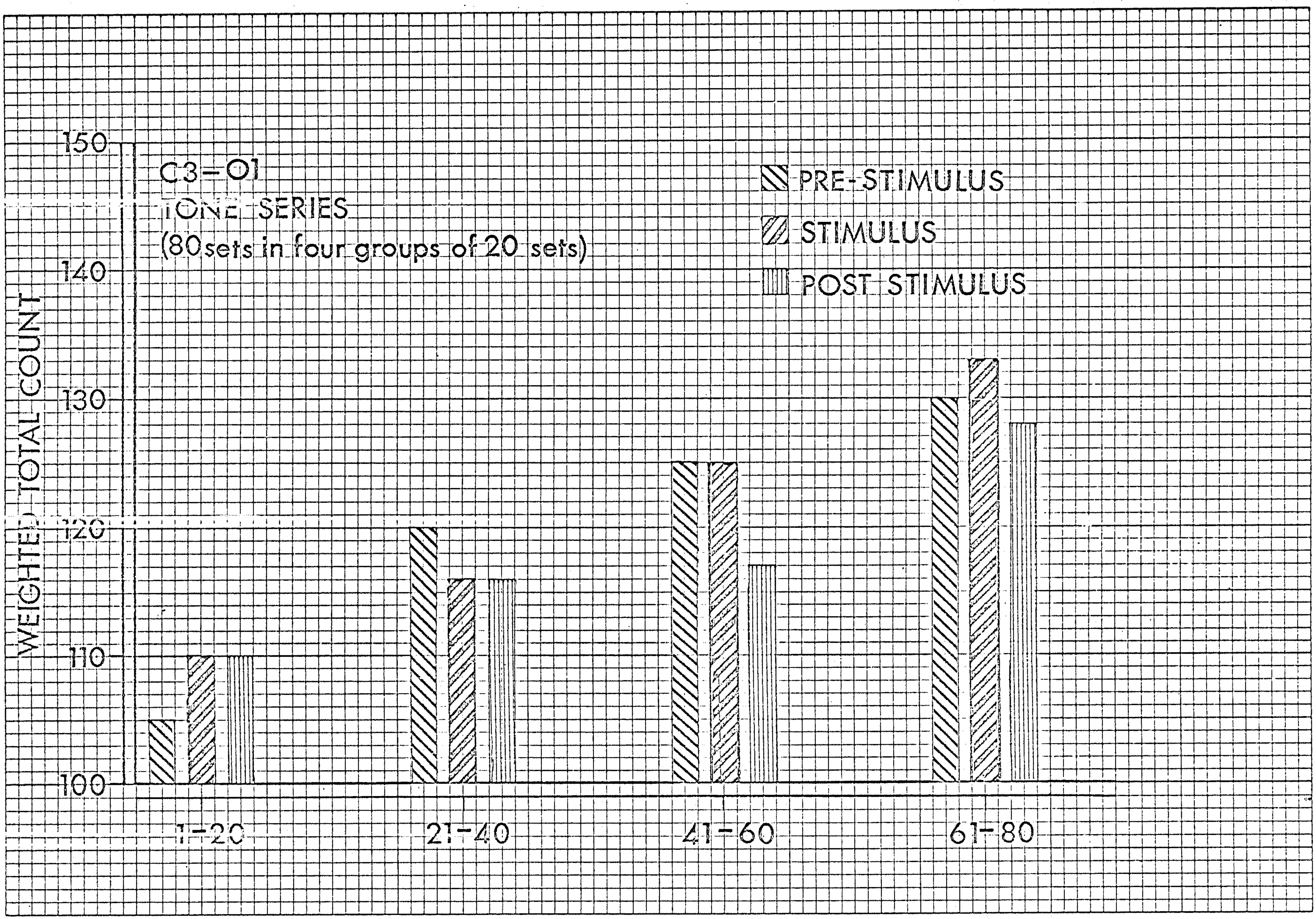


Figure 5

NO. 341-10 DIETZGEN GRAPH PAPER, 10 X 10 PER INCH
EUGENE DIETZGEN CO. MADE IN U. S. A.

