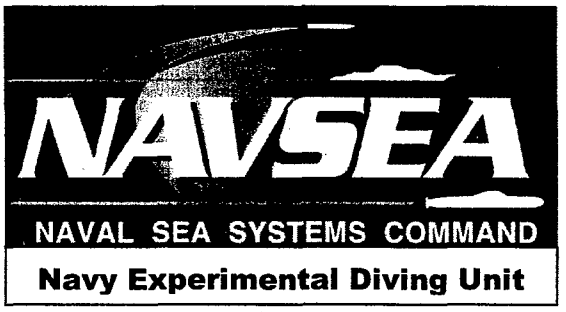
Navy Experimental Diving Unit (NEDU)
321 Bullfinch Rd.
Panama City, FL 32407-7015

NEDU TR 05-10
July 2005

EVALUATION OF THE JOINT SERVICE GENERAL PURPOSE MASK, XM50



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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING AUTHORITY	
4. PERFORMING ORGANIZATION REPORT NUMBER (S) NEDU TR No. 05-10	5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION Navy Experimental Diving Unit	6b. OFFICE SYMBOL (If Applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) 321 Bullfinch Road, Panama City, FL 32407-7015		7b. ADDRESS (City, State, and Zip Code)
8a. NAME OF FUNDING SPONSORING ORGANIZATION Joint Program Management Office - Individual Protection	8b. OFFICE SYMBOL (If Applicable) JPMO-IP	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code) US Army Edgewood Chemical Biological Command, SFAE-CBD-IP-M, APGEA, MD 21010-5424	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO. 01A	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

(U) Evaluation of the Joint Service General Purpose Mask, XM50

12. PERSONAL AUTHOR(S)

Dale Hyde, Ph.D.; Meave Garigan; Dennis Johnson

13a. TYPE OF REPORT	13b. TIME COVERED FROM	14. DATE OF REPORT (MMM/YYYY)	15. PAGE COUNT
TECHNICAL REPORT	June 2004 - July 2004	july 2005	75

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Joint Service General Purpose Mask, JSGPM, XM50, MCU-2/P, C2, chemical protective mask, sweat, fogging, chemical agent, biological agent, radiological agent, toxic industrial chemicals, TIC, ammonia.

19. ABSTRACT.

INTRODUCTION: This study evaluated the fogging resistance and sweat expulsion of the XM50 chemical protective mask. OBJECTIVES: This evaluation compared the XM50 to the MCU-2/P chemical protective mask in a simulated operational test environment. Objectives included: (1) assessing XM50 primary lens to resistance to fogging, (2) assessing XM50 vision correction lenses resistance to fogging, (3) assessing XM50 primary lens resistance to fogging when the mask is configured with toxic industrial chemical (TIC) filters and vision correction, and (4) assessing the ability of the XM50 to expel sweat. **METHODS AND PROCEDURES**: The study was conducted in the environmental chamber at the Navy Experimental Diving Unit (NEDU), Panama City, FL, and assessed four mask configurations: (1) MCU-2/P, basic mask; (2) XM50, basic mask; (3) XM50 with TIC filters and (4) XM50 with TIC filters and vision correction. All configurations were evaluated at three temperature profiles: Profile 1 was 90 ± 3 °F, relative humidity (RH) of 90 ± 3%; Profile 2 was 40 ± 3 °F, RH of 90 ± 3%; Profile 3 was 6 ± 3 °F, RH of approximately 50%. **RESULTS**: XM50, basic mask fogging performance was similar to the MCU-2/P during Profiles 1 and 2, and performed slightly worse than the MCU-2/P during Profile 3. During Profiles 2 and 3, the XM50 with TIC filters and XM50 with TIC filters and vision correction had more fogging than the XM50, basic mask and the MCU-2/P. Subjects indicated that the XM50 accumulated more sweat than the MCU-2/P. **CONCLUSIONS**: The MCU-2/P provides fogging resistance superior to that of the XM50 at temperatures ≤14 °F. XM50 fogging worsens when the mask is configured with TIC filters and vision correction. At times, fogging degraded the subject's ability to complete his mission. XM50 sweat accumulation did not degrade mission performance.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
| | UNCLASSIFIED/UNLIMITED |X| SAME AS RPT. | | DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
NEDU Librarian	(850) 230-3100	

DD Form 1473

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

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INTRODUCTION

The Joint Service General Purpose Mask (JSGPM) is the next generation chemical protective mask intended to replace the MCU-2 and M-40 series masks. Developmental testing and user assessment of the XM50, a variant of the JSGPM, indicated that the XM50 lacked sufficient fogging mitigation[1] and sweat reduction capabilities. Lens fogging and sweat accumulation in the mask degrade user confidence, impose a physiological burden upon the user, and can seriously degrade operational effectiveness. These performance shortcomings resulted in joint service concern,[2] and design changes to the mask were made. In 2003, a field evaluation[3] indicated that the sweat reduction issues had been resolved, but the evaluation was limited and did not challenge the XM50's ability to mitigate fogging.

The JSGPM System Manager Office funded this study to determine the XM50's fogging mitigation and sweat reduction capabilities. This study was intended to address program requirements that the XM50 mask will not fog prior to donning or during wear,[4] and that the mask will allow the expulsion of sweat and other fluids without compromising protection.[5] This study was intended to evaluate:

1. the ability of the XM50 primary lens to resist fogging,
2. the ability of the XM50 vision correction lenses to resist fogging,
3. the ability of the XM50 primary lens to resist fogging when the mask is configured with toxic industrial chemical (TIC) filters and vision correction, and
4. the ability of the XM50 to expel sweat.

The XM50's performance of objectives 1 and 4 was directly compared to that of the MCU-2/P chemical protective mask.

METHODS AND PROCEDURES

The JSGPM evaluation was conducted in an environmental chamber at the Navy Experimental Diving Unit (NEDU), Panama City, FL. Six test subjects, all active duty Navy personnel stationed at NEDU, participated in the study. All had routinely participated as test subjects in manned evaluations of protective equipment and were

familiar with the function of chemical protective masks and other life-support equipment. All subjects had signed consent forms (Appendix A) before participating in this study. After being sized before the first trial, each was assigned a properly fitting XM50, MCU-2/P, Joint Service Lightweight Suit Technology (JSLIST) coat and trousers, 25 mil butyl gloves, chemical protective footwear covers (CPFCs), and extreme cold weather parka. Subjects were briefed on the design and function of the XM50 and MCU-2/P and verbally confirmed to be familiar with the two masks.

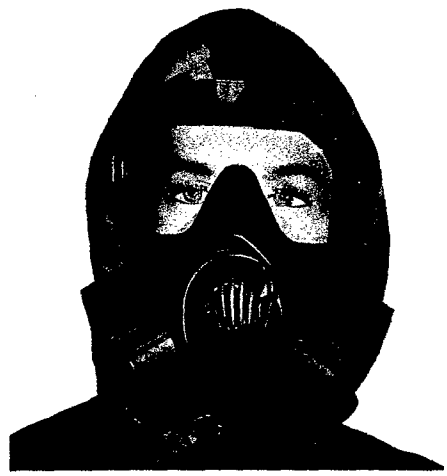


Figure 1. XM50 mask with primary filter canisters

Figure 2. MCU-2/P mask with C2 filter canister.

The study assessed the performance of the XM50, with and without selected accessories, during operation at three different temperature-humidity profiles. The study also included the MCU-2/P to provide direct comparison to a currently fielded mask. The XM50 was required to perform as well as or better than the MCU-2 and M-40 series respirators; due to cost constraints, the MCU-2/P was the only currently fielded mask included in this study.

The temperature profiles did not encompass the entire range of operational conditions (–25 to 120 °F) required for the JSGPM. Temperature profiles were selected to challenge the XM50's capabilities to mitigate fogging and sweat accumulation, but these

Figure 3. XM50 with primary and TIC filter canisters and vision correction insert. The TIC filters (arrows) attach to the top surface of the primary filters.

profiles should not be considered comprehensive. In addition to the basic configuration of the XM50, TIC filters and vision correction inserts were included in the evaluation. TIC filters and vision correction inserts affect airflow inside the mask and possibly increase the likelihood of fogging. In total, four respirator configurations were tested:

1. the XM50 mask with JSGPM primary filters,
2. the MCU-2/P mask with a C2 or C2A1 filter,
3. the XM50 mask with JSGPM primary and TIC filters, and
4. the XM50 mask with JSGPM primary and TIC filters in addition to vision correction inserts.

Test subjects wore their respirators during the following temperature-humidity profiles:

1. hot and humid: 90 ± 3 °F, with relative humidity (RH) of 90 ± 3%;
2. cool and humid: 40 ± 3 °F, with RH of 90 ± 3%; and
3. very cold: 0 ± 3 °F, with RH of approximately 50%.

Each subject wore one of the four configurations during a 30- to 40-minute exposure at one of the three temperature profiles, for a total of 12 exposures. Due to technical difficulties with the environmental chamber, the temperature during the very cold exposures fluctuated between 6 and 14 °F.

Test subjects were advised to forgo alcohol and strenuous exercise for 24 hours before an exposure. During the evaluation, subjects were encouraged to hydrate, and body weights were recorded before and after each exposure. Each test subject self-inserted a temperature sensor (Yellow Springs Instruments 401 Series) 15 cm past the anal sphincter, and this sensor was connected to a thermometer with a digital readout to allow the subject's rectal temperature (T_{re}) to be monitored. To minimize the possibility of subject hypothermia or hyperthermia, T_{re} was monitored before and during each exposure, and the following were established as criteria for terminating an exposure:

1. a T_{re} that reached 95.9 °F (35.5 °C) at any given time,
2. a T_{re} that reached 104.9 °F (40.5 °C) at any given time,
3. a T_{re} of $\leq$96.9 °F (36.1 °C) that occurred continuously for five minutes, or
4. a T_{re} of $\geq$104.0 °F (40.0 °C) that occurred continuously for five minutes.

Before each exposure, subjects were instrumented and T_{re} was checked. Before entering the chamber, subjects wore shorts, T-shirts under JSLIST jackets and trousers, issue boots, CPFCs, and butyl gloves with liners. Respirators were stationed in the chamber and were temperature soaked for a minimum of one hour. Upon entering the chamber, each subject donned his assigned respirator in one of the four configurations. A subject matter expert checked the donning and adjusted the mask head harness before the subject began the exercise profile.

Figure 4. Inside the chamber, expert check of respirator donning prior to beginning the exercise profile.

The exercise profile (Appendix D) remained constant throughout the trials. For the first 20 minutes of each exposure, subjects engaged in cycle ergometry, alternating between 150 and 100 W work rates. For an additional 10 minutes after completing the cycle ergometry, subjects engaged in a series of exercises intended to represent head and body positioning during normal operations. To facilitate the data collection process, subjects rotated through the environmental chamber so that only one at a time was operating the cycle ergometer or engaging in operationally representative exercises.

Figures 5 and 6. Above, a subject performs the weapon firing exercise while his tender records data. At right, a subject performs the box-carrying exercise.

During the exposures two video cameras were stationed in the chamber: Camera One was positioned in a corner to give a view of the operational exercises, and Camera Two was positioned in front of the cycle ergometer. Each camera continuously recorded events on VHS videotapes. Camera Two recorded the mask lens while the subject was on the cycle ergometer. When the subject walked to the corner and looked into Camera One, it recorded the mask lens after the subject had completed each operationally representative exercise. During the exposures each test subject had a tender responsible for ensuring timely transition between exercises, monitoring T_{re}, and providing any assistance the subject needed. Tenders were also responsible for recording observations and filling out the Test Incident Response (TIR) forms (Appendix C).

Figure 7. Subject performing cycle ergometry while positioned in front of Camera Two. The tripod for Camera One is visible on the left in the background.

Figure 8. Subject positioned in front of Camera One after completion of an operational exercise.

During the very cold (6 °F) exposures, the XM50 respirator configurations were outfitted with bidirectional pressure sensors (Honeywell part # DC020NDR5). The masks' drink tube couplers were removed, and pressure transducers were inserted to allow oral differential pressures to be measured without damaging the masks. Unmanned testing of the XM50 was conducted to provide a baseline for analysis. Discussion of the manned differential pressure results and unmanned testing is in Appendix G.

After each exposure, the Environmental Study Questionnaire (Appendix B) was used to interview test subjects.

The exposures were completed in accordance with the following schedule and exposure profile key:

Table 1.
Evaluation Schedule

TIME	Day 1	Day 2	Day 3	Day 4	Day 5
Morning		Trial 3		Trial 8	Trial 10
Midday	Rest Period	Trial 4	Rest Period	Chamber Climate Change	Trial 11
Afternoon		Trial 5		Trial 9	Trial 12

Table 2.
Exposure Profile Key

Configuration	Exposure Profile		
	90 °F 90% RH	40 °F 90% RH	6 °F 70% RH
MCU-2/P	Trial 1	Trial 3	Trial 9
XM50, basic	Trial 2	Trial 4	Trial 10
XM50, TIC filters	Trial 6	Trial 5	Trial 11
XM50, TIC filters and vision correction	Trial 7	Trial 8	Trial 12

RESULTS

Four of the original six test participants completed the 12 trials. Test subject 2270 dropped out during the first trial, after he suffered a severe physiological reaction to the high level of ammonia desorption from the C2 canister installed on his MCU-2/P. Desorption of ammonia from C2 canisters has been previously documented and evaluated.[6,7] Subject 2270 was immediately replaced by subject 1755, who completed the 12 trials. Due to a schedule conflict unrelated to the study, test subject 4827 completed only the first trial and was then replaced by subject 9229, who completed the remaining 11 trials.

Table 3.
Demographic and Sizing Information

Test Subject	Age	Weight (lb)	Mask Size	Face Length (in)	Face Breadth (in)	Neck Circumference (in)	XM50 Serial No.	MCU-2/P Serial No.
3299	49	185	M	4.6	5.8	15.5	PST 3-205	msa-04-245
4827	36	213	M	4.9	5.0	16.0	PST 3-207	msa-04-245
1755	33	210	L	4.8	5.8	16.5	PST 3-106	msa-04-248
2270	45	175	M	4.6	5.4	16.0	PST 3-206	msa-04-245
2079	29	195	M	4.5	5.4	16.0	PST 3-209	msa-04-245
7770	28	187	L	5.2	5.9	15.0	PST 3-106	msa-04-248
7795	29	192	M	4.4	5.7	16.0	PST 3-204	msa-04-262
9229	31	200	M	4.5	5.8	16.5	PST 3-207	msa-04-245

The evaluation trials were scheduled so that the most physically demanding test (MCU-2/P with C2 or C2A1 canister operated at 90 °F, 90% relative humidity) occurred first. However, the investigators had not anticipated the extremely high level of ammonia desorption from the filters, and desorption from both C2 and C2A1 canisters was so severe that most subjects were unable to complete the exercise profile and were extremely stressed when they exited the chamber. Their extremely negative experiences during the first trial may have biased them against using the MCU-2/P mask.

Fogging Resistance

During the hot and humid (90 °F, 90% RH) exposures, no fogging resulted in the four mask configurations evaluated. Subject 4827 reported "barely noticeable" fogging during his trial with the MCU-2/P; however, no fogging was visible to test observers.

The XM50 basic mask's resistance to fogging was comparable to the MCU-2/P's resistance during the 90 °F and 40 °F exposures. During the 6 °F exposure the XM50

basic mask performed slightly worse than the MCU-2/P, as the fogging diagrams (Appendix F) indicate. One subject (9229) experienced fogging in the MCU-2/P and reported a "moderate" effect on mission performance. Subjects 1755, 3299, 7770, and 9229 experienced fogging in the XM50: 3299 reported a "slight" effect on mission performance, while 1755, 7770, and 9229 reported no effect.

The XM50's fogging resistance was degraded at the 40 °F and 6 °F exposures when the mask was configured with TIC filters and plano lenses. This degradation was expected, since both components reduce airflow within the mask. The most severe fogging during the evaluation occurred during Trial 11 (6 °F, XM50 with TIC filters) and Trial 12 (6 °F, XM50 with TIC filters and vision correction). Although no analogous MCU-2/P data exist, the level of fogging subjects 1755 and 2079 experienced during Trial 12 would undoubtedly affect operations significantly, since their vision was partly or completely obscured by extreme fog. Fogging diagrams are in Appendix F.

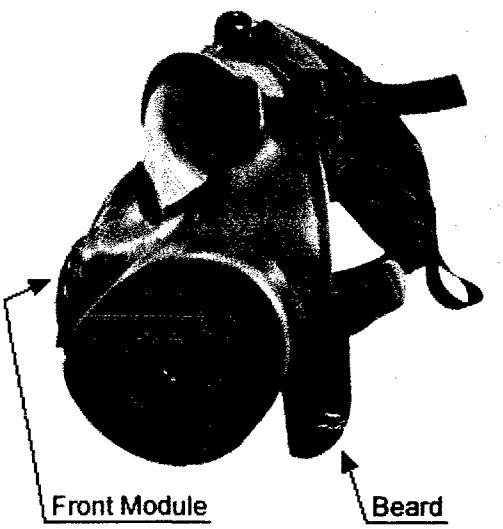


Figure 9. Side view of unworn XM-50.

Sweat Accumulation

During the 90 °F and 40 °F exposures, sweat was often observed to be expelled from the XM50 front module when a subject exhaled forcefully or looked down. However, a lack of visible sweat expulsion and of reported or observed mask beard malfunction characterized a few incidences. During Trial 2 (90 °F, XM50 basic mask), subject 7795's mask beard (Figure 9) protruded from his JSLIST suit and sweat drained down the exterior of his overgarment. After Trial 2, subject 1755 reported that sweat was draining behind his mask beard. Although there was no way to verify his report, no fluid expulsion from his mask's front module was observed during Trial 2.

The subjective nature of assessing sweat accumulation made it difficult to gauge the test subject's ability to expel sweat through the XM50's front module. Several subjects commented that collected sweat ran across their faces during the low crawl on their backs and that the XM50 appeared to accumulate more sweat and fluids than the MCU-2/P accumulated. However, the subjects did not report that sweat accumulation caused a greater incidence of degraded mission performance with the XM50 than with the MCU-2/P.

Mask Seal Breakages

XM50 mask seals were repeatedly reported to break. During Trial 4 (40 °F, XM50 basic mask) subjects 3299, 2079, 1755, and 9229 reported mask seal breakage at the cheek. During Trial 5 (40 °F, XM50 with TIC filters), subject 2079 reported mask seal breakage while low crawling on his back; subject 1755 reported mask seal breakage and experienced extreme fogging while he was doing push-ups. After Trial 7 (90 °F, XM50 with TIC filters and vision correction), subject 1755's mask beard was observed to have folded at his neck, and no moisture expulsion had been observed during the trial. During Trial 8 (40 °F, XM50 with TIC filters and vision correction), subject 2079 reported seal breakage at his temple while he was low crawling on his back. Subjects 1755 and 2079 both reported that interference between their mask beards and their necks and collarbones caused their mask seals to break. This interference occurred when they moved their heads to one side and tipped forward during the steam engine exercise and their low crawls on their backs.

The JSGPM System Manager Office has reported that seal breakages can result from the mask moving on the face and exposing warm, moist skin to the ambient environment. To some individuals, this exposure creates the sensation of a broken mask seal even when no actual breakage or degradation of protection occurs. However, this explanation does not account for the breakages observed and reported during this evaluation, due to the following reasons:

1. Some reported seal breakages were accompanied by mask malfunctions such as acute lens fogging (subject 1755, Trial 5) and mask beard protrusion (subject 7795, Trial 2) observed by the subject tenders.
2. Reported breakages were acute events often accompanied by specific body movements or positioning.
3. Except for subject 7770 during Trial 3 (40 °F, MCU-2/P basic mask), reported seal breakages did not occur when subjects were wearing masks that they rated as "unstationary" in the questionnaires.

CONCLUSIONS

The XM50's sweat mitigation characteristics are satisfactory: subjects felt that their mission performance was not degraded by sweat accumulation. However, the propensity for sweat to accumulate in the eyes of XM50 users is a concern.

The XM50's resistance to fogging is also satisfactory for operations at the 90 °F and the 40 °F with 90% RH climates. The XM50 basic mask's fogging resistance was slightly worse than the MCU-2/P mask's at 6 °F, as the fogging diagrams (Appendix F) indicate. Fogging can be expected to increase at low temperatures down to –25 °F within the XM50's required operating range. Configuring the XM50 with TIC filters and vision correction inserts significantly increased primary lens fogging.

Of significant concern were the reports of XM50 seal breakages, most of which were attributed to interference between the subject's neck and the mask beard. In addition to mask malfunctions observed by the subject tenders, some subjects reported that seal breakages occurred during specific body movements and positioning. One breakage occurred when the subject was performing push-ups: the XM50 with TIC filters pulled away from his face and caused the mask seal to break.

Ammonia desorption from the C2 and C2A1 canisters was an unexpected occurrence that imposed severe physiological stress on the test subjects during Trial 1. Assessing the operational suitability of the C2 series canisters is far outside the scope of this JSGPM evaluation. However, results indicate that at the very least, C2 series canisters may not be suitable for operations in hot and humid conditions, and future study is warranted.

REFERENCES

1. United States Marine Corps, Marine Corps Combat Development Command letter, *Recommended Change to the Operational Requirements Document for Joint Service General Purpose Mask (JSGPM)*, 3900 Ser C443 of Mar 26 2003.

