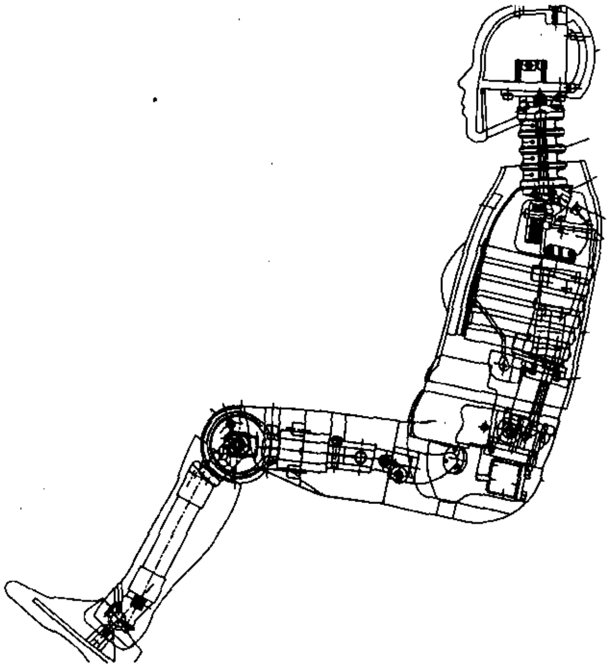
Technical Report

Development and Evaluation of the Hybrid III Fifth Percentile Female Crash Test Dummy (H-III5F)



August 1998

Prepared by:

OFFICE OF CRASHWORTHINESS STANDARDS
and
VEHICLE RESEARCH and TEST CENTER

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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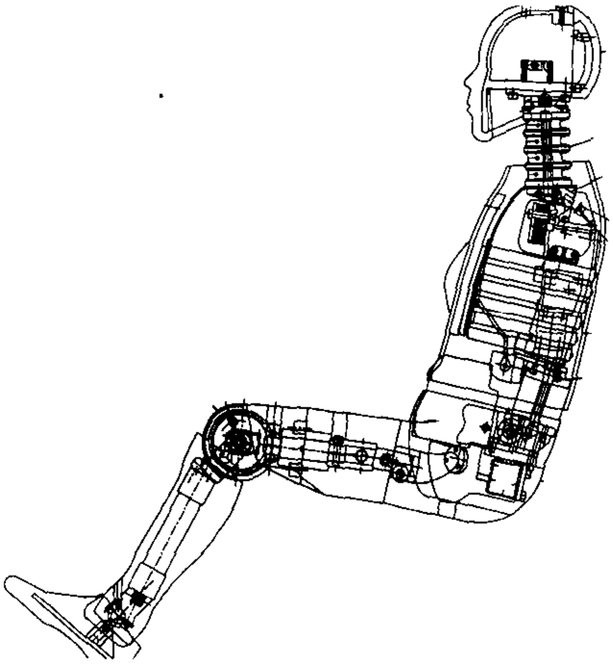

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Summary

The Hybrid III Fifth Percentile Female Crash Test Dummy, known from here on as H-IIISF, is the third of the family of Hybrid III-type dummies being proposed for adoption into the Code of Federal Regulation at 49 CFR Part 572, Subpart 0. The first Hybrid III dummy was a 50th percentile male dummy. As of 1986, NHTSA has specified use of this dummy for compliance testing under Standard No. 208, Occupant Crash Protection, initially on an optional basis, and more recently on a mandatory basis. The second dummy, the Hybrid III six-year-old, was proposed in the Notice of Proposed Rulemaking on June 29, 1998.

Soon after the agency completed the adoption of the Hybrid III dummy 50th percentile male dummy into Part 572, the Centers for Disease Control and Prevention (CDC) thought that further safety benefits could be attained by having a whole family of Hybrid III-type dummies available for crash safety assessment. After some consultation with interested parties, the CDC awarded a contract to the Ohio State University in 1987 under the title "Development for Multi-sized Hybrid III Based Dummy Family." At that time, CDC funding covered the development of a small female and a large male dummy. In 1989, CDC provided additional funding to develop a design foundation for a Hybrid III type 6-year child dummy.

Development of the H-IIISF dummy has continued since then under the guidance of the SAE Task Force on Small Female and Large Male Dummies (SAE Task Force) which was renamed in 1995 as the SAE Hybrid III Dummy Family Task Group (SAE DFTG). NHTSA has also been involved in the development of the dummy, initially as observer in meetings of the SAE Task Force, and lately as an evaluator of the dummy's performance. As the development of the dummy approached maturity, the agency began to prefer using this dummy in its research programs over the Hybrid II type 5th percentile dummy, because of its advanced instrumentation capability and better biofidelity.

NHTSA began substantial use of the H-IIISF dummy in late 1994. However, it found that inconsistencies in impact response and durability problems necessitated modifications. This prevented the agency from conducting an assessment of the dummy's capabilities as an objective and stable test tool and its ability to function in a variety of impact environments without structural deficiencies. The agency advised the SAE DFTG of its interest in seeing the dummy development accelerate and brought to a quick conclusion because of the need to support air bag safety assessment and use of the dummy in crashworthiness research and consumer information development programs.

The SAE DFTG and NHTSA then initiated an expedited program to correct the known structural and performance deficiencies. After the most serious problems were eliminated, the agency subjected a pair of Hybrid III 5^{th} % female production prototype dummies to a rigorous evaluation program. In the program, the dummies were exposed to a variety of crash environments to determine their suitability and stability as measuring test tools in the most severe crash exposures. This Technical Report provides the technical background for the H-IIISF, discusses its suitability for use in safety assessment, and includes all of the test data developed during this dummy's evaluation. It was prepared to accompany a notice of proposed rulemaking to add the H-IIISF dummy to 49 CFR Part 572.

I. Background

Soon after the agency adopted the Hybrid III 50^{th} percentile d-y into Part 572 in 1986, CDC thought that further benefits would be accrued if a whole family of Hybrid III type dummies were available for crash safety assessment. Accordingly, it awarded in 1987 a contract to the Ohio State University under the title "Development for Multisized Hybrid III Based D-y Family", which included funding for the development of a small female and a large male dummy. To support this work, the Ohio State University asked the SAE to form an appropriate working group that would provide advice and guidance from the automotive perspective. As a result, the Task Force invited experts from biomechanics, instrumentation, and dummy design to guide this development. During the next several years they defined the specifications for an adult small female and large male dummy having the same level of biofidelity and measurement capability as the Hybrid III 50th percentile size male dummy. Key body segment lengths and weights were selected for each dummy based on anthropometry data for the extremes of the United States adult population. Geometric and mass scale factors were developed to assure that each body segment had the same mass density as the corresponding Hybrid III body segment. Other pertinent dimensions were scaled from their corresponding Hybrid III dimensions using the geometric scale factors.

The biomechanical response requirements for the head, neck, chest and knees for the H-IIISF d-y were developed by applying appropriate scaling factors to the biofidelity response requirements of the Hybrid III 50^{th} % size dummy. Subsequently, using these geometric scaling factors, the Task Force guided the development of design specifications and drawings for the prototype dummy. This procedure gave assurance that the new 5th percentile dummy would meet the newly derived biofidelity requirements, which would be assessed by crash sensors in locations equivalent to those in the Hybrid III 50th% male dummy. Calibration procedures were drafted paralleling existing test procedures for the Hybrid III 50th% dummy.

The agency has been cognizant of the H-IIISF dummy development since its inception in 1987 and participated as observer in most of the SAE Task Force meetings. The agency was not actively involved in early stages of the dummy development, because it did not want to provide the appearance of actively guiding or impeding the dummy's development. Early use of the dummy, as noted in the SAE H-IIIDFTG minutes, indicated the need for further improvements and refinements. However, as the dummy's development approached maturity, the agency began to prefer its use in research programs, because of its advanced instrumentation capability and better biotidelity. The agency began substantial use of the dummy in late 1994. However, its continuous use had to be supported by significant repairs and modifications, which did not allow the agency to conduct a conclusive assessment of the dummy's capabilities and utility. The agency indicated to the SAE Task Group as early as 1994 its interest to see the dummy development brought to a quick conclusion because of the urgent need to support air bag developments and safety assessments as well as its use in other related vehicle test programs. Subsequent testing of the H-III5F dummy revealed additional problems requiring additional redesigns in the neck and thorax areas, which stretched the first availability of preproduction dummies into midsummer of 1997. At that time the agency began an extensive test and evaluation program of the dummy as a prerequisite for initiating the incorporation process into Part 572.

II. Description of the Crash Test Dummy

Preliminary concept of the H-III5F test dummy was formulated in 1987 by the Ohio State University. The responsibility for the dummy's further development was transferred in 199 1 to the SAE Task Force on Small Female and large male Dummies, which subsequently invited the dummy manufacturers to participate in this effort. First Technology Safety Systems (FTSS) and Vector Research (now Applied Safety Technology Corporation-ASTC) volunteered to implement, under the Task Force guidance, this part of the design effort. The dummy's initial design is based on established scaling procedures (Minutes of the SAE Task Force of May 10. 1990) from the Part 572 Subpart E 50th percentile male Hybrid III crash test dummy. Careful attention was given to assure that the H-III5F dummy had the anthropometry, mass distribution, sitting and standing heights, and motion ranges of the average 5" % small adult female. Primary sources for anthropometry and weight of the small female included studies by: Schneider, Robbins, Pflug, and Snyder: "Development of Anthropometrically Based Design Specifications for an Advanced Adult Anthropomorphic Dummy Family", Volume I, NHTSA Contract DTNH22-80-C-07502, December 1983, and Mertz, Irwin, Melvin, Stalnaker, and Beebe: Size, Weight and Biomechanical Impact Response Requirements for Adult Size Small Female and Large Male Dummies", SAE 890756, March 1989.

The H-III5F dummy's construction is configured to match the posture of a seated vehicle occupant (Figure 11.1) to allow the user to replicate realistic driver and passenger positions , restrained and unrestrained, in environments with and without air bag deployment. Selected anthropometric dimensions and the weight of the dummy's body segments as initially targeted by the SAE Task Group and as delivered in the first production prototypes are shown in Tables II. 1 and II.2 respectively.

13	1		78051-231	RING, LIFTING
12	4		9000144	SCREW, SHCS 1/4-20 X 5/8
11	1		9000021	SCREW, SHCS 3/8-16 X 1 NYLOK
10	1		78051-305	WASHER, CLAMPING
9	1		880105-728-2	ARM, COMPLETE ASSEMBLY RIGHT
8	1		880105-728-1	ARM, COMPLETE ASSEMBLY LEFT (SHOWN)
7	1		880105-360-2	LEG, COMPLETE ASSEMBLY RIGHT
6	1		880105-360-1	LEG, COMPLETE ASSEMBLY LEFT (SHOWN)
5	1		880105-450	TORSO, LOWER ASSEMBLY
4	1		880105-300	TORSO, UPPER ASSEMBLY
3	1		880105-207	NECK BRACKET UPPER
2	1		880105-250	NECK ASSEMBLY
1	1		880105-100	HEAD ASSEMBLY
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

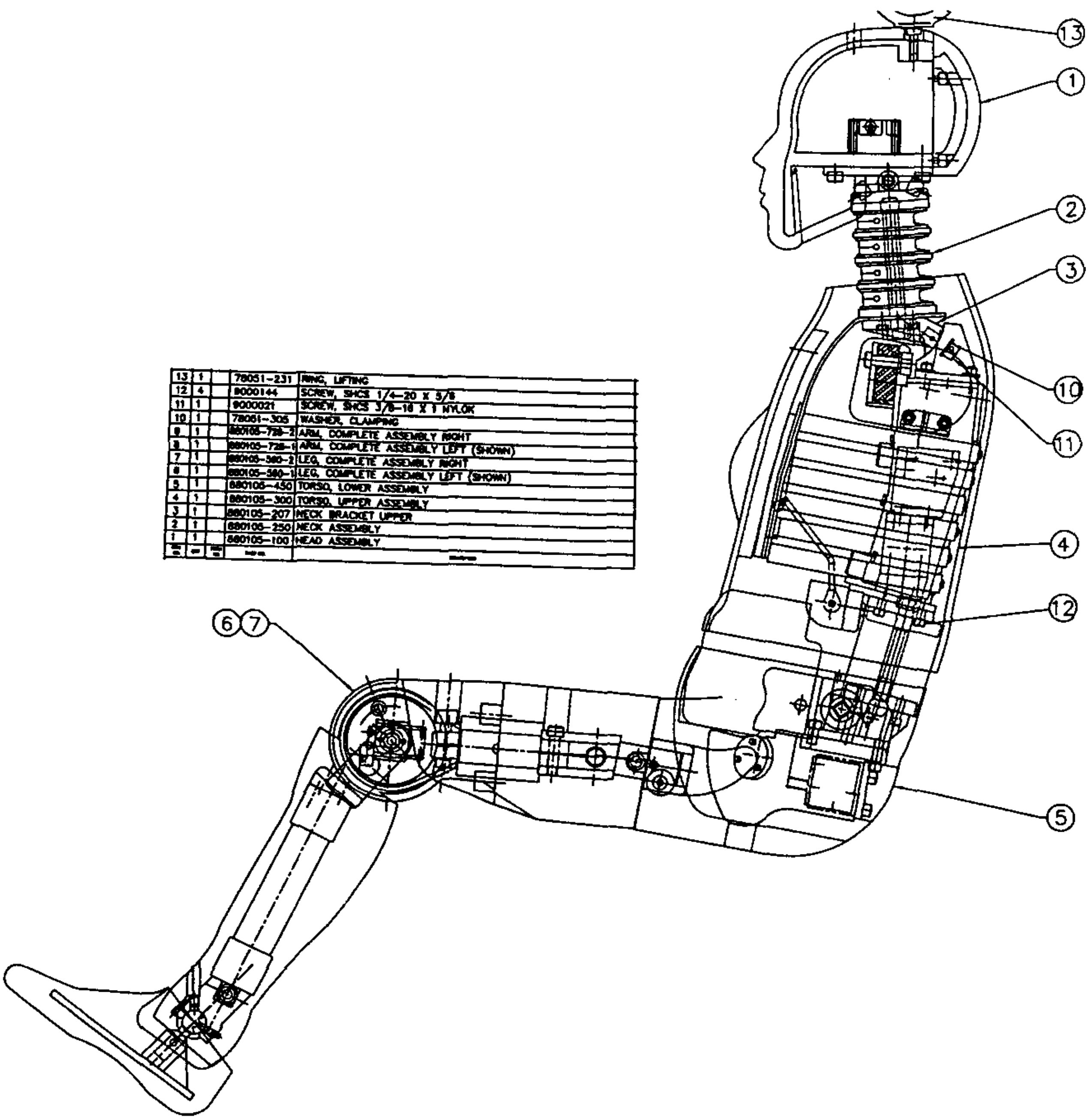

Figure II.1 Complete Assembly Hybrid III Type 5th Percentile Female Crash Test Dummy

Table II.1 EXTERNAL DIMENSIONS

Part /Dimensions	SAE TG (in)	H-III5F Prod. Proto. (in)
Head Circumference	21.0	21.4
Head Width	5.6	5.6
Head Length	7.2	7.2
Erect Sitting Height	32.0	31.1
Shoulder/Elbow	12.0	11.6
Elbow/Fingertip	15.7	15.8
Buttock/Knee	20.5	20.5
Knee/Floor	18.3	18.0
Stature-erect standing (estimated)	N/A	N/A

Table II.2 SEGMENT and ASSEMBLY WEIGHT

/Weight	SAE TG (lbs)	H-III5F Prod Proto (lbs)
Head	8.1	8.1
Neck	2.0	2.0
Upper Torso	22.7	25.8
Lower Torso	30.4	30.4
Upper Arms (both)	5.1	5.1
Lower Arms and Hands (both)	5.2	5.2
Upper Legs (both)	15.9	15.9
Lower Legs and Feet (both)	13.6	17.7
Total	103.0	110.2

The dummy's design, construction, and instrumentation installation are defined in a drawing package consisting of approximately 300 separate drawings. All drawings of individual components, subassemblies and assemblies are contained in a Parts List by part number, part name, date of drawing and change letter. A separate User Manual addressing assembly, disassembly and adjustments of the dummy will be made available at issuance of the Final Rule. In the interim, to facilitate the use and evaluation of the dummy, the agency has employed as guides two draft draft documents: 1. "Calibration Procedures for for the Small Female Hybrid III Type Test Dummy" of December 1994, and 2. " "User's Manual for the Small Adult Female Test Dummy" of February 1998, which is still under development by the SAE Dummy Testing Equipment Subcommittee (SAE DTESC). These documents provided sufficient information to determine if the dummies had expected exterior dimensions and mass distribution and its body segments were capable of meeting specified responses in prescribed impact tests.

Head-Neck Construction

The skull and the skull cap cover are of aluminum construction. They are covered by removable vinyl skins. The skull cap cover is removable to provide access to head based accelerometers. The neck is of segmented construction made of flexible, molded butyl rubber with steel disks as end plates designed to provide human-like flexion (forward bending), extension (rearward bending), and dynamic response to meet biofidelity response requirements. A pretentioned steel cable, through an axial hole in the neck, limits stretching, controls to some extent dynamic response of the head-neck complex, and increases its durability. The head is attached to the neck via a six axis neck load transducer through an occipital pivot pin. Rocking of the head around the occipital pin is stabilized by front and rear rubber nodding blocks. The neck transducer provides 3 force and 3 moment channels measurement capability.

Upper Torso and Shoulders

a. The torso is made up of a welded steel thoracic spine and six spring steel ribs that are attached in the back to the spine box and in front to the sternum assembly. The ribs are lined with polymer based damping material. The sternum assembly on the inside of the ribcage contains a Dehin slider which guides the motion of the chest deflection potentiometer arm ball during ribcage deflection. The sternum is capable of compression displacement towards the spine for approximately 2.5 inches before contacting spine based bumper stops. The spine box contains provisions for mounting three nniaxial accelerometers at the T4 level, nniaxial accelerometers at its upper, middle and lower portions, and the chest deflection potentiometer. The sternum has also provisions for attachment of uniaxial accelerometers at the upper, middle and lower ends in co-linear alignment with those of the spine. Upper and lower rib guides have been installed to limit vertical movement of the ribs.

b. The shoulder complex, consisting of aluminum clavicle and steel clavicle link assemblies having cast integral scapulae, provides an interface with shoulder belts. Steel shoulder yokes contain provisions for the attachment of arm assemblies and their articulation. The shoulder has fore and aft, up and down, and rotation motion capabilities. The torso is covered by a one piece vinyl jacket, zippered in the back and incorporating an Ensolite foam pad in the inside front. The spine box at the upper end provides for attachment of a neck mounting bracket which allows the mounting of either a 6 axis force/moment transducer or its structural replacement.

Lower Torso

The lower torso is made up of a lumbar spine, pelvis bone and an abdominal insert. A butyl rubber cylindrical lumbar spine mounted on a 5 axis lumbar load cell connects the upper and lower torso halves and provides human-like motion capabilities between them. A steel cable through the axis of the spine limits its stretch, controls transmission of tension forces and increases durability. The pelvis bone is an aluminum casting covered by a molded vinyl skin and foam flesh over it and configured in a seated posture. Hip ball joint sockets are machined into the casting. Instrument cavity at the rear of the pelvis casting allows placement of three uniaxial accelerometers. The pelvis has provisions for mounting submarining indicating transducers on the front face of the iliac wings. A vinyl skinned and closed foam abdomen surrounds the lumbar spine and is located between the thorax and the interior surface of the pelvis bone cavity. It helps the dummy to maintain an upright posture and contributes towards the control of motion between the upper and lower torso halves.

Lower Appendages

Upper legs (femurs) are made up of vinyl skin and foam flesh which house welded steel tube femoral shafts with provisions for mounting of either uniaxial or multi axial force transducers or their simulators. The proximal end of the femoral shaft contains ball joint provisions for attachment to the pelvis bone and at the distal end a knee complex which allows attachment of the tibia for human-like articulation. Mounted on each upper femur is a hard plastic bumper which limits the amount the femur can rotate in flexing motion and prevents metal-to-metal contact with the metallic pelvic bone. Optional knee slider mechanisms allow limited displacement of tibia relative to femur with provisions for mounting deflection transducers. The lower legs (tibias) have removable vinyl skin and foam flesh molded over welded steel tibia shaft. The feet are made of steel skeleton with vinyl skin and molded foam flesh. They are attached to the tibias via a ball joint ankle, which allows motion of the foot in plantar flexion, dorsi flexion, inversion and eversion as well as medial and lateral rotations. A rubber bumper mounted on the ankle limits the range of motion of the foot and prevents metal-to-metal contact between the foot and the ankle. Also incorporated into the heel of the foot is an Ensolite pad which provides a degree of human-like heel compliance.