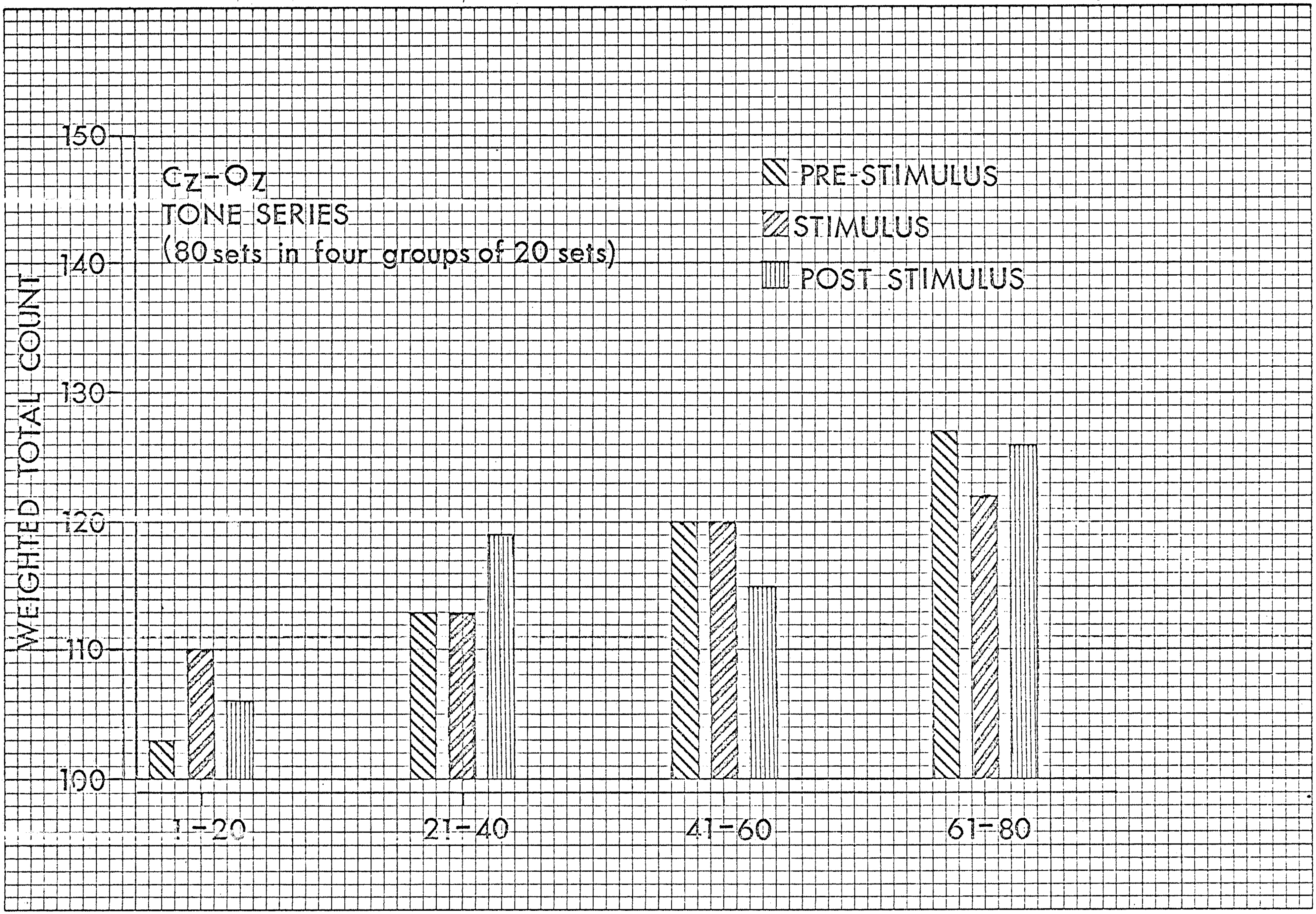


Figure 6

NO. 341-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