2. Department of the Air Force Headquarters 311th Human Systems Wing (AFMC) memorandum, *Joint Service General Purpose Mask (JSGPM)*, of 20 March 2003.

3. U. Stutz and T. J. Kiggins, *Joint Service General Purpose Mask Customer Test*, JSGPM-TR-0316, U.S. Army Special Operations Command, 9 August 2003.

4. *Operational Requirements Document for a Joint Purpose General Purpose Mask*, section 4.a.(3)(c). Joint Requirements Office Chemical Biological Radiological Nuclear Defense (JRO-CBRND), unpublished acquisitions document, 24 March 1998.

5. *Operational Requirements Document for a Joint Purpose General Purpose Mask*, section 4.a.(6)(e). Joint Requirements Office Chemical Biological Radiological Nuclear Defense (JRO-CBRND), unpublished acquisitions document, 24 March 1998.

6. Department of the Army, Office of the Project Manager for NBC Defense Systems, *Memorandum on C2 Canister Evaluation*, AMCPM-NN (70-1r), 31 August 1995.

7. R. C. Grue and R. W. Morrison, *Desorption of Ammonia From C2 Canisters as Used in the TAERS and PIHM Aircrew Filtration Systems*, CRDEC-TR-207, Chemical Research, Development & Engineering Center, July 1990.

APPENDIX A

Test Subject Consent Form

Consent to Participate in Protocol 04-24 / 32150
EVALUATION OF THE JOINT SERVICE GENERAL PURPOSE MASK
Principal Investigator: Dr. Dale Hyde
JUNE 2004

1. As a test subject, you must sign this consent form before your participation in the studies described in the above numbered protocol.

2. Before signing this consent form, you should carefully read and thoroughly understand the entire protocol. Special attention should be paid to the following sections:

   a. Risks / Benefits (pp.1–2)

   The risk of hypothermia or hyperthermia in extreme thermal conditions is minimal. Short (30–40 min) exposures and appropriate garments will minimize this risk. With a warming tank and a water mister and fan, provisions for rewarming and cooling body temperatures will be available outside the NEDU Environmental Chamber. The risk of dehydration during the hot and humid condition (90 °F, 90% relative humidity) is minimal. To guard against this risk, participants will be directed to forego alcoholic beverages and strenuous exercise for 24 hours prior to an exposure. Guidance on proper hydration before data collection will be provided, and drinking water will be available during the hot exposures. Risk of injury during insertions of temperature sensors to monitor rectal temperatures (T_{re}) is minimal. Proper instruction regarding the placement of rectal sensors will minimize this risk. To ensure participant safety during testing, a corpsman will be present and a medical officer (MO) will be available in the building.

   Benefits include the assessment of the XM50's fogging resistance and sweat mitigation characteristics. This will provide data to aid in determining future JSGPM development and design efforts.

   b. Termination Criteria (p. 5)

   An exposure will be terminated if any of the following events occur:

   1. a subject terminates testing voluntarily,
   2. a T_{re} reaches 95.0 °F (35 °C) at any given time,
   3. a T_{re} reaches 104.9 °F (40.5 °C) at any given time,
   4. a T_{re} of $\leq$95.9 °F (35.5 °C) occurs continuously for five minutes,
   5. a T_{re} of $\geq$104.9 °F (40.5 °C) occurs continuously for five minutes,
   6. a medical monitor (available in the building) terminates testing, or

7. the Principal Investigator (PI; Dr. Dale Hyde) or Associate Investigator (Meave Garigan) terminates testing.

3. As explained in the protocol, participating in this research includes the risks to health from:

    a. Hypothermia (p. 1)
    b. Hyperthermia (p. 1)
    c. Dehydration (p. 1)
    d. Insertion of T_{re} sensors (p. 1)

4. Preparations have included briefing you as a test-subject for this series. You have had all applicable operating and emergency procedures thoroughly explained to you.

5. Qualified NEDU personnel have thoroughly explained all parts of the protocol, and you are confident that you understand them. You have been urged to participate in the planning, evolution, and critique of all procedures described in the protocol and feel that the exposure can be performed safely.

6. The PI (Dr. Dale Hyde) and/or a Medical Officer have explained the attendant risks outlined in the protocol to you. Any questions you may have had regarding these risks have been answered to your satisfaction. Also, you understand the benefits the U.S. military will receive from your performing the studies described in the protocol, and you accept the attendant risks.

7. You understand that you may voluntarily terminate or withdraw from any study described in the protocol. If you decide to withdraw from a study, you will notify either the Chairman of the Internal Review Board (IRB; LT Vic Ruterbusch) at (850) 230-3149 or the Medical Director at (850) 230-3100 to ensure an orderly and safe termination process.

8. If you have any questions about this research, you may contact the Associate Investigator, Meave Garigan, at (850) 235-5796.

9. If you have any questions regarding your rights as a subject in a research study, you may speak to IRB Chairman (LT Ruterbusch) at (850) 230-3149.

10. During or after this study, medical or dental treatment — including hospitalization, if necessary — will be provided to you if you require such treatment or hospitalization as a result of participating in the study, as soon as such need is recognized. Except for medical treatment, no special compensation is available for injuries you might incur during participation in this study. If you believe that participating in this study has injured you but appropriate care or redress has not been provided, you may discuss possible remedies with LCDR Kevin Gillam, NEDU Executive Officer, at (850) 230-3151.

11. The tenets of the Privacy Act, SECNAVINST 5211.5D, will be adhered to. This means that the information gained from the studies described in the protocol will be used only by Departments of the Navy and Defense and other U.S. Government agencies, provided the use is compatible with the purpose for which the information was collected. Any reports or publications containing data resulting from studies will not identify you by name or initials, unless your express permission is obtained. The Commanding Officer, NEDU, may grant use of the information to nongovernment agencies or individuals that request it. You should understand that all information contained in this statement or derived from the experiment described herein will be retained permanently at NEDU, and salient portions thereof will be entered into your medical record. By signing this form, you voluntarily agree to its disclosure to agencies or individuals identified in this paragraph, and you understand that failure to agree to such disclosure may negate the purposes for which the experiment was conducted.

12. I have read paragraphs 1 through 12 of this form and concur with all of them. My consent to participate as a test subject is given as an exercise of free will, without force or duress of any kind. I understand that my consent to participate does not release the U.S. Navy from any future liability attributable to the studies. I understand that by exercising my option to withdraw from any or all studies, I will incur no prejudice against myself or against my military or civilian career. In making my decision to volunteer, I am not relying upon any information or representation not set forth in this consent form or the protocol.

SUBJECT'S NAME (PRINTED): _____ _____
(Last, First, MI/Rate/Rank) (Date)

SIGNED: _____ _____
(Date)

WITNESS'S NAME (PRINTED) _____
(Last, First, MI/Rate/Rank))

SIGNED: _____ _____
(Date)

SIGNED: _____ _____
P. J. KEENAN, CAPT, USN (Date)
Commanding Officer
Navy Experimental Diving Unit

APPENDIX B

Environmental Study Questionnaire

The following questionnaire will document your experiences and opinions while you were wearing the MCU-2/P and XM50 chemical protective masks. Please be as accurate as possible in your responses, since the data you provide will be critical in determining future XM50 development and design efforts. Your answers will be kept completely confidential. Please be sure to follow all directions provided on the questionnaire or given to you by the administrator(s).

You are strongly encouraged to provide comments to explain any responses. If there is not enough room in the questionnaire for all your comments, feel free to write on the back of the page. If you do write on the back, be sure to label your comments with the question numbers that you are responding to.

Today's date _____

Test participant number _____

Mask type worn in this trial (check one):

- ☐ MCU-2/P, basic mask
- ☐ XM50, basic mask
- ☐ XM50 with secondary filters
- ☐ XM50 with secondary filters and spectacle insert

Chamber environmental condition during this trial (check one):

- ☐ 90 °F, relative humidity 90%
- ☐ 40 °F, relative humidity 90%
- ☐ 0 °F

Check the box of the response that best describes your experience or opinion.

PART ONE: VISION

1. Did the *mask lens* accumulate fog, ice, or moisture at any time during this trial?

   ☐ Yes ☐ No

2. If yes, during which test activity did the fogging, icing, or moisture accumulation occur? (Check more than one response, if necessary.)

   ☐ Activity 1: Cycling
   ☐ Activity 2: Operational Exercises

3. **If yes, rate the amount of fog, ice, or moisture accumulation. Circle the related activities during which the fog, ice, or moisture accumulated.**

☐ Extreme	☐ Moderate	☐ Slight	☐ Barely Noticeable
Activity 1 2	Activity 1 2	Activity 1 2	Activity 1 2

4. If yes, what impact did this have on your mission performance and weapon sighting?

   ☐ Extreme ☐ Moderate ☐ Slight ☐ No impact

5. Add any comments you have about vision while you were wearing the mask:

_____

_____

_____

PART TWO: PERSPIRATION

6. During this trial, the mask on your head and face was

☐ Very Stationary
☐ Stationary
☐ Slightly Stationary
☐ Unstationary
☐ Very Unstationary

7. Did your mask accumulate perspiration or other fluids during this trial?

☐ Yes ☐ No

8. If yes, during which test activity was this accumulation most noticeable?

☐ Activity 1: Cycling
☐ Activity 2: Operational Exercises

9. If yes, rate the amount of accumulation and circle the related activities:

☐ Extreme	☐ Moderate	☐ Slight	☐ Barely Noticeable
Activity 1 2	Activity 1 2	Activity 1 2	Activity 1 2

10. If yes, what impact did this have on your mission performance and weapon sighting?

☐ Extreme ☐ Moderate ☐ Slight ☐ No impact

11. Add any comments you have about perspiration and fluid accumulation while you were wearing the mask:

_____

_____

_____

12. Add any additional comments you have about wearing the mask:

_____

_____

_____

_____

APPENDIX C

Test Incident Report Form

Test Name	JSGPM Environmental Study
Person Filing Report	
Phone No.	
Date	
Time	
Wear Time at Time of Incident	
TP #(s)	
Mask ID(s)	
Description of Activity	
State Incident	
Immediate Corrective Action	

Person Filing Report	Signature	Date
Test Director	Signature	Date

APPENDIX D

Exercise Profile

The exercise profile was designed to represent work rates, body movements, and positioning that the warfighter may engage in during missions.

Test subjects completed the entire profile inside an environmental chamber and were monitored by a tender who was responsible for maintaining and tracking the sequences during an exposure. Between each exercise, subjects walked to Camera One to record an image of their mask lenses.

Exercise times are approximate and do not include transition times between each activity.

Exercise	Time (min)
Cycle Ergometry, 4-minute intervals: 100 W -150 W - 100 W - 150 W - 100 W *	20
Touch the floor and reach for the ceiling	0.75
Bend at waist, look down, and breathe deeply	0.75
Carry 50 lb box from one point to another	1.5
PAB Shooting System	0.5
Push-ups	1
Steam Engines**	2
Low crawl on belly	1.5
Low crawl on back	1.5

* During the first day of the protocol, subjects worked at 150 W – 100 W – 150 W – 100 W – 150 W. This was altered to mitigate subject fatigue.

** During the first day, subjects performed flutterkicks. Due to subject fatigue, flutterkicks were replaced by steam engines (with hands on shoulders, bring one elbow to the opposite side knee and alternate).

APPENDIX E

Questionnaire Responses and TIR Results

The tabulated questionnaire responses are sorted by trial number (rows) and subject number (columns). All assessments are as reported by the test subjects and are subjective.

The TIR results provided by the subjects' tenders matched the questionnaire responses for the most part. TIR results that were not captured in the subjects' questionnaire responses are italicized.

Ratings of persistent fogging, moisture (sweat) accumulation, effect on mission performance, and mask stability on the face are in boldface font. Other important details, including incidences of intermittent fogging, remain in standard font.

Unless otherwise noted, reported fogging and sweat accumulation had no perceived effect on mission performance. Unless otherwise noted, subjects reported masks to be "very stationary."

Trials with the MCU-2/P are highlighted.

Table 2.
Exposure Profile Key

	Exposure Profile		
Configuration	90 °F 90% RH	40 °F 90% RH	6 °F 70% RH
MCU-2/P	Trial 1	Trial 3	Trial 9
XM50, basic	Trial 2	Trial 4	Trial 10
XM50, TIC filters	Trial 6	Trial 5	Trial 11
XM50, TIC filters and vision correction	Trial 7	Trial 8	Trial 12

TRIAL	3299	7795	2079
1	No comment on sweat or fogging	No comment on sweat or fogging	Did not finish exercises. No comment on sweat or fogging.
2	During operational exercises, **barely noticeable** sweat accumulation	*While bending at the waist, the subject's mask broke seal at beard, beard protruded from JSLIST and sweat drained from mask. This incident can be seen on video (2nd Series, Camera 1, at 1hr 50 min playing time).*	Subject found it more difficult to sight weapon with XM50 than with MCU-2/P
3	No comment on sweat or fogging	During both activities, **slight** fogging with **slight** impact on mission performance. Fogging cleared w/in a couple of seconds.	Reported slight intermittent fogging. During cycling, **barely noticeable** amount of sweat sprayed back in his face when speaking.
4	During both cycling and exercises, **barely noticeable** fogging. During operational exercise, **barely noticeable** sweat accumulation. During steam engine exercise, reported mask seal leakage at cheek.	Intermittent fogging.	During low crawl on back and steam engines, mask seal broke at cheek. Seal breaks occur on side opposite to chin movement. Breakage on inhale and exhale during low crawl, exhale only on steam engine. Mask was **stationary**. During operational exercises, **barely noticeable** sweat accumulation.
5	During cycling, could feel aerosolized sweat in nose cup; sweat was **barely noticeable** during operational exercises. Difficult to adjust to weapons firing position.	During 150 W cycling, intermittent fogging. During operational exercises, **slight** sweat accumulation: when looking down, mask seemed to pull away from his face and was only **slightly stationary**. Sweat pooled above visor during low crawl on back and ran across his face upon standing up. TIC filters degraded weapons firing.	During low crawl on back, seal broke at right cheek and **barely noticeable** accumulated sweat sprayed across the inside of the lens. Mask was **stationary**.

TRIAL	7770	1755	9229	4827
1	Did not finish exercises. No comment on sweat or fogging. Reported that mask was **slightly stationary**.	Did not finish exercises. No comment on sweat or fogging.		During cycling, **barely noticeable** fogging. During operational exercises, **slight** sweat accumulation.
2	During operational exercises, **moderate** sweat accumulation.	Reported that sweat was draining behind his mask beard, *no observed sweat expulsion from voicemitter, nor is any sweat expulsion visible on the video of the trial (3rd Series, Cameras 1 and 2).*	During cycling, **slight** sweat accumulation	
3	Reported poor fit, mask slippage, and lost seal; mask was **very unstationary**.	During both cycling and exercises, **slight** intermittent fogging occurred on forceful exhalation, **slight** sweat accumulation, mask was **slightly stationary**.	During both cycling and exercises, **slight** fogging with **slight** impact on mission performance. Mask was **stationary** (slight mask slippage). During operational exercises, **slight** sweat accumulation w/ **slight** impact on mission performance.	
4	No comment on sweat or fogging.	During steam engine exercise, reported mask seal leakage at cheek. Mask was **stationary**. Reported that seal breakage was due to bead interference with throat, which caused the mask to buckle.	During cycling, intermittent fogging over right eye. During steam engine exercise, reported mask seal leakage at cheek. Weapon firing slightly degraded compared to MCU-2/P. Mask was **stationary**.	
5	During operational exercises, **slight** fogging with **slight** impact on mission performance.	During push-ups, **extreme** lens fogging, **extreme** impact on mission performance. Mask was **unstationary** during push-ups, mask weight pulling down on head harness. Reported that mask seal was breaking at temple on side opposite downward head movement.	During operational exercises, **slight** sweat accumulation, no impact on mission performance.	

TRIAL	3299	7795	2079
6	During cycling and exercises, inhaled droplets of sweat. Rated sweat accumulation as **slight**. Remarked that mask was harder to breathe than with just primary filters, and that he was limited by airflow, not workload.	During operational exercises, **moderate** sweat accumulation; during low crawl on back, sweat moved to top of mask and "cascaded" down his face. Mask was **slightly stationary**.	About 10 minutes into cycling, persistent **barely noticeable** fog over lens. During operational exercises, sweat accumulation was **moderate**, with **slight** impact on mission performance. Accumulated sweat rolled across face and got in eyes during low crawl on back; inhaled sweat droplets on deep inhalation.
7	During cycling and exercises, inhaled droplets of sweat. Rated sweat accumulation as **slight**. Remarked that airflow in mask was better without vision correction inserts.	During cycling, **barely noticeable** fogging on Plano lens. Mask was **slightly stationary**, chin movement in chip cup. During operational exercises, sweat accumulation was **moderate**, with **slight** impact on mission performance. During low crawl on back, right eye socket filled with sweat each time head leaned to the left.	During operational exercises, subject reported **slight** sweat accumulation; reported that when his head was down he inhaled droplets of sweat. Mask was **stationary**. Subject exited chamber after completing push-ups.
8	During cycling, **moderate** fog spot developed over left eye (upper medial) and persisted throughout trial, having **slight** impact on mission performance. Mask was **stationary**. *During low crawl on back, JSLIST suit was observed to have unzipped approximately 4 inches.*	During low crawl on back, **slight** accumulated sweat slid across face. Mask was **slightly stationary**.	During cycling, lower left of Plano lens fogged, cleared after cycling was over, and then recurred during low crawl on back. During operational exercises, barely noticeable sweat accumulation. Reported seal breakage on inhale and exhale at right temple during low crawl on back.
9	When bent at waist during operational exercises, **slight** fogging started and persisted. Intermittent fogging during cycling. Mask was **stationary**; it felt like it was pulling away from face during operational exercises.	During heavy breathing while cycling, slight intermittent fogging. Reported nose cup discomfort.	During cycling, intermittent fogging on right side of lens. During low crawl on back, **slight** sweat accumulation with **slight** impact on mission performance (inhaled large drop of sweat).

TRIAL	7770	1755	9229
6	During low crawl on belly and back, accumulated sweat ran into mouth and over lens; felt like he was "drowning" at first. Rated impact on vision as **moderate**, impact on mission performance **extreme**. Rated sweat accumulation as **extreme**, impact on mission performance **extreme**.	No comment on sweat or fogging.	During operational exercises, **moderate** moisture accumulation. Had "issues" sighting weapon due to interference with mask filter.
7	Subject had difficulty breathing while cycling and reported that the mask was pressing on his nose. After completing push-ups, subject exited chamber, complaining of shortness of breath. During operational exercises, reported **extreme** sweat accumulation, with **slight** impact on mission performance. Reported "a lot of sweat in the eyes."	During cycling, subject reported choking sensation. During operational exercises, **moderate** fogging with **moderate** impact on mission performance. Plano lens fogged after bending at waist and tilted when weapon stock was pressed against the mask. Mask was **stationary**; reported **moderate** amount of sweat accumulation, with sweat going across face during low crawl on back. *When JSLIST was removed at the end of the test, mask beard was folded (no sweat expulsion from the voicemitter had been observed).*	During operational exercises, **moderate** moisture accumulation.
8	During box carry, **moderate** fogging started and persisted, worsening during low crawl on back; **slight** impact on mission performance.	During cycling, **extreme** fogging over left eye with **moderate** impact on mission performance. Lens cleared about 10 minutes into cycling. During operational exercises, sweat accumulation was **slight**. During low crawl on back, sweat ran across face.	After donning, **slight** Plano lenses fogging persisted <10 minutes. During operational exercises, slight sweat accumulation.
9	After box carry, **moderate** fogging, with slight intermittent fogging on right-hand side throughout operational activities.	Left side of lens fogged at donning and persisted several minutes. **Slight** sweat accumulation during operational exercises; sweat dripped on face during low crawl on back.	At donning, **moderate** lens fogging over right eye — fogging which persisted throughout cycling and operational exercises, with **moderate** impact on mission performance.

TRIAL	3299	7795	2079
10	**Barely noticeable** fogging (over left eye, upper medial) started after initiation of cycling and persisted throughout trial and had **slight** impact on mission performance. **Barely noticeable** sweat accumulation during cycling.	During operational exercises, **barely noticeable** sweat accumulation (sweat was sliding across subject's face during low crawl on back).	During box carry, **barely noticeable** fogging on right lens periphery that persisted throughout the remainder of the exposure. During operational exercises, **slight** sweat accumulation (sweat rolling across face during low crawl on back). Mask was stationary.
11	No comment on sweat or fogging. Subject reported discomfort due to mask beard.	During operational exercises, **barely noticeable** sweat accumulation (during low crawl on back, noticed sweat accumulated at temple).	Center of lens fogged at start of cycling; at second 150 W interval fogging started at right side of lens. By the end of cycling, the lens had fogged completely. By the end of the first operational exercise (box carry), the lens had cleared. Lens fogged again during low crawl on back. Overall, **moderate** fogging with **slight** impact on mission performance. **Barely noticeable** sweat accumulation during low crawl on back. Mask was **stationary**.
12	**Moderate** lens fogging (could have been Plano lens) at donning and persisted a few minutes. Intermittent fogging when bent at waist and exhaling.	Intermittent fogging on Plano lens during 150 W cycling. Persistent **moderate** fogging over right eye that developed during low crawl on back, with **slight** impact on mission performance (subject is a left-handed shooter). During low crawl on back, noticed slight sweat accumulation on left side of mask.	**Extreme** fogging on left side of lens throughout exposure; right side of lens began to fog during low crawl on back and persisted. **Extreme** impact on mission performance. Mask was **stationary**.