Upper Appendages

Upper and lower arms are of vinyl skin and foam flesh molded over welded steel shafts. Hinge type pivots are provided at the shoulder, the elbow and the wrist to provide human-like motion capability. The hand is a single piece vinyl molding with structural support extending from the wrist pivot to the palm.

Available Instrumentation

The dummy has provisions for mounting the following electronic impact sensors:
o Head: 3 accelerometers in triaxial array;
o Neck upper: Six axis neck force and moment transducer at Cl/occipital condyle;
lower: (optional) neck force and moment transducer at C7/T1;
o Upper torso: Triaxial set of accelerometers in the spine box at T4 level;
Uniaxial set of accelerometers at the upper, middle and lower ends of the spine box (optional);
Uniaxial set of accelerometers at the upper, middle and lower ends of the sternum in collinear alignment with spine based accelerometers (optional);
Chest deflection transducer;

o Thoracic five axis force and moment transducer (optional)
o Lumbar spine: Five axis load cell (optional);
o Pelvic bone: Iliac load cells (2) (optional);
triaxial set of accelerometers;
o Knee shear indicator (optional);
o Femur load transducer: uniaxial, and optional six axis;
o Instrumented lower legs (optional): Knee clevis - 2 z-axis,
Upper tibia - 2 axis,
Lower tibia - 3 axis.

III. Biomechanical Response Requirements

The dummy's initial configuration and biomechanical response corridors were developed through a scaling process from the 50th percentile male Hybrid III dummy based on anthropometty and mass distribution characteristics of the 5th percentile size female (ref. L. W. Snyder, D.H. Robbins. "Anthropometry of Motor Vehicle Occupants", NHTSA contract No. DTNH22-80-07502, 1983; Kathleen Robinette, Thomas Churchill, John McConville. "A comparison of Male and Female Body Sizes and Proportions",AMRL-TR-79-69, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio, July, 1979). The scaling techniques are based on Mertz and Irwin procedures (ref. SAE Task Force correspondence of October 6, 1987). The scaling takes into account mass distribution and dimensional differences of particular body segments and their elastic properties. The selected dummy's biomechanical-biofidelity performance corridors (Mertz, Irwin, Melvin, Stallnaker, and Beebe: Size, Weight and Biomechanical Impact Response Requirements for Adult Size Small Female and Large Male Dummies", SAE 890756, March 1989), cover head impact in drop tests, neck flexion-extension in pendulum tests, chest acceleration and deflection, and knee impact responses in impactor tests. Inasmuch as the dummy responses can not meet the biofidelity performance corridors in their entirety, it has been past practice to require only certain portions of the impact responses to fall within the specified " performance windows". The SAE DTESC selected as H-III5F dummy acceptance windows the following response specifications (ref. Calibration Procedures for the Hybrid III Small Female Test dummy, SAE Dummy Testing Equipment Subcommittee, December 1994): 1) the head is to measure a peak resultant acceleration between 240 G and 295 G when dropped from 376 mm (14.8 in) onto a flat rigid surface; 2) the neck allows the head to articulate in pendulum tests in flexion not less than 78 deg and not more than 96 deg and the value of the maximum moment is to be between 69 Nm and 84 Nm (5 1 and 62 ft-lbs), and in extension not less than 97 deg and not more than 119 deg and the value of the maximum moment is to be between 54 Nm and 67 Nm (40-49 ft-lbs); 3) the chest in pendulum impact at 6.7 m/s is to develop a resistance force between 3.8 an and 4.3 an (854-967 lbf) at peak sternum deflection between 5 lmm and 58 mm (2.0-2.3 in). The force deflection plot is to have an internal hysteresis between the loading and unloading portions of the curve between 69 percent and 85 percent. 4), the peak femur response force in a pendulum impact at 2.1 m/s (6.9 ft/s) is between 3.4 kN and 4.2 kN (764-944 lbf).

Calibration responses of the first prototype dummies are reported in the October 12, 1989, minutes of the SAE Task Force meeting. lnitial tests revealed that 1) acceleration responses of the head in drop tests met the biomechanical response corridors, 2) the necks had distorted moment-time response curves, 3) the chest force was too high and sternum deflection was too low, 4) the knees appeared to have acceptable impact biofidelity, 5) the dummy was nearly 4 lbs over the target weight as defined by the Task Force, 6) the pelvis orientation in the seated posture appeared to be off by approx. 10 deg., and 7) the ball retention mechanism in the chest deflection potentiometer arm ball slider needed redesign for better retention.

The Task Force reported on June 3, 1991, that it considers its work completed, and from here on it is the DTESC responsibility of defining calibration and positioning procedures and requirements. Pelvis modifications and means of reducing the dummy's tendency to submarine have been discussed by the Task Force beginning with the December 10, 199 1, meeting and continued well into 1993. On July 12, 1993, a special Task Group reported to the Task Force on the resolution of this problem. At the July 14, 1993, Task Force meeting, Ford reported femoral neck fractures in unrestrained occupant air bag tests and concern with a protrusion at the dummy's back in the interface area between the lumbar and thoracic spines, which could cause problems of positioning the dummy in seats containing lumbar supports. Similar femoral neck fractures were reported by another user at the September 15, 1993 Task Force meeting. Ford noted at the January 26, 1994 Task Force meeting its program to evaluate two types of neck shields. FTSS was requested by the Task Force at the April 7, 1994, meeting to complete the necessary modifications to the dummy's back that would provide a smoother contour and to make revisions to the pelvis-femur design for meeting the hip flexion requirements similar to that of the Hybrid III 50th % size dummy. Ford noted at the meeting that their tested neck shields have minimal effects on the neck response.

At the January 26, 1995 H-IIIDFTG meeting, Melvin of GM Research recommended to consider softer nodding blocks in the neck to give more human-like articulation of the head at the Atlanto-occipital joint. At the same meting, the Task Group established recommendations for hip flexion requirements, Further discussions were conducted at the March 15, 1995, meeting noting that softer nodding blocks would increase the total neck flexion and extension motion beyond the allowable limits unless the neck was redesigned. Minutes of that meeting note the Task Force recommendation to delay the modification of the small female hip joint area until the 50th percentile Hybrid III male dummy hips were revised. The minutes also contain a supporting vote by ISO/TC22/SC12/WG5 to use the Hybrid III small female dummy for frontal impact tests, Subsequently, the same recommendations were issued by ISO/TC22/SC12/WG5 on October 1996 in a draft Technical Report N490, and submitted for ISO/TC22/SC12 approval on December 29, 1997, as a DTR 12349-1 IS0 document At the December 20, 1995, Task Force meeting, proposed hip modifications were reviewed and FTSS was directed to add cushioned bump stops to the femurs in order to limit the hip flexion motion to 65 deg of rotation from an erect seated posture. At the June 5, 1996, Task Force meeting, further discussions were conducted on the need to speed up implementation of the hip joint and foot-ankle modifications, to define neck extension corridors for out-of-position air bag loading, and to incorporate Delrin spacers in the design of the neck and lumbar spines.

At the September 1, 1996, H-IIIDFTG meeting, FTSS reported that foot-ankle and hip joint modifications are expected to be completed by the end of the year. Questions were also raised regarding need of a neck shield and type to be used in air bag tests without coming to consensus of what if anything needs to be done. Further discussions based on evaluation of several neck shields were conducted at the December 2, 1996, H-IIIDFTG meeting without coming to any resolution. FTSS reported at the January 24, 1997, meeting that prototypes incorporating feet, ankle and femur-hip joint modifications will be available in March 1997. Further discussions about the functions of neck skins and shields and the method of testing them took place at the February 28, 1997, H-IIIDFTG meeting. Several users also reported chest deflection potentiometer arm ball being dislodged from the sternum mounted ball retaining guide during air bag testing. This appears to be caused by excessive upward rib motion. A modification was suggested by the H-IIIDFTG to instal shoulder mounted bumpers to restrict upward rib motion. FTSS reported at the May 28, 1997, meeting that the hip joint and foot-ankle modifications were completed and prototypes will be made available in June. GM noted that it expected to complete the evaluation of the modifications in late July or early August.

At the August 20, 1997, H-IIIDFTG meeting, the status of the various modifications were reviewed. It was noted that the modified dummies are still awaiting sled testing. FTSS reported at the September 30, 1997, meeting that it had developed a soft foam plug-skin that would till the void at the back of the chin and the front of the neck. FTSS also noted that the weight of the head and its center of gravity were slightly out of specification when the six axes load cell is installed, and that sternal bumpers would allow 67-70 mm compression instead of the current 63 mm.

The October 30, 1997, minutes of the H-IIIDFTG discuss FTSS implemented design modifications to the 1) head which accommodate a piece of vinyl from the back of the jaw to the occiput on each side of the head; 2) sternum and spine box incorporating sternal bumper changes; 3) results of ankle tests; 4) torso jacket revisions; and 5) pelvis orientation during d-y positioning. It was noted that the hip joint changes still need to be evaluated. FTSS indicated at the December 3, 1997, meeting the need to add bump stops to the femur flanges so as to limit the hip flexion angle to 40-50 deg at which time 120 ft-lbs resistance moment would be encountered. It was also noted that the development of a neck skin and chin insert plug remain an unresolved issue. Dummy interaction with various air bags using different types of neck wraps and chin plugs were reviewed at the January 16, 1998, H-IIIDFTG meeting. Several modifications were considered to make them more effective in out-of-position air bag tests. FTSS noted that the d-y's femur is capable of symmetrical flexion motion up to 60 deg. without interacting with the pelvis structure. Since the dummy was to be used in belted tests and in air bag inflation induced injury assessment tests, hip flexion, under those test conditions, is minimal. Accordingly, hip flexion is not an important consideration. Consequently, H-IIIDFTG recommended that the hip joints develop a resistance torque of approx 60 ft-lbs at a hip flexion angle between 55-60 deg. and that such a specification be a design rather than a calibration requirement.

IV. Applicable Literature

1. Literature dealine with the anthrooometrv and mass distribution that provided the foundation for fifth percentile female dummy include:

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l-2. D.H. Robbins et al, "Anthropometry of Motor Vehicle Occupants", Volume 1-3, NHTSA Contract No. DTNH22-80-C-07502, December 1983.

l-3. Kathleen Robinette et al, "A Comparison of Male and Female Body Sizes and Proportions" AMRL-TR-79-69, Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio, July 1979.

1-4. Kathleen Robinette, "Male/Female Proportional Differences and the Implications for Protective Equipment, Technical Paper, Anthropology Research Project, Inc., Yellow Springs, Ohio, June 1982.

1-5. R.P.M. Hubbard and D. G. Macleod, "Definition and Development of a Crash Dummy Head", Proceedings of the 18th Stapp Car Crash Conference, SAE 741193, December, 1974.

l-6. Metz H. J. Et al., "Size Weight and Biomechanical Impact Requirements for Adult Size Small Female and Large Male Dummies", SAE SP-782, SAE # 890756, March 1989.

1-7. J. W. Young et al, "Anthropometry and Mass Distribution Characteristics of the Adult Female ", FAA-AM-83-16, FAA Civil Aeromedical Institute, Oklahoma City, Ok., September 1983.

l-8. Hertzberg, H.T.E., "The Anthropology of Anthropomorphic Dummies", SE 690805, Proceedings of the 13th Stapp Car Crash Conference, December, 1969.

1-9. SAE Task Force correspondence of October 6, 1987

2. Literature dealine with develonment of the biomechanical impact reouirements for the 5th percentile female H-III are contained in:

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Characteristics of a Small Female and Large Male Dummy, 10/9/1987.

2-1. Mertz H. J. Et al., “Size Weight and Biomechanical Impact Requirements for Adult Size Small Female and Large Male Dummies”, SAE SP-782, SAE # 890756, March 1989.

2-3. Minutes of the SAE Small Female and Large Male Dummies Task Force meeting, October 12, 1989.

2-4. “Calibration Procedures for the Hybrid III Small Female Test dummy”, SAE Dummy Testing Equipment Subcommittee, December 1994.

2-5. “User’ Manual for the Small Adult Female Test Dummy”, SAE Dummy Testing Equipment Subcommittee, February 1998,

3. Literature dealine with Dummy Use in Research

3-1. Steve Rouhana et al., “Assessing Submarining and Abdominal Injury Risk in the Hybrid III Family of Dummies: Part II- Development of the Small Female Frangible Abdomen”, Proceedings of the 36th Stapp Car Crash Conference, SAE 902317, November, 1990.

3-2. Dave Viano, Sudhaker Arepally, “Assessing the Safety Performance of Occupant Restraint Systems”, Proceedings of the 36th Stapp Car Crash Conference, SAE 902328, November, 1990.

3-3. Melvin, J. W. et al., “Assessment of Air Bag Deployment Loads with the Small Female Hybrid III Dummy, Proceedings of the 37th Stapp Car Crash Conference, SAE 933 119, November, 1993.

3-4. Mertz H. J., “Anthropomorphic Test Devices” Accidental Injury: Biomechanics and Prevention, A Nahum and J. W. Melvin, Springer Verlag, New York, NY, 1993.

3-5. Husher S. E. Et al., “An Analysis of ATD Seating Positions in NHTSA Frontal Crash Testing”, SAE 950890, SP1077, SAE, Warrendale, Pa., 1995.

3-6. SAE Human Biomechanics and Simulation Standards Committee., “Hip Flexion Requirements for Adult Dummies”, SAE 950660, SP 1077, SAE, Warrendale, Pa., 1995.

3-7. Agard Advisory Report 330 “Anthropomorphic Test Dummies for Crash and Escape System Testing, AGARD-AR-330, North Atlantic Treaty Organization, Neuilly-Sur Seine, France, 1996.

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V. Dummy Manufacturers and the Dummy's Current Use Status

FTSS of Plymouth, Mi. and Applied Safety Technologies Corporation (ASTC) of Milan, Ohio are the only current manufacturers of the H-III5F dummy. Although the dummy's commercial distribution began several years ago, its use, because of various deficiencies, has been limited primarily to research applications mostly for air bag effectiveness assessment. Contacts with automobile and safety component manufacturers indicate that most of them have one or even several H-III5F dummies and have used them in air bag related research and vehicle development programs particularly for frontal offset collision tests. Inasmuch as the agency evaluation of the modified dummy shows reasonably good and consistent performance, it is expected that upon issuance of the NPRM, current dummy users will rush either to upgrade the dummies in their possession or to procure new ones.

VI. Comparison of Other Dummies by their Design and Construction

To the best of our knowledge there are no other Hybrid III type dummies currently being manufactured in the 5th percentile small female size. Of the three small female dummies that were available in the 60’s and 70's (the Sierra SCSI, the VIP 5th and the Hybrid II 5th percentile (H-IISF)) only the VIP and the Hybrid II 5th percentile dummies can still be procured from commercial sources. Both the VIP 5th and the H-IISF dummies have similar external anthropometry and mass distribution as the H-IIISF dummy, but are considerably different in skeletal construction and in the design of body joints. While the H-IIISF dummy is constructed to conform to the seating posture of the vehicle occupant, the VIP 5th and the H-IISF percentile dummies were constructed to an erect “military type” seating posture. Both the VIP 5th and the H-IISF dummies have steel skeletons, covered by vinyl skin, with joints allowing principal body segments to articulate with respect to each other, but with very little control to provide consistency and conformance to human ranges of motion. The ribcage is fitted with hydraulic cylinders to allow deflection and dampen the ribs from resonating oscillations, but in the absence of biomechanical data they did not have to meet any performance requirements. The dummies had provisions for accelerometer and load cell mountings to measure only head and thoracic accelerations as well as femur loads, but unlike the H-III small female, they did not have provisions for neck, lumbar spine, pelvis, and chest deflection response measurements (ref. 3-7).

VII. Comparison of Impact Responses of the Hybrid III Small Female with Hybrid II and VIP Fifth Percentile Female Dummies

A literature search does not reveal any comparable kinematic and crash impact response studies between the VIP 5th or the H-II5F female dummies on one side and the Hybrid III small female dummies on the other side. Because the VIP 5th and the H-IISF percentile female dummies were not standardized and are of relatively primitive design, they were used primarily for research purposes as anthropometrically shaped and sized mass distribution devices to evaluate belt restraint loadings (ref. 3-12, 3-13). Accordingly, the existing data from these types of applications can not be considered for comparison or assessment purposes particularly with the H-IIISF dummy.

VIII. Need for the Hybrid III Small Female Dummy

Anthropomorphic dummies are mechanical surrogates of the human body. They are used as test devices by the automotive and aircraft industries, insurance and consumer interests as well as regulatory bodies to evaluate occupant safety in crash and escape system environments. While earlier dummies, such as VIP and Hybrid II, were used primarily as loading devices for the assessment of the efficacy of restraint systems, and therefore required mostly human-like size and weight distributions, the new generation of dummies is used to assess type and severity of injury, and is designed to replicate the human dynamic response. These new dummies require a sensor suite of instrumentation to measure the severity of impact interactions with passive and particularly active restraint systems. While the 50th percentile Hybrid III dummy was sufficient for the development and evaluation of the safety environment for vehicle occupants with essentially passive restraint systems, the introduction of air bags and injury experience on highways showed that a singular size surrogate does not sufficiently address safety problems for other size occupants, Accordingly, the developers of occupant restraint systems, vehicle manufacturers, insurance industry and consumer advocates asked the government to select and standardize different size crash test dummies that would represent vehicle occupants who are most vulnerable to injury in the crash environment. In the case of the 5th percentile size dummy, it is representative of a small stature, by weight and size the 5th percentile female. Crash test experience with air bag equipped vehicles has shown that the small female occupant is fairly vulnerable to certain deploying air bags in out-of-position impact environment. For example, as of April 1998 NHTSA's Special Crash Investigation Program contains a census of known fatalities that are due to air bags. Since 1990, a total of 15 females, 62 inches tall or less, have been fatally injured by air bags. Also NHTSA's NASS data indicate that over one-quarter (26.1%) of female drivers involved in towaway crashes are 62 inches in stature or less. In this category, about 20.8 % receive fatal injuries. Thus, the addition of the 5^{th} percentile female test dummy will satisfy a need to measure the effects of occupant crash protection devices on this important group of the driving population.

The immediate application of this dummy is both for the development and evaluation of advanced air bag systems and their use in evaluating the efficacy of the crash protection provided by FMVSS No. 208, Occupant Crash Protection.. The availability of the Hybrid III 5th percentile with good biofidelity and extensive instrumentation capability, will provide a suitable tool to assess objectively the effectiveness of not only advanced air bag systems in variety of crash scenarios, but also in IS0 Out-of-Position (OOP) static deployments, FMVSS 208, NCAP and experimental offset collision tests.

IX. Agency Test Program to Evaluate the Dummy

1X.1. Test plan

The objective of this evaluation was to provide the agency with sufficient technical data and documentation to support the incorporation of the fifth percentile Hybrid III small female dummy into Part 572. To that end, this evaluation sought to establish the integrity of the dummy's structure and instrumentation as well as the repeatability and reproducibility of its responses in a variety of test conditions including static OOP air bag tests, calibration tests, and dynamic sled crash simulations. Prior to conducting these tests, the dummy's anthropometry and mass distribution were evaluated. Also, preliminary structural robustness tests were conducted to provide an initial assessment of the dummies' structural integrity. This would allow for any necessary changes to be made to the dummy before initiating the remainder of the test plan.

1X.2. Test Dummy Configuration

VRTC had available for the initiation of the test series dummy serial #273 and dummy #019 which were received in spring of 1997. However, shortly before the start of tests, the dummies' thoraxes were modified, at the suggestion of GM/SAE, to provide improved capabilities for the measurement of the sternum velocity and compression. These measurements could subsequently be used to calculate the viscous criterion of the thorax. The following changes were made:

- Three accelerometer pairs were added to the sternum and spine box.
- Rib guides limiting upward and downward movement of the ribs were added to achieve improved accuracy of the measurements taken by the spine/sternum accelerometer pairs.

Preliminary OOP and structural robustness (elevated severity calibration) testing indicated shortcomings in the thorax deflection measurement system. In particular, the lower portion of the sternum plate could contact the chest deflection potentiometer arm in severe out-of-position air bag tests, forcing the ball-end of the arm out of the sternum slider track. Therefore, several additional modifications were required. These changes included:

- The rib bumpers on the spine were increased in height to 16 mm. This would allow approximately 63 mm of sternal compression before contact with the bumpers was made.
- An additional bumper was added at the top spine accelerometer location to insure protection of the sternum and spine accelerometers.
- The lower sternum bumpers were moved outward from the spine to allow more space for lateral motion of the chest deflection rod. This required flanges to be added to the sides of the spine-box on which the lower rib bumpers are mounted.
- The shape of the chest deflection rod was optimized to prevent interference with other internal dummy parts.
- The lumbar-to-thoracic spine adapter was chamfered to prevent potential contact with the chest deflection rod.
- The lower end of the sternum slider was milled flush with the sternum plate to prevent potential contact with the chest deflection rod.
- The lower sternum/spine accelerometer pair was shifted upward by approximately 10 mm to provide increased clearance with the chest deflection rod.