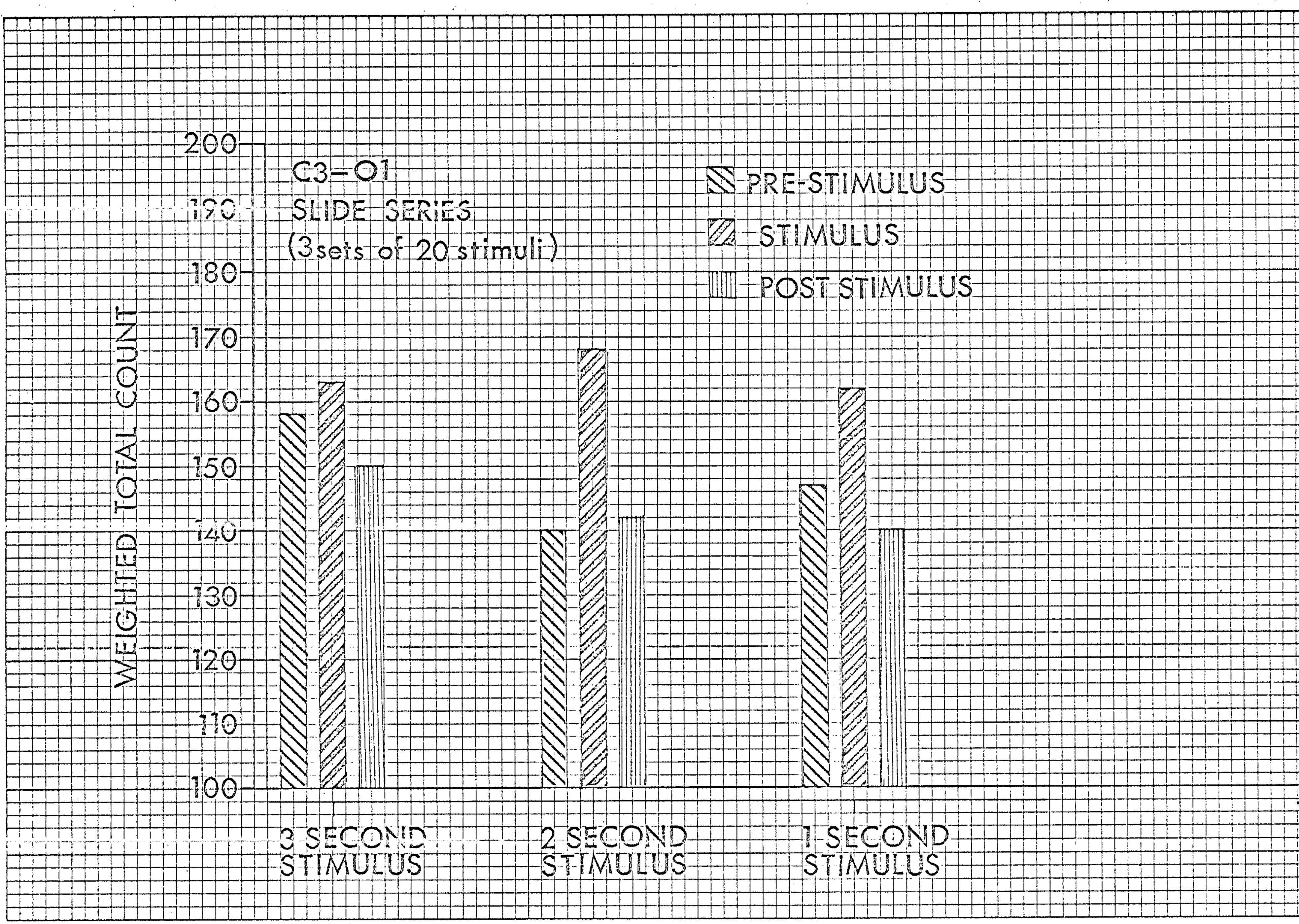


Figure 7

NO. 341-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