TRIAL	7770	1755	9229
10	Slight intermittent fogging throughout both cycling and exercises. Fogging increased when subject was bent at waist yet was still transient.	No comment on sweat or fogging.	No comment on sweat or fogging.
11	Slight intermittent fogging throughout both cycling and exercises. Mask was **stationary**.	During cycling, **barely noticeable** sweat accumulation.	Slight intermittent fogging throughout trial.
12	**Moderate** fogging on left side of lens. Lens fogged at donning, cleared, then fogged again during cycling and persisted throughout the remainder of the exposure. No reported performance degradation. Mask was **stationary**.	At donning and during cycling, **extreme** fogging with **extreme** impact on mission performance. Subject reported that lens cleared after about 10 minutes of cycling. Plano lens fogged after cycling and subject reported that he could not focus during weapons firing.	At donning and during cycling, **moderate** fogging that persisted for about 5 minutes; **slight** impact on mission performance. Intermittent fogging throughout exposure. Had difficulty shooting, although subject was not sure why.

APPENDIX F

Fogging Diagrams

The following diagrams represent the fogging visible to test observers during the exposures. There are several instances where fogging was reported by the test subject and recorded in the questionnaire responses (Appendix E), but the fogging was not evident at the prescribed fogging assessment intervals. These instances are not represented in the following fogging diagrams.

Persistent fogging was assessed as "light," "moderate," or "extreme." Fogging was described as "intermittent" if it was visible only when the subject exhaled and if it cleared upon inspiration. Fogging was described as "persistent" if it did not clear immediately upon inspiration.

The diagrams are shaded in accordance with the following key. Plano lens fogging (versus mask lens fogging) is discerned by a black outline on the affected lens.

Due to unforeseen issues, fogging data from the Trial 10, 11, and 12 operational exercises (the 25–35 minute wear times) were lost and are not represented in the following diagrams.

Table 4: Fogging Severity Key

Persistent Light Fog	
Persistent Moderate Fog	
Persistent Extreme Fog	
Intermittent Fog	

Table 2: Exposure Profile Key

Configuration	Exposure Profile		
	90 °F 90% RH	40 °F 90% RH	6 °F 70% RH
MCU-2/P	Trial 1	Trial 3	Trial 9
XM50, basic	Trial 2	Trial 4	Trial 10
XM50, TIC filters	Trial 6	Trial 5	Trial 11
XM50, TIC filters and vision correction	Trial 7	Trial 8	Trial 12

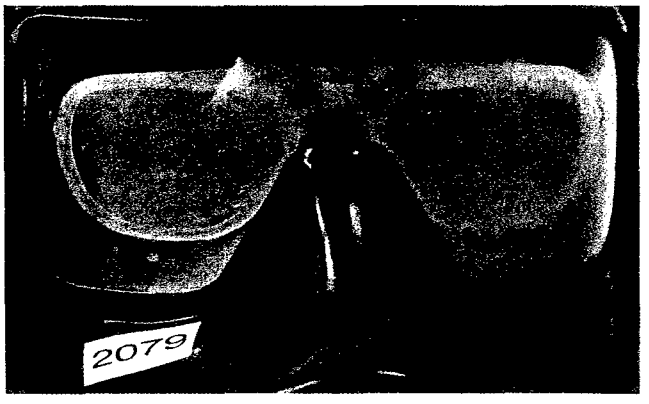
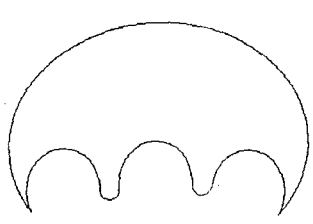


Figure F-1. Example of fogging. Subject has "moderate" fog over his right eye and "extreme" fog over his left eye.

TRIAL 3 SUBJECT 1755



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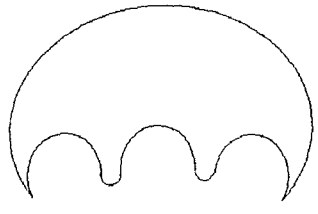

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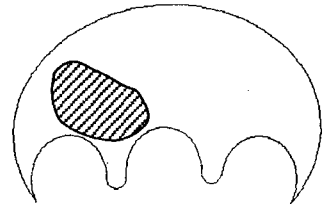

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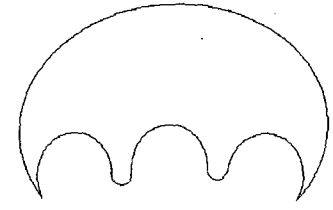

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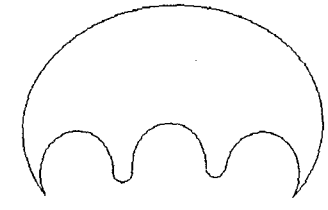

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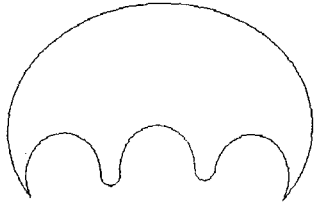

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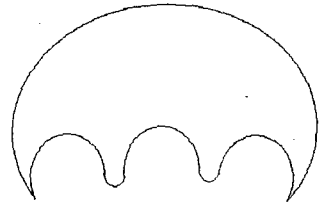

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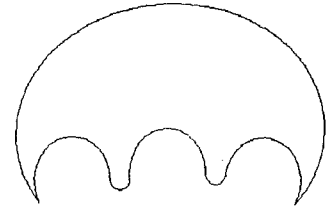

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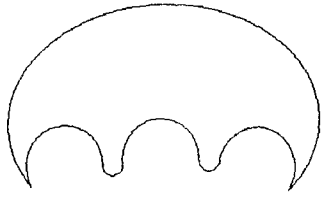
TRIAL 3 SUBJECT 3299



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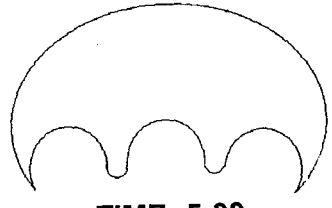

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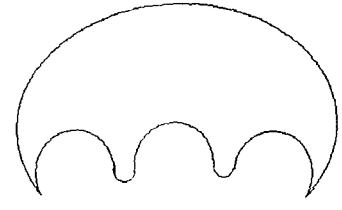

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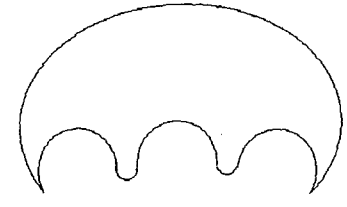

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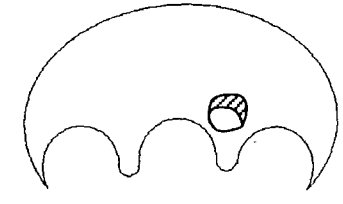

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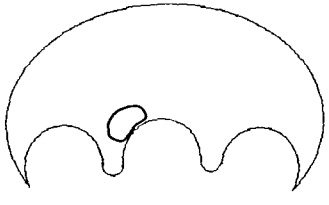

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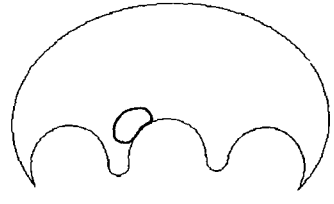

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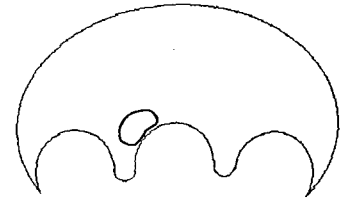

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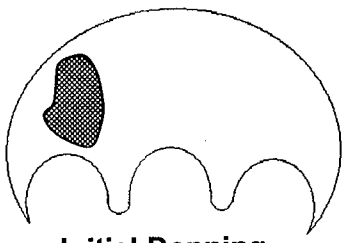
TRIAL 3 SUBJECT 9229



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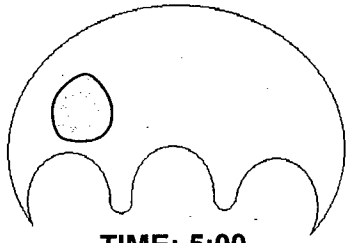

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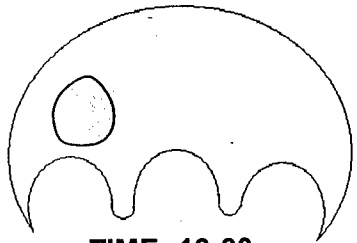

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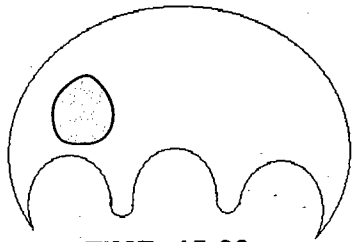

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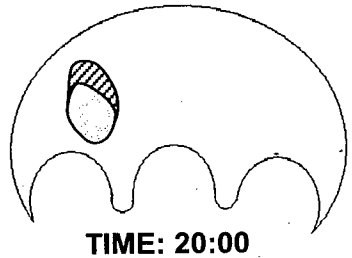

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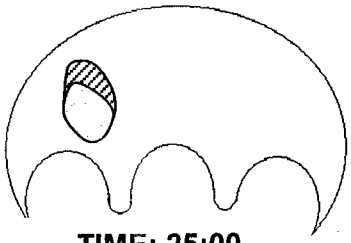

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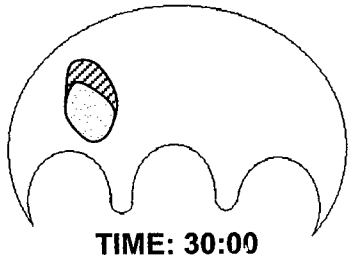

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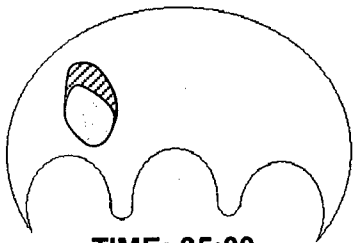

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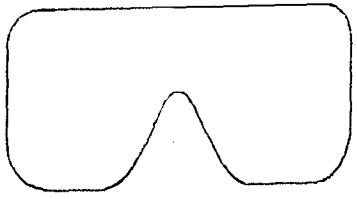
TRIAL 4 **SUBJECT 3299**



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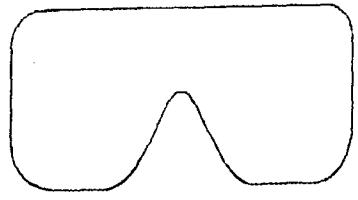
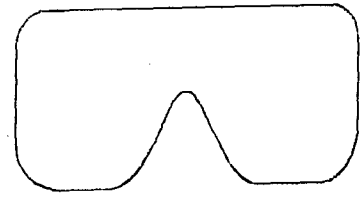
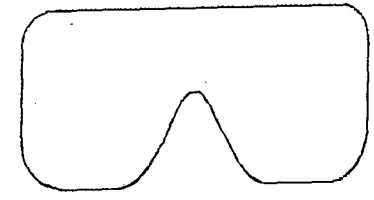


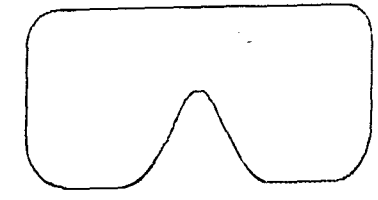
TIME: 5:00



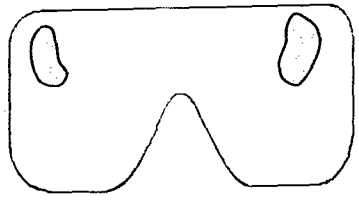
TIME: 10:00



TIME: 15:00

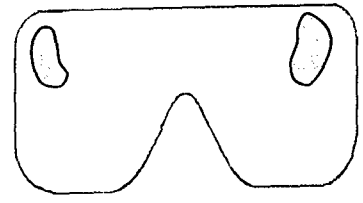


TIME: 20:00



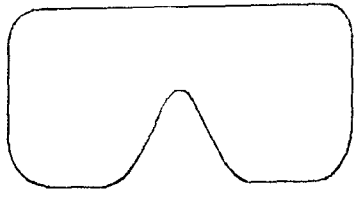
TIME: 25:00

TIME: 30:00

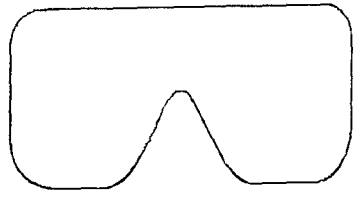


TIME: 35:00

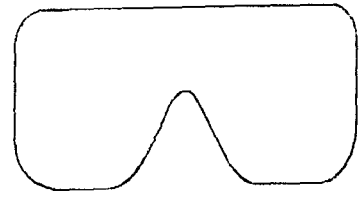
TRIAL 5 **SUBJECT 1755**



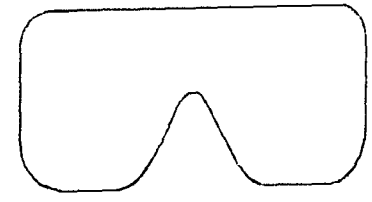
Initial Donning



TIME: 5:00



TIME: 10:00



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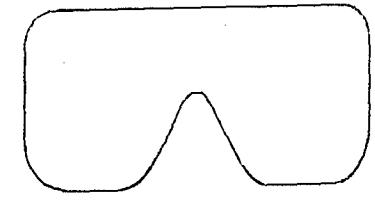
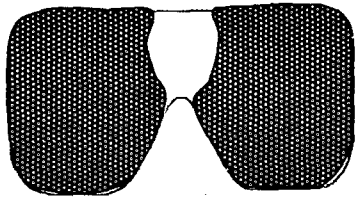
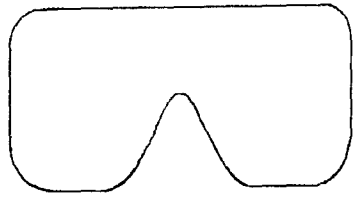


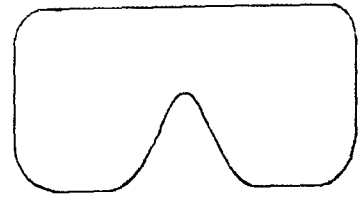
TIME: 20:00



TIME: 25:00



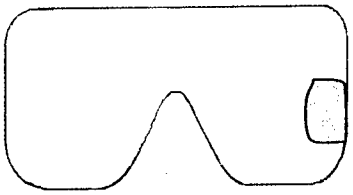
TIME: 30:00



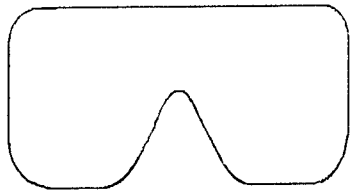
TIME: 35:00

NOTE: Subject attributed extreme fogging at 25:00 to the mask pulling away from his face and breaking the seal when he performed push-ups. The fogging cleared within 2 minutes.

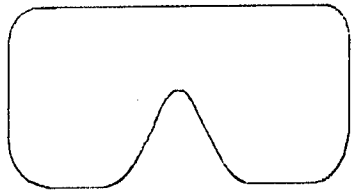
TRIAL 5 SUBJECT 2079



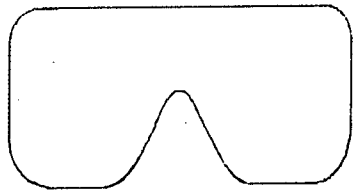
Initial Donning



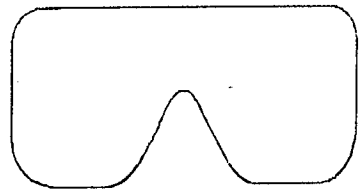
TIME: 5:00



TIME: 10:00



TIME: 15:00



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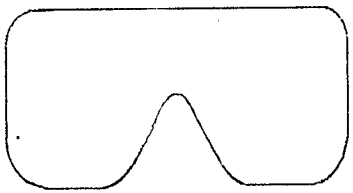
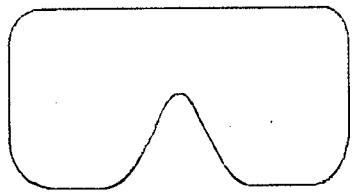
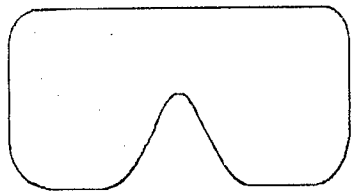


TIME: 25:00

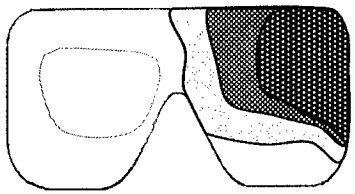


TIME: 30:00

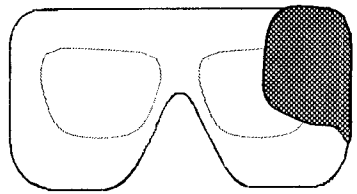


TIME: 35:00

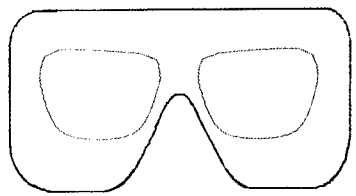
TRIAL 8 SUBJECT 1755



Initial Donning



TIME: 5:00



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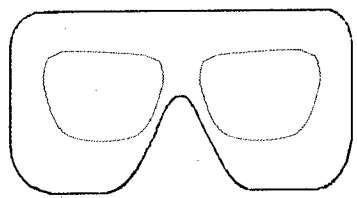

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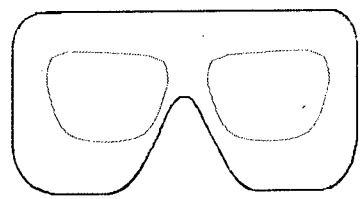

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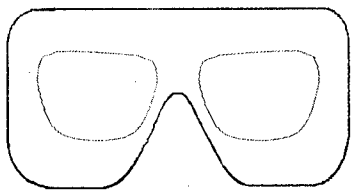
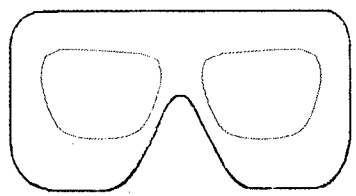


TIME: 25:00



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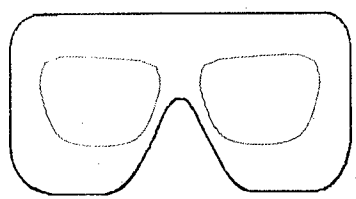
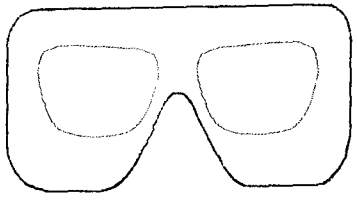
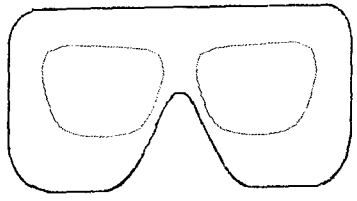


TIME: 35:00

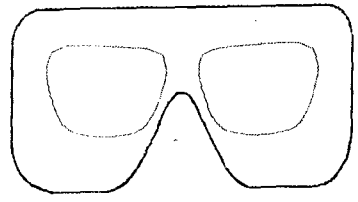
TRIAL 8 SUBJECT 2079



Initial Donning



TIME: 5:00



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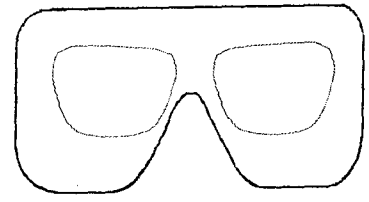

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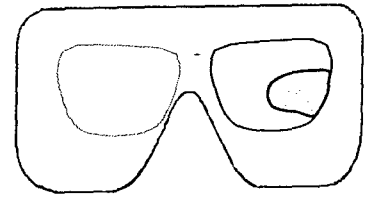

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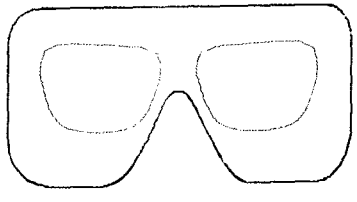

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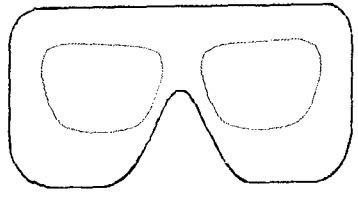
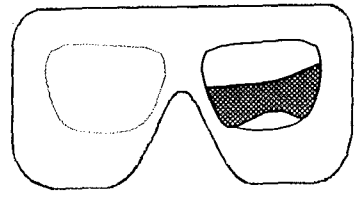
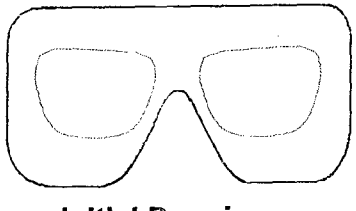