Another problem was uncovered during the dynamic sled testing portion of the evaluation. Post-test observations indicated that the lap belt was getting trapped in the abdominal region of dummy #019. High speed films of the events confirmed that dummy #019 was "submarining;" that is, the lap belt was not retained on the iliac surface during the test. Inspection of the pelvic region of both dummies revealed some differences in the way the molded skin fitted around the pelvis structure. After reviewing the problem, it was determined that dummy #273 contained an improved pelvis design as recommended by the SAE H-IIIDFTG to minimize excessive submarining tendencies in belted tests, while dummy #019 had an older version of the pelvis design In order to complete the test series on schedule, dummy #0 19 was replaced with dummy #289 which contained the latest thorax and pelvis modifications described above.

Additional sled testing revealed yet another problem with the dummy. Analysis of the measured response indicated the existence of significant spikes in the z-axis data channels of the dummy, This noise was evident in pelvis, chest, and head accelerometers; and lumbar, thoracic, and neck load cells. Inspection of the dummy revealed that the lumbar spine cable was not isolated and could move in snapping action within its mounting, causing metal-to-metal impact. Plastic bushings were inserted around both ends of the cable and the test conditions repeated. The results indicated that the bushings eliminated the spiking problems. These findings were shared with the SAE H-IIIDFTG on Feb. 12, 1998. The H-IIIDFTG agreed that in addition to the lumbar spine cable bushing kit, a neck cable bushing kit should be incorporated into the dummy.

1X.3. External Dimensions and Seement Weights

Dummy number 273 was inspected as received for external dimensions and segment weights. The results were then compared to the targets provided in the draft SAE User Manual of Feb. '98 and also against the original targets developed by the SAE Task Force.

The results of the external dimension measurements are found in Table 1X.3.1. As indicated in the table, dimensions L (popliteal height) did not meet the specification in the User Manual.

The results of the segment weights measurements are contained in Table 1X.3.2. There were two body segments which did not meet the weight specifications in the user manual: the lower torso assembly, and the right and left feet.

Table 1X.3.1. External Dimensions

Dim.	Description	Initial SAE Targets (in)	Feb. '98 SAE Targets (inches)	Actual (right)	Actual (left)
A	Total Sitting Height	32.0	31.00 +/- 0.50	30.63	
B	Shoulder Pivot Height		17.50 +/- 0.50	17.56	17.38
C	Hip Pivot Height		3.30 +/- 0.10	3.15	
D	Hip Pivot from Back-line		5.80 +/- 0.10	5.75	
E	Shoulder Pivot from Back-line		3.00 +/- 0.30	2.9	3.0
F	Thigh Clearance		5.00 +/- 0.30	5.1	5.1
G	Back of Elbow to Wrist Point		9.90 +/- 0.30	9.75	9.75
H	Head Back from Back-line		1.70 +/- 0.10	1.8	1.8
I	Shoulder to Elbow Length	12.0	11.30 +/- 0.40	11.3	11.3
J	Elbow Rest Height		7.60 +/- 0.40	7.3	7.4
K	Buttock to Knee Length	20.5	21.00 +/- 0.50	21.4	21.25
L	Popliteal Height		14.40 +/- 0.40	13.38	13.38
M	Knee Pivot Height		16.00 +/- 0.50	15.7	15.7
N	Buttock Popliteal Length		16.80 +/- 0.50	17.0	17.0
O	Chest Depth without Jacket		7.20 +/- 0.30	7.2	
P	Foot Length		8.90 +/- 0.30	8.8	8.8
Q	Stature		56.40 +/- 1.70	56.43	
R	Buttock to Knee Pivot Length		18.50 +/- 0.50	19.0	19.0
S	Head Breadth	5.6	5.60 +/- 0.20	5.6	
T	Head Depth	7.2	7.20 +/- 0.20	7.2	
U	Hip Breadth		12.10 +/- 0.30	12.15	
V	Shoulder Breadth		14.10 +/- 0.30	14.05	
W	Foot Breadth		3.40 +/- 0.30	3.30	3.35
X	Head Circumference	21.0	21.20 +/- 0.40	21.25	
Y	Chest Circumference with Jacket		34.10 +/- 0.60	34.1	
Z	Waist Circumference		30.50 +/- 0.60	30.5	
AA	Reference Location for Chest Circumference		12.00 +/- 0.20	n/a	
BB	Reference Location for Waist Circumference		6.50 +/- 0.20	n/a	

'able 1X.3.2. Segment Weights

Segment	Original SAE Target (lbs)	Feb. '98 SAE Target (lbs)	Actual Weight (lbs)
Head Assembly	8.1	8.10 +/- 0.10	8.13
Neck Assembly	2.0	2.00 +/- 0.20	2.09
Upper Torso Assembly with Torso Jacket	22.7	26.44 +/- 0.30	26.30
Lower Torso Assembly	30.4	30.40 +/- 0.30	28.88
Upper Arm - left	2.55	2.60 +/- 0.10	2.56
Upper Arm - right	2.55	2.60 +/- 0.10	2.58
Lower Arm - left	2.60'	1.98 +/- 0.10	1.96
Lower Arm - right	2.60'	1.98 +/- 0.10	1.99
Hand - left		0.62 +/- 0.10	0.64
Hand - right		0.62 +/- 0.10	0.66
Upper Leg - left	1.95	6.90 +/- 0.20	6.92
Upper Leg - right	1.95	6.90 +/- 0.20	6.94
Lower Leg - left	6.80"	7.20 +/- 0.20	7.34
Lower Leg - right	6.80"	7.20 +/- 0.20	7.26
Foot - left		1.60 +/- 0.10	1.72
Foot - right		1.60 +/- 0.10	1.76
Total Dummy Weight	103.0	108.74 +/- 2.00	107.73

includes hands
** includes feet

1X.4. Preliminaw Structural Robustness Tests

Selected standard dummy calibration tests were conducted at increased severity levels in order to provide an initial assessment of the dummy's structural integrity and the ability of the instrumentation to provide useful measurements. If deficiencies are found, this would allow for any necessary changes to be made to the d-y before investing additional time and money in more complex and extensive testing. The tests were conducted in accordance with the procedures outlined in Appendix A of the User's Manual of December '94 with the exception of the input energy levels.

Neck Tests

Neck flexion and neck extension tests were conducted on dummy #273. The height of the pendulum was incrementally raised until the response of the neck moment about the occipital condyle approximated a level of 100 Nm When the height of the pendulum for flexion and extension tests was determined, the test was repeated three times for a total of four tests. The neck responses are summarized in Table 1X.4.1 and in Figures B.l.l and B.1.2 of Appendix B Thorough post-test inspection indicated that no significant damage was sustained by the neck assembly.

Table 1X.4.1 Neck Structural Robustness Tests in Pendulum Impacts

Test #	Dummy S/N	Test Type	Peak Rotation Angle (deg)	Peak Moment (Nm)
273C1NE2	273	extension	113.5	-103.3
273C1NE3	273	extension	112.7	-118.9
273C1NE4	273	extension	110.7	-116.7
273C1NE5	273	extension	114.1	-112.7
273C1NF3	273	flexion	92.7	92.8
273C1NF4	273	flexion	91.7	94.9
273C1NF5	273	flexion	92.9	98.3
273C1NF6	273	flexion	96.0	94.1

Thorax Impact Tests

Thorax impact tests were conducted on dummy #273 at impact speeds between 5.66 m/s and 8.93 m/s with an impact ram having a mass of 23 kg (the standard thorax impact test is conducted with a 14 kg impactor at 6.7 m/s). Small amounts of clay were placed on the rib bumpers located on the spine-box to provide information regarding contact between the ribs and the bumpers. The test results are summarized in Table 1X.4.2. and in Figure B.2.1 and B.2.2 of Appendix B.

During the course of this testing, several important findings were observed which resulted in modifications to the d-y configuration. Following test # 04340003, it was noted that the back side of the chest deflection potentiometer arm was making contact with the lumbar-to-thoracic spine adapter. As a result, the lumbar-to-thoracic spine adapter was chamfered to prevent additional clearance for the chest potentiometer arm. After tests # 04340005 and # 04340006, it was observed that the ball end of the chest deflection potentiometer rod had become dislodged from the sternum slider track. Based on the findings of these initial tests, it was necessary to make significant changes to the thorax as described in Section 1X.2.

Table 1X.4.2 Thorax Structural Robustness Evaluation in 23 kg Mass Impactor Tests

Test #	Impact Speed (m/s)	Peak Chest Deflection (mm)	Comments
04340002	6.51	63.8	
04340003	7.51	73.9	pot arm contacted lumbar-to-thoracic spine adapter
04340004	8.24	82.5	
04340005	8.90	n/a	chest pot arm ball popped out of slider track
04340006	8.93	n/a	chest pot arm ball popped out of slider track
04340033	5.66	48.0	
04340034	6.57	61.0	
04340035	6.75	62.3	ribs made light contact with bumpers
04340036	7.88	65.8	ribs contacted bumpers
04340037	7.90	66.1	ribs contacted bumpers

After the thoracic modifications were completed, additional elevated severity thorax impacts were conducted. These tests (#04340033 through #04340037) confirmed that the modifications had indeed improved the durability of the chest deflection measurement system. Furthermore, it was determined that the sternum could deflect between 61 .0 mm and 62.3 mm before the ribs would contact the rib bumpers. Note that in tests #04340036 and #04340037, the observed chest deflection exceeded 62.3 mm. This can be attributed to two sources: compression of the rib bumpers and deflection of the end of the rib (where the sternum slider is attached) around the rib bumpers.

Thorax Impact Tests - Obliaue and Reclined

Additional thorax impacts were conducted to investigate the durability of the thorax when exposed to impacts which were not coincident with either the dummy's midsagittal plane or its upright orientation in the midsagittal plane. These tests are referred to as oblique and reclined thorax impact tests. For oblique tests, the dummy was positioned the same as it would be for a standard thorax impact, except the dummy was turned 15 degrees about it vertical axis (z-axis) relative to the impactor. The purpose of this test was to determine the effect of lateral sternum motion on the chest deflection measurement system. Two tests were conducted in this position (#04340007 and #04340008) with dummy #273. As before, clay was placed on the rib bumpers to provide visual feedback on rib contact. Post-test inspection of the thorax revealed no damage sustained to the chest deflection measurement system.

The final test configuration utilized to evaluate the thorax was the reclined thorax impact. For these tests, the dummy was positioned the same as it would be for a standard thorax impact, except the dummy's upper torso was reclined 25 degrees relative to the impactor. The purpose of this test was to investigate the interaction of the upper rib guides with the ribs during an off-axis impact. Three tests were conducted in this position (#04340009, #04340012, and #04340038) with dummy #273. Post-test inspection of the thorax revealed no damage to either the rib guides or to the ribs.

Results of the oblique and reclined thorax impact tests are summarized in Table 1X.4.3. and in Figures B.3.1 and B.3.2 of Appendix B.. Note that the chest deflection in test #04340038 exceeded 62.3 mm. Again, this is possibly due to the compression of the rib bumpers and deflection of the end of the rib around the rib bumpers.

Table IX.4.3 Thorax Structural Robustness Evaluation in Oblique and Reclined Torso Impacts

Test #	Test Type	Impact Speed (m/s)	Peak Chest Deflection (mm)	Comments
04340007	oblique	6.61	59.1	
04340008	oblique	7.53	68.0	ribs contacted bumpers
04340009	reclined	4.58	55.5	
04340012	reclined	5.72	lost data	
04340038	reclined	8.11	67.6	ribs contacted bumpers

1X.5. Static Out-of-Position (OOP) Testing

Setup

Driver and passenger static OOP tests were conducted in several different vehicle systems. Driver tests were conducted in system A and system B , while passenger tests were performed in system C and system D. System A is considered to be a mildly aggressive air bag for a SUV and system B a mildly aggressive for a mid-sized passenger car. System C is a mildly aggressive mid-mount air bag for a SUV and system D is a very aggressive mid-mount air bag from a minivan. Tests involving systems A and C were carried out in an actual vehicle using standard seats, dash panels, and air bags; except for the passenger position tests in which the seats were removed and the dummy was seated on either the floor pan or on blocks of wood stacked on the floor pan to achieve proper OOP position. Tests involving systems B and D were conducted in a generic setup. The driver test environment was made up of a flat, steel seat pan with a padded seat back, standard air bags and steering wheels, and a reusable steering column. The passenger tests utilized a standard dash panel and air bag. For all passenger OOP tests, the lower legs were removed to achieve the proper d-y positioning. Pictures of typical dummy set-up conditions can be found in Appendix C.

For driver OOP tests, the International Standards Organization (ISO) seating procedures were followed as closely as possible. The procedures are contained in Appendix C. 1. IS0 Position 1 is intended to maximize head and neck loading while IS0 Position 2 is intended to maximize chest loading. For the passenger tests, however, the IS0 has not yet developed a standard positioning procedure. Therefore, the dummy was positioned in what was considered to be a reasonable OOP testing configuration in close proximity to the air bag using the driver positioning format. In this configuration passenger position 1 is intended to maximize head and neck loading while passenger position 2 is intended to maximize chest loading.

The dummies were instrumented for these tests with crash test sensors as shown in Table 1X.5.1.

Table IX.5.1. Instrumentation for Static OOP Testing

Segment	Instrumentation	Manufacturer	Model No.
Head	3 accelerometers in tri-axial array	Endevco	7264
Neck	6 channel upper neck load transducer	Denton	1716
Upper Torso	3 accelerometers in tri-axial array	Endevco	7264
	3 uni-axial accelerometers on sternum	Endevco	7264
	3 uni-axial accelerometers on spine	Endevco	7264

Results

The results of the driver OOP tests are shown in Table 1X.5.2, the passenger OOP responses are contained in Table 1X.5.3, and their respective time plots in Appendix C, For the purposes of these tables, V*C was computed using the sternum/spine accelerometer pairs for velocity and the chest pot for displacement, except where noted in the comments. Also, unless otherwise noted in the tables, the neck wrap and chin insert were used.

As indicated in the comments in Tables 1X.5.2 and 1X.5.3, in tests #29 and #3 1 dislodgement of the ball of the chest deflection potentiometer arm from the sternum slider track following tests was observed. As a result of these failures, additional modifications were required for the thorax deflection measurement system. Following the modifications, tests #04340039 - #04340047 were conducted to confirm the improvement to the thorax deflection measurement system. After these tests, some of which deflected the sternum over 50 mm, there was no evidence of the chest potentiometer ball dislodging from the sternum slider track.

Table IX.52 Driver Static OOP Testing Results

test # 043400-		13	14	15	18	19	20	30	31	32
-		A	A	A	B	B	B	B	B	B
ISO position		2	1	1	2	1	2	1	2	2
dummy S/N		273	273	273	019	019	019	273	273	273
HIC		48	103	83	217	182	192	98	235	177
Neck Fx	N	-1588	-1799	-1507	-2555	-1974	-2472	-2102	-2739	-2201
Neck Fz	N	1358	2359	1962	2640	2533	2721	1911	3324	2332
Neck Moc	Nm	-65	-81	-66	-88	-70	-98	-86	-117	-95.1
Cst X	mm	-35.6	-27.6	-26.8	-66.6	-33.8	-49.5	-34.0	lost data	-59.2
Cst G	g	32	60	94	170	113	107	57	98.6	93.5
V*C	m/s	0.72	0.27	0.60	4.13	0.81	2.08	0.56	lost data	2.15
Comments				no chin insert or neck wrap	V*C from chest pot only	V*C from chest pot only	V*C from chest pot only		chest pot ball ejected	

test # 043400--		39	40	41	42	43	44	45
system		B	B	B	B	B	B	B
ISO position		2	2	1	1	1	1	1
dummy S/N		273	273	273	273	273	273	273
HIC		lost	214	228	281	234	135	151
Neck Fx	N	-2659	-2463	-1715	-2055	-1681	-1764	-1276
Neck Fz	N	2672	2560	2568	3005	2587	2383	2143
Neck Moc	Nm	-112	-101	-71	-85	-71	-80	-60
Cst X	mm	-62.4	-56.5	-33.6	-30.4	-26.6	-27.9	-24.9
Cst G	g	lost	81	97	63	74	64	67
V*C	m/s	3.49	2.46	0.54	0.42	0.31	0.37	0.32
Comments				no chin insert or neck wrap	no chin insert		TMJ head skin	one piece neck skin

Table 1X.5.3. Passenger Static OOP Testing Results

test # 043400--		16	17	28	29	46	47
system		C1	C1	D	D	C1	C2
ISO position		Pass.1	Pass.1	Pass. 1	Pass.2	Pass.1	Pass.1
dummy S/N		273	273	019	019	273	273
HIC		259	387	3319	571	490	595
Neck Fx	N	-4447	-2981	-9918	-1788	-2316	-3369
Neck Fz	N	5423	4550	9884	4497	4898	3788
Neck Moc	Nm	-136	-136	-143	-79	-119	-152
Cst X	mm	-59.5	-53.5	-19.9	lost data	-53.1	-34.3
Cst G	g	183	107	358	249	125	78
V*C	m/s	2.94	2.37	0.35	lost data	4.02	1.49
Comments					chest pot ball ejected		

1X.6. Calibrations

After all of the thorax modifications were instituted and prior to the first dynamic sled test, dummy #273 was subjected to calibration testing. The calibration test procedures are described in Appendix A. In order to evaluate repeatability of the dummy over time using calibration data, the following calibration tests were conducted: head drop, neck extension, neck flexion, thorax impact, and knee impact. The responses were then compared to the criteria suggested by the DTESC (Appendix A), except where noted. The calibration tests were repeated throughout the dynamic sled test series after every sixth test. After sled test number 18, dummy number 289 was introduced into the evaluation. A summary of the calibration test results is shown in Table 1X.6.1.

Table 1X.6.1 Summary of Calibration Test Results

Dummy	Response	Head	Neck Flexion		Neck Extension		Thorax		Knees	Lumbar spine-abdomen
Nr.	Statistical	Res g	Peak Moment (Nm)	Peak Head Rotation (deg)	Peak Moment (Nm)	Peak Head Rotation (deg)	Sternum Max. Defl. (mm)	Force at Max. Defl.(N)	Peak Force (N)	Force at 45 deg. (N)
273	Average	276.6	73.29	83.66	-60.74	102.37	52.17	3710.9	3713.3	342
273	Std. Dev.	4.32	1.53	1.44	2.48	1.68	0.94	83.3	190.2	
273	% CV	1.56	2.09	1.72	4.09	1.64	1.81	2.24	5.12	
289	Average	269.1	78.9	88.76	-63.82	104.14	51.55	3881.0	3722.3	
289	Std. Dev.	NA	1.83	1.19	4.02	1.46	1.66	71.78	150.9	
289	% CV	NA	2.32	1.34	6.29	1.40	3.21	1.85	4.05	
Both	Average	274.1	75.78	85.92	62.02	103.11	51.92	3779	3716	
Both	Std. Dev.	5.36	3.25	2.86	3.55	1.81	1.31	114.75	179.59	
Both	% CV	1.95	4.29	3.33	5.73	1.76	2.53	3.04	4.83	

Head Drop

The DTESC suggests that the head responds with resultant peak acceleration between 240 and 295 g's when it is dropped onto a rigid steel plate. Additionally, DTESC notes that the resultant head acceleration versus time history curve should be unimodal with subsequent oscillations after the main pulse not to exceed 10% of the peak resultant acceleration and the lateral acceleration shall **not** be above 15 **g's.**

Table D. 1. in Appendix D contains the results of all head drop tests. A total of nine head drop test were conducted with two different heads. The average peak resultant acceleration was 274.07 g and the coefficient of variation was 1.95%. All head responses were within the suggested response boundaries and their mean slightly above the mean of the corridor.

Neck Flexion

The neck flexion calibration recommended by DTESC suggests that the D-plane of the head should rotate between 78 and 96 degrees with respect to the pendulum when subjected to a 7.01 m/s pendulum impact. Maximum moment about the Y-axis of the head, measured with respect to the occipital condyle, should be between 69 and 84 Nm. The decaying positive moment vs time curve should cross zero between 41 ms and 50 ms after reaching its peak value, and the decaying head rotation should cross the **zero** angle between 57 and 69 ms after reaching its peak value.

The results of all neck flexion tests are contained in Table D.2. of Appendix D. A total of 18 neck flexion tests were conducted with two different necks. The average peak D-plane rotation was 85.92 degrees and the average peak moment was 75.78 Nm. The coefficient of variation was 3.33% for peak D-plane rotation and 4.29% for peak moment. D-plane rotations and peak moments about the condyle were within the suggested response boundaries and, on average, were fairly well centered within the corridor's upper and lower limits.