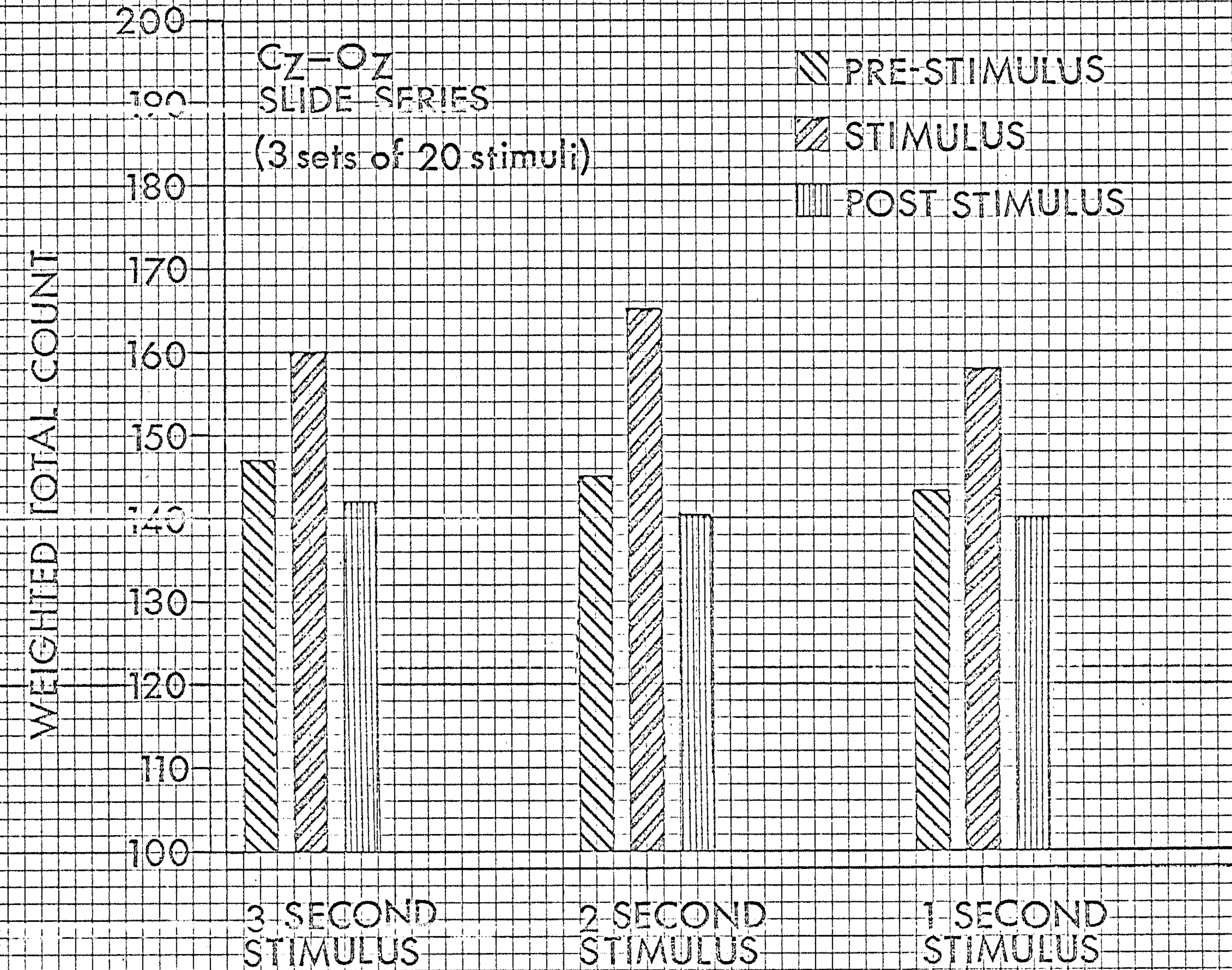
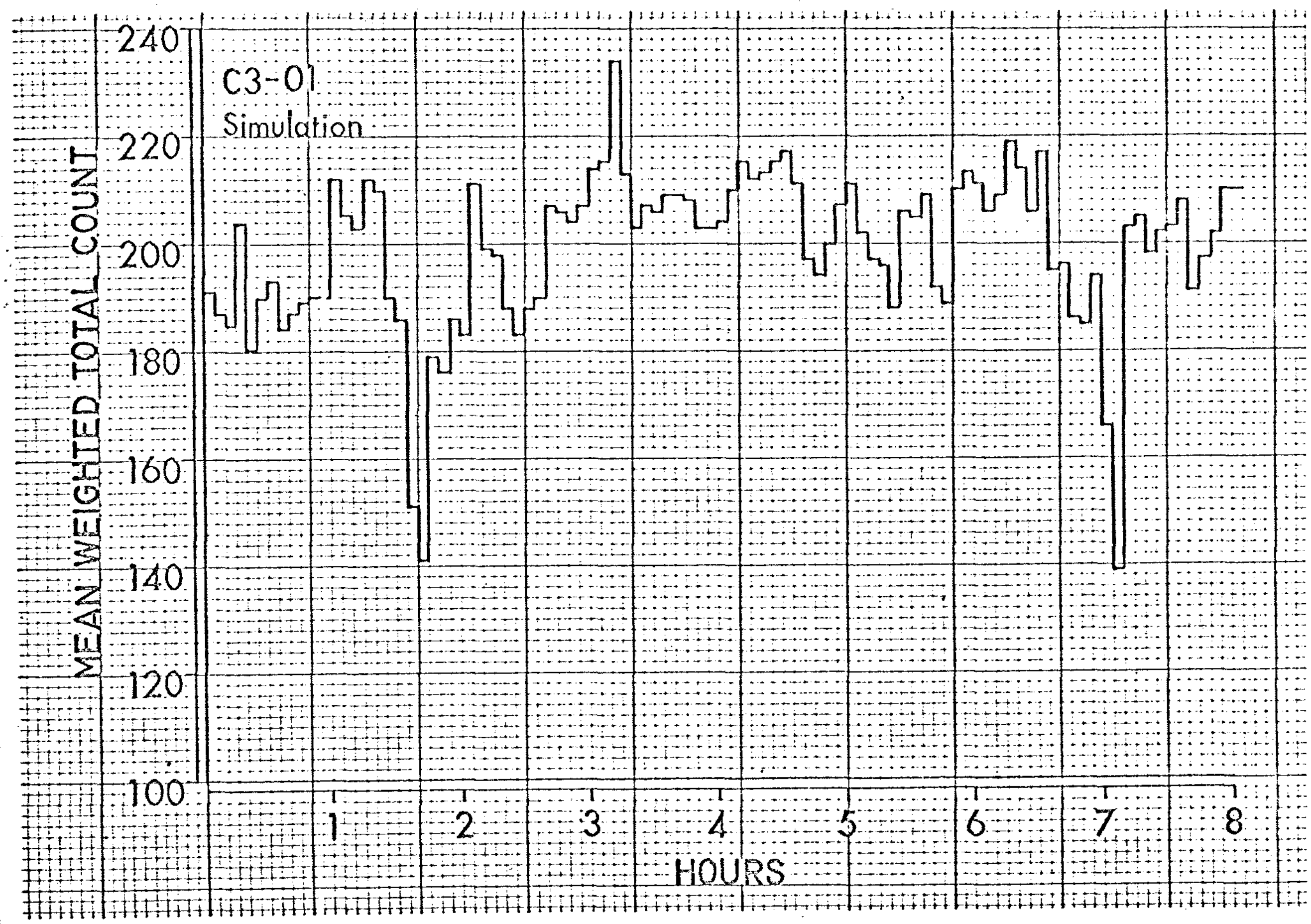