TIME: 30:00

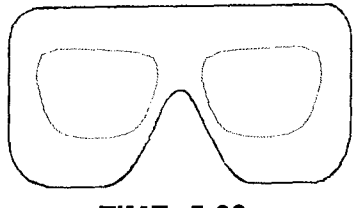


TIME: 35:00

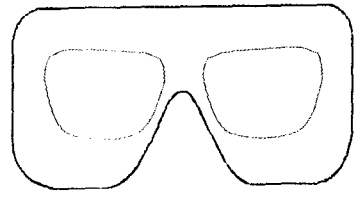
TRIAL 8 SUBJECT 3299



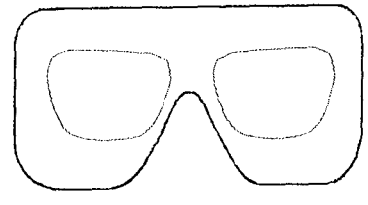
Initial Donning



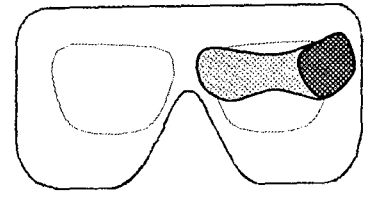
TIME: 5:00



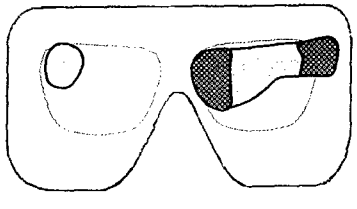
TIME: 10:00



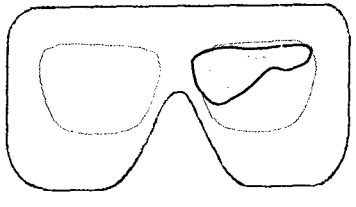
TIME: 15:00



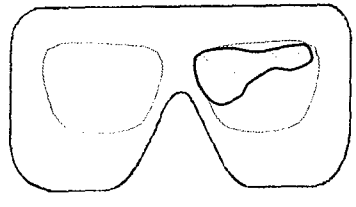
TIME: 20:00



TIME: 25:00

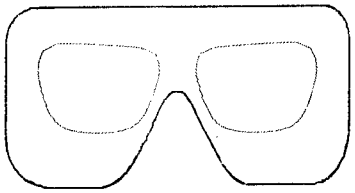


TIME: 30:00

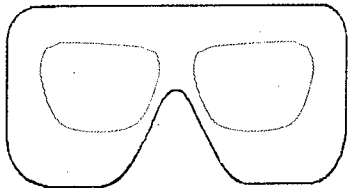


TIME: 35:00

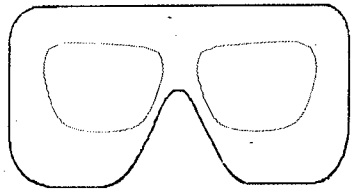
TRIAL 8 **SUBJECT 7770**



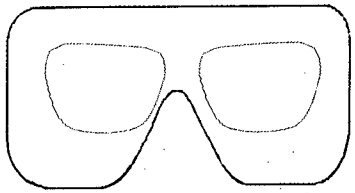
Initial Donning



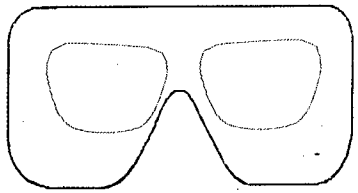
TIME: 5:00



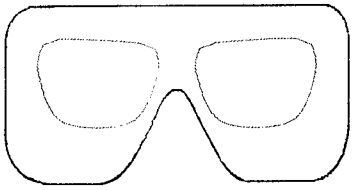
TIME: 10:00



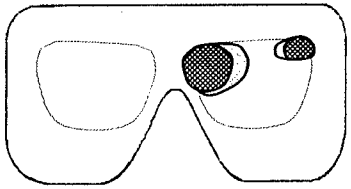
TIME: 15:00



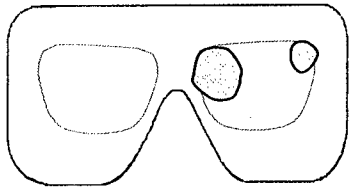
TIME: 20:00



TIME: 25:00

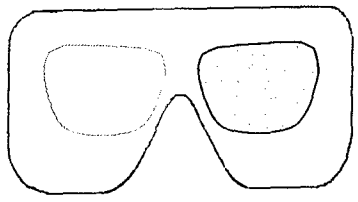


TIME: 30:00

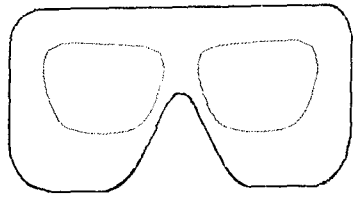


TIME: 35:00

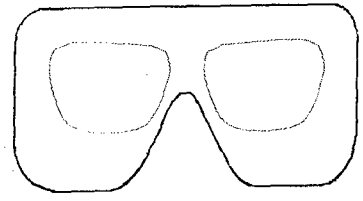
TRIAL 8 SUBJECT 9229



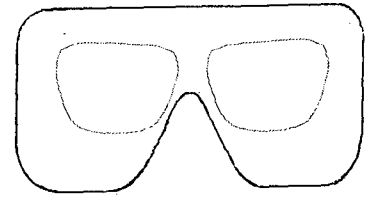
Initial Donning



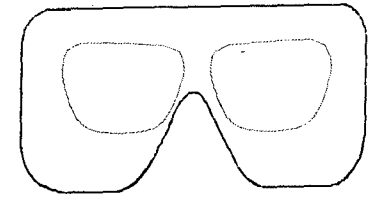
TIME: 5:00



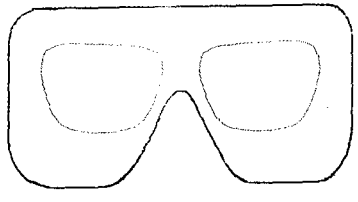
TIME: 10:00



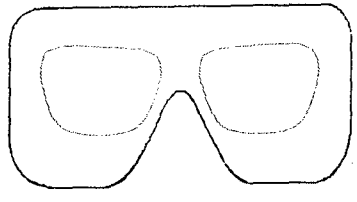
TIME: 15:00



TIME: 20:00



TIME: 25:00



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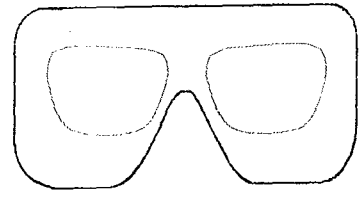
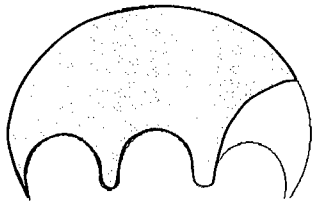


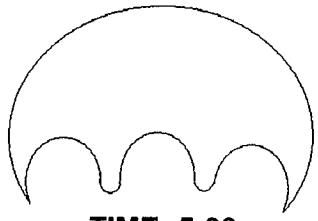
TIME: 35:00

NOTE: The initial plano lens fogging cleared within 2 minutes.

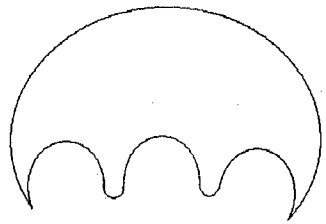
TRIAL 9 SUBJECT 1755



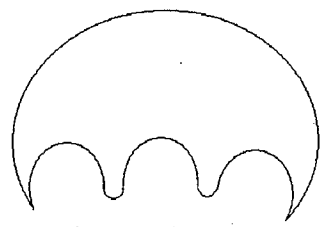
Initial Donning



TIME: 5:00



TIME: 10:00



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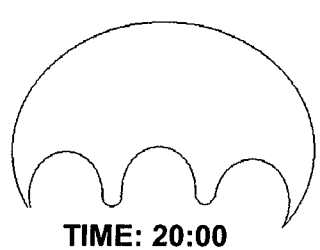

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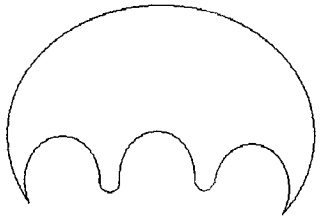

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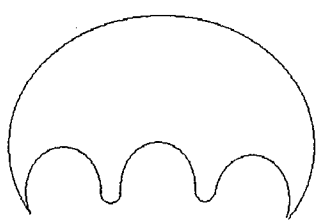
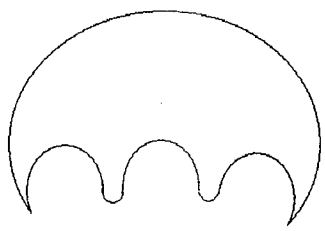


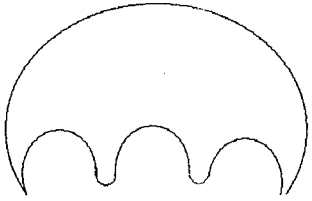
TIME: 30:00



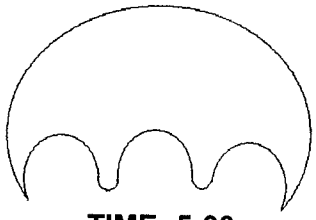
TIME: 35:00

NOTE: The initial lens fogging cleared within the first 4.5 minutes.

TRIAL 9 SUBJECT 3299



Initial Donning



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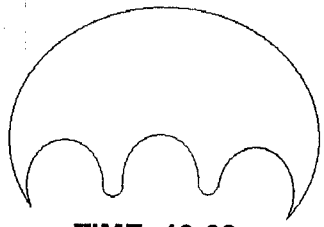

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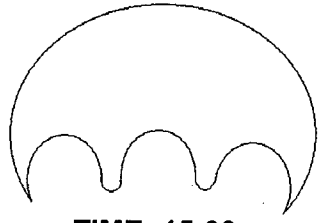

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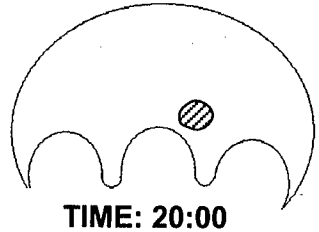
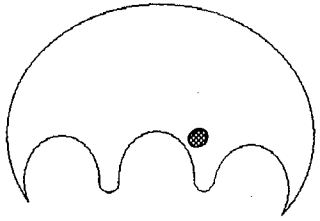
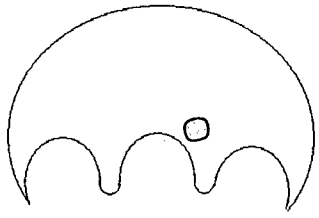


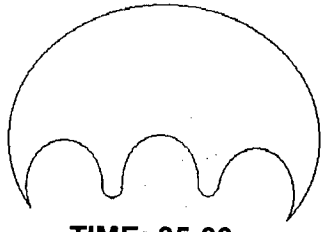
TIME: 20:00



TIME: 25:00

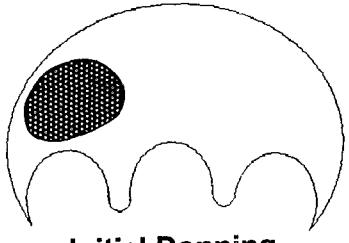


TIME: 30:00

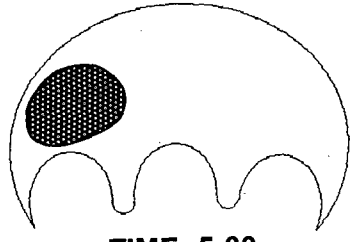


TIME: 35:00

TRIAL 9 SUBJECT 9229



Initial Donning



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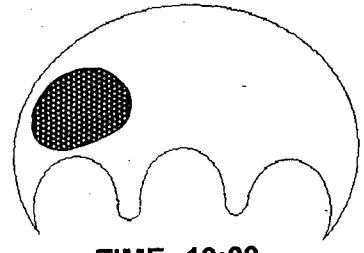
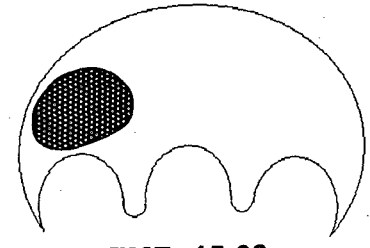


TIME: 10:00



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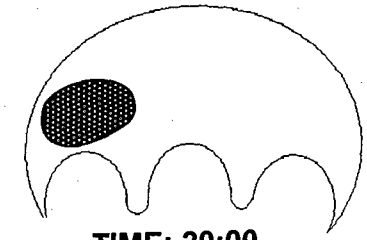

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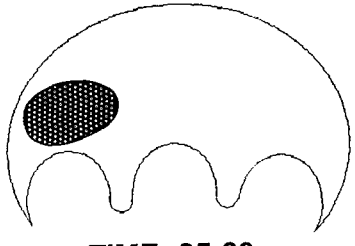

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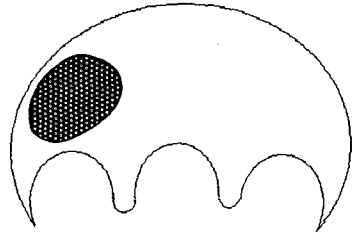

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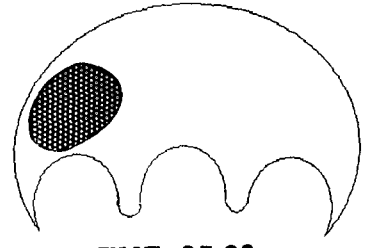
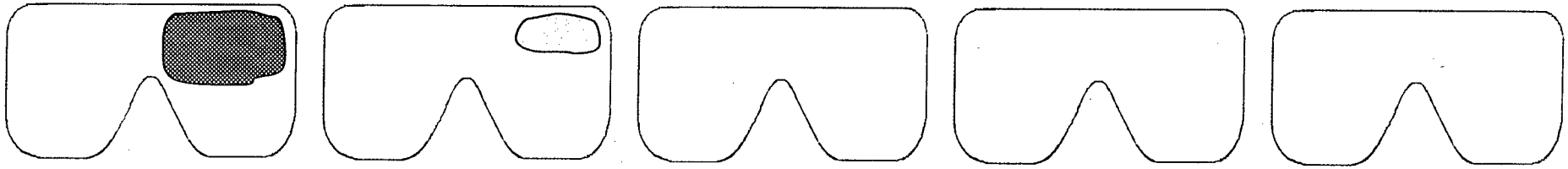


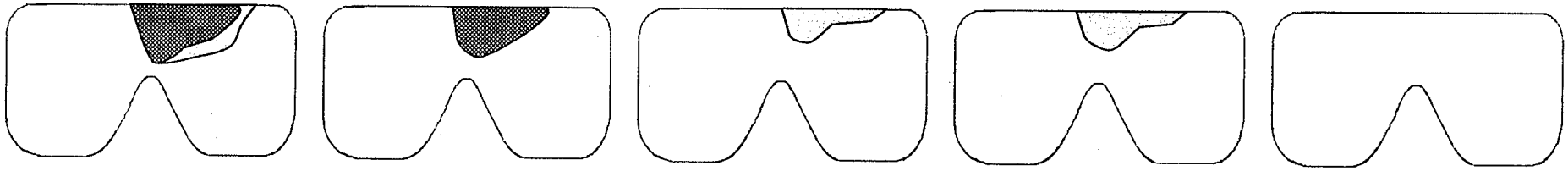
TIME: 35:00

TRIAL 10 SUBJECT 1755



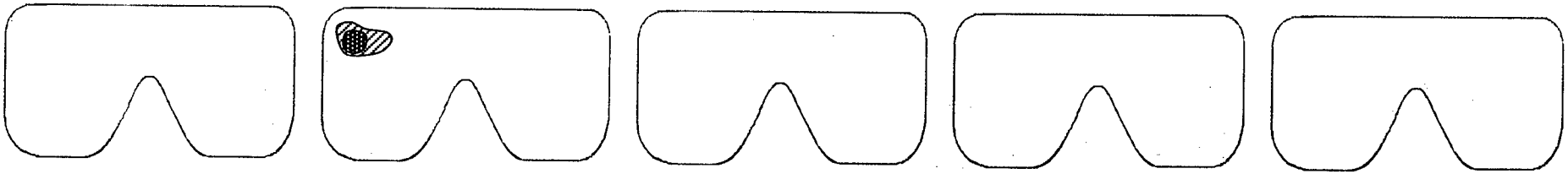
Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

TRIAL 10 SUBJECT 3299



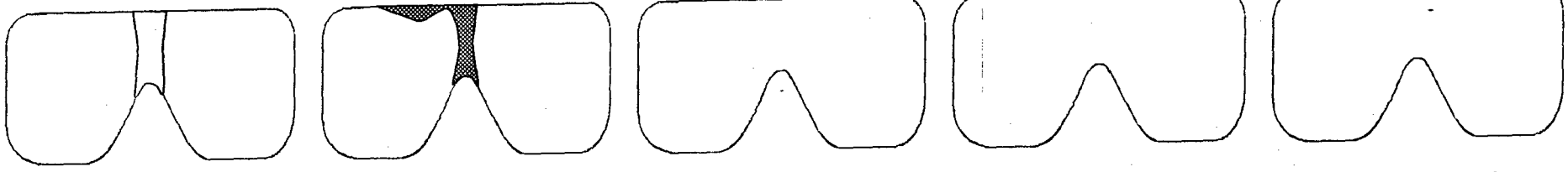
Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

TRIAL 10 SUBJECT 7770



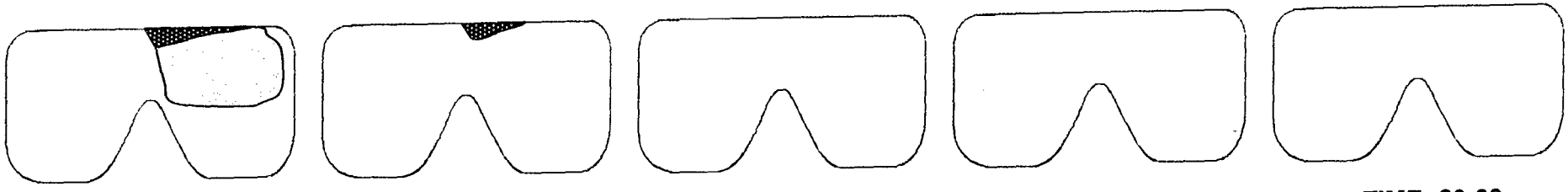
Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

TRIAL 10 SUBJECT 9229



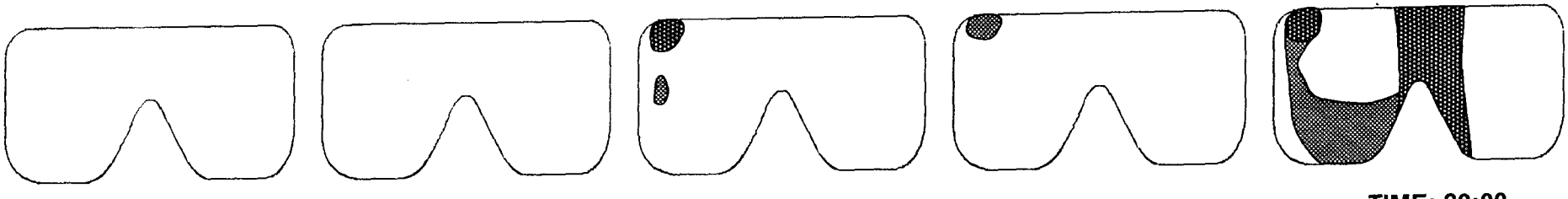
Initial Donning TIME: 5:00 TIME: 10:00 TIME: 15:00 TIME: 20:00

TRIAL 11 SUBJECT 1755



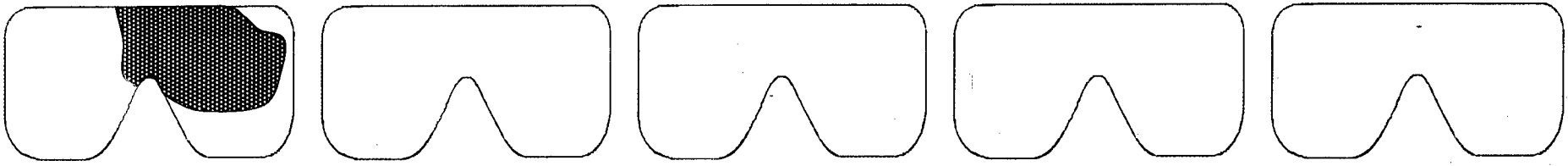
Initial Donning TIME: 5:00 TIME: 10:00 TIME: 15:00 TIME: 20:00

TRIAL 11 SUBJECT 2079



Initial Donning TIME: 5:00 TIME: 10:00 TIME: 15:00 TIME: 20:00

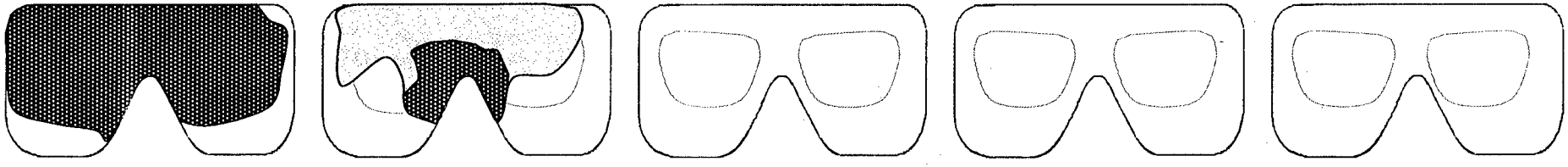
TRIAL 11 SUBJECT 7770



Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

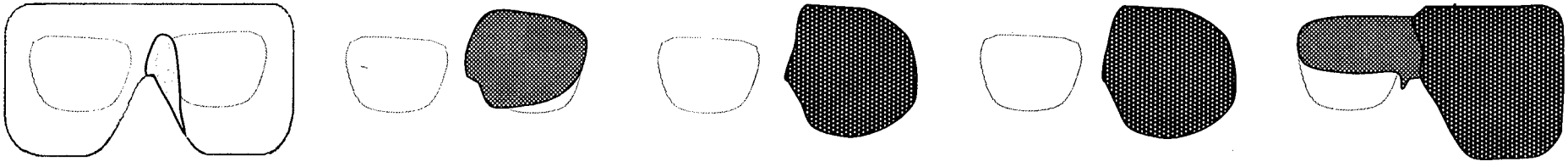
NOTE: The initial lens fogging cleared within the first 5 minutes.