Neck Extension

The neck extension calibration recommended by DTESC suggests that the D-plane of the head should rotate between 97 and 119 degrees with respect to the pendulum when subjected to a 6.07 m/s pendulum impact. Maximum moment about the Y-axis of the head, measured with respect to the occipital condyle, should be between -54 and -67 Nm. The decaying moment vs time curve should first cross the -10 Nm level between 28 ms and 38 ms after reaching its peak value, and the decaying head rotation vs time curve should be between 80 and 96 deg when the decaying Y-moment vs time curve is at the - 10 Nm level.

Table D.3 of Appendix D contains the results of all the neck extension tests. A total of 12 tests were conducted with two different necks. The average peak D-plane rotation was 103.11 degrees and the average peak moment was -62.02 Nm. The coefftcient of variation was 1.76% for peak D-plane rotation and 5.73% for peak moment. The requirement for D-plane rotation met the proposed criteria for all tests; however, the results were, on average, on the low side of the corridor. The peak moment requirement was well centered in the proposed corridor.

Thorax Imuact

The DTESC suggests for the thorax impact test that the maximum sternum-to-spine displacement, as measured by the chest displacement transducer, should be between 51 and 58 mm when impacted with a 13.97 kg probe at 6.71 m/s. The maximum force applied by the test probe to the thorax should be between 3.8 kN and 4.3 kN and the internal hysteresis should be greater than 69 and but less than 85 percent.

Results of all thorax tests can be found in table D.4 of Appendix D. A total of ten tests were conducted on 2 dummies. The average peak sternum deflection was 5 1.92 mm, the average force at peak deflection was 3779 N, and the average internal hysteresis was 75.01%. The coefftcient of variation for the peak sternum deflection was 2.53%; for force at peak deflection it was 3.04%; and for internal hysteresis it was 1.42%. The internal hysteresis specification was satisfied in all tests.

Knee Imuact

The DTESC recommends that in the knee impact tests the peak force exerted on the knee/femur by the test probe should be between 3.4 and 4.2 kN when impacted at 2.1 m/s with a 2.99 kg probe. The impact force is computed by multiplying the test probe mass by its deceleration

Table D.5 of Appendix D contains the results of all the knee impact tests. A total of 17 tests were conducted using both right and left femurs of 2 different dummies. The average peak force was 3715.96 N and the coefficient of variation was 4.83%. The results in all cases were reasonably well centered within the corridor.

Torso Flexion

Over the years, the agency has observed that stiffness of the lumbar spine-abdomen area is an important factor in the ability of the dummy to retain it seating posture during its set-up in the vehicle seat while the vehicle is being prepared for the crash test and also up to the instant of the crash itself. The agency has also observed that lumbar spine-abdomen area stiffness plays an important role on how the d-y will initiate its forward kinematics in a frontal crash event as well as how the upper half of the torso will move relative to the lower half of the torso. Currently, this important connection between the upper and lower torso halves are neither adequately defined by design nor by performance specifications. A review of stiffness characteristics of that body area, yielded in some instances nearly 2 to 1 stiffness variations (ref. Figure D1 of Appendix D). Absent a test, the user has no way of knowing if the flexion stiffness of the lumbar spine-abdominal region is even remotely correct, if the next d-y is similar or substantially different, and if invisible to the eye failure or malfunction in the lumbar spine-abdomen area could have been a cause of a faulty test outcome.

Only recently lumbar spine-abdomen flexion stiffness was recognized of being of importance, particularly in slow speed and/or low g level crashes where the upper torso flexes substantially with respect to the lower part of the torso. Such flexing brings the dummy's head close to the air bag. Initially industry members of the SAE Task Force felt that the flexion of the torso through its mid-section is not an important issue for the belted occupant in normal crash tests. It appeared that criticality of upper torso kinematics regarding head-neck protection in slow speed and offset impacts in air bag deployment cases were not of primary concern and some variations in stiffness would not produce significant differences in response measurements. It appears now that that line of thinking is changing since the agency had demonstrated the stiffness variations in the lumbar spine-abdomen area are substantial and that out-of-position testing could become a reality. Recently, the SAE DTESC has incorporated the torso flexion test procedure in its proposed User Manual. To avoid further confusion and to assure similarity between dummies in this important area of connection between the upper and lower halves of the torso, the agency is proposing resistance to torso flexion specifications. Torso flexion tests, similar to those specified in 572.76 for the Subpart I the six-year-old child dummy, indicate that the dummy's lumbar spine-abdominal region develops a resistance to motion of approximately 339.8N (76.38 lbs) (Table D.6 of Appendix D) when the torso is flexed 45 degrees from vertical.

1X.7. Dynamic Crash Simulation (Sled) Testing

Following OOP testing, thirty dynamic sled tests were conducted, 28 of which utilized 2 dummies simultaneously. Two different vehicle systems were employed in these tests: a compact car and a mid-size car. The tests were conducted in actual vehicle bodies using standard seats, instrument panels, steering wheels and columns, air bags, and 3 point belt restraints. The seat tracks were reinforced and welded into the forward-most seating location. The seat belt buckle harness was removed from the seat track and secured to the vehicle frame. These two changes allowed repeated use of the same seat which, in turn, improved the ability to position the dummy in a repeatable seating location.

The test matrix, shown in Table 1X.7.1, was developed to evaluate the dummy's responses to several different restraint systems. Emphasis was placed on 3-point belt restraint tests because such an environment was considered to be the best condition for evaluating the repeatability of the dummies' response.

Sled Pulse Characteristics

The pulse for the compact car had a peak acceleration of approximately 32 g's, a duration of 90 ms, and its peak velocity was approximately 59 kph (Figure E.1, Appendix E). The pulse for the mid-size car had a peak acceleration of approximately 25 g's and a duration of 88 ms. The peak velocity was approximately 49 kph (Figure E.2, Appendix E).

Seating Procedure

One of the goals of the sled testing is the ability to demonstrate that the dummy is capable of repeatable responses when subjected to similar test conditions. To achieve this, it is important not only to replicate the impact environment, but also to position the dummies in a repeatable manner for subsequent testing. This is accomplished for the fifth percentile dummy by locating the seats in the forward-most track position and placing the dummy in the seat in what would be considered a reasonable posture of a seated vehicle occupant. To assure that the torso is in human-like and repeatable posture, the pelvic angle was set at approximately 22.5 degrees while the torso was leaned back resting along the recline of the seat-back and the head D-plane was adjusted to horizontal orientation. For the driver, the left and right hands were placed at the outer edge of the steering wheel rim at the 9 o'clock and 3 o'clock positions, respectively. The driver's left foot was placed on the floor pan while the right foot was set with the heel on the floor pan and the toes on the accelerator. The passenger's hands were placed along the outside of the thighs with the elbows against the sides of the torso. The feet of the passenger were placed on the floor pan.

Table 1X.7.1. Dynamic Sled Test Matrix

VRTC Test # V434H350--	TRC Test # TRC---	Buck	Driver S/N	Driver Condition	Passenger S/N	Passenger Condition
01	585	Compact	019	A	273	A
02	586	Compact	273	A	019	A
03	587	Compact	019	A	273	A
04	589	Compact	019	A	273	A
05	590	Compact	019	C	273	C
06	591	Compact	273	D	019	D
07	604	Midsize	019	A	273	A
08	605	Midsize	273	A	019	A
09	606	Midsize	273	A	019	A
10	607	Midsize	273	A	019	A
11	608	Midsize	273	C	019	C
12	609	Midsize	019	D	273	D
13	615	Midsize	273	A	019	A
14	616	Midsize	019	A	273	A
15	617	Midsize	273	A	019	A
16	618	Midsize	273	A	019	A
17	619	Midsize	019	A	273	A
18	620	Midsize	019	A	273	A
19	628	Midsize	273	A	289	A
20	629	Midsize	273	A	289	A
21	630	Midsize	289	A	273	A
22	631	Midsize	289	A	273	A
23	632	Midsize	289	A	273	A
24	633	Midsize	289	A	273	A
25	642	Midsize	273	A	289	A
26	643	Midsize	289	A	273	A
27	644	Midsize	273	A	289	A
28	645	Midsize	273	A	289	A
29	646	Midsize	n/a	n/a	289	B
30	647	Midsize	n/a	n/a	289	C

condition legend:
A = 3 point belt restraint; B = 3 point belt and air bag; C = air bag (only); D=unrestrained

Instrumentation of the Dummies

The dummies were instrumented for these tests with the sensors as shown in Table 1X.7.2.

Table 1X.7.2

Segment	Instrumentation	Manufacturer	Model No.
Head	3 accelerometers in tri-axial array	Endevco	7264
Neck	upper neck load cell	Denton	1716
Upper Torso	3 accelerometers in tri-axial array	Endevco	7264
	3 uni-axial accelerometers on sternum	Endevco	7264
	3 uni-axial accelerometers on spine	Endevco	7264
	thoracic load cell	Denton	2151A
Lower Torso	3 accelerometers in tri-axial array	Endevco	7264
	lumbar load cell	Denton	2152A
	iliac load cell	Denton	3743, 3744
Upper Leg	femur load cell	Denton	1914
Lower Leg	upper tibia load cell	Denton	3115
	lower tibia load cell	Denton	3287

Results

Summary of the more important results of driver tests is shown in Tables 1X.7.3.1 and passenger responses are contained in 1X.7.3.2. Summary of all measurements and their data traces are shown in Appendix E. In these tables, the V*C was computed using measurements from the sternum/spine accelerometer pairs for velocity and the chest pot for sternum compression.

Analysis of the d-y based test measurements indicate reasonably consistent responses without any apparent tendencies to drift as a function of time or frequency to impact exposure. Post-test inspections of the d-y hardware did not reveal any damage, visual indications of wear and tendencies of the hardware to take on permanent deformation.

Table IX.7.3.1.a Dynamic Sled Test Results - Driver

Test #V434H350--		01	02	03	04	05	06	07	08	09	10
dummy s/n		019	273	019	019	019	273	019	273	273	273
buck		small	small	small	small	small	small	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	air bag	unrestr	belted	belted	belted	belted
HIC		527	1295	1193	1199	148	816	1644	2382	968	1239
Neck Fx	N	-927	-1253	-1289	-1244	533	735	772	836	-882	-779
Neck Fz	N	2016	2572	2380	2459	1244	1994	3555	3040	3115	3299
Neck Moc+	Nm	34	13	15	14	33	34	50	15	48	40
Neck Moc-	Nm	-37	-44	-51	-50	-25	-39	-24	-23	-34	-33
Chest Res.	G	59	62	61	61	61	55	57	53	67	56
Chest X	mm	-45	-46	-47	-41	-50	-56	-40	-36	-49	lost data
V*C	m/s	0.57	0.56	0.54	0.50	0.42	1.45	0.40	0.54	1.10	lost data
Pelvis Res.	g	52	53	56	67	64	69	53	57	71	57
L. Femur Fz	N	-2265	-1749	-1629	-1785	-3849	-3737	-2026	1517	-2004	-922
R. Femur Fz	N	-756	-713	-292	-895	-4723	-5672	1456	1572	888	2037
comments		d-ring bolt failed									lost chest pot data

Table IX.7.3.1.b Dynamic Sled Test Results - Driver

Test #V434H350--		11	12	13	14	15	16	17	18	19	20
dummy s/n		273	019	273	019	273	273	019	019	273	273
buck		ms*	ms	ms	ms	ms	ms	ms	ms	ms	ms
condition		airbag	unrestr	belted	belted	belted	belted	belted	belted	belted	belted
HIC		189	1206	1399	1121	953	1040	1747	1368	1140	1292
Neck Fx	N	-695	-804	-831	-907	-761	-856	-775	-841	-722	-759
Neck Fz	N	1570	4582	3070	3391	2755	3290	3179	3008	1982	2084
Neck Moc+	N	31	23	57	36	23	29	46	43	21	32
Neck Moc-	N	-74	-33	-33	-36	-33	-36	-34	-35	-29	-31
Chest Res.	G	63	77	59	55	59	58	51	56	59	54
Chest X	m	-36	-54	-36	-38	-40	-40	-36	-36	-39	-37
V*C	m	0.55	2.02	0.39	0.39	0.63	0.52	0.35	0.33	0.38	0.35
Pelvis Res.	g	57	114	56	68	69	61	63	54	67	52
L. Femur Fz	N	-3693	-3883	-1491	-1857	-1684	-1674	-1982	-2298	-1510	-1226
R. Femur Fz	N	-3741	-8780	1847	1717	1849	2071	1825	1753	1597	1848
comments											

• ms - mid-size

Table IX.7.3.1.c Dynamic Sled Test Results - Driver

Test #V434H350--		21	22	23	24	25	26	27	28
dummy s/n		289	289	289	289	273	289	273	273
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	belted	belted	belted	belted
HIC		1050	919	1079	1259	859	981	1436	1392
Neck Fx	N	-765	-752	-741	-768	-824	-706	-814	-888
Neck Fz	N	2296	2480	3039	2477	2128	2257	2440	2909
Neck Moc+	Nm	33	32	66	29	23	46	42	35
Neck Moc-	Nm	-34	-34	-31	-35	-31	-36	-36	-39
Chest Res.	G	55	57	52	53	55	52	51	58
Chest X	mm	-41	-43	-40	-43	-40	-37	-33	-39
V*C	m/s	0.38	0.47	0.35	0.50	0.36	0.26	0.26	0.43
Pelvis Res.	g	51	56	49	50	59	49	61	56
L. Femur Fz	N	-1364	-1854	-1726	-1907	-2107	-1504	-1472	-1648
R. Femur Fz	N	1667	1697	1720	1610	1898	1600	1737	1898
comments									

Table IX.7.3.2.a Dynamic Sled Test Results - Passenger

Test #V434H350--		01	02	03	04	05	06	07	08	09	10
dummy s/n		273	019	273	273	273	019	273	019	019	019
buck		small	small	small	small	small	small	ms*	ms	ms	ms
condition		belted	belted	belte	belted	air bag	unrestr	belted	belted	belted	belted
HIC		1759	1950	1937	1937	283	2646	761	829	876	947
Neck Fx	N	-1051	-1341	-	-1383	1248	2629	-1588	-1661	-1792	-1979
Neck Fz	N	2488	2576	2438	2334	404	1092	2167	2422	2270	2375
Neck Moc+	N	21	15	22	25	95	20	77	45	50	47
Neck Moc-	N	-40	-42	-39	-38	-20	-390	-20	-22	-22	-24
Chest Res.	G	53	53	56	56	40	100	54	46	47	53
Chest X	m	-37	-47	-39	-39	-13	-27	-37	-43	-39	-35
V*C	m	0.32	0.32	0.32	0.29	0.09	0.94	0.32	0.26	0.39	0.24
Pelvis Res.	g	53	58	61	62	57	70	61	44	50	50
L. Femur Fz	N	-2277	-1570	-	-1933	-3236	-4767	1586	831	1073	1323
R. Femur Fz	N	-2864	-490	-	-897	-4063	-4065	1438	-958	-2048	-1200
comments											

Table IX.7.3.2.b Dynamic Sled Test Results - Passenger

Test #V434H350--		11	12	13	14	15	16	17	18	19	20
dummy s/n		019	273	019	273	019	019	273	273	289	289
buck		ms	ms	ms	ms	ms	ms	ms	ms	ms	ms
condition		air bag	unrestr	belted	belted	belted	belted	belted	belted	belted	belted
HIC		270	984	839	713	1001	960	862	915	963	924
Neck Fx	N	720	-1312	-1991	-1478	-2016	-2027	-1747	-1674	-1631	-1561
Neck Fz	N	2888	994	2420	2000	2758	3001	2310	2385	2348	2525
Neck Moc+	N	29	25	48	60	53	46	72	68	83	67
Neck Moc-	N	-94	-150	-39	-46	-46	-36	-40	-42	-43	-38
Chest Res.	G	69	76	56	56	56	58	55	51	55	53
Chest X	m	-12	-46	-33.1	-30.4	-33.6	-35.2	-37.4	-32.1	lost	-34
V*C	m	0.10	1.92	0.24	0.36	0.26	0.25	0.38	0.33	lost	0.27
Pelvis Res.	g	55	63	57	56	58	55	53	49	70	51
L. Femur Fz	N	-3721	-5460	1623	1455	1439	1524	1489	1487	1517	1463
R. Femur Fz	N	-3275	-3780	599	756	1145	938	1656	1405	1210	1329
comments										lost chest pot data	

Table IX.7.3.2.c Dynamic Sled Test Results - Passenger

Test #V434H350--		21	22	23	24	25	26	27	28	29	30
dummy s/n		289	289	289	289	289	273	289	289	289	289
buck		ms	ms	ms	ms	ms	ms	ms	ms	ms	ms
condition		belted	belted	belted	belted	belted	belted	belted	belted	ab+ belt	air bag
HIC		780	824	780	693	792	626	897	912	483	393
Neck Fx	N	-1633	-1666	-1523	-1433	-1547	-1492	-1601	-1587	-1174	-454
Neck Fz	N	2204	2316	2177	2177	2209	2027	2490	2442	1724	1913
Neck Moc+	N	69	70	74	59	70	56	71	75	11	21
Neck Moc-	N	-42	-38	-43	-43	-25	-18	-26	-26	-64	-89
Chest Res.	G	54	53	55	57	55	52	53	54	57	101
Chest X	m	-33	-31	-32	-33	-35	-34	-36	-37	-35	-12
V*C	m	0.26	0.24	0.25	0.30	0.27	0.25	0.26	0.31	0.34	0.11
Pelvis Res.	g	58	52	55	61	60	57	53	57	52	51
L. Femur Fz	N	1561	1471	1435	1622	1613	1627	1449	1481	1393	-3628
R. Femur Fz	N	1378	1276	1193	937	1038	1112	1167	1026	1444	-3944
comments											

1X.8. Neck Wrap and Head Skin Modifications

Background

Historically, industry testing of the small female dummy in out-of-position (OOP) scenarios has generated questions about the biotidelity of the neck and chin. Specifically, there were concerns raised in the SAE Hybrid III Family Task Group that the airbag material was expanding into the chin cavity and around the neck during OOP testing and this phenomena was believed to result in unrealistic neck responses.

To eliminate this problem the SAE Task Group proposed a modified head skin and the addition of a neck wrap. The head skin, referred to as the TMJ skin, contains vinyl which closes out the chin cavity and which also provides a more realistic jaw line. Pictures of the TMJ head skin are shown in Figs. F.l. and F.2. in Appendix F. The neck wrap consists of a rectangular wet-suit-like material with a Velcro closure which allows the material to be wrapped around the neck. This wrap covers the metal disks in the neck and prevents airbags from catching on the disks. The agency has evaluated the neck wrap and TMJ head skin by conducting OOP tests and neck calibration tests.

Static Out-of-Position (OOP) Testing

To evaluate the TMJ skin and neck wrap, VRTC conducted driver OOP tests in the IS0 1 position using the '98 Ford Explorer airbag system (see Fig. F.3). Of a total of 10 tests four were conducted with the standard head skin and no neck wrap, three with the TMJ head skin and the neck wrap, and three with the TMJ head skin and no neck wrap. The results of significance appear in Tables F.1, F.2, and F.3 in Appendix F. Table 1X.8.1. below compares the computed averages for the neck responses for each set of tests.

Table 1X.8.1. Average Neck Responses for OOP Tests

		standard head skin, no neck wrap	TMJ head skin, neck wrap	TMJ head skin, no neck wrap
		AVG	AVG	AVG
Neck Fx	**N**	-70 1.4	-777.6	-603.3
Neck Fz	**N**	1024.5	1029.1	1042.3
Nèck Moc	m	-33.7	-43.1	-27.2

Review of the high speed films of the OOP events and post-test observations of the air bag cushion indicate that, in the case of the standard configuration head skin, the cushion is inflating into the chin cavity area. At that time, the cushion snags slightly behind the jaw as the d-y begins to move rearward in the vehicle. With the TMJ head skin and the neck wrap, the cushion does not penetrate the chin cavity region. Also, the TMJ feature of the head skin, with its improved jaw-line, prevents the cushion from snagging behind the jaw as it did in the standard head skin configuration. Thus, even though the TMJ-neck wrap configuration had some effect on the responses, it contained some desirable features.

Calibration Testing

In Fall '97, VRTC conducted standard neck calibration tests with two configurations: (1) the standard configuration head and neck and (2) the standard head skin with a soft foam chin insert and the SAE-proposed neck wrap. This neck wrap was the same as the one used in the OOP testing in conjunction with the TMJ skin. Three tests were conducted for each condition - flexion with neck skin, flexion without neck skin, extension with neck skin, and extension without neck skin - for a total of 12 tests.

Tables F.4. and F.5. in Appendix F. summarize the results of the tests. Review of Tables F.4. and F.5. indicate that pendulum tests appear to be unable to establish differences between the response with and without the neck skin when used with the standard head skin.