Figure 8


C3-01
Simulation
MEAN WEIGHTED TOTAL COUNT
240
220
200
180
160
140
120
100
1
2
3
4
5
6
7
8
HOURS

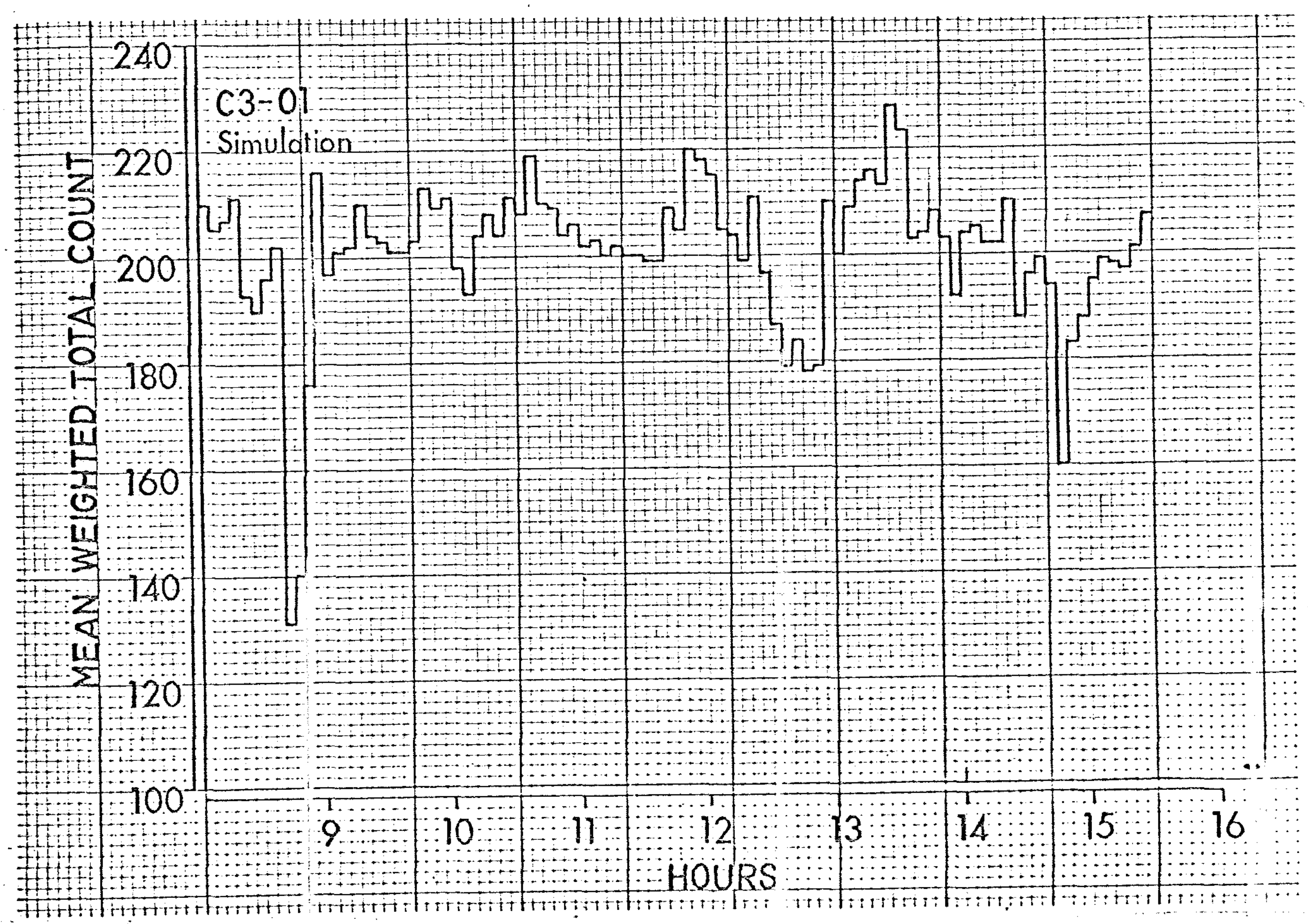