TRIAL 12 SUBJECT 1755



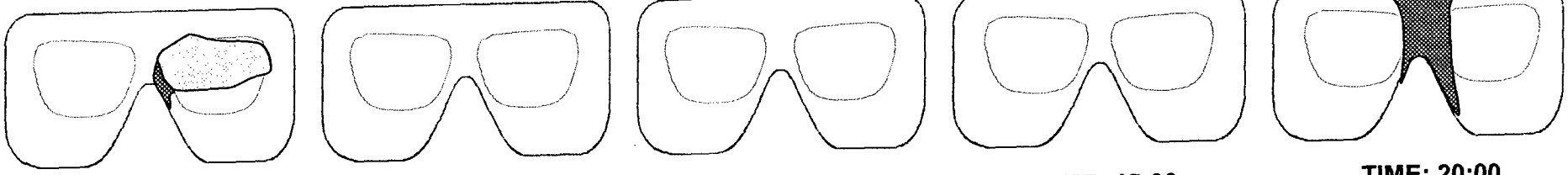
Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

TRIAL 12 SUBJECT 2079



Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

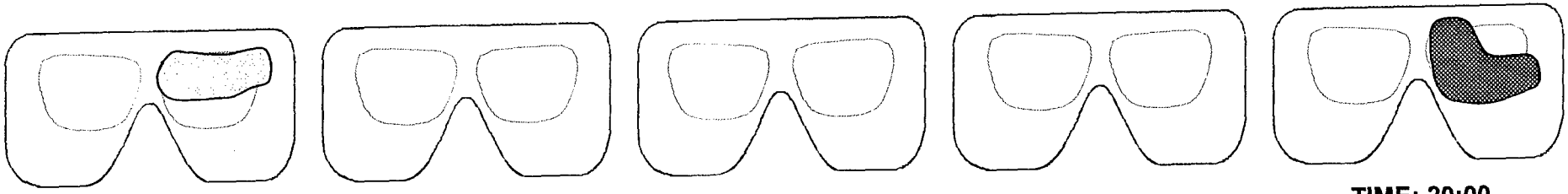
TRIAL 12 **SUBJECT 3299**



Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

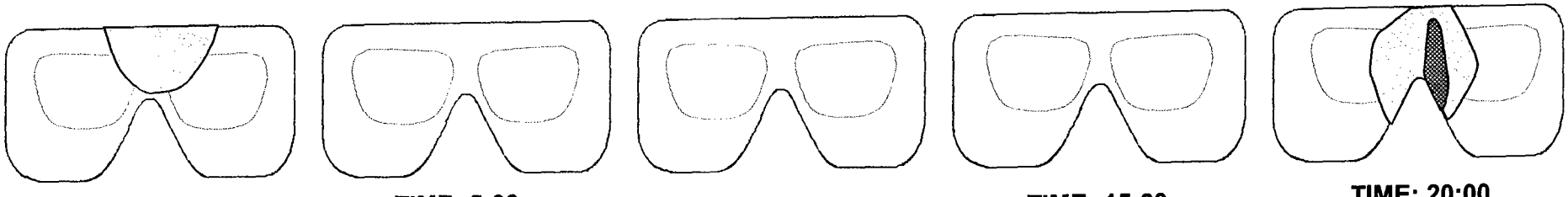
NOTE: The initial lens fogging cleared within the first 5 minutes.

TRIAL 12 **SUBJECT 7770**



Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

TRIAL 12 **SUBJECT 9229**



Initial Donning | TIME: 5:00 | TIME: 10:00 | TIME: 15:00 | TIME: 20:00

NOTE: The initial lens fogging cleared within the first 3 minutes.

APPENDIX G

DIFFERENTIAL PRESSURE ASSESSMENT

INTRODUCTION

The XM50 is required to be operational at temperatures as low as –20 °C (–4 °F). However, mask protective integrity cannot be verified during operations in very cold climates because mask fit test equipment cannot function at low temperatures. A primary concern for mask operation at low temperatures is exhaust valve function. Exhaust valve malfunction can cause unfiltered air to enter the mask and pose a serious risk to the wearer. Due to properties of their materials, exhaust valves can malfunction at low temperatures by becoming stiff or by forming ice from the moisture that develops from air exhaled on or around the outlet valve. Another concern is the integrity of the mask face seal: mask materials stiffen at very low temperatures and may not adequately conform, as required, to fit the wearer's face.

OBJECTIVES

The primary objective of the differential pressure assessment was to verify that low operating temperatures do not degrade the XM50's protective integrity. The secondary objective was to determine the work of breathing associated with operating the XM50.

METHODS

Unmanned testing was conducted to provide a baseline for comparison with the manned differential pressure data. An XM50 was placed on a head form outfitted with a differential pressure transducer (model PTX-317-9219; Druck, Inc., New Fairfield, CT) and allowed to temperature soak for one hour in an environmental chamber. The XM50 was operated by a custom-made sinusoidal mechanical breathing simulator (serial #0; Battelle, Columbus, OH). Two XM50 configurations were tested: the XM50 with primary filters, and the XM50 with primary and TIC filters. (Vision correction inserts were not included in the assessment, since they are assumed to have a negligible effect on the work of breathing.) The two configurations were subjected to breathing loop trials conducted at the ambient (80 °F) and the extremely cold (6 °F) temperatures.

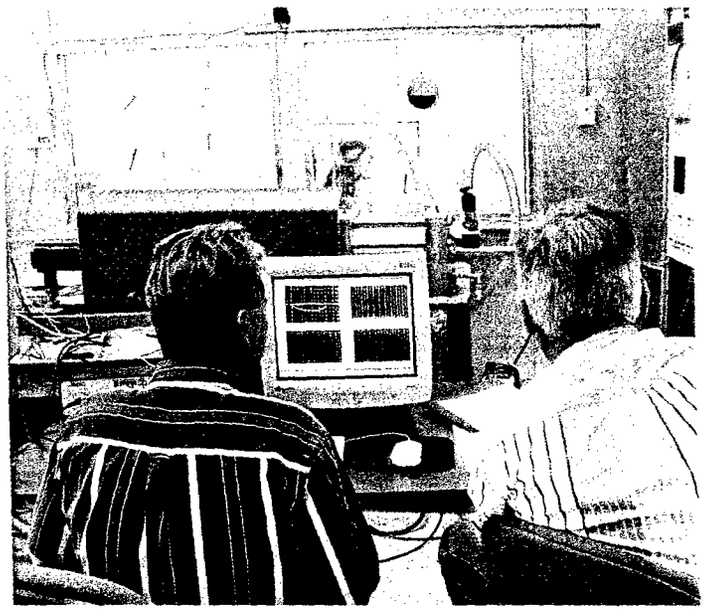


Figure G-1. Data collection during unmanned testing. The head form and XM50 are in the background, inside the chamber.

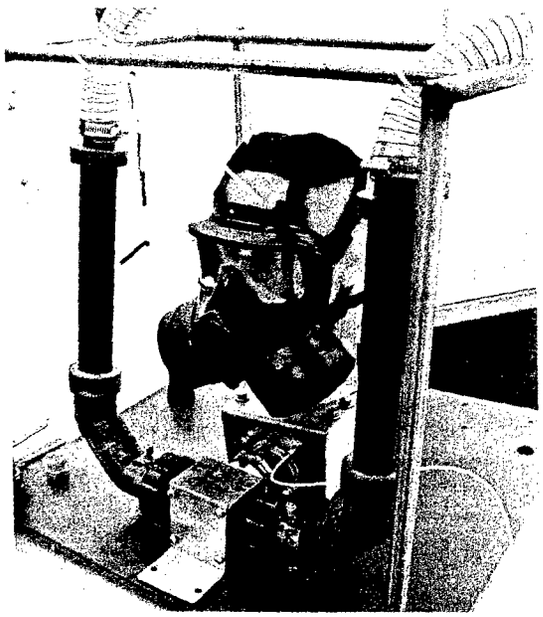


Figure G-2. Unmanned testing setup with head form and XM50 with primary and TIC filters.

To provide oral differential pressure data during the manned evaluation, XM50 masks were outfitted with bidirectional pressure sensors (Honeywell DC020NDR5) before the extremely cold exposures of Trials 10, 11, and 12. This was done by removing the drinking couplers from the masks and installing the pressure sensors at the end of the external drink tubes. The real-time readout from the pressure sensors was captured with LabVIEW. Data was acquired from each subject during exposures with the three XM50 configurations.

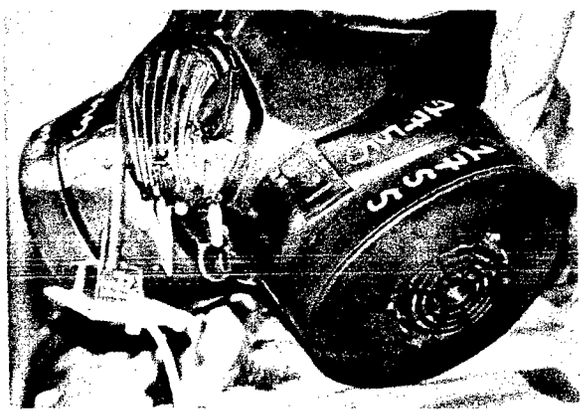


Figure G-3. XM50 mask with pressure transducer inserted into the end of the external drink tube to measure oral differential pressure during manned evaluation.

RESULTS

Work of Breathing

The breathing loop data collected at 80 °F and 6 °F showed no significant variation due to temperature. It can be assumed that XM50 work of breathing is not affected over the

assessed temperature range. Figure G-4 compares the work of breathing results to previously acquired data from the MCU-2/P and FM-12 masks (S. Fitzgibbon, *Chemical Biological Warfare Masks, Assessing Effectiveness in NSW Applications,* United States Navy Coastal Systems Station, 1997).

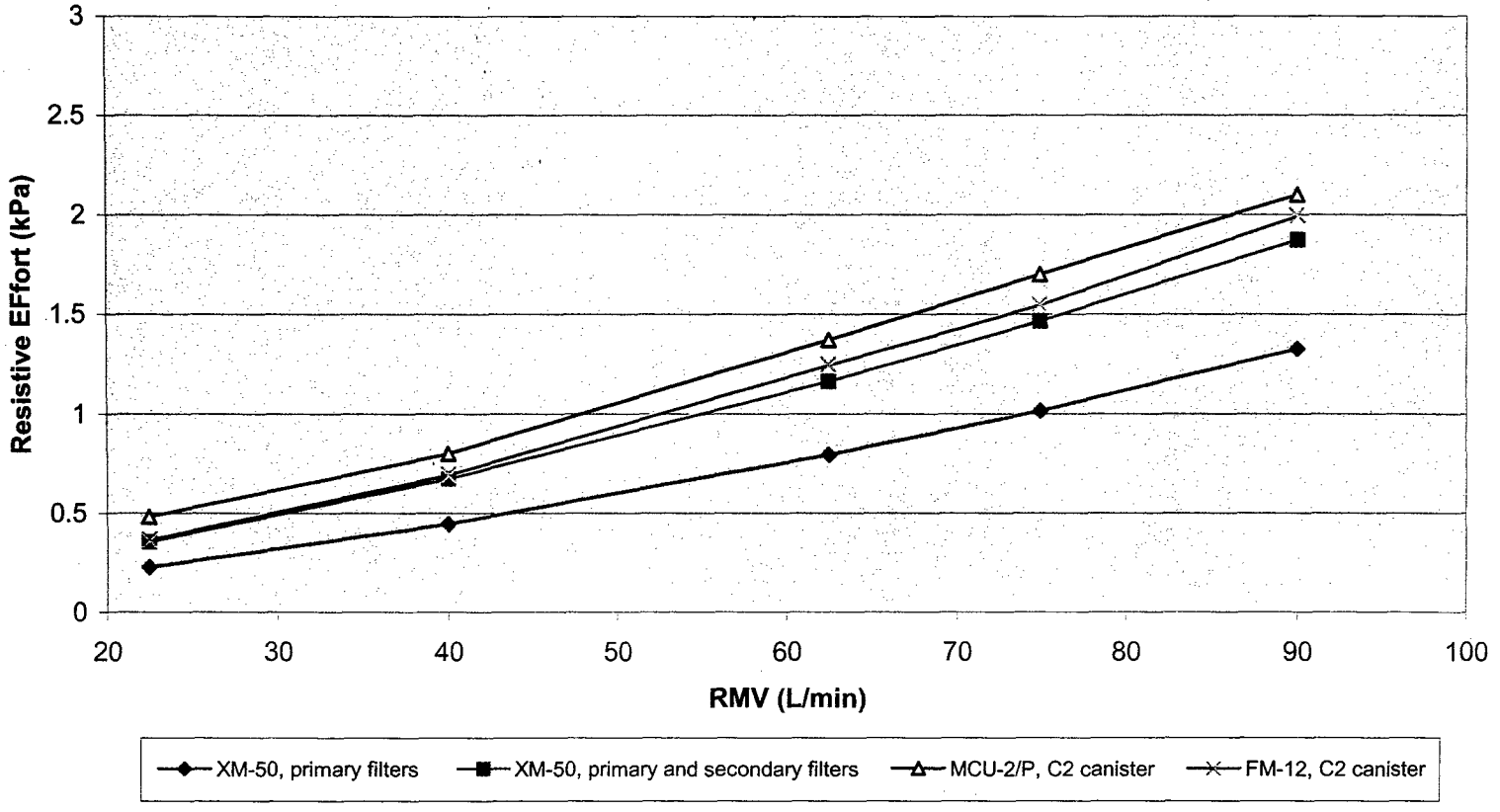


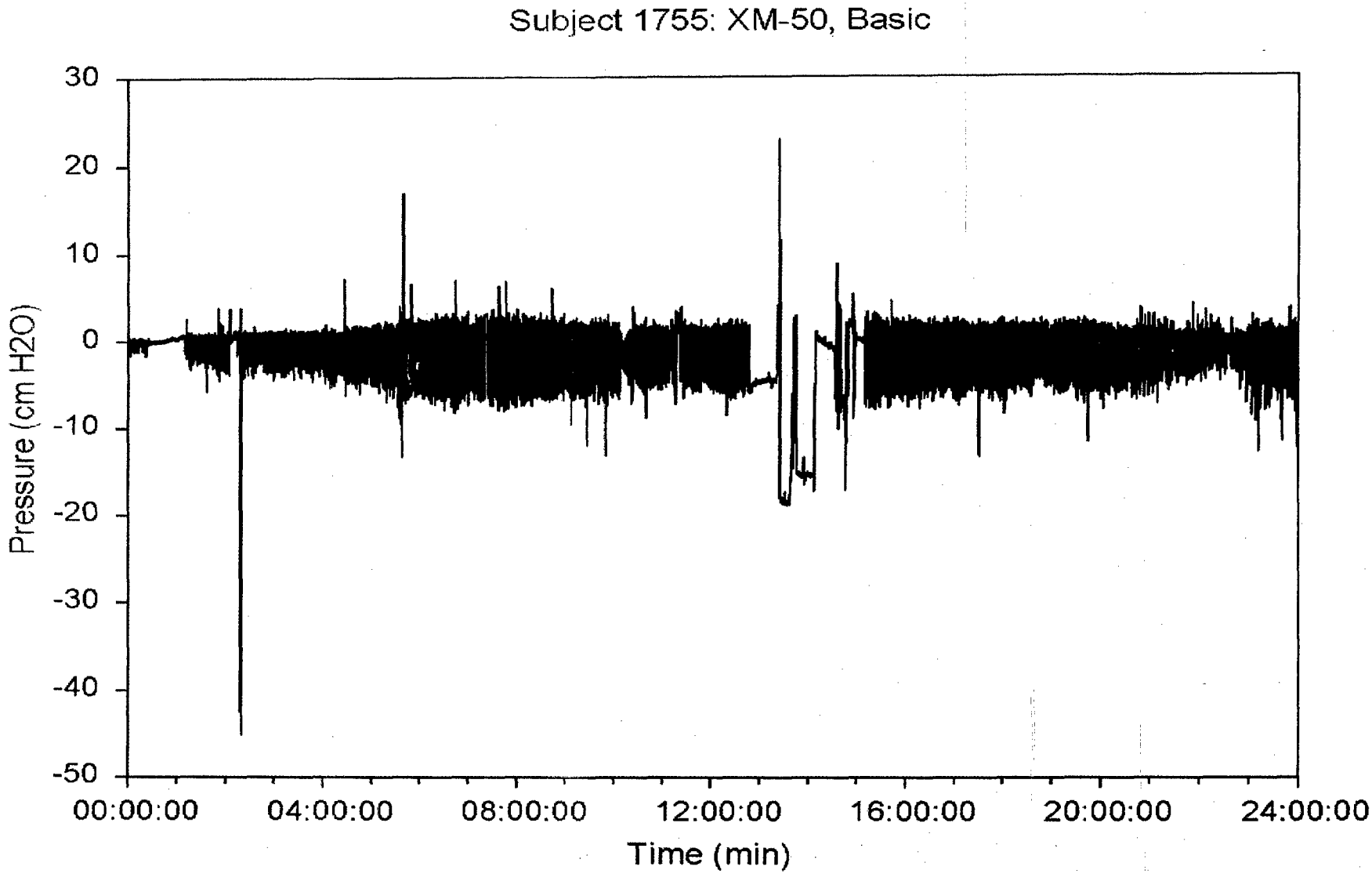
Figure G-4. Work of Breathing Measurement.