X. Discussion

X.1 Anthropometry and Weight Distribution

Data in Table 1X.3.1 indicate that the d-y's external dimensions and weight are within the range of SAE Task Force targets except for minor discrepancies in popliteal height (anthropometry), and the weights of lower torso assembly and the feet. The discrepancy in popliteal height is approximately one inch: the d-y measures 13.38 inches vs. the Task Force target of 14.4 inches. The popliteal height on the other hand for the 5th percentile U.S. female population (ref. l-l) is on the average 14.0 inches and the extremes of that size population group vary from 14.2 inches at the high end to 13.5 inches at the low end. Similarly, the dummy's overall weight (Table 1X.3.2) at 107.7 lbs is 4.7 lbs higher than originally target set by the SAE Task Force at 103 lbs, but lower by 1 lb than suggested weight by the DTESC at 108.74 lbs (Appendix A.l). Ref. 1 indicates that the average weight for the 5th percentile female is 104 lbs. The extremes of that size population group range from 112 lbs at the high end to 95 lbs at the low end.

It is our judgement that the noted discrepancies in one external dimension and the weights of the lower torso and feet as a whole would have minimal effects on the performance of the dummy as a surrogate for the 5th percentile female vehicle occupant. In a vehicle crash test, the popliteal height, unlike the seated height of the dummy which is identical to the average fifth percentile female, would appear to be of minor importance in the test outcome. The popliteal height is a partial but incomplete indicator of lower leg length. We do not know if minor differences in popliteal height would have any effect on the dummy's impact response, but expect their effects to be extremely small and difficult to measure. Similarly, differences of 3 lbs in body weight between the d-y and real world small female occupant population is only three percent from the mean and falls well within the weight range for that segment of the female population.

X.2 Static OOP Testing

The OOP test results were not intended to demonstrate repeatability or reproducibility, mainly due to the variability inherent with this type of testing where the results are highly dependent on several factors, including: air bag fabric unfolding characteristics, air bag inflator variability, and precise d-y positioning. Therefore, these tests were primarily geared toward the evaluation of the dummies' durability and the integrity of the instrumented measurements.

After eliminating the initially encountered chest potentiometer arm ball dislodgement problem, the results of the tests demonstrate good structural integrity and measurement capability of the d-y. Table C.1 in Appendix C indicates that the d-y, when tested in the driver position, can sustain significant loading to both the neck and chest without experiencing disabling damage. For example, in test # 39 the d-y "survived" loading to the chest which resulted in 62.4 mm of sternum deflection (nearly full compression of the ribs). During this test the neck also experienced significant shear loads (Neck Fx) reaching -2659 N and a neck moment (Neck Moc) measuring -112 Nm. Post-test inspections of the d-y did not indicate any structural and durability problems. The results in Table C.2. demonstrate through the consistency of the responses that the d-y has adequate structural integrity. In test #28, the dummy sustained extremely high loading levels to the head and neck without evidence of structural damage. In this extreme loading condition the HIC was 33 19, the neck shear load (Neck Fx) -9918 N, the neck axial load (Neck Fz) 9884 N, and the neck moment (Neck Moc) -143 Nm. Similarly, the thorax of the d-y experienced high loadings in tests # 16, 17, and 46 without developing structural damage and loss of measurement integrity. Additional data and figures for the static OOP testing can be found in Appendix C.

X.3 Calibration

Repeatability and reproducibility analysis were performed on the calibration responses. Repeatability is the measure of one d-y's ability to repeat its responses over time. Reproducibility is the measure of two or more dummies' ability to provide similar results. The analysis computes the average, standard deviation, and the coefficient of variation (%cv) for comparable data sets. By ISO/TC22/SC12/WG5 d-y rating practice, %cv between 0 and 5% is considered excellent; above 5% is good and as the %cv approaches 10% it becomes borderline acceptable. Any %cv value above 10% is considered poor. These computed cv-s appear at the bottom of each of the tables in Appendix D. In some instances, repeatability for d-y number 289 has not been assessed, due to small sample sizes. Response traces of measurements from the calibration tests are contained in Appendix D.

Head Drop. The average impact response for d-y #273 head was 276.6 g and the average for both dummies was 274.1 g (statistical analysis for #289 was omitted due to small sample size).

These results match the proposed DTESC acceptance corridor of 240g-295g, but are better centered within 250G to 300g range Repeatability of peak resultant head acceleration for dummy #273 is excellent as is the reproducibility for both dummies.

Neck Flexion The average peak D-plane rotation of the head for d-y #273 was 83.66 degrees while the average for d-y #289 was 88.76 degrees. The average for both dummies was 85.92 degrees. These average responses all fall within the DETSC suggested corridor of 78 to 96 degrees. The %cv of D-plane rotation for d-y #273 was 1.72% and for d-y #289 was 1.34%. The %cv of D-plane rotation for both dummies combined was 3.33%. Thus the repeatability of D-plane rotation for each d-y and the reproducibility of both dummies was considered to be excellent for this test series. Based on statistical distribution of neck flexion responses, it appears that the DETSC recommended corridor is considerably larger and would allow significant variations of the neck than it needs to be. Accordingly, the neck flexion corridor is adjusted to a range of +/- two standard deviations from the mean of the measured data, which sets the lower rotation limit at 80 degrees and the upper limit at 92 degrees. As a consequence of this adjustment, all of the d-y neck flexion responses are better centered and within the boundaries of the corridor.

The average peak moment occurring during the rotation interval was 73.29 Nm for d-y #273 and 78.90 Nm for d-y #289. The average for both dummies was 75.78 Nm. Again, these average response are well within the DTESC suggested criteria for neck moment (69-84 Nm). The %cv of peak moment was 2.09% for d-y #273 and 2.32% for dummy #289. The %cv of peak moment for both dummies was 4.29. The results indicate excellent repeatability and reproducibility for the peak moment response. Based on statistical distribution of neck moment responses, it appears that the DTESC recommended corridor's upper limit is slightly higher than it needs to be. Accordingly, the neck maximum moment in flexion corridor is adjusted to a range of +/- two standard deviations from the mean, which sets the lower moment limit at 69 Nm and the upper limit at 83 Nm. This adjustment provides for better centered data within the proposed boundaries and assures fewer calibration rejections.

Inasmuch as the DTESC procedure was somewhat indefinite on how to address the determination of the decay time from either the rotation or the moment base when multiple peaks occur in the moment vs. time response, the agency selected to calculate the decay time from initial point at time of contact to the time the decaying positive moment first crosses the 10Nm value. This corridor's lower limit was set at 80 ms and the upper limit at 100 ms. The average time for the positive moment to decay to 10Nm was 89.19 ms for d-y #273 and 89.54 ms for d-y #289. Combining the results of both dummies yields an average time of 89.34 ms. The %cv of time for positive moment decay to zero was 0.67 for d-y #273 and 1.33 for d-y #289. The %cv for both dummies was 1.04. These extremely low cv values indicate excellent repeatability and reproducibility of the d-y neck for positive moment decay measurement.

Neck Extension The average peak D-plane rotation of the head for d-y #273 was 102.37 degrees and the average for d-y #289 was 104.14 degrees. The average for both dummies was 103.11 degrees. These average responses all fall within the DTESC corridor of 97 to 119 degrees. The %cv of D-plane rotation for d-y #273 was 1.64% and for dummy #289 was 1.40%. The %cv of D-plane rotation for both dummies combined was 1.76%. Thus the repeatability of D-plane rotation for each dummy and the reproducibility of both dummies was considered to be excellent for this test series. Based on statistical distribution of neck extension responses, it appears that the DTESC recommended corridor is somewhat miss-centered relative to the dispersion range of the tested necks and is larger and would allow significant variations of the neck than needs be. Accordingly, the neck extension corridor is proposed for adjustment to a range of +/- two standard deviations from the mean of the measured data, which suggests the lower rotation limit at 97 degrees and the upper limit at 109 degrees. With this adjustment, the dummies' thorax responses are better centered and within the boundaries of the revised corridor.

The average peak moment occurring during the rotation interval was -60.74 Nm for d-y #273 and -63.82 Nm for d-y #289. The average for both dummies was -62.02 Nm. These average responses fall within the specified range for neck moment of -54 to -67 Nm. The %cv of peak moment was 4.09% for d-y #273 and 6.29% for d-y #289. The %cv of peak moment for both dummies was 5.73. The repeatability of peak moment response was excellent for d-y #273 and good for d-y #289. The reproducibility of peak moment response for both dummies was good. Based on statistical distribution of neck moment responses, it appears that the DTESC recommended corridor is somewhat miss-centered relative to the dispersion range of the tested necks. Accordingly, the neck moment in extension corridor is proposed for adjustment to a range of +/- two standard deviations from the mean of the data, which suggests the lower moment limit at -55 Nm and the upper limit at -69 Nm. With this adjustment, all of the d-y neck responses are better centered and within the boundaries of the revised corridor.

To be generally consistent with the selected moment decay criteria for neck flexion the agency calculated the decay time from initial point at time of contact to the time the decaying negative moment crosses the -10 Nm level. Statistical distribution of the data suggests that the corridor's lower limit at +/-2 standard deviations is 100 ms and 110 ms for the upper limit. The average time for the negative moment to decay to -10 Nm was 102.67 ms for d-y #273 and 105.50 ms for d-y #289. Combining the results of both dummies yields an average time of 103.85. The %cv of time for negative moment decay to zero was 1.11% for d-y #273 and 1.47% for d-y #289. The %cv for both dummies was 1.85. The %cv data indicate that repeatability and reproducibility of the d-y's neck response in extension moment decay time was excellent for this test series. However, closer inspection of the test results also revealed that the data is not normally distributed and accordingly, the limits should be set higher than 2 standard deviations. To accommodate for the skewness of the data distribution, the limits were somewhat expanded, allowing the moment decay to occur between 94 ms and 114 ms. As a consequence of this adjustment, the d-y neck responses are better centered and well within the boundaries of the revised corridor.

<u>Thorax Impact</u> The average peak sternum-to-spine deflection was 52.17 mm for d-y #273 and 5 1.55 mm for d-y #289. The average deflection for both dummies combined was 5 1.92

mm. These average responses, although within the DTESC range of 5 1 to 58 mm, are on the low side of the corridor. D-y #273 had a %cv for deflection of 1.8 1% while d-y #289 had a %cv of 3.21%. The combined %cv for both dummies was 2.53%. Thus the repeatability of each d-y's deflection response and the reproducibility for both dummies was considered excellent. Based on statistical distribution of the deflection responses, it appears that the DETSC recommended corridor is considerably miss centered relative to the dispersion range of the tested thoraxes. The data at +/- two standard deviations from the mean suggest that the lower deflection limit be set at 48 mm and the upper limit at 55 mm. With this adjustment, the d-y neck responses are better centered and within the boundaries of the revised corridor.

The average force at time of peak deflection for d-y #273 was 3710.88 N and for d-y #289 was 3881.00 N. The average for both dummies was 3779.00 N. The %cv for force at peak deflection for d-y #273 was 2.24% and the %cv for d-y #289 was 1.85%. The combined results of both dummies' responses yielded a %cv of 3.04%. Although the cv values indicate excellent repeatability and reproducibility, it appears that the DTESC recommended corridor is considerably miss-centered relative to the dispersion range of the tested thoraxes. The data at +/- two standard deviations from the mean indicate that the entire corridor would need to be raised by approximately 250N.

To resolve these differences, the agency reviewed the force-time and force-deflection traces generated in thorax impact tests as shown in Appendix D. The review indicates that specification of force at maximum deflection is subject to possible misinterpretations and disputes on what the real magnitude of the force is. For example, misinterpretations may be caused by small variations in the slope of the force as it approaches maximum deflection, particularly if the loading presents a long line of tangency at the deflection limit. Also, the specification of force only at maximum deflection, besides being potentially disputable as to its magnitude, would permit exceedingly high or low force level responses anywhere prior to reaching maximum displacement. While data traces would obviously indicate, based on qualitative judgement, inappropriate chest performance, the inadequacy of the chest could not be ascertained because the force requirement at maximum deflection would be fully met. In addition, biomechanical response corridors for the chest in impactor tests indicate that the chest should respond with fairly gradually increasing force which peaks out before reaching the maximum deflection limit. Specification of force at only maximum deflection would fail to address this specific biomechanical response characteristic. For this reason, the agency investigated an approach that has been used in the past: to specify a peak force-sternum deflection window, which would provide more assurance that the ribcage has appropriate force resistance levels immediately prior to the point of maximum deflection rather than only at maximum deflection. To ascertain whether the d-y's thorax performance falls in line with biomechanical response characteristics, the agency re-reviewed the thorax response data to determine which of the response parameters would best define what the chest is capable of. Force deflection data traces in these tests reveal that the dummies' thoraxes respond reasonably consistently with a force that peaks out within the specified deflection corridor. The specification of maximum peak forces would also assure that those forces are reasonably close to the biomechanical corridor's upper limit established by the SAE HIII DFTG. Of the 9 thorax impacts, all of the peak force responses cluster closely around the mean value of 4160.7 N, except that in one impact test (289C3TH1) the peak force occurs just barely outside the specified deflection corridor, missing the lower deflection limit by less than 1 mm. Both the peak force outside and the peak force inside the deflection corridor for test 289C3TH1 were within the specified peak force limits. Peak forces for all tests within the deflection corridor averaged at 4148 N with a standard deviation at 111.2 N, and peak forces irrespective of the deflection corridor showed an average force level of 4160.7 N with a standard deviation at 111.2N. The %cv for the combined dummy responses is less than 2.7.

Accordingly, it is proposed that the thorax acceptance be based on peak force minimum and maximum limits which must occur within the specified deflection corridor. The force limits are proposed at +/- two standard deviations from the mean, with a minimum peak force of 3900 N and max. at 4400 N. To assure that the d-y thorax response approximates biomechanical response corridors throughout the chest compression event, it is also proposed that the force response level at any compression prior to reaching the minimum required deflection limit, does not exceed by 5 % the maximum recorded peak force value within the specified deflection corridor. The latter requirement would not exclude use of the dummy whose responses are similar to test 289C3TH1 since they would be within permissible force limits both inside and outside the specified deflection corridor.

The average internal hysteresis for d-y #273 was 74.27%, 76.13% for d-y #289, and 75.01% for both dummies combined. All of these results are well within the corridor of 69 to 85 %. The %cv for internal hysteresis was 0.62% for dummy #273, 0.90% for d-y #289, and 1.42% for both dummies combined. These assessment values indicate excellent repeatability and reproducibility based on measured internal hysteresis responses.

Knee Impact The average peak impact force was 3713.32 N for dummy #273, 3722.32 N for d-y #289, and the combined average response for both dummies was 3715.96 N. These responses fall reasonably well within the DETSC suggested corridor of 3400 to 4200 N. The %cv for peak impact force was 5.12 % for d-y #273 and 4.05% for d-y #289. The combined %cv for both dummies was 4.83. Thus the repeatability of peak impact force for dummy #273 was good, while the repeatability for #289 and reproducibility for both dummies are considered to be excellent. However, based on statistical distribution of the deflection responses, it appears that the DTESC recommended corridor is somewhat miss-centered and excessively large. The response data at +/- two standard deviations from the mean suggests that the lower force limit be set at 3360N and the upper limit at 4080N. With this adjustment, the dummy neck responses are better centered and fall well within the boundaries of the revised corridor.

Torso Flexion. In response to the need to control the resistance forces to torso flexion and to assure that structural failures or miss-fining assembly of the lumbar spine-abdomen components would not be a cause of a faulty test outcome, the agency conducted torso flexion tests. The tests were based on a dummy set-up and a single-point pulley configuration for application of loading as shown in Figure 04. In this set-up, the dummy is attached to the test fixture at the pelvis while the pelvis angle is set to zero (horizontal). The spine is then held upright such that the rear surface of the spine box is vertical and the angle rotation instrumentation is electronically set to a value of zero. Next, the dummy is released from vertical and allowed to settle into position under its own weight. Then the upper half of the torso is flexed at a rate of 1 degree per second until a back angle of 45 degrees is achieved. The force is continuously recorded during the flexion.

The results of three tests show (Table D.6 of Appendix D) that the dummy in initial set-up tests tends to sag approximately 15 degrees under its own weight. Thus to achieve a final angle of 45 degrees, the torso must be rotated through an additional 30 degrees. The results indicate that an average force of 339.8 N (76.38 lbs), applied at the occipital condyle level, was required to achieve a flexed spine back angle of 45 degrees. The force level for the three loading applications ran between 75.03 lbs and 78.32 lbs. Although additional tests are suggested to reaffirm the width of the performance corridor, it appears that +/- 7% variability, based on variablities of other body segment responses, is a reasonable level for this application. Accordingly, a corridor for resistance to torso flexion is proposed between 289 N and 378 N (65 lbs and 85 lbs).

X.4 Sled Testing

Thirty dynamic sled tests were conducted, 28 of which utilized 2 dummies simultaneously, for a total of 58 exposures. Two different vehicle systems were employed in these tests: a compact car and a mid-size car. The tests were conducted in actual vehicle bodies using standard vehicle equipment (dashes, restraint systems, etc.) The test matrix was developed with an emphasis placed on 3-point belt restraints because such an environment was considered to be the best condition for evaluating repeatability of the dummies' responses. To that end, a total of 48 exposures (driver and passenger, both vehicles considered) were conducted with 3-point belt systems. A small number of additional tests were conducted to evaluate the dummy's ability to distinguish the effects of different crash pulses and restraint systems and to analyze the durability of the dummy's structural integrity and instrumentation. These additional tests included dummies in air bag restraints, combination of air bag and 3-point belt restraints, and no restraints (see Table 1X.7.1).

Compact Car - Driver Responses (Table X.4.1) Tests conducted in the compact car with seats full forward placed the small female dummy in very close proximity to the steering wheel. As in typically belt restrained tests, the d-y's pelvis remained in the seat and the upper torso pitched forward. The subsequent forward head excursion would result in the dummy's head contacting the steering wheel and this in turn would lead to higher resultant head accelerations (HICs) and higher neck loads as compared to the other test conditions. In the air bag and unrestrained tests, the torso and lower extremities shared in the absorbtion of more of the impact energy, leading to higher chest displacements, V*C, pelvis accelerations, and femur loads than in comparable belt restrained tests. It is interesting to note that the HIC and neck loads were generally lower on unrestrained than on belt restrained dummies. This phenomena can be explained by the aforementioned head excursion in the belted tests which resulted in severe impacts of the head with the steering wheel.

Table X.4.1. Selected Average Responses of the Driver Dummy (Compact Car Sled Tests)

	sample size	3	1	1
	condition	belted	air bag	unrestrained
HIC		1229	148	816
Head Res.	G	92	47	93
Neck Fx	N	-1262	533	735
Neck Fz	N	2470	1244	1994
Neck Moc+	Nm	14	33	34
Neck Moc-	Nm	-48	-25	-39
Chest Res.	G	68	61	66
Chest X	mm	-45	-50	-56
V*C	m/s	0.53	0.42	1.45
Pelvis Res.	G	55	64	69
L. Femur Fz	N	-1881	-3849	-3737
R. Femur Fz	N	-587	-4723	-5672

Compact Car - Passenner Responses (Table X.4.2) The full forward seat placement positioned the dummy in close proximity to the instrument panel (I/P). In belt restrained tests, the dummy's kinematics was similar to those observed in the compact car driver tests. The forward head excursion resulted in contact with the I/P, leading to relatively high HIC's and neck loads. The air bag test was very successful in terms of reducing the loading to the head, neck, and thorax. The unrestrained test resulted in severe contact of the dummy's head with the windshield. The severity of the test is demonstrated in the high HIC response (2646), neck shear load (2629 N), neck extension moment (-390 Nm), and chest acceleration (100 g).

Table X.4.2. Selected Average Responses of the Passenger Dummy (Compact Car Sled Tests)

	sample size	4	1	1
	condition	belted	air bag	unrestrained
HIC		1896	283	2646
Head Res.	G	130	48	194
Neck Fx	N	-1305	1248	2629
Neck Fz	N	2459	404	1092
Neck Moc+	Nm	21	95	20
Neck Moc-	Nm	-40	-20	-390
Chest Res.	G	55	79	113
Chest X	mm	-41	-13	-27
V*C	m/s	0.31	0.09	0.94
Pelvis Res.	G	59	57	70
L. Femur Fz	N	-1745	-3236	-4767
R. Femur Fz	N	-1591	-4063	-4065

Mid-size Car - Driver Resuonses (Table X.4.3) As compared to the compact car, the forward located seat in the mid-sized car provided slightly more clearance between the dummy and the steering wheel. However, in sled tests, the forward excursion of the belt restrained dummy's head still resulted in contact with the steering wheel. As a consequence, the HIC values and neck loads are higher than expected. The air bag test significantly reduced the dummy's head and chest loading, however, the neck extension moment was considerably elevated. Review of the high speed films revealed that this extension moment was due to the high degree of neck hyperextension. Compared to compact car driver responses, the unrestrained driver dummy experienced in the mid-size car test higher HIC values (1206 vs 816), chest accelerations (77 g vs 66 g), pelvis accelerations (114 g vs 69g), right femur load (8780 N vs. 5672 N) and V*C (2.02 vs 1.45), but lower sternum compression (54 mm vs 56 mm) and neck extension moments (33 Nm vs 39 Nm).