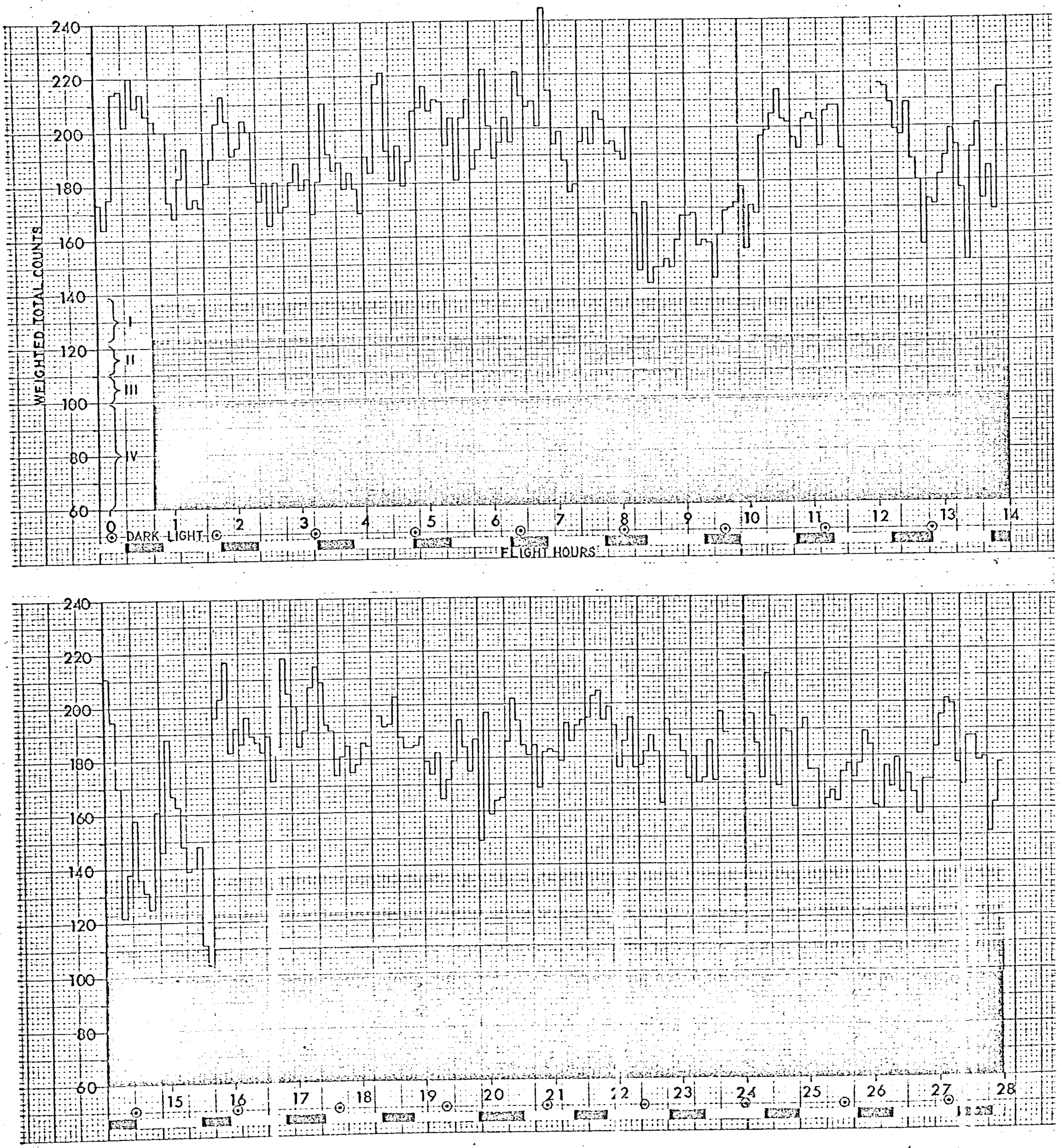
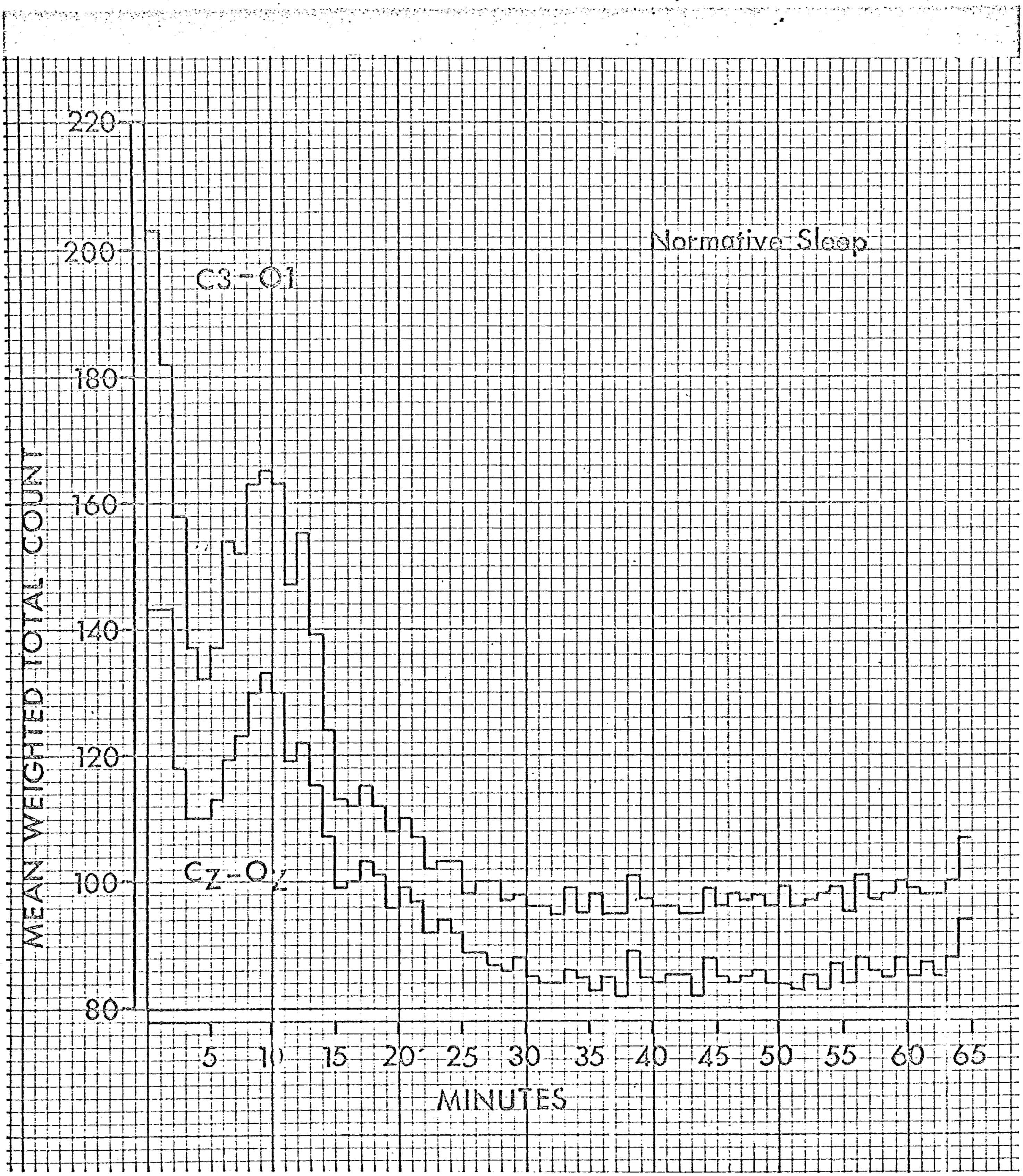