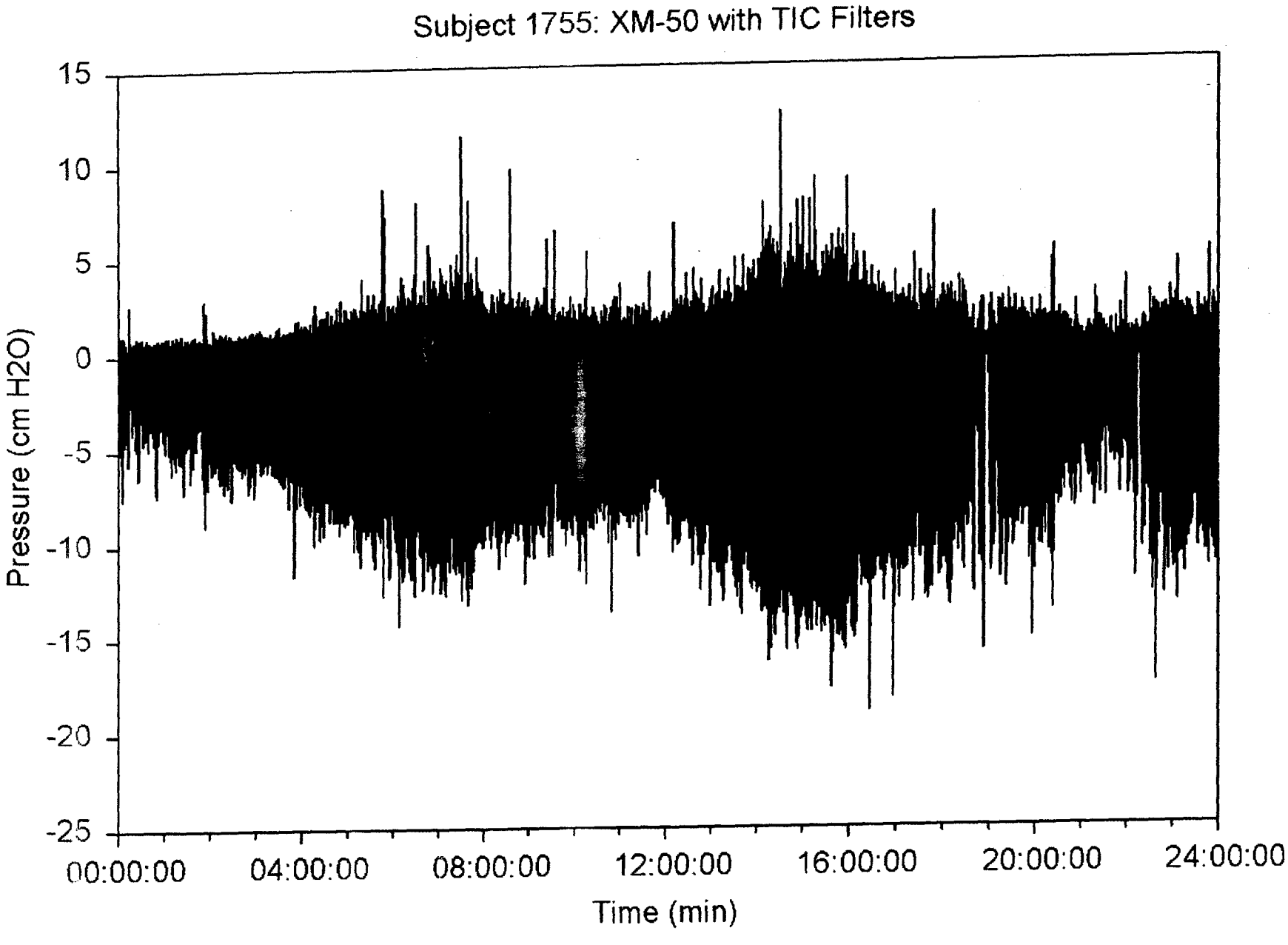
Differential Pressure

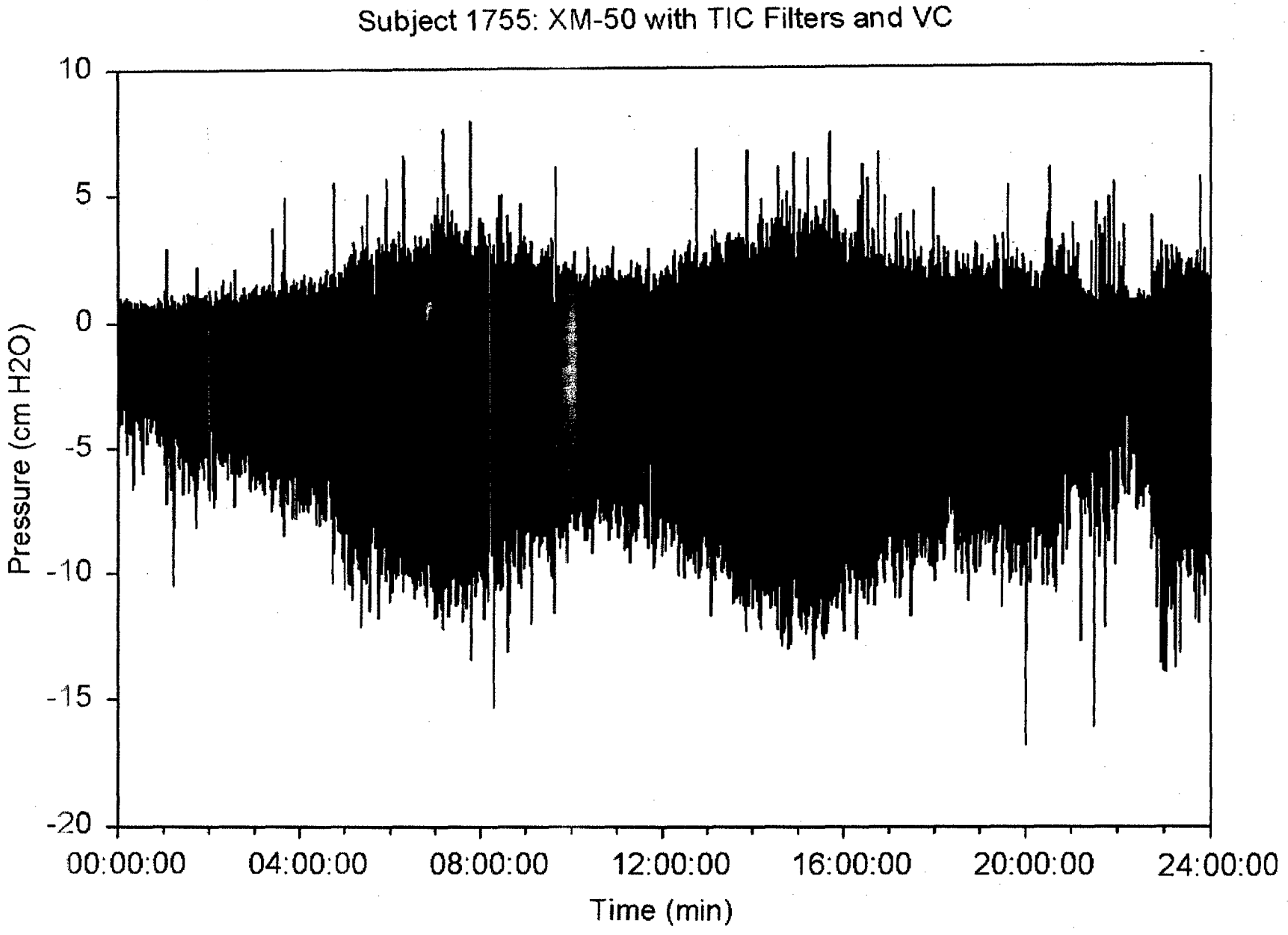
The oral differential pressure data collected during the extremely cold (6 °F) exposures exhibited no anomalies, indicating adequate exhaust valve function over a 6–14 °F temperature range. (The plot, "Subject 1755: XM50, Basic," exhibits anomalous behavior between the times of 12:45 and 15:15; this is the result of pressure transducer adjustment and does not indicate mask malfunction). However, these data do not

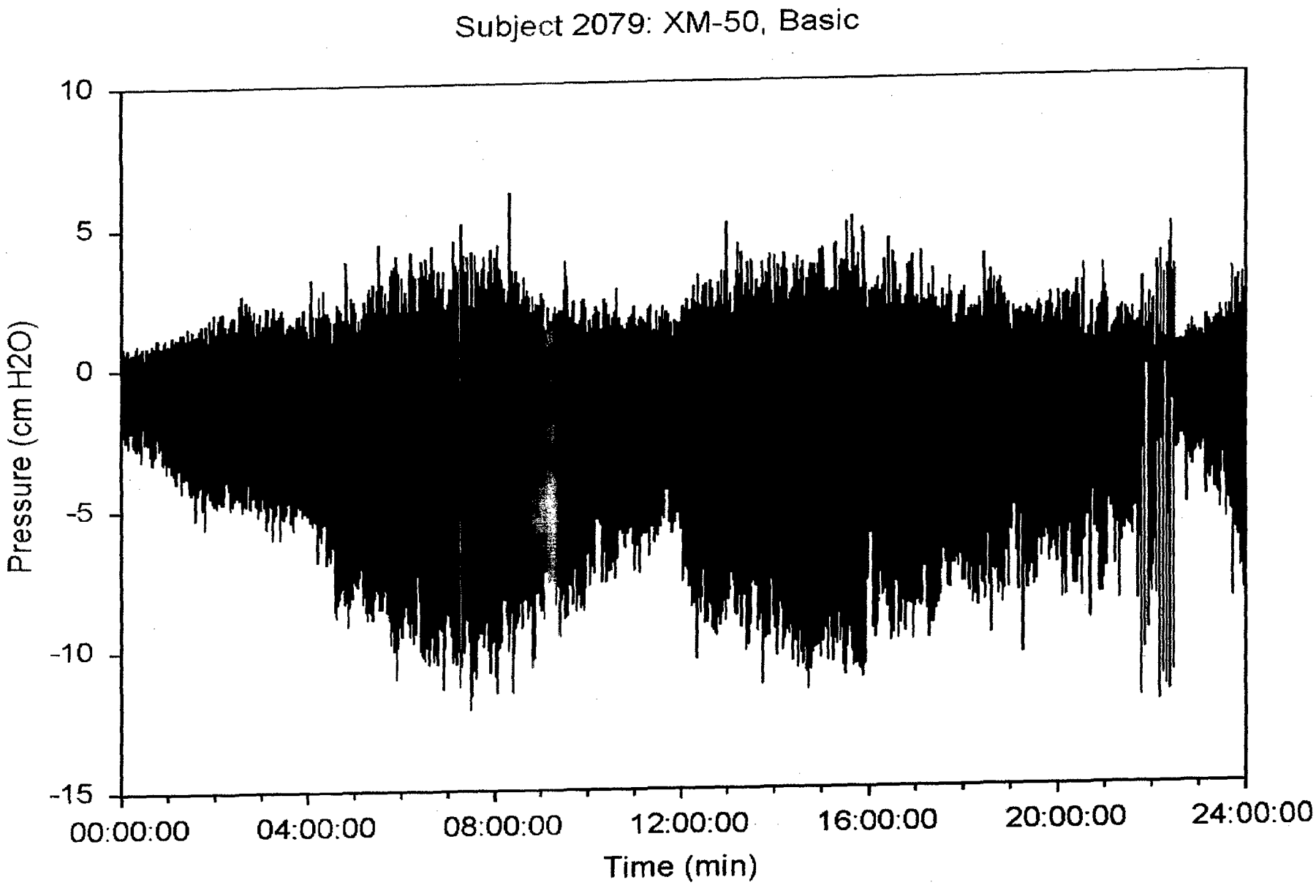
demonstrate proper exhaust valve function for the lowest temperature (–25 °F) at which the XM50 is required to function.

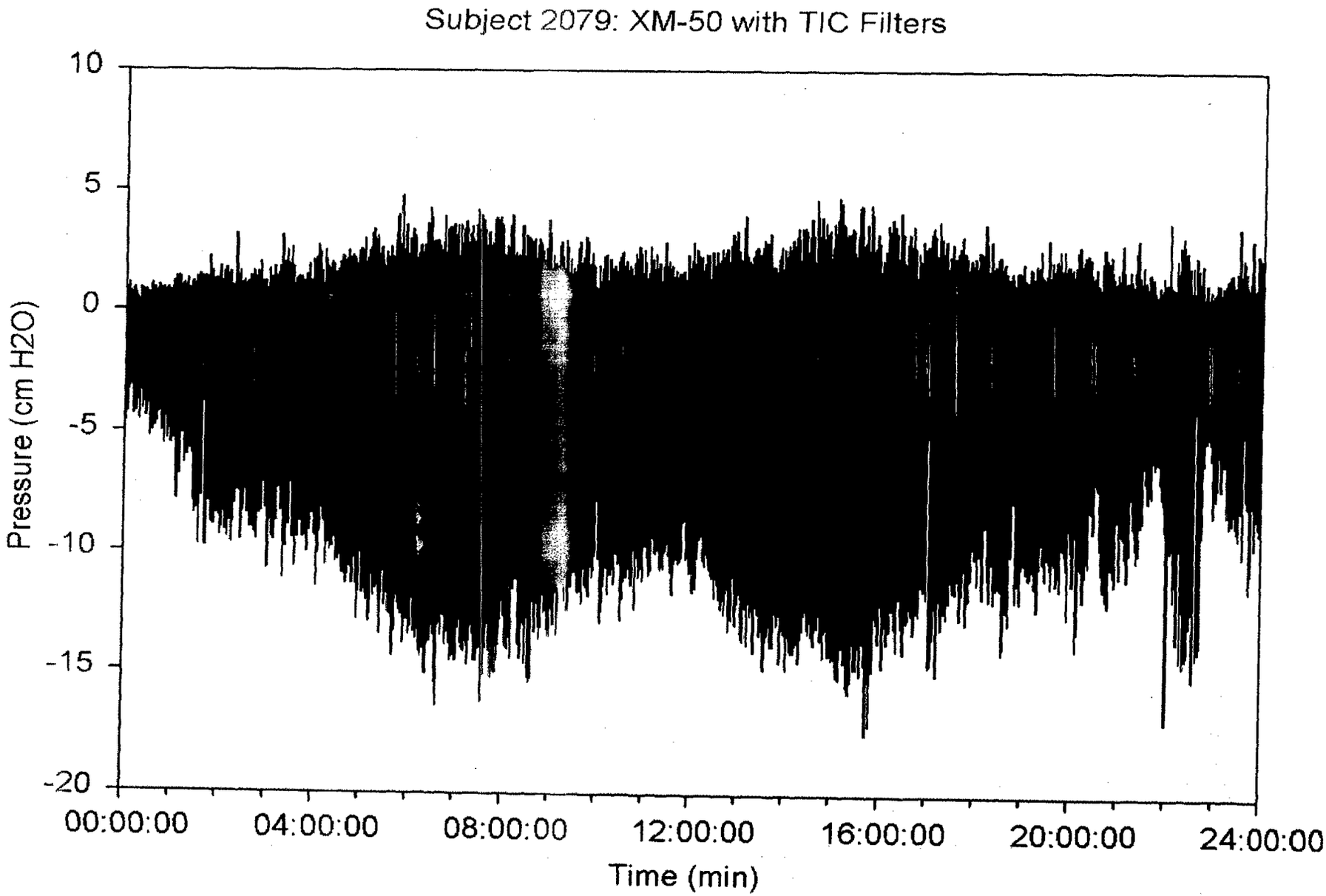
The oral differential pressure plots begin on the next page and are grouped by test subject. The plots from Trial 11 (XM50 with TIC filters) and Trial 12 (XM50 with TIC filters and vision correction) are analogous: it can be assumed that the vision correction assembly has negligible impact on oral differential pressure.

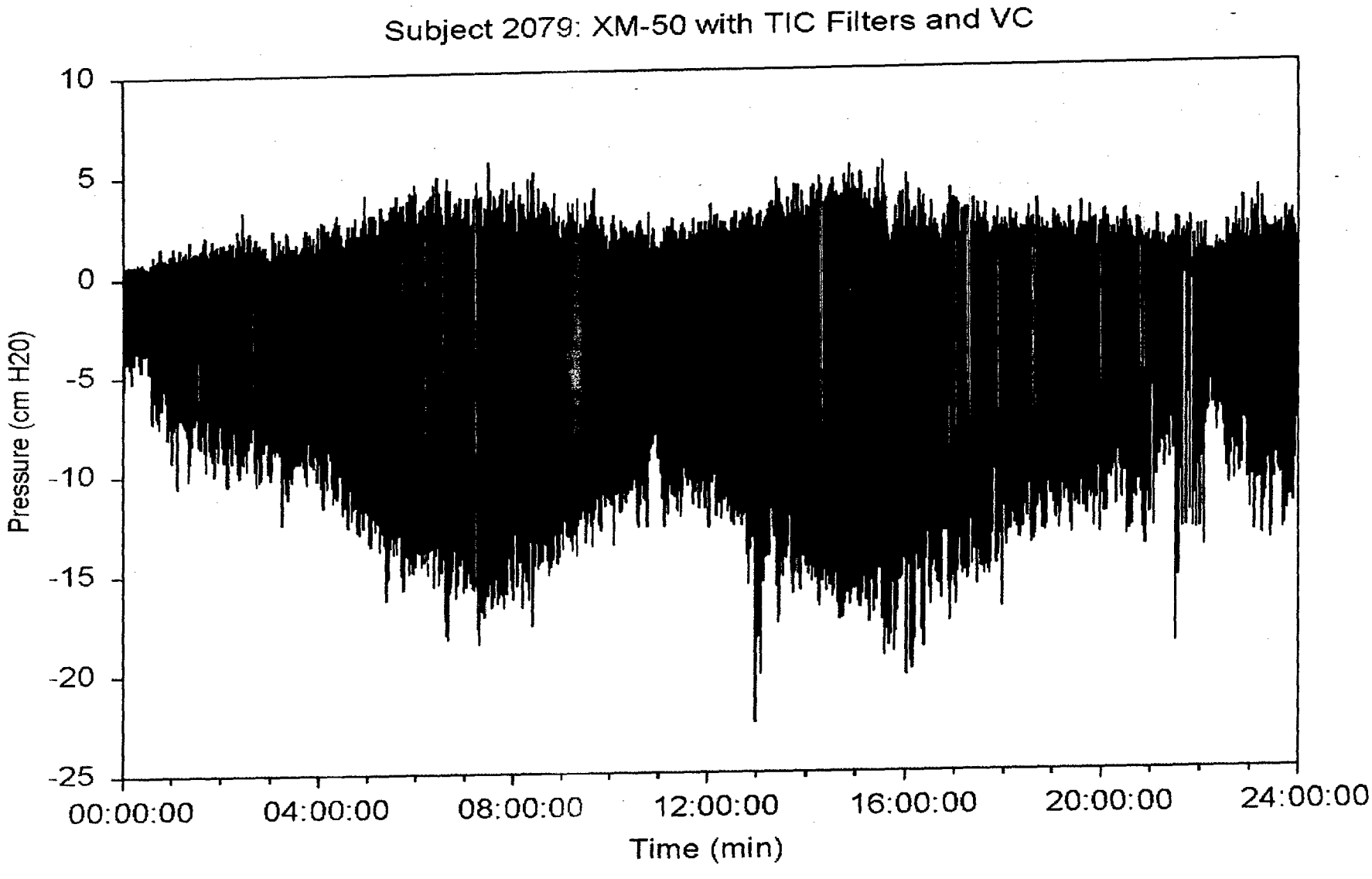

Subject 1755: XM-50, Basic
Pressure (cm H2O)
30
20
10
0
-10
-20
-30
-40
-50
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)

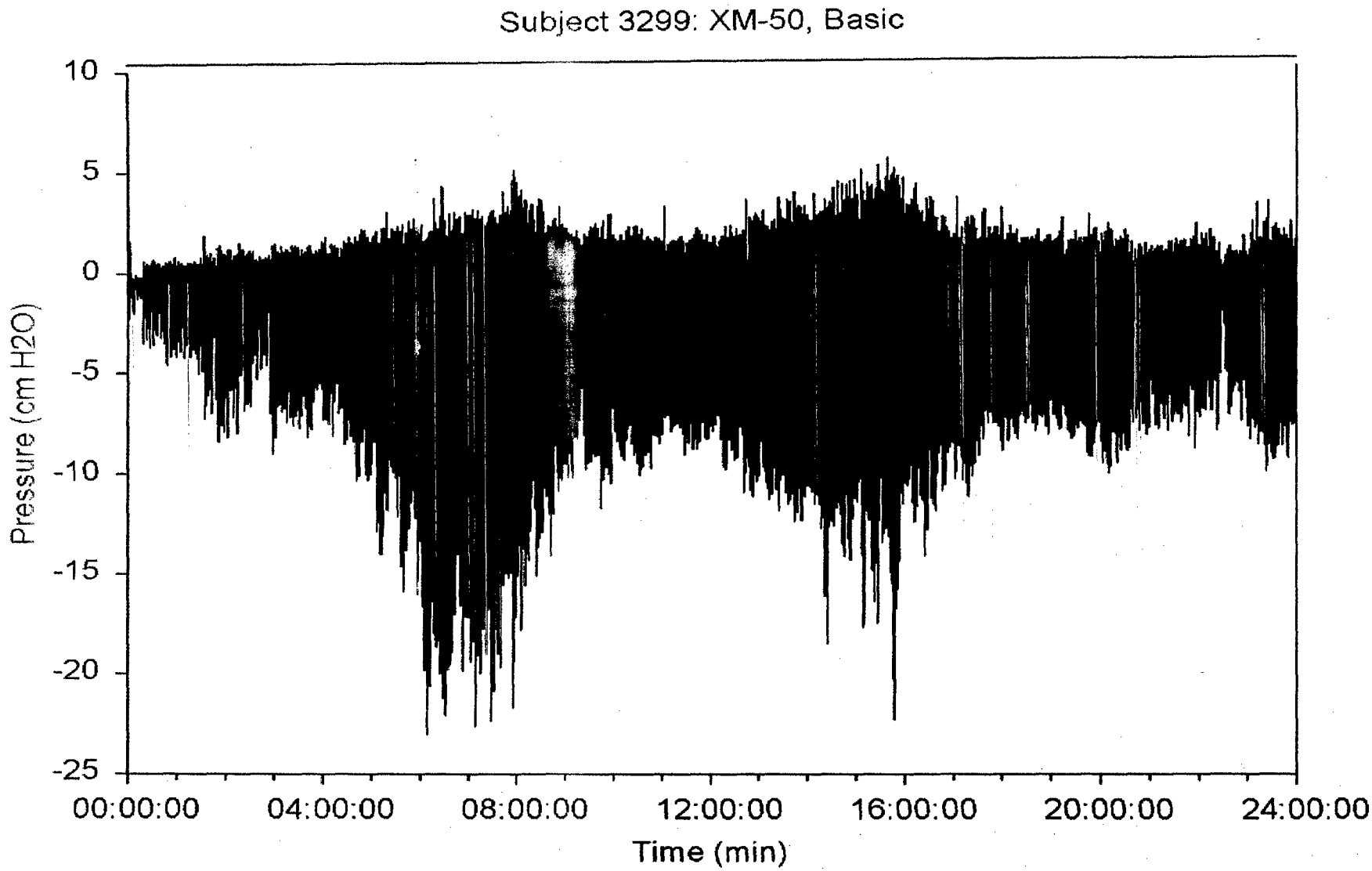

Subject 1755: XM-50 with TIC Filters
15
10
5
0
-5
-10
-15
-20
-25
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)