Mid-size Car - Passenger Resuonses (Reference Table X.4.4) Whereas head contact with the I/P was observed in the compact car with the 3-point belt restraint, the selected mid-size car interior afforded enough space such that the dummy's head would not make contact with the I/P. As a result, the head accelerations and HIC responses were considerably lower for the belt restrained dummies in the sled tests of the mid-size car as compared to the corresponding belted tests in the compact vehicle. The air bag was successful at reducing the head and chest loading, but there was, once again, unusual neck kinematics which resulted in high neck extension moments. Use of air bag and belts to restrain the dummy produced an improvement in terms of relatively low HIC, lower neck extension moment and chest acceleration. In the unrestrained test, the dummy's head made severe contact with the windshield. Compared to compact car passenger responses, the unrestrained passenger dummy experienced in the mid-size car test lower HIC value (984 vs 2646), chest acceleration (76 g vs 113 g), neck extension moment (150 Nm vs 390 Nm), pelvis accelerations (63 g vs 70 g), left femur load (3780 N vs. 4065 N), but higher sternum compression (46 mm vs 27 mm), right femur load (5460 vs 4767) and V*C (1.92 vs 0.94).

Table X.4.3 Selected Average Responses of the Driver Dummy (Mid-size Car Sled Tests)

	sample size	9	1	1
	condition	belted	airbag	unrestrained
HIC		1238	189	1206
Head Res.	G	186	58	195
Neck Fx	N	-795	-695	-804
Neck Fz	N	2618	1570	4582
Neck Moc+	Nm	39	31	23
Neck Moc-	Nm	-34	-74	-33
Chest Res.	G	54	63	77
Chest X	mm	-38	-36	-54
V*C	m/s	0.36	0.55	2.02
Pelvis Res.	G	56	57	114
L. Femur Fz	N	-1742	-3693	-3883
R. Femur Fz	N	1783	-3741	-8780

Each dummy was inspected for structural integrity following each test. These inspections revealed no significant structural deficiencies present in the dummy design.

One important discovery took place during the sled testing. Analysis of the measured responses revealed significant spikes in the z-axis data channels of the dummy. This noise was evident in a number of pelvis, chest, and head accelerometers; and lumbar, thoracic, and neck load cells. In some instances, the spikes were coincident with the peak response values, rendering data from certain channels contaminated. However, in some cases, the spikes did not affect the peak responses and the data was still useful. Inspection of the dummy revealed that the lumbar spine cable was not isolated and could move within its mounting, causing metal-to-metal impact. Plastic bushings-spacers were inserted around both ends of the cable and the test conditions repeated. The results indicated that the inserts eliminated the spiking problems. These findings were shared with the SAE H-III DFTG on Feb. 12, 1998, and the consensus was that the lumbar spine bushings-spacers should be added to the standard equipment of the d-y.

Appendix E contains additional data and response traces from measurements made in the sled tests.

Ta e X.4.4 Selected Average Responses of the Passenger Dummy (Mid-size Car Sled Tests)

samplesize		9	2	1	1
condition		belted	air bag	bag & belt	unrestrained
HIC		854	332	483	984
Head Res.	G	66	79	73	113
Neck Fx	N	-1615	-541	-1174	-1312
Neck Fz	N	2340	2401	1724	994
Neck Moc+	N	71	25	11	25
Neck Moc-	N	-25	-92	-64	-150
Chest Res.	G	54	85	57	76
Chest X	m	-34	-12	-35	-46
V*C	m/	0.29	0.11	0.34	1.92
Pelvis Res.	G	54	53	52	63
L. Femur Fz	N	1494	-3675	1393	-5460
R. Femur Fz	N	1274	-3610	1444	-3780

X. 5 Repeatability nd Reproducibility

Repeatability and reproducibility analysis are based on sled tests of belt restrained dummies #273 and #289 in the passenger position. The sled pulse was for the mid-size car with peak acceleration of approximately 25 g's, 88 ms in duration and a peak velocity of 49 kph. The analysis is based on impact responses of the head, neck, chest, pelvis, and right and left femurs.

In order to make a reasonable comparison of responses, the agency analyzed the results of those tests in which the d-y was subjected to repeatable test conditions. The most repeatable test condition was when the d-y was seated in the passenger seat of the mid-size vehicle and the 3-point belt system was the only restraint. The tests conducted matching these conditions were #'s 7, 14, 17, 18, 21-24, and 26 with d-y #273; and #'s 19, 20, 25, 27, and 28 with d-y #289. Some of these tests were omitted from the analysis, however, due to events which make them poor candidates for repeatability analysis. For example, tests # 7, 19, 24, and 26 each have data in which the peaks are affected by the noise phenomena emanating from the lumbar spine cable problem discussed earlier. In addition, test # 7 utilized a different seat than did the other tests, causing the seating position of the d-y to be altered slightly. Finally, test # 14 experienced submarining on one side of the pelvis due to improper positioning of the lap belt. It should also be pointed out that tests conducted in the compact vehicle were not considered for repeatability analysis. In these tests, the dummies' heads would contact surfaces within the vehicle compartment. Inasmuch as we had no knowledge about the structural consistency of the impacted surfaces, we could not make a judgement at this time that the variability observed in the head response was solely caused by the variabilities within the dummy.

Reneatabilitv - dummv # 273

Repeatability analysis of dummy #273, refer to Table X.5.1. In general, there was no observed tendency for the responses to drift in any particular direction.

Head. The head injury criterion (HIC) has been computed from the resultant head acceleration response. The average HIC was 832.2 and the %cv was 6.9. The repeatability of the HIC response was good for this test series.

Neck. The neck responses considered for this analysis include the neck shear force in the x-direction (Neck Fx), the neck axial force (Neck Fz), and the neck moment about the occipital condyle (Neck Moc). The average shear force was -1648.6 N and the average axial force was 2278.4 N. The average moment in flexion was 70.6 Nm and the average moment in extension -24.4 Nm. The %cv for shear force and axial force was 5.0% and 3.8%, respectively. The %cv for flexion moment was 3.5% while the %cv for extension moment was 7.2%. Therefore, the repeatability of the neck responses are excellent except for the neck extension moment (Neck Moc) which still demonstrates reasonably good repeatability. In fact, the standard deviation of the neck extension moments is lower than that of the flexion responses. However, the magnitude of the average extension moment is considerably lower, thus making its coefficient of variation higher.

Chest. The resultant chest acceleration (Chest Res.), chest deflection (Chest X), and the viscous criterion (V*C) are all considered in the repeatability analysis. The viscous criterion is computed by taking the product of the sternum velocity relative to the spine and the normalized sternum displacement. The sternum velocity is computed by integrating the acceleration of the sternum relative to the spine. The average chest resultant acceleration was 53.6 g's, the average chest deflection was 33.2 mm and the average V*C was 0.29. The %cv for acceleration, deflection, and V*C was 3.4%, 7.4%, and 20.7%, respectively. The resultant chest acceleration demonstrates excellent repeatability. The chest deflection response exhibits good repeatability. With the exception of test #17, the chest deflection responses has a range of less than 2 mm. It appears that the shoulder belt in test #17 might have been positioned slightly differently, thus presenting the sternum with a modified loading path. The repeatability of the V*C measurement is poor. There are two possible explanations for this: one - the integration required for computing the sternum velocity introduces mathematical errors; and two - the magnitude of the V*C response is quite small which substantially exaggerates the importance of the %cv value.

Pelvis. The peak resultant pelvis acceleration (Pelvis Res.) was also considered for this analysis. The average peak resultant pelvis acceleration was 53.4 g and the %cv of the response was 6.3%. Thus, the repeatability of the resultant pelvis acceleration was good.

Femurs. Due to the geometry of the interior components, the femurs in these tests experienced primarily inertial loading. As a result, the femurs were mainly loaded in a tensile mode as knee contact with the knee bolster was only slight, at best (note: for the femur load cell, positive output indicates tension while negative output indicates compression). Analysis of the responses reveal that the left leg does not appear to make any contact with the knee bolster, while the right leg seems to make slight contact at approximately 45 - 55 ms. The timing and degree of knee bolster contact varies with each test depending on the knee bolster-to-d-y knee clearance. This clearance will vary with each test depending on such factors as precision of the dummy seating position and shape/location of the knee bolster. Consequently, the femur responses reflect the effects of these variables.

Reoeatabilitv - dummv # 289

For the repeatability analysis of dummy #289, refer to Table X.5.2. In general, the response data do not appear to indicate the existence of tendency for the responses to drift in any particular direction under continuous use.

Head, The average HIC was 88 1.3 and the %cv was 6.9. The repeatability of the HIC response was good for this test series.

Neck. The average shear force was -1574.0 N and the average axial force was 2416.3 N. The average moment in flexion was 70.8 Nm and the average moment in extension -26.3 Nm. The %cv for shear force and axial force was 1.6% and 5.9%, respectively. The %cv for flexion moment was 4.2% while the %cv for extension moment was 4.7%. Therefore, the repeatability of the neck responses are excellent except for the neck axial force which still demonstrates good repeatability.

Chest. The average chest resultant acceleration was 53.8 g, the average chest deflection was 35.7 mm and the average V*C was 0.28. The %cv for acceleration, deflection, and V*C was 1.8%, 3.5%, and 8.3%, respectively. The resultant chest acceleration and chest deflection both demonstrate excellent repeatability. The V*C response exhibits good repeatability.

Pelvis. The average peak resultant pelvis acceleration was 55.3 g and the %cv of the response was 6.5. Thus, the repeatability of the resultant pelvis acceleration was good.

Femurs. Same observation as for dummy #273.

Renroducibilitv of Both Dummies

In order to demonstrate reproducibility of the measured responses for two different dummies, all nine tests involving dummies # 273 and # 289 are summarized in Table X.5.3. Note that the tests selected for this analysis are the same tests that were selected for the individual repeatability analysis.

Head. The average HIC response was 854 and the %cv was 7.1%, leading to the conclusion that the reproducibility of the head responses is good.

Neck. The average shear force was -1615.4 N and the average axial force was 2339.7 N. The average moment in flexion was 70.7 Nm and the average moment in extension -25.2 Nm. The %cv for shear force and axial force was 4.4% and 5.5%, respectively. The %cv for flexion moment was 3.6% while the %cv for extension moment was 7.1%. Therefore, the reproducibility of the shear force and flexion moment responses are excellent, while the axial force and extension moments exhibit good reproducibility.

Chest. The average chest resultant acceleration was 53.7 g, the average chest deflection was 34.3 mm and the average V*C was 0.29. The %cv for acceleration, deflection, and V*C was 2.6%, 6.7%, and 16.1%, respectively. The resultant chest acceleration demonstrate excellent reproducibility, the chest deflection response exhibits good reproducibility, and the V*C response exhibits poor repeatability. Again, the poor reproducibility of the V*C are attributed to the integration errors and the low magnitude of the response.

Pelvis. The average resultant pelvis acceleration was 54.2 g and the %cv was 6.2%. Accordingly, the reproducibility is considered to be good.

Femurs. Same observation as for dummies #273 and #289 in the repeatability section.

Table X.5.1. Repeatability Analysis for Dummy S/N 273

Test #V434H350--		17	18	21	22	23			
dummy s/n		273	273	273	273	273			
buck		mid-size	mid-size	mid-size	mid-size	mid-size			
condition		belted	belted	belted	belted	belted	Avg.	Std. Dev.	% CV
HIC		862	915	780	824	780	832.2	57.6	6.9
Neck Fx	N	-1747	-1674	-1633	-1666	-1523	-1648.6	81.6	5.0
Neck Fz	N	2310	2385	2204	2316	2177	2278.4	86.0	3.8
Neck Moc+	Nm	72	68	69	70	74	70.6	2.4	3.5
Neck Moc-	Nm	-27	-25	-22	-23	-25	-24.4	1.9	7.2
Chest Res.	G	55	51	54	53	55	53.6	1.7	3.4
Chest X	mm	-37.4	-32.1	-32.7	-31.2	-32.4	-33.2	2.4	7.4
V*C	m/s	0.38	0.33	0.26	0.24	0.25	0.29	0.06	20.7
Pelvis Res.	g	53	49	58	52	55	53.4	3.4	6.3
L. Femur Fz	N	1489	1487	1561	1471	1435	1488.6	45.9	3.1
R. Femur Fz	N	1656	1405	1378	1276	1193	1381.6	175.1	12.7

Table X.5.2. Repeatability Analysis for Dummy S/N 289

Test #V434H350--		20	25	27	28			
dummy s/n		289	289	289	289			
buck		mid-size	mid-size	mid-size	mid-size			
condition		belted	belted	belted	belted	Avg.	Std. Dev.	% CV
HIC		924	792	897	912	881.3	60.5	6.9
Neck Fx	N	-1561	-1547	-1601	-1587	-1574.0	24.5	1.6
Neck Fz	N	2524	2209	2490	2442	2416.3	142.2	5.9
Neck Moc+	Nm	67	70	71	75	70.8	3.3	4.2
Neck Moc-	Nm	-28	-25	-26	-26	-26.3	1.3	4.7
Chest Res.	G	53	55	53	54	53.8	1.0	1.8
Chest X	mm	-34.2	-35.4	-35.9	-37.2	-35.7	1.2	3.5
V*C	m/s	0.27	0.27	0.26	0.31	0.28	0.0	8.3
Pelvis Res.	g	51	60	53	57	55.3	4.0	6.5
L. Femur Fz	N	1463	1613	1449	1481	1501.5	75.5	5.0
R. Femur Fz	N	1329	1038	1167	1026	1140.0	141.2	12.4

Table X.5.3. Reproducibility Analysis

Test #V434H350-		17	18	21	22	23	20	25	27	28			
dummy s/n		273	273	273	273	273	289	289	289	289			
buck		ms*	ms	ms	ms	ms	ms	ms	ms	ms		Std.	
condition		bltd	bltd	bltd	bltd	bltd	bltd	bltd	bltd	bltd	Avg.	Dev.	% CV
HIC		862	915	780	824	780	924	792	897	912	854.0	60.8	7.1
Neck Fx	N	-1747	-1674	-1633	-1666	-1523	-1561	-1547	-1601	-1587	-1615.	71.4	4.4
Neck Fz	N	2310	2385	2204	2316	2177	2524	2209	2490	2442	2339.7	128.7	5.5
Neck Moc+	N	72	68	69	70	74	67	70	71	75	70.7	2.6	3.6
Neck Moc-	N	-27	-25	-22	-23	-25	-28	-25	-26	-26	-25.2	1.9	7.1
Chest Res.	G	55	51	54	53	55	53	55	53	54	53.7	1.3	2.6
Chest X	m	-37.4	-32.1	-32.7	-31.2	-32.4	-34.2	-35.4	-35.9	-37.2	-34.3	2.3	6.7
V*C	m	0.38	0.33	0.26	0.24	0.25	0.27	0.27	0.26	0.31	0.29	0.05	16.1
Pelvis Res.	g	53	49	58	52	55	51	60	53	57	54.2	3.6	6.2
L. Femur Fz	N	1489	1487	1561	1471	1435	1463	1613	1449	1481	1494.3	56.9	3.8
R. Femur Fz	N	1656	1405	1378	1276	1193	1329	1038	1167	1026	1274.2	197.5	15.5

* [illegible]
** bltd - belted

X.6 Biotidelity

Estimate of the H-III5F dummy biofidelity level was based on methodology developed for side impact dummies by ISO/TC22/SC12/WG5 in document N455, the biomechanical impact response requirements based on SAE Publication 890756 (ref. 1-6) and DTESC based dummy response corridors in Appendix A.2. Inasmuch as an accepted methodology for biofidelity rating for a frontal impact d-y does not exist, the biotidelity estimate provided here is only a ball park estimate of where the dummy may generally fit in an overall rating scheme if one was available. The biofidelity ratings and weighting factors for the body regions considered in this assessment are shown in Table X.6.1.

Table X.6.1 Estimation of Biofidelity of the H-III5F Dummy

Body Segment	Biofdelity Rating Estimate		Weighting Factor
	SAE 890756	DTESC-Users Manual. Aug.'94	
Head	10	10	7
Neck	8.75	5	6
Thorax	5	1.3	5
Femurs/Knees	5	5	8
Overall	7.2	6.8	

To assess the quality of dummy's biotidelity, ISO/TC22/SC12/WG5 established in document N455 a ten point scale system. Five classifications within the ten point system indicate the degree of the dummy's biofidelity. They are as follows:

Excellent Biotidelity	10 to 8.6
Good Biotidelity	6.5<8.6
Fair Biotidelity	4.4<6.5
Marginal Biotidelity	2.6<4.4
Unacceptable Biotidelity	0.0<2.6

The data in the Table X.6.1 indicate that the dummy would have either a 7.2 overall rating based on biomechanical corridors provided in the SAE # SAE 890756 or a 6.8 rating based on DTESC response corridors. Regardless of which base is used for this estimate, it indicates that the dummy has good biofidelity.

X.7 Durability

Dummy # 273 was exposed to 17 OOP tests, 28 sled tests, and 41 component level tests, dummy

#019 was subjected to 5 OOP tests and 18 sled tests, and dummy #289 was subjected 12 sled tests and 25 component level tests. Following each test throughout the evaluation, each dummy was thoroughly inspected for structural integrity. After OOP and sled tests, the ribs were measured to assess indications of permanent deformation. These inspections of the ribs and other body segments did not reveal any observable deteriorations of or deficiencies with the dummies. Excellent durability is demonstrated by the dummies' endurance of significant loadings in both OOP and sled tests, and is further illustrated by the dummies' ability to withstand a large number of impact exposures.

X.8 Effects of Head Skin and Neck Wrap

Discussion and Conclusions

The results of the calibration testing indicate that the &%-proposed neck wrap has no significant effect on the neck responses. However, the static OOP testing presents results which are contradictory to this conclusion. The OOP test results indicate that the WE-proposed neck wrap has a significant effect on the neck responses. The data contained in Table 1X.8.1. show that the neck wrap increases the average neck shear force (Neck Fx)by approx. 29% and the neck moment about the condyle (Neck Moc) increased 58% when comparing the TMJ head skin with and without neck wrap.

Similar testing has been conducted by GM under the auspices of SAE. In passenger OOP tests GM compared the standard head skin with the TMJ skin and neck wrap. The results of the GM testing (Table X.8.1) were very similar to the results observed in agency tests. That is, the neck responses for the TMJ head skin with the neck wrap were larger in magnitude than those of the standard configuration (reference minutes of 4/17/98 SAE Hybrid Ill Family meeting).

The OOP test results demonstrate that the SAE-proposed neck wrap causes a significant increase in neck responses. On the other hand, visual observations from the OOP tests illustrate that the TMJ head skin prevents the cushion from getting into the chin cavity and snagging on the rearward edge of the jaw-line. In this regard, the TMJ head skin appears to eliminate an undesirable air bag to head interaction. OOP tests indicate that the dummy that is equipped with TMJ head skin only (no neck wrap) generates lower neck responses than those seen in tests in which the standard head skin and neck were used.

Additional data and response traces from evaluation tests of the neck wrap and head skin modifications are provided in Appendix F.

Table X.8.1 Average Responses and Percent Difference at GM in OOP Tests

		standard head skin, no neck wrap	TMJ head skin, neck wrap	difference between standard and TMJ
		AVG	AVG	%
Neck Fx	N	-1350	-1580	17.0
Neck Fz	N	1660	1790	7.8
Neck Moc	Nm	-50.8	-67.2	32.3
Head Res	g	36.6	40.7	11.2
Chest Res	g	27.3	26.7	-2.2

Xl. Dummy Based Impact Sensors

In previous rulemakings, the Part 572 dummies were normally required to be equipped with crash test sensors that were specified by make and model. As a result. the agency received numerous comments and requests to remove this restrictive designation and to issue generic sensor specifications. In this rulemaking the agency is taking such a step and proposing generic specifications for all of the dummy based sensors. They include accelerometers, force and moment transducers, as well as the thorax based chest deflection potentiometer (for details of specifications see Appendix G). The proposed specifications reflect essentially the characteristics of sensors used in the agency dummy evaluation series that are identified by make and model in Chapter X. Interested parties are encouraged to comment on the adequacy of the proposed specifications, their potential impact on the quality of the measured test data, problems related to calibration assurance tests, and questions related to competitive comparability claims.