C3-01
Simulation
MEAN WEIGHTED TOTAL COUNT
240
220
200
180
160
140
120
100
9
10
11
12
13
14
15
16
HOURS

Figure 9



WEIGHTED TOTAL COUNTS
240
220
200
180
160
140
120
100
80
60
I
II
III
IV
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DARK LIGHT
FLIGHT HOURS
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Figure 10



Normative Sleep
C3-O1
Cz-Oz
MEAN WEIGHTED TOTAL COUNT
220
200
180
160
140
120
100
80
5
10
15
20
25
30
35
40
45
50
55
60
65
MINUTES

Figure 11

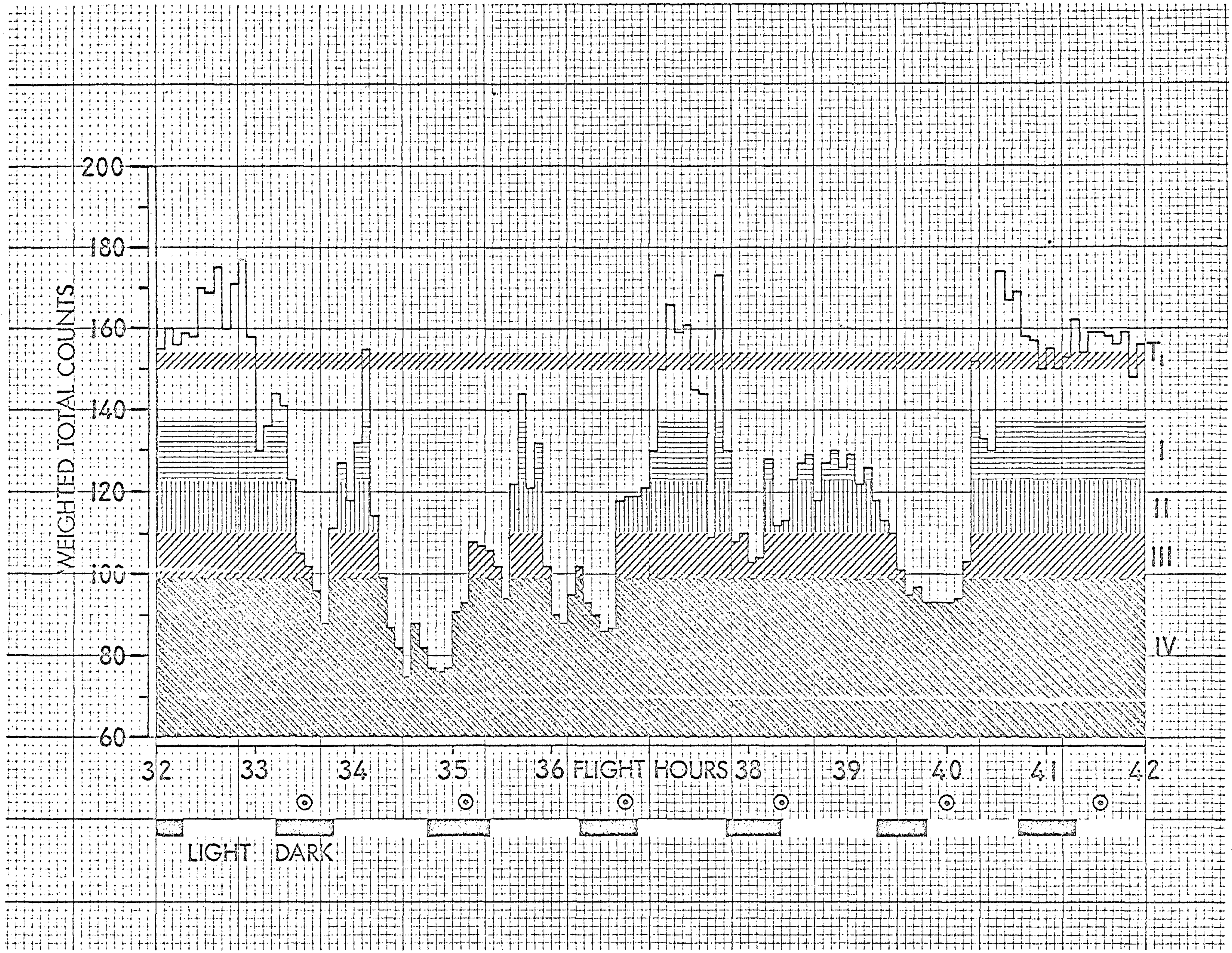

WEIGHTED TOTAL COUNTS
200
180
160
140
120
100
80
60
32
33
34
35
36
FLIGHT HOURS
38
39
40
41
42
T₁
I
II
III
IV
LIGHT
DARK

Figure 12