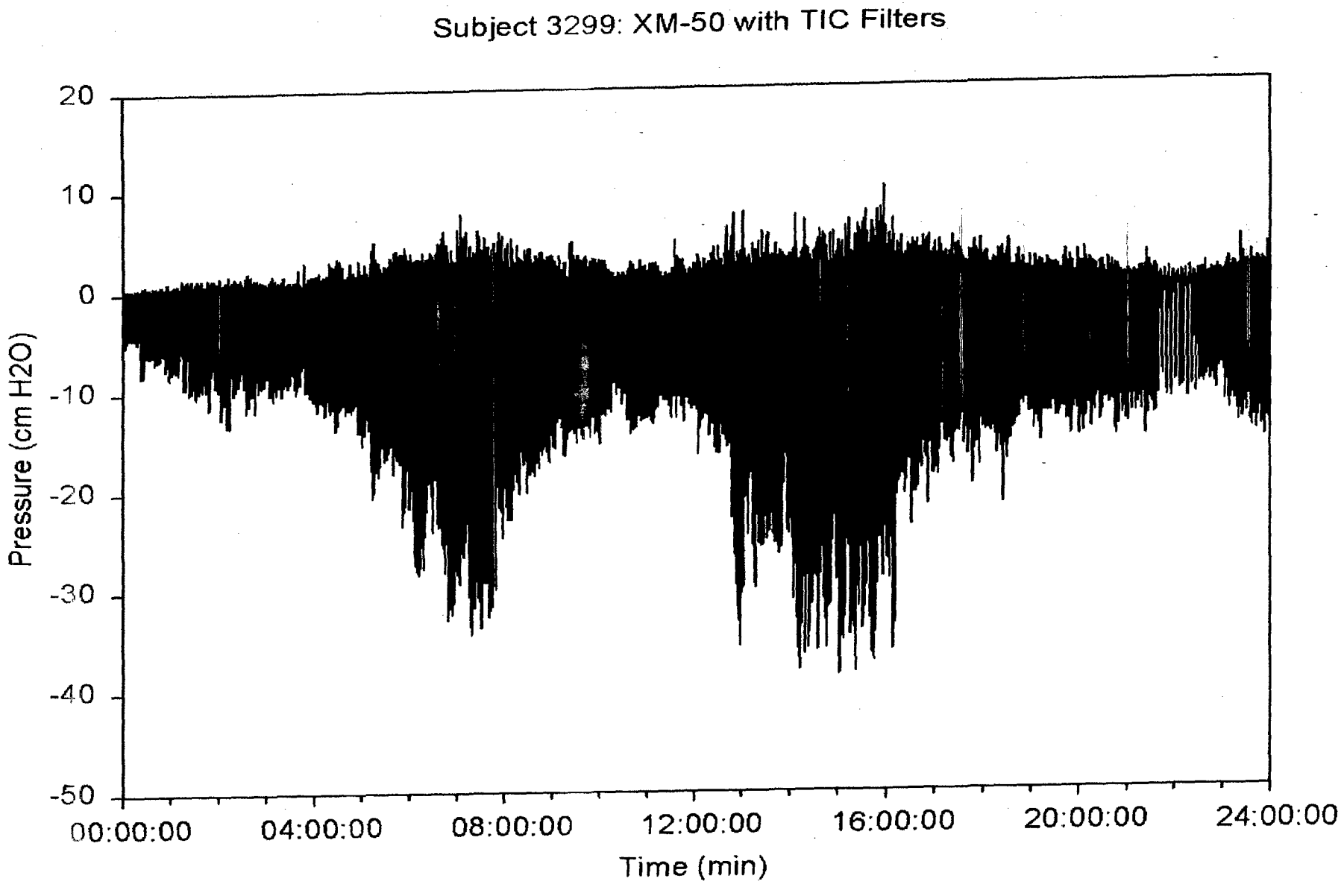

Subject 1755: XM-50 with TIC Filters and VC
10
5
0
-5
-10
-15
-20
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)

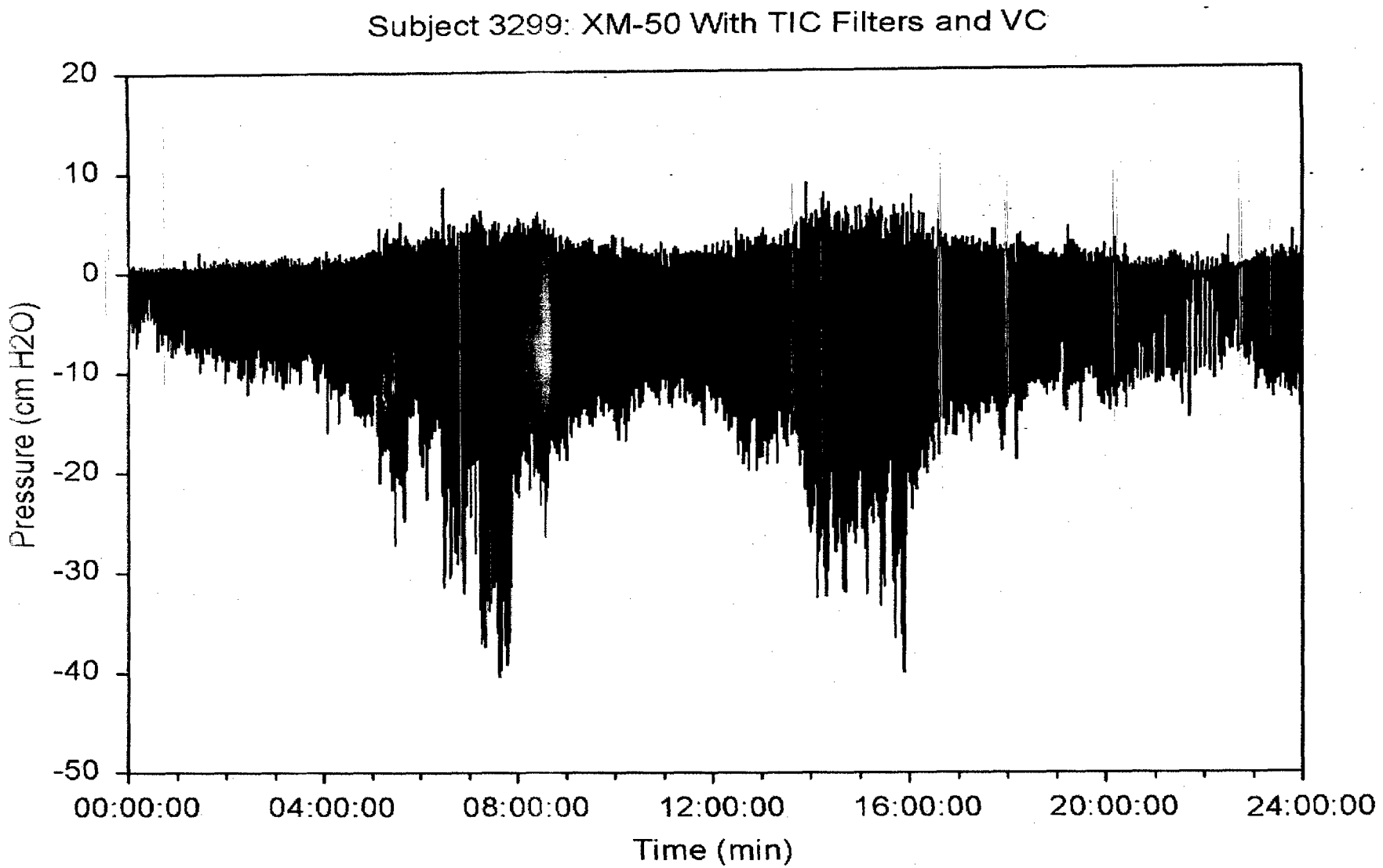

Subject 2079: XM-50, Basic
10
5
0
-5
-10
-15
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)

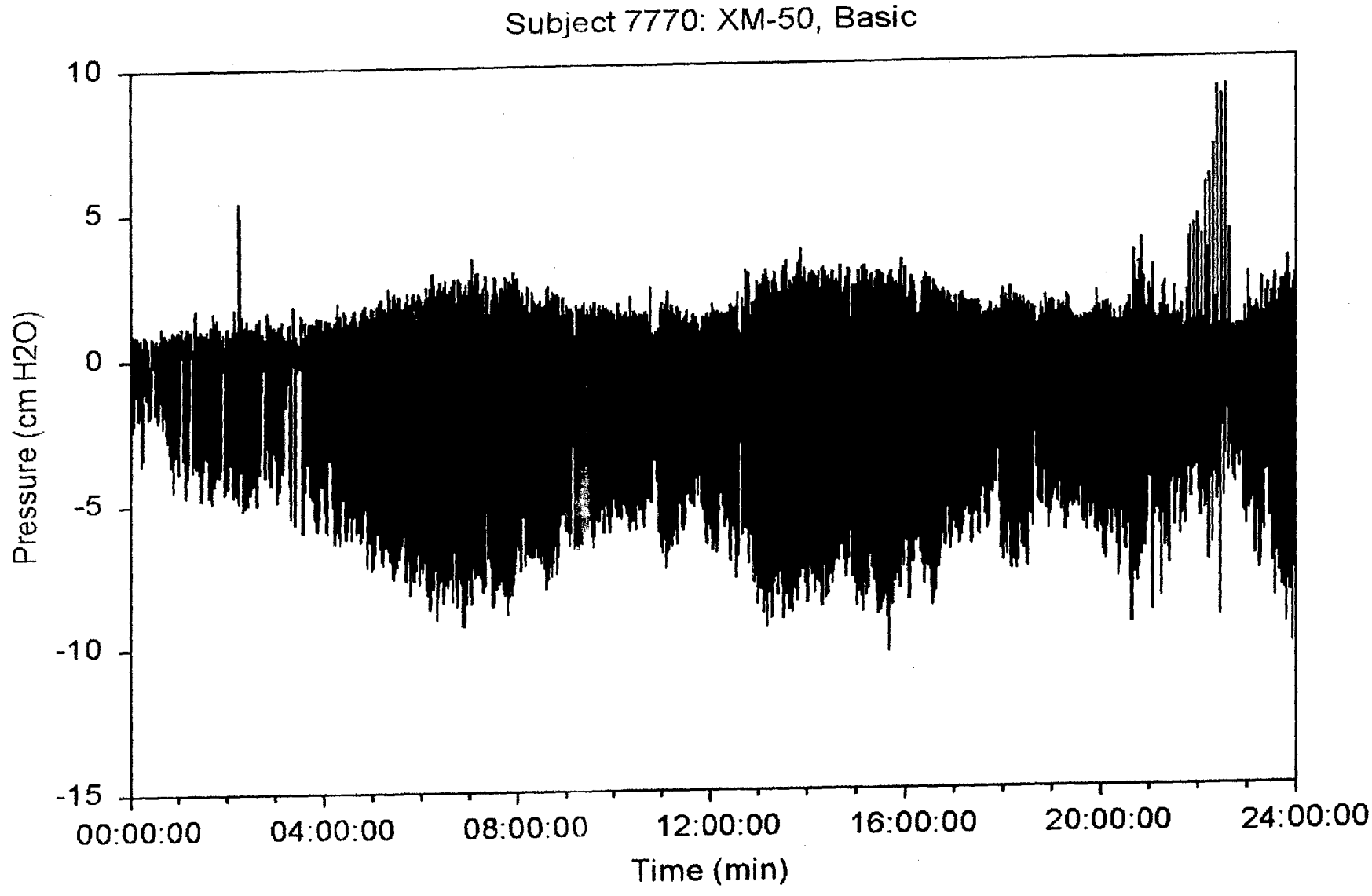

Subject 2079: XM-50 with TIC Filters
10
5
0
-5
-10
-15
-20
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)