XII. Overall assessment.

Agency evaluation of the H-IIISF dummies with modifications as of late September, 1997 , show that they meet anthropometry and mass distribution requirements of the 5^{th} percentile female, their body segment construction is more human-like and conform to the SAE defined biotidelity norms. The dummies have sufficient structural integrity and are capable of obtaining repeatable and useful measurements in the most severe impact and out-of- position impact environments. The H-IIISF dummies have an extensive injury assessment capability through a substantially increased number of strategically located impact sensors in a number of critical-to-injury body components. They include load transducers in the neck, the lumbar spine, at the iliac anterior-superior wings, and femurs. In addition, the thorax, besides being equipped with a chest deflection measuring potentiometer, has provisions for mounting accelerometers at the upper, middle and lower portions of the thoracic spine in collinear alignment with paired accelerometers mounted on the sternum. While the H-IIISF dummy has considerably higher levels of biofidelity than the also commercially available H-II5F dummy, past studies of their comparative responses in identical belt restraint systems show relatively similar head and torso impact response measurements except for the head trajectory. As expected, dummies that are fully restrained, even though they are of different construction but have similar body segment masses and joints, will produce fairly similar responses, as long as they do not experience external impact contacts. For such events, the H-IIISF dummy provides little, if any, advantage. However, for contact impacts, particularly those involving interactions with air bags, use of a dummy, such as the H-III5F, that has a higher degree of component and systems biofidelity and increased impact sensing capabilities, is the only currently available and uniquely suitable to assure that occupant protection systems can be designed for and provide adequate protection for this population segment.

APPENDICES

Appendix A

Calibration Procedures for the Hybrid III Small Female Test Dummy, SAE Engineering Aid 25,. Society of Automotive Engineers, Dummy Testing Equipment Subcommittee, December 1994.

This document is available for public inspection in Docket No. NHTSA-98-4283 at NHTSA, Room 5 111 of the Nassif Building, 400 Seventh Street, S.W., Washington, D.C.
Copies may be obtained through the SAE, 400 Commonwealth Drive, Warrendale Pa. 15096 by contacting Penny Brown either in writing , by telephone at 1 (412)772-7156, or by E-mail penny@sae.org.

APPENDIX A

able A. 1. Instrumentation

Type	Location	Measurements	Mfg. & Model No.	# Channels
Accelerometers	Head CG	x, y, z accelerations	Endevco 7264-2000	3
	Thorax	x, y, z accelerations	Endevco 7264-2000	3
	Pelvis	x, y, z accelerations	Endevco 7264-2000	3
	Sternum - Upper, Middle, Lower	x acceleration	Endevco 7264-2000	3
	Spine - Upper, Lower, Middle	x acceleration	Endevco 7264-2000	3
Rotary Potentiometer	Thorax (Chest Deflection)	x deflection	Servo	1
Linear Potentiometer	Knee Slider	deflection	Servo	1
Load Cells	Upper Neck	x, y, z forces x, y, z moments	Denton 1716	6
	Lumbar Spine	x, y, z forces x, y, moments	Denton 2152	5
	Thoracic Spine	x, y, z forces x, y, moments	Denton 2151	5
	ASIS	x force y moment	Denton 3743/3744	2
	Femur - 6 channel	x, y, z forces x, y, z moments	Denton 1914	6
	Upper Tibia Load Cell	x, z forces x, y moments	Denton 3115	4
	Lower Tibia Load Cell	x, z forces x, y moments	Denton 3287	4

APPENDIX B. STRUCTURAL ROBUSTNESS TESTS

Table B. 1. Preliminary Neck Structural Robustness

Test #	Dummy S/N	Test Type	Peak Rotation Angle (deg)	Peak Moment (Nm)
273C1NE2	273	extension	113.5	-103.3
273C1NE3	273	extension	112.7	-118.9
273C1NE4	273	extension	110.7	-116.7
273C1NE5	273	extension	114.1	-112.7
273C1NF3	273	flexion	92.7	92.8
273C1NF4	273	flexion	91.7	94.9
273C1NF5	273	flexion	92.9	98.3
273C1NF6	273	flexion	96.0	94.1

Table B.2. reliminary Thorax Structural Robust ss Tests

est #	Dummy S/N	Impact Speed (m/s)	Impact Force (N)	Peak Chest Deflection (mm)	Comments
04340002	273	6.51	5150	63.8	
04340003	273	7.51	6547	73.9	pot arm contacted lumbar-to-thoracic spine adapter
04340004	273	8.24	7836	82.5	
04340005	273	8.90	8975	n/a	chest pot arm ball popped out of slider track
04340006	273	8.93	9022	n/a	chest pot arm ball popped out of slider track
04340033	273	5.66	4134	48.0	
04340034	273	6.57	5202	61.0	
04340035	273	6.75	5833	62.3	ribs made light contact with bumpers
04340036	273	7.88	7908	65.8	ribs contacted bumpers
04340037	273	7.90	8230	66.1	ribs contacted bumpers

Note: pend um mass = 2 1.3 kg.

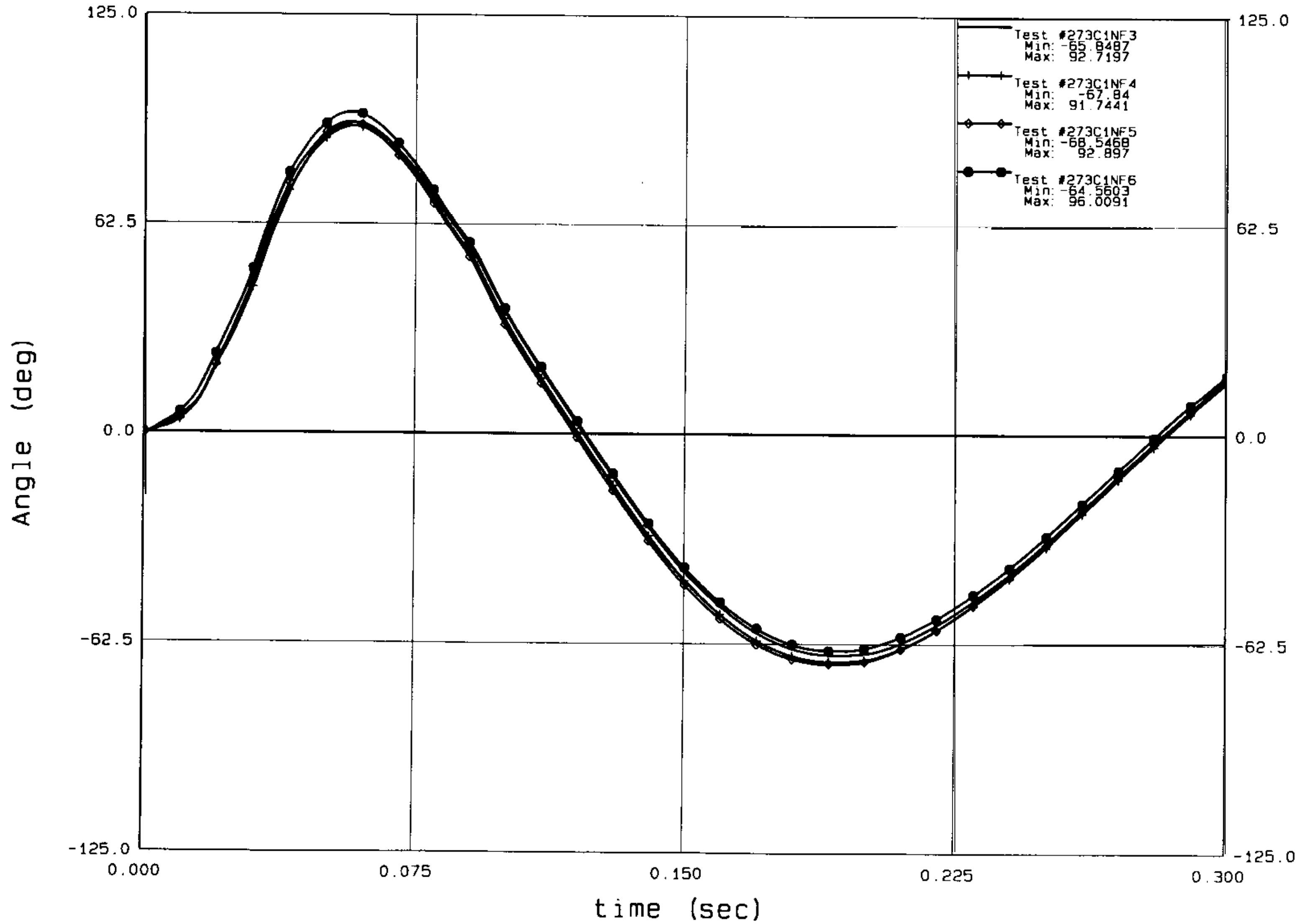
Table B.3. Obliaue and Reclines Thoracic Impacts

Test #	Dummy S/N	Test Type	Impact Speed (m/s)	Impact Force (N)	Peak Chest Deflection (mm)	Comments
04340007	273	oblique	6.61	4983	59.1	
04340008	273	oblique	7.53	6540	68.0	ribs contacted bumpers
04340009	273	reclined	4.58	2693	55.5	
04340012	273	reclined	5.72	lost data	lost data	
04340038	273	reclined	8.11	lost data	67.6	ribs contacted bumpers

Note: pendulum mass = 21.3 kg.

Figure B. 1

Neck Flexion Structural Robustness



Jul 02, 1998 09:19 54AM

Figure B.2

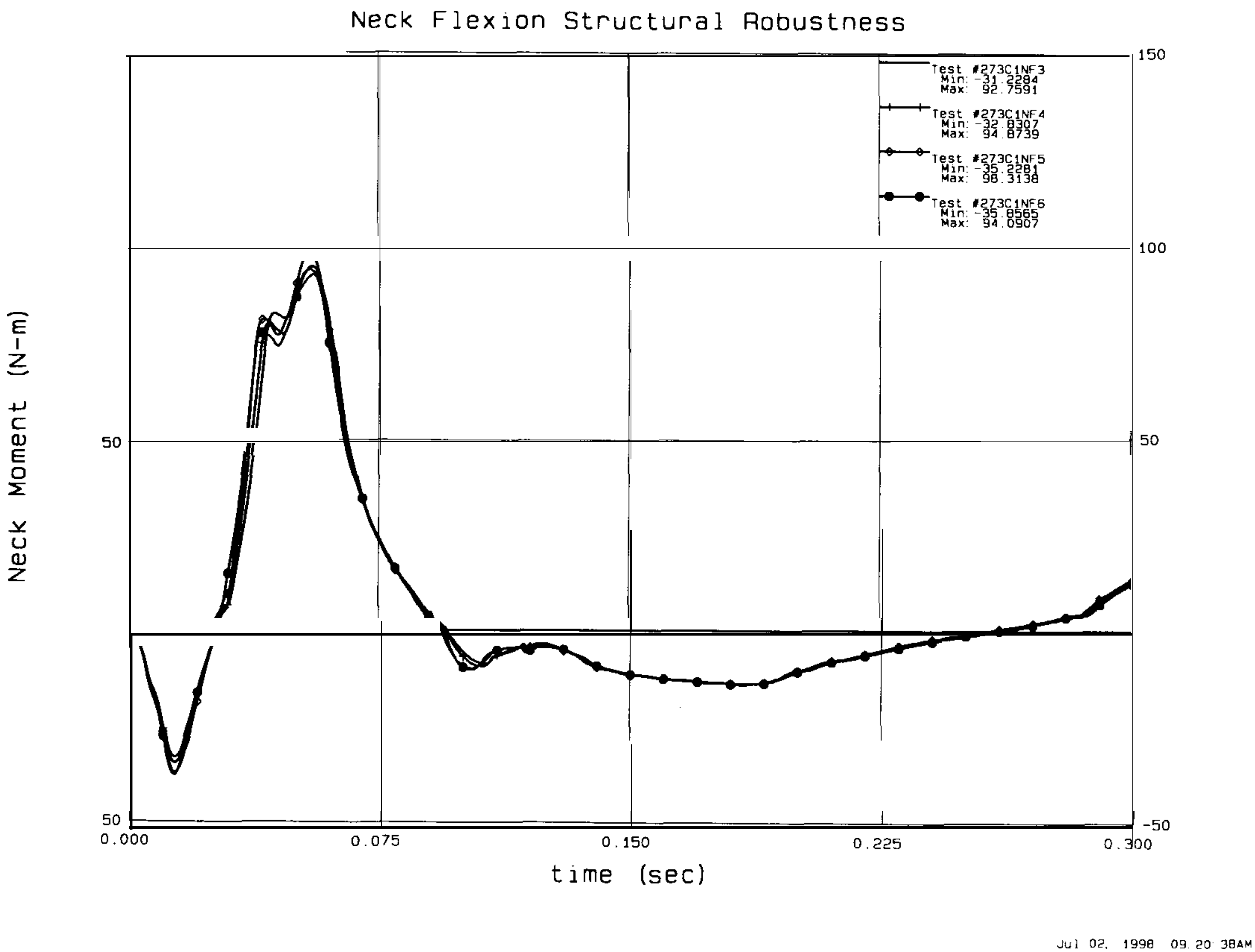

Neck Flexion Structural Robustness
Test #273C1NF3 Min: -31.2284 Max: 92.7591
Test #273C1NF4 Min: -32.8307 Max: 94.8739
Test #273C1NF5 Min: -35.2281 Max: 98.3138
Test #273C1NF6 Min: -35.8565 Max: 94.0907
150
100
50
50
-50
50
0.000
0.075
0.150
0.225
0.300
time (sec)
Neck Moment (N-m)
Jul 02, 1998 09:20:38AM

Figure B.3

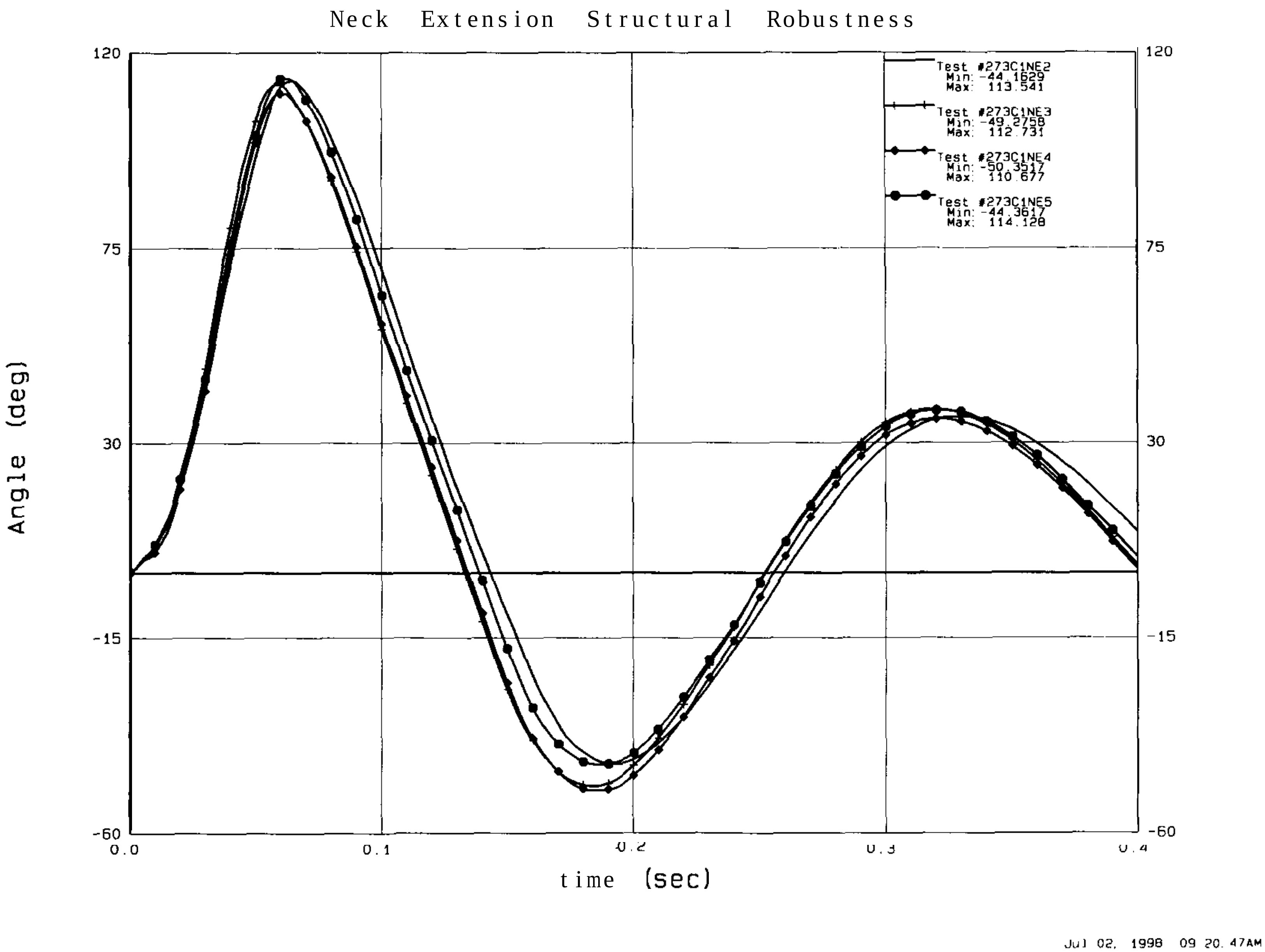

Neck Extension Structural Robustness
120
75
30
-15
-60
0.0
0.1
0.2
0.3
0.4
time (sec)
Angle (deg)
Test #273C1NE2
Min: -44.1629
Max: 113.541
Test #273C1NE3
Min: -49.2758
Max: 112.731
Test #273C1NE4
Min: -50.3517
Max: 110.677
Test #273C1NE5
Min: -44.3617
Max: 114.128
Jul 02, 1998 09 20.47AM

Figure B.4

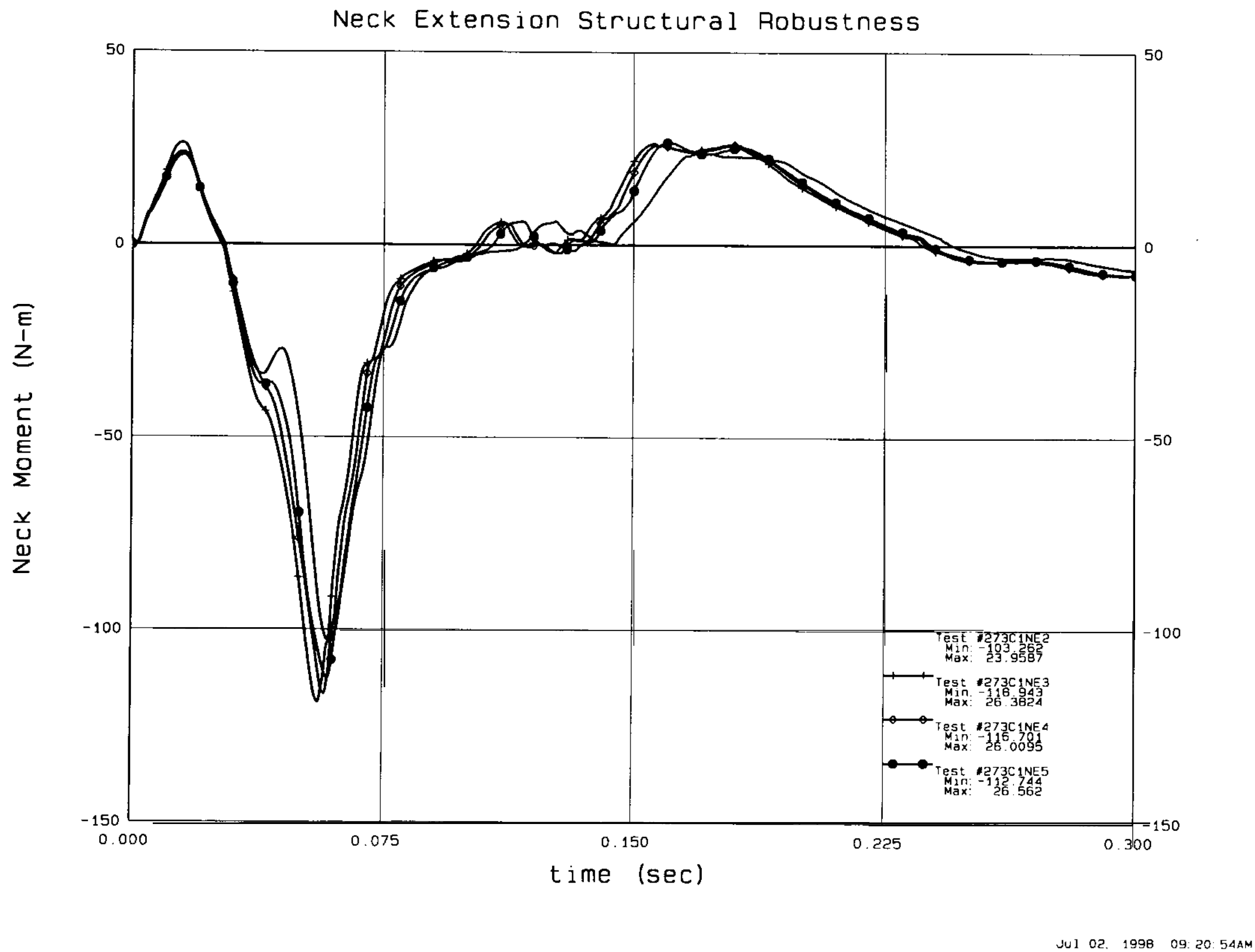

Neck Extension Structural Robustness
50
0
-50
-100
-150
0.000
0.075
0.150
0.225
0.300
time (sec)
Neck Moment (N-m)
Test #273C1NE2
Min: -103.262
Max: 23.9587
Test #273C1NE3
Min: -116.943
Max: 26.3824
Test #273C1NE4
Min: -116.701
Max: 26.0095
Test #273C1NE5
Min: -112.744
Max: 26.562
Jul 02, 1998 09:20:54AM