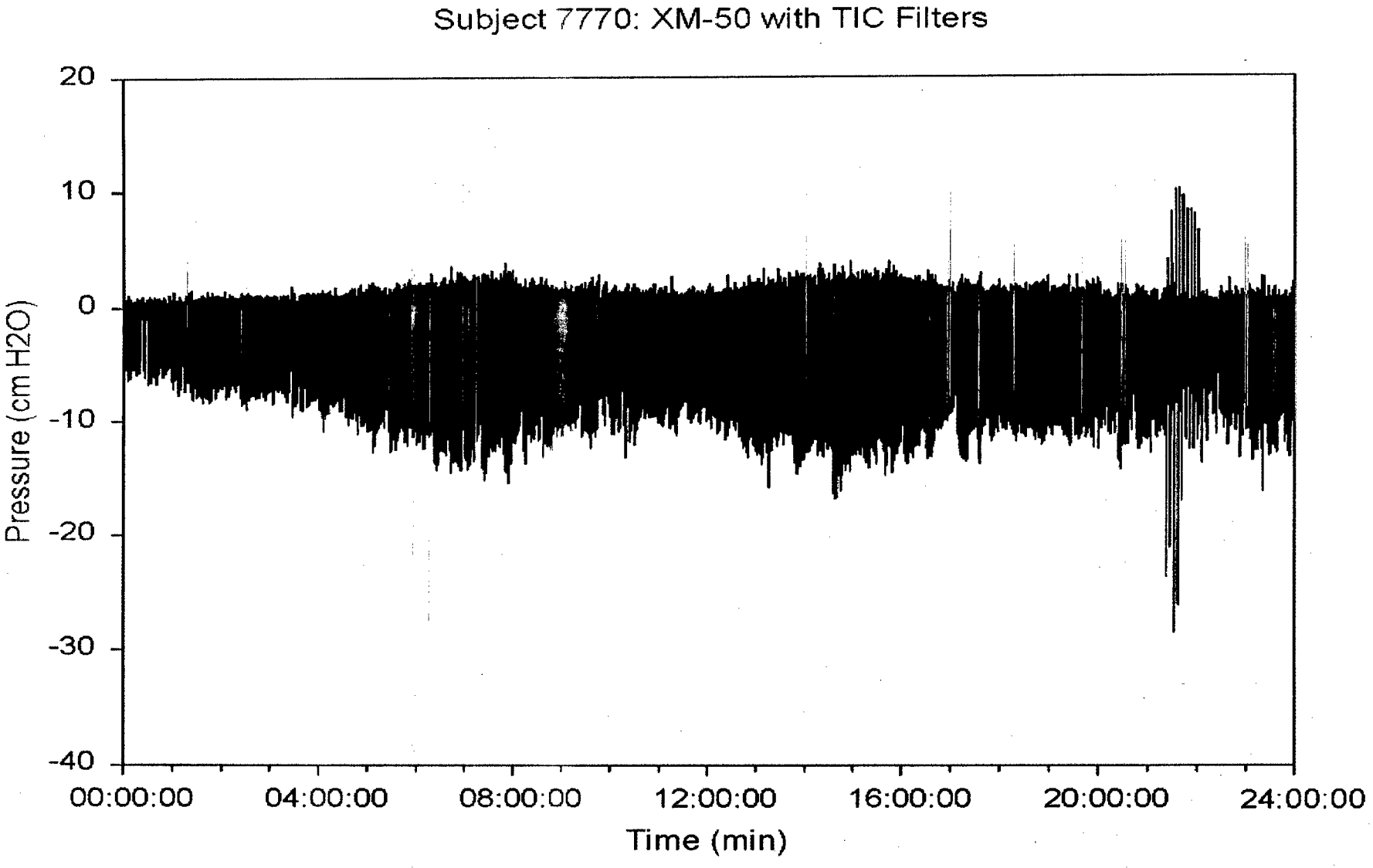

Subject 2079: XM-50 with TIC Filters and VC
10
5
0
-5
-10
-15
-20
-25
Pressure (cm H20)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 3299: XM-50, Basic
10
5
0
-5
-10
-15
-20
-25
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 3299: XM-50 with TIC Filters
20
10
0
-10
-20
-30
-40
-50
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 3299: XM-50 With TIC Filters and VC
20
10
0
-10
-20
-30
-40
-50
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7770: XM-50, Basic
10
5
0
-5
-10
-15
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7770: XM-50 with TIC Filters
20
10
0
-10
-20
-30
-40
Pressure (cm H2O)
00:00:00
04:00:00
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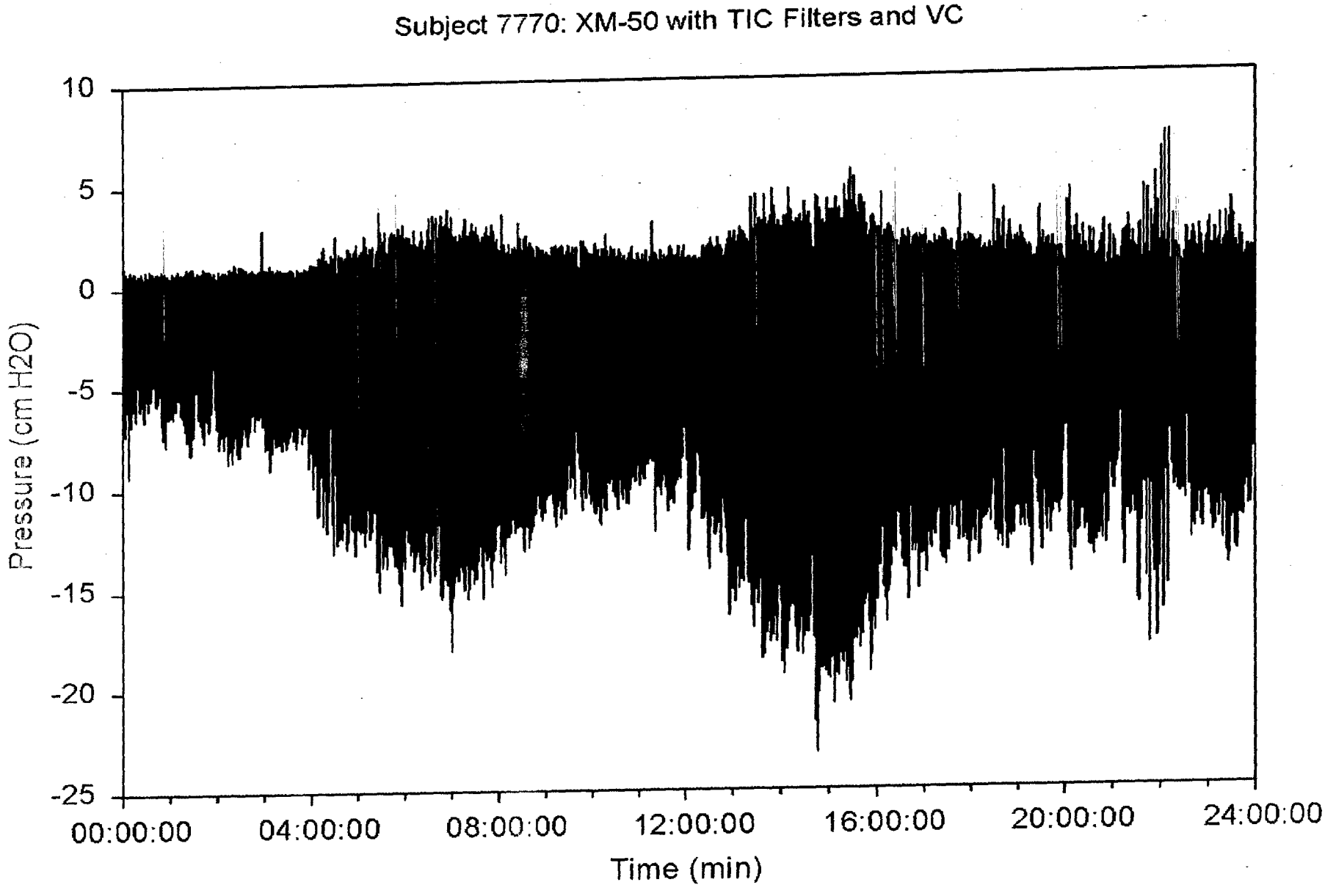
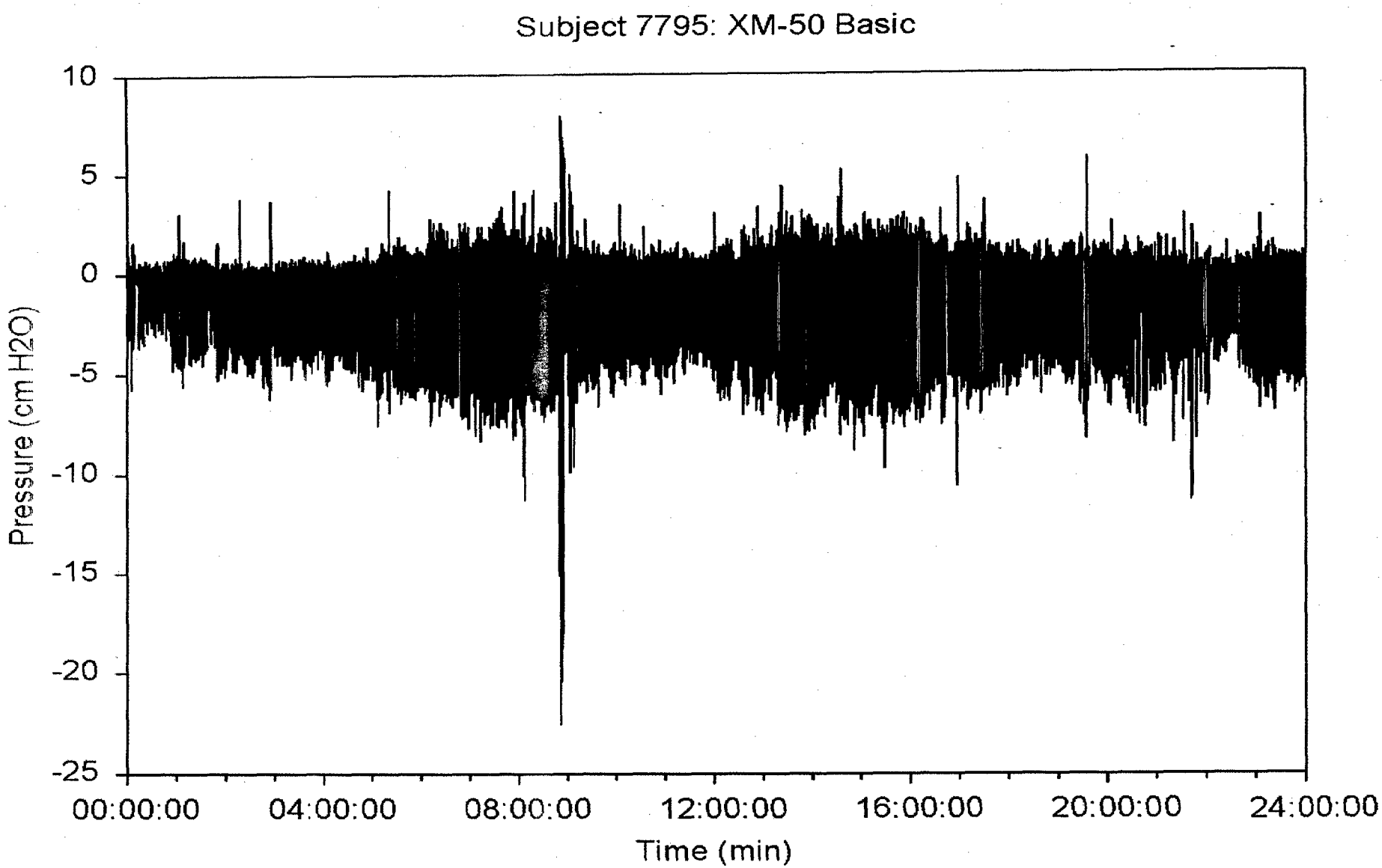
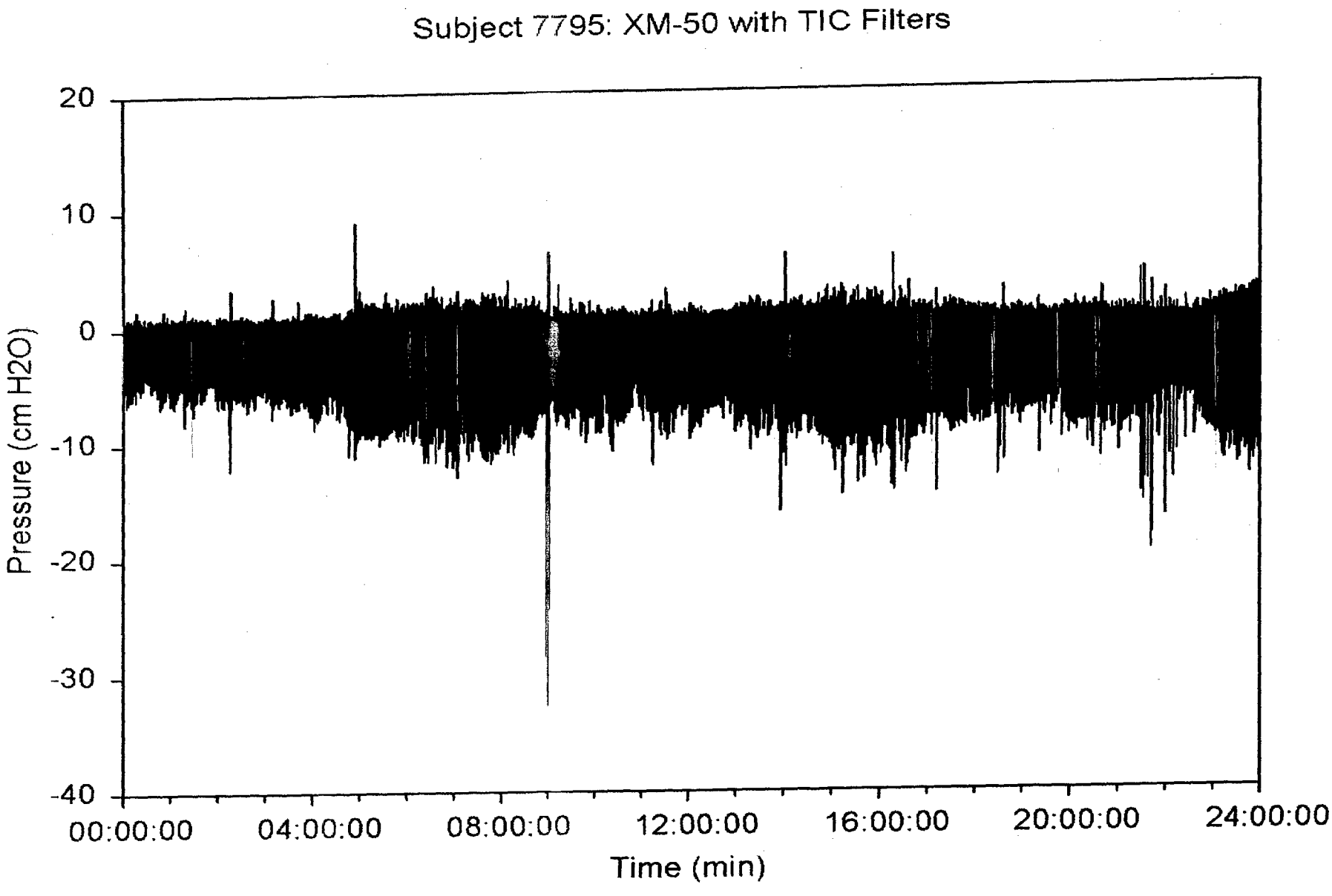
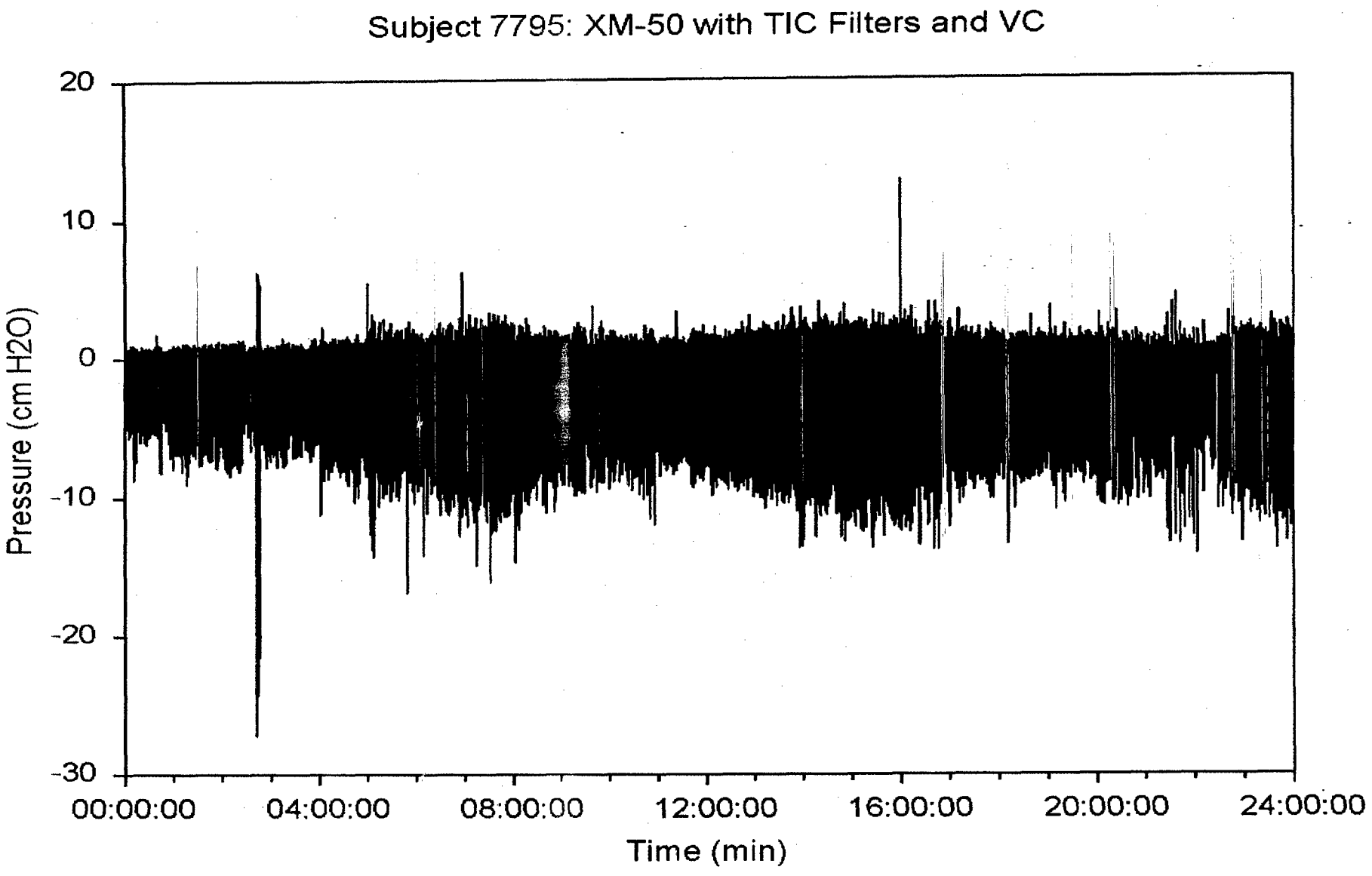
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7770: XM-50 with TIC Filters and VC
10
5
0
-5
-10
-15
-20
-25
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7795: XM-50 Basic
10
5
0
-5
-10
-15
-20
-25
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7795: XM-50 with TIC Filters
Pressure (cm H2O)
20
10
0
-10
-20
-30
-40
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 7795: XM-50 with TIC Filters and VC
20
10
0
-10
-20
-30
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
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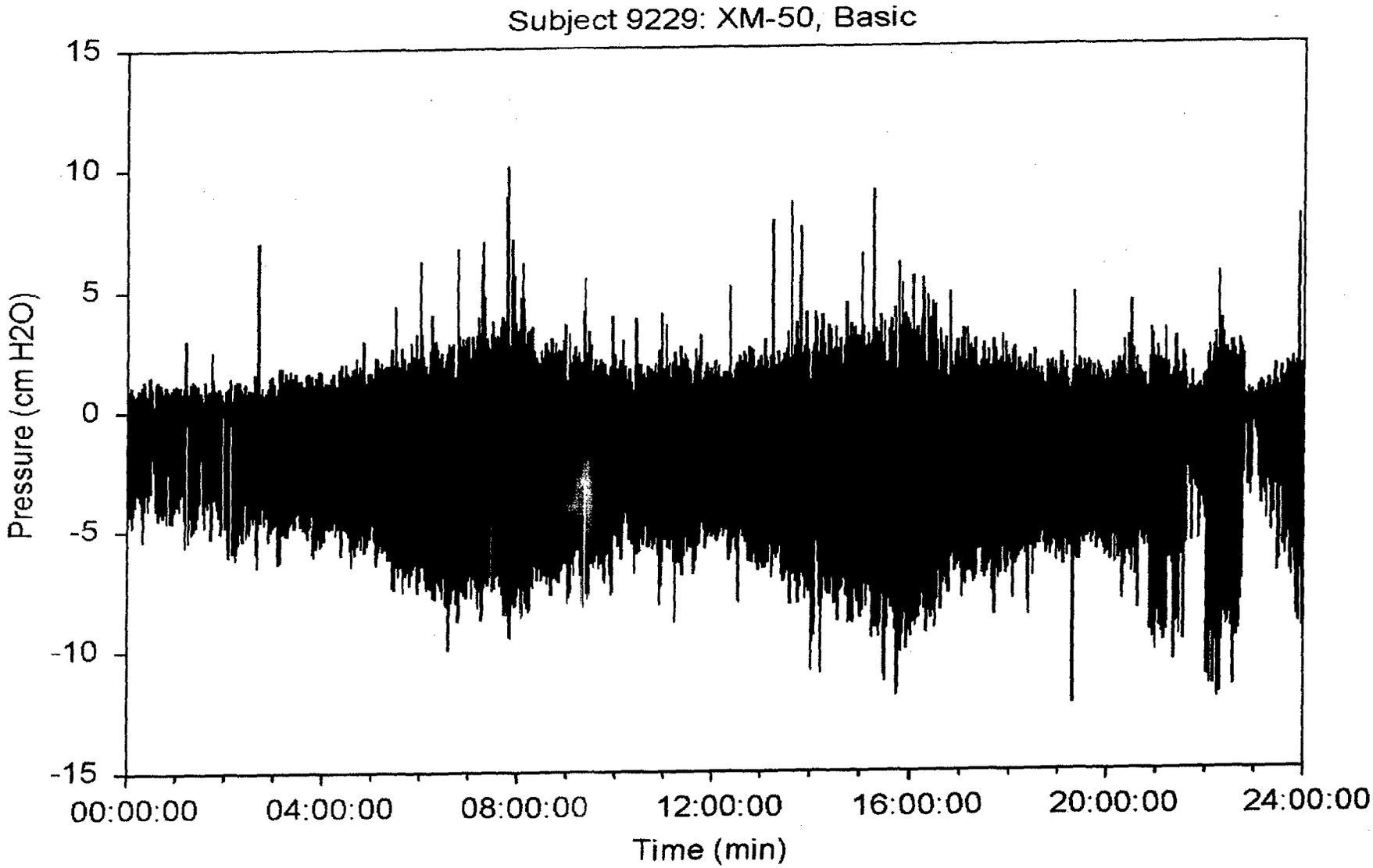
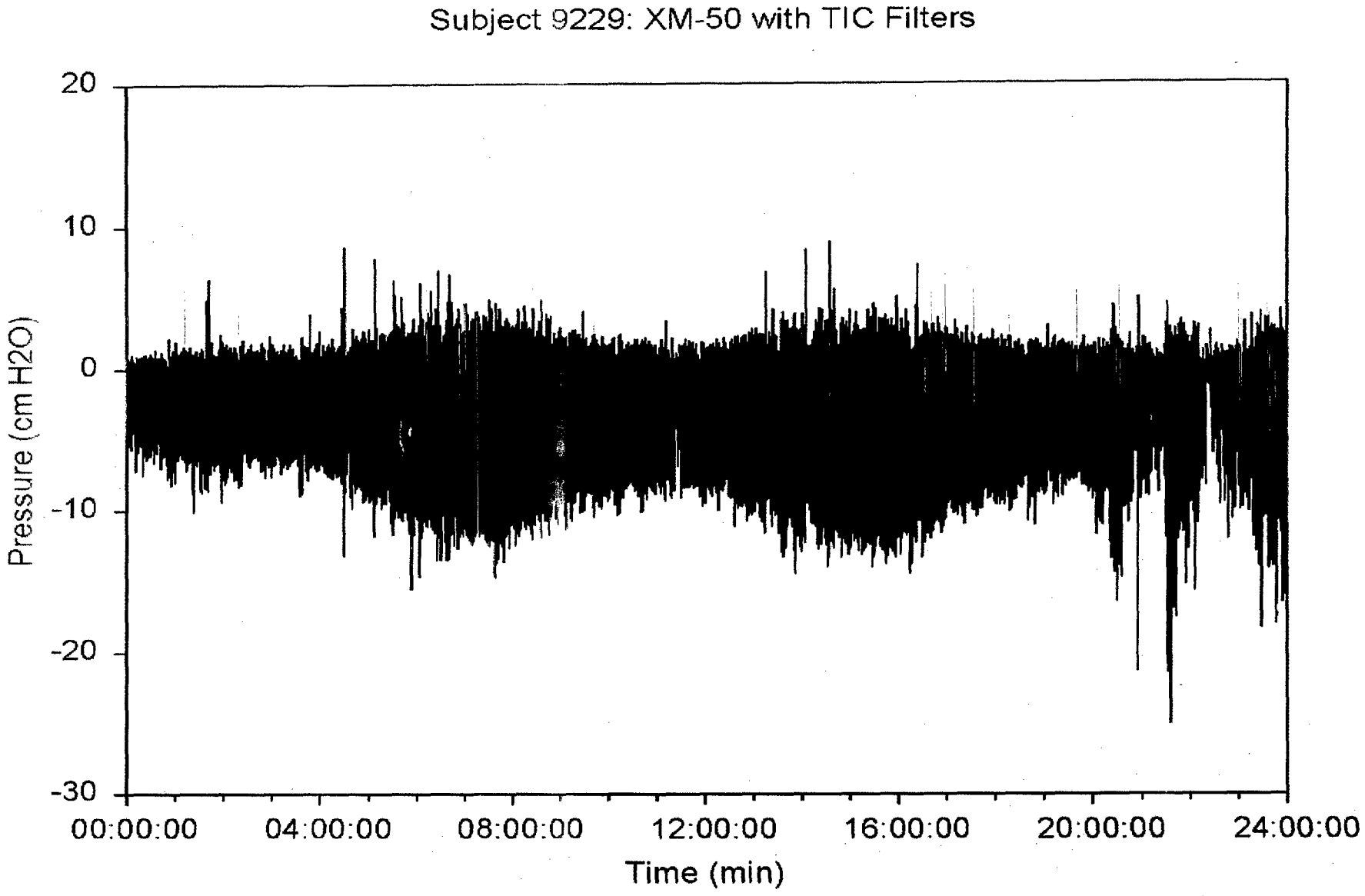
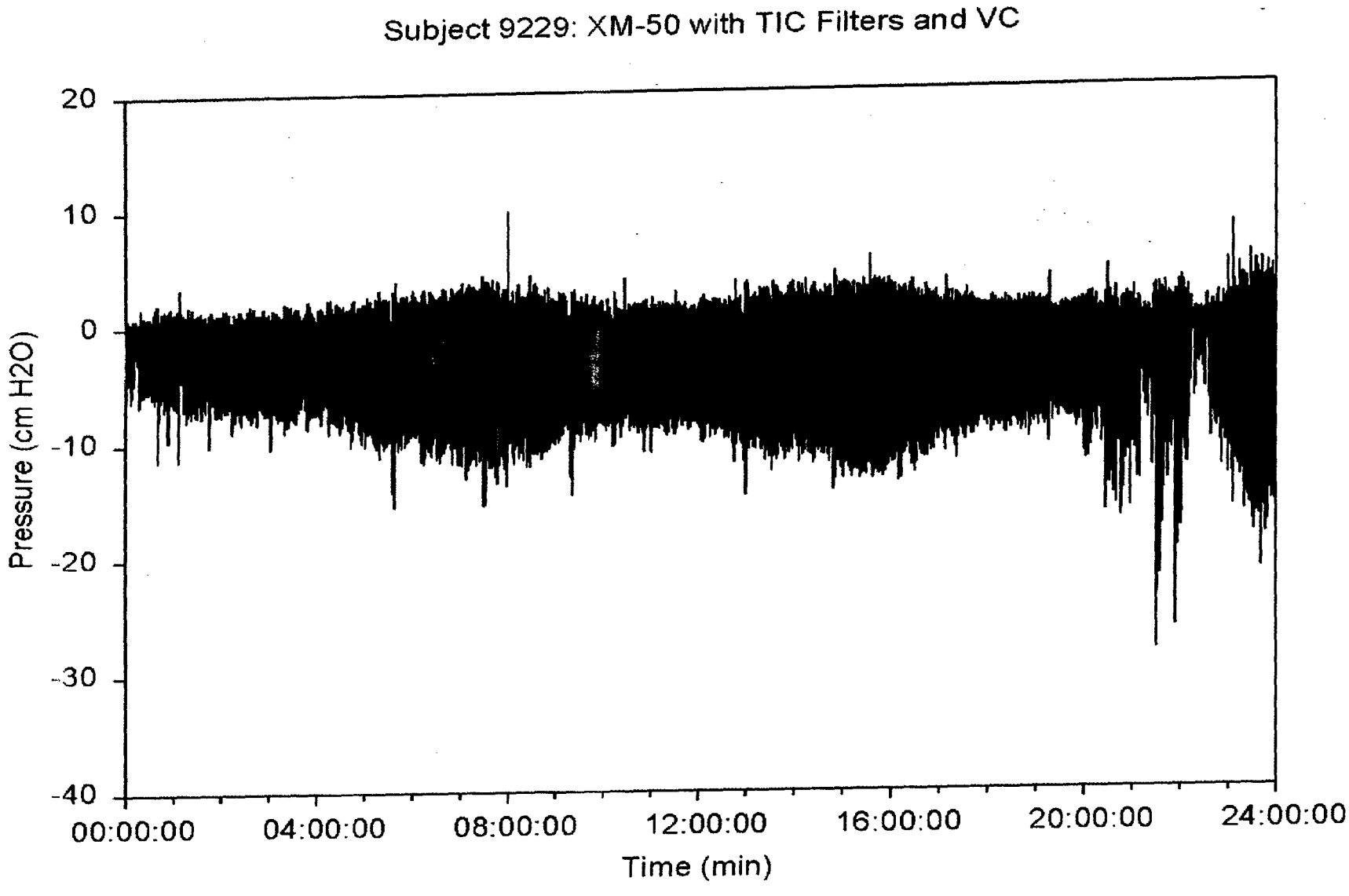
16:00:00
20:00:00
24:00:00
Time (min)


Subject 9229: XM-50, Basic
15
10
5
0
-5
-10
-15
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 9229: XM-50 with TIC Filters
20
10
0
-10
-20
-30
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)


Subject 9229: XM-50 with TIC Filters and VC
20
10
0
-10
-20
-30
-40
Pressure (cm H2O)
00:00:00
04:00:00
08:00:00
12:00:00
16:00:00
20:00:00
24:00:00
Time (min)