Figure B.5

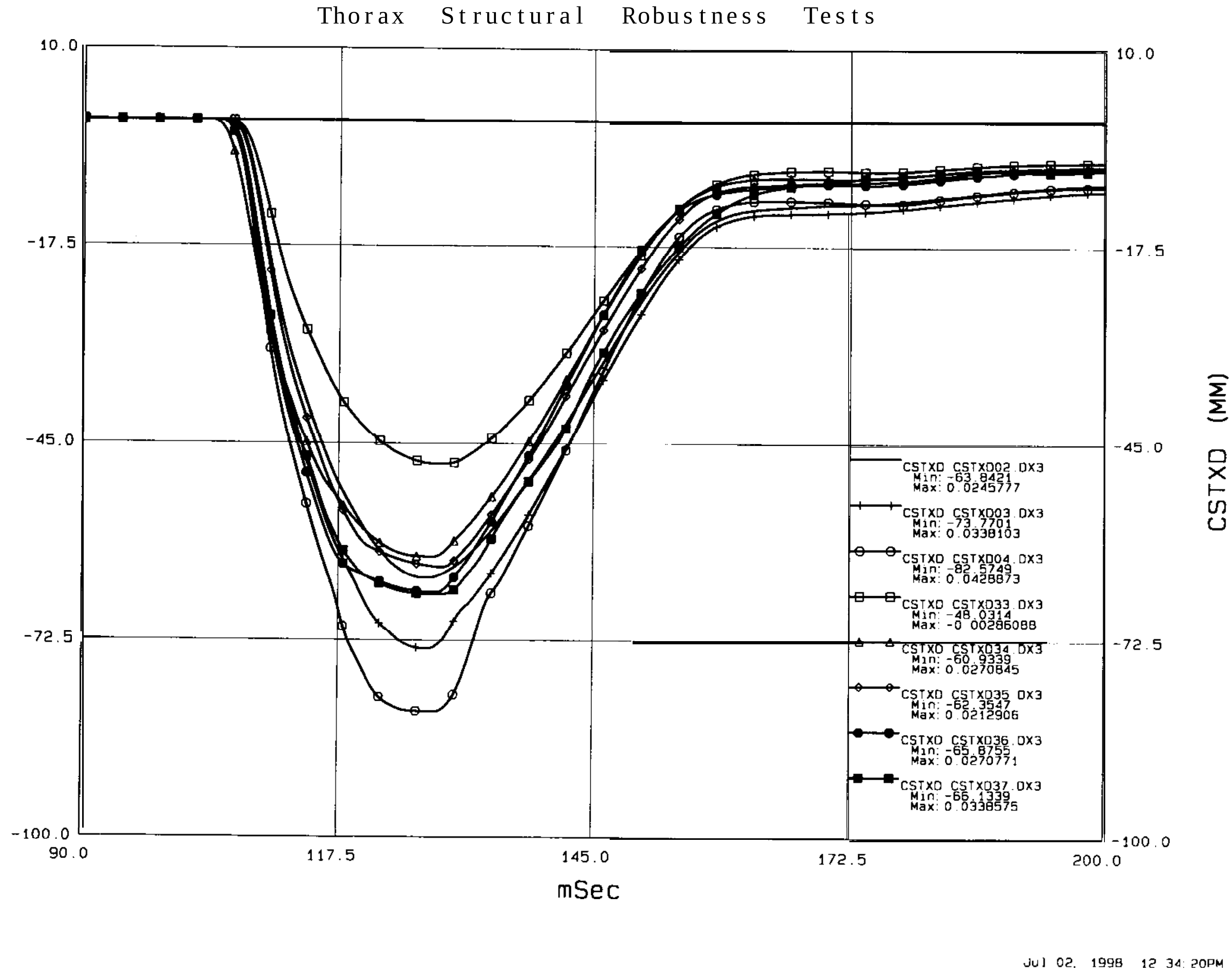
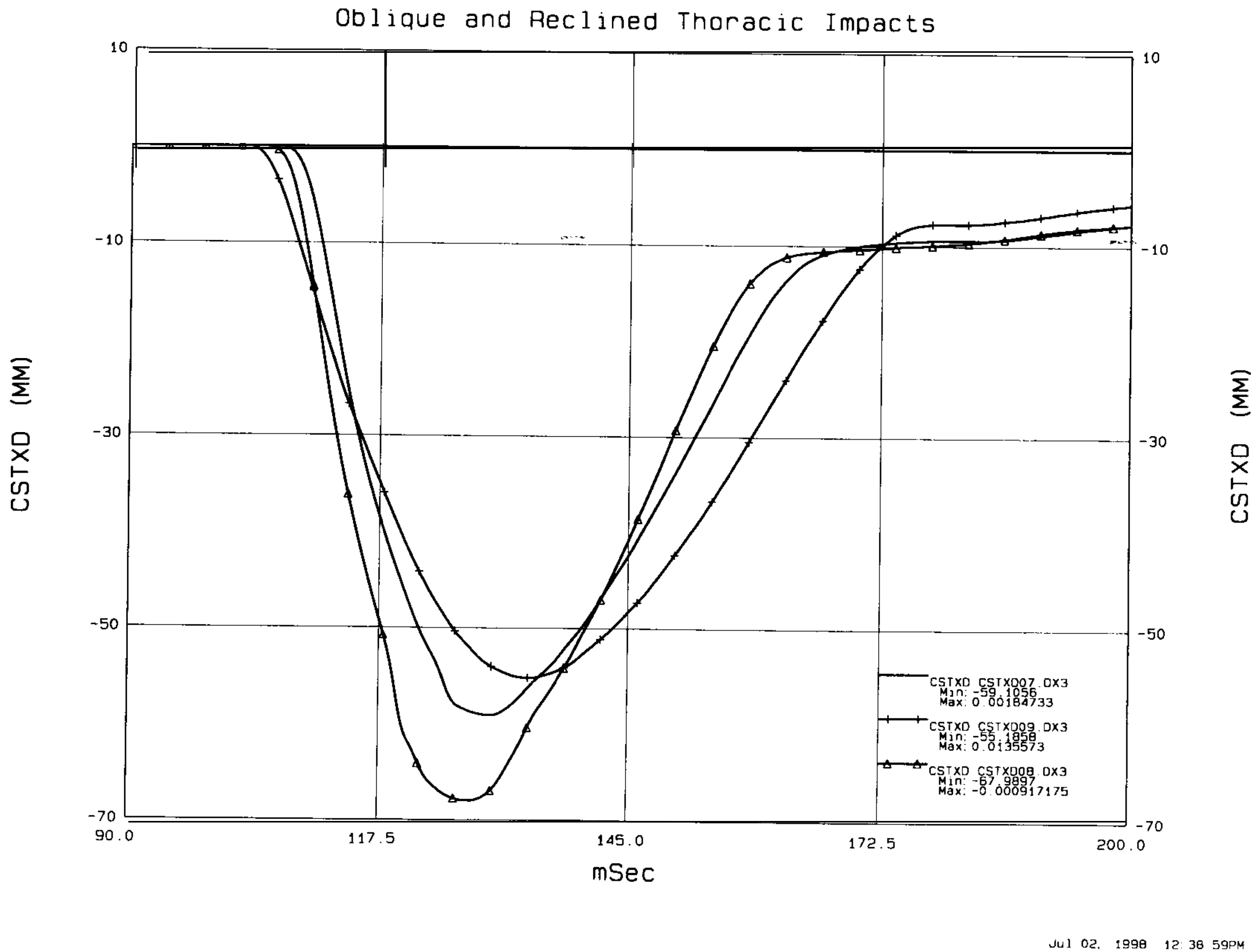

Thorax Structural Robustness Tests
10.0
-17.5
-45.0
-72.5
-100.0
90.0
117.5
145.0
172.5
200.0
mSec
CSTXD (MM)
CSTXD (MM)
CSTXD CSTXD02.DX3
Min: -63.8421
Max: 0.0245777
CSTXD CSTXD03.DX3
Min: -73.7701
Max: 0.0338103
CSTXD CSTXD04.DX3
Min: -82.5749
Max: 0.0428873
CSTXD CSTXD33.DX3
Min: -48.0314
Max: -0.00286088
CSTXD CSTXD34.DX3
Min: -60.9339
Max: 0.0270845
CSTXD CSTXD35.DX3
Min: -62.3547
Max: 0.0212906
CSTXD CSTXD36.DX3
Min: -65.8755
Max: 0.0270771
CSTXD CSTXD37.DX3
Min: -66.1339
Max: 0.0338575
Jul 02, 1998 12:34:20PM

Figure B.6


Oblique and Reclined Thoracic Impacts
10
-10
-30
-50
-70
CSTXD (MM)
90.0
117.5
145.0
172.5
200.0
mSec
CSTXD CSTXD07.DX3
Min: -59.1056
Max: 0.00184733
CSTXD CSTXD09.DX3
Min: -55.1858
Max: 0.0135573
CSTXD CSTXD08.DX3
Min: -67.9897
Max: -0.000917175
Jul 02, 1998 12:38 59PM

APPENDIX C. STATIC OOP TESTING

Figure C. 1. Typical Driver OOP Test Setup for IS0 Position #1

Figure C.2. Typical Driver OOP Test Setup for ISO Position #2

Figure C.3. Typical Passenger OOP Test Setup in Position #1

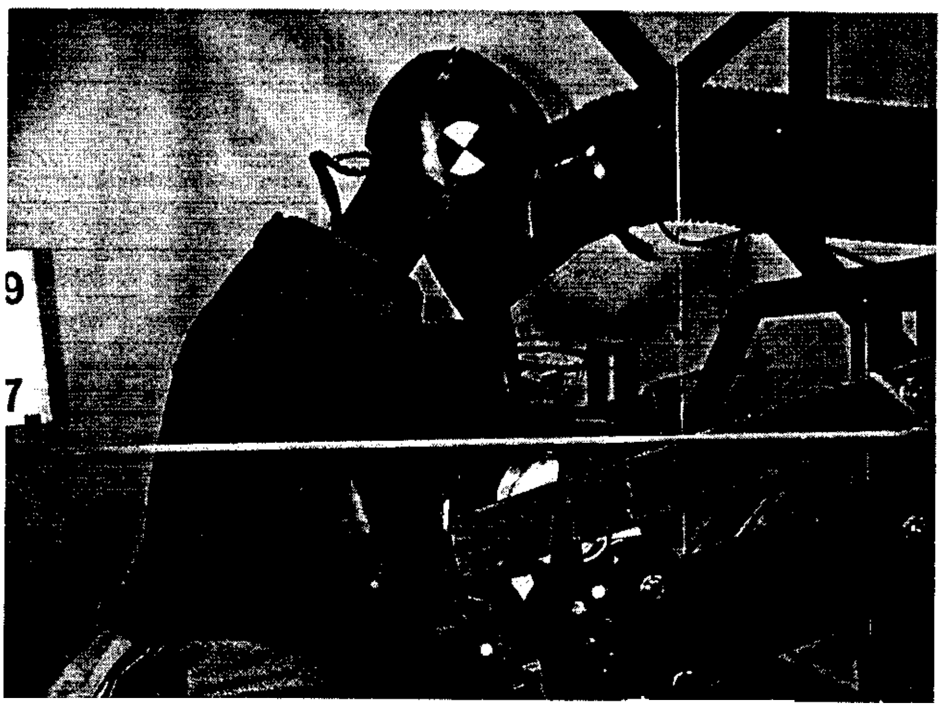


Figure C.4. Typical Passenger OOP Test Setup in Position #2

Appendix C.1. Hybrid III 5th Percentile Female Positioning for OOP Testing

The dummy positioning procedure for the driver side airbag tests is based on the positioning procedure adopted by ISO.

Position 1

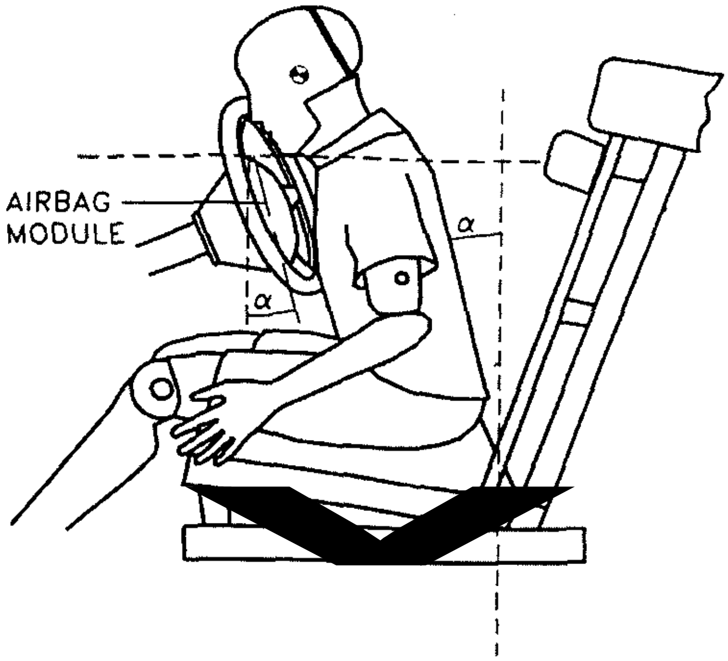
Position 1 is intended to position the d-y to maximize head and neck loading. For this seating procedure, the driver's seat is moved to the full forward position. The dummy is placed on the seat and torso arranged so that the spine is parallel to the plane defined by the rim of the steering wheel.

Position 2

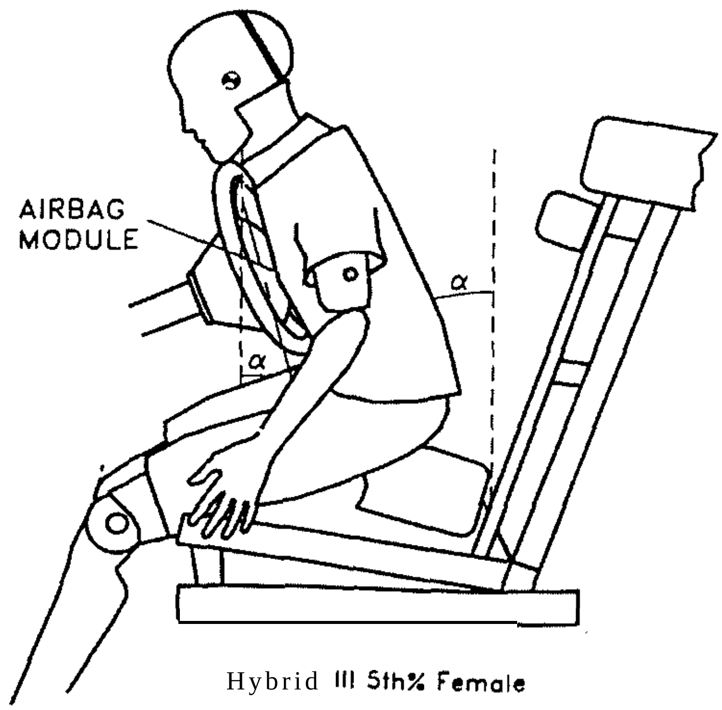
Position 2 is intended to position the dummy to maximize chest loading. This in turn will create significant neck and head loadings. The driver's seat track position is not specified and may be positioned to best facilitate the positioning of the d-y. The dummy is placed on the seat and the torso is arranged so that the spine is parallel to the plane of the steering wheel. The dummy is positioned so that the center of the chin is in contact with the upper most portion of the rim of the steering wheel. Note: The chin is not hooked over the top of the rim of the steering wheel. It is positioned to rest on the upper edge of the rim.

Appendix C. 1.

ISO # 1



ISO # 2



Hybrid III 5th% Female

APPENDIX C - OOP TEST RESULTS

Table C.1. Driver Static OOP Testing Results

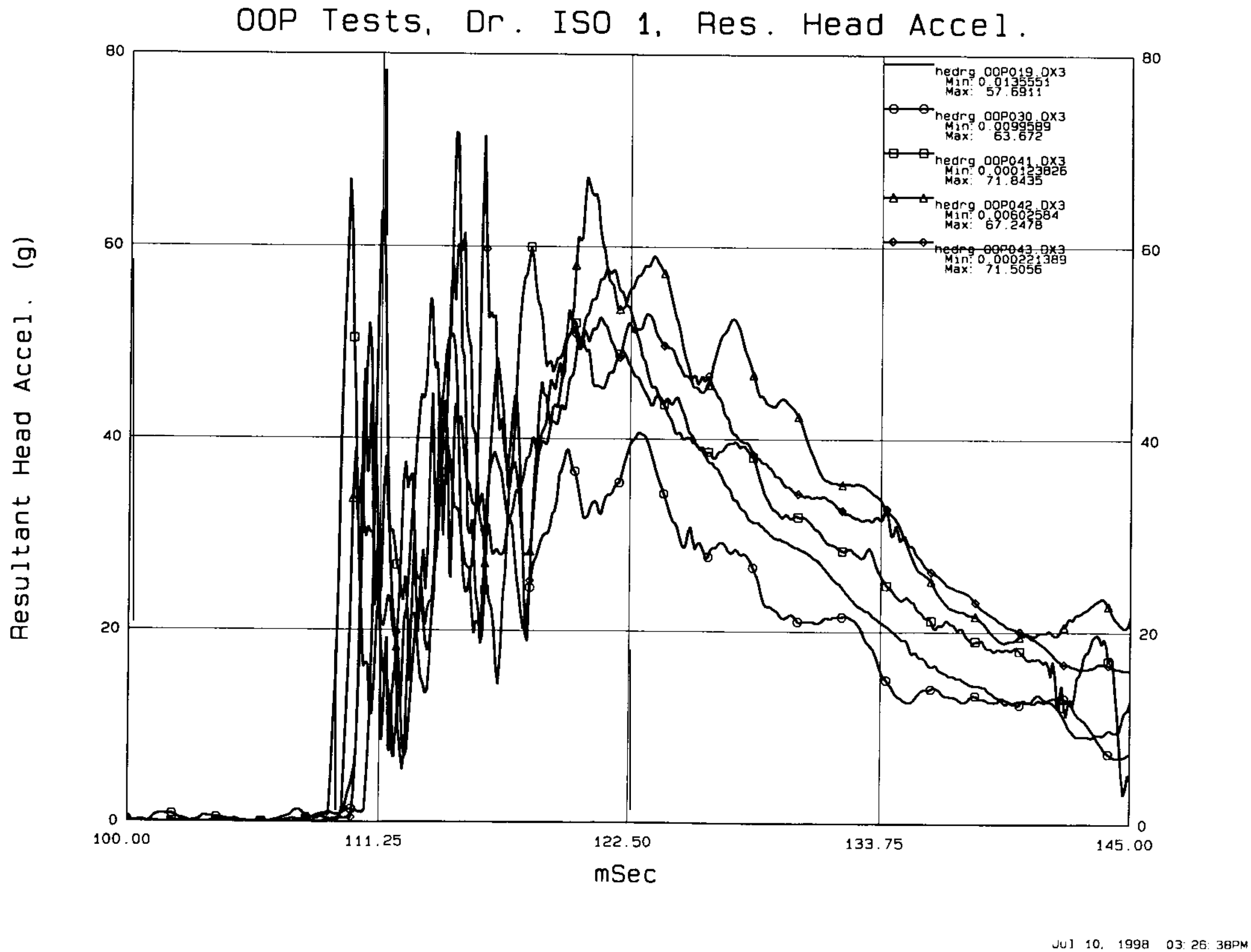
test # 043400--		13	14	15	18	19	20	30	31	32
system		A	A	A	B	B	B	B	B	B
ISO position		2	1	1	2	1	2	1	2	2
dummy S/N		273	273	273	019	019	019	273	273	273
HIC		48	103	83	217	182	192	98	235	177
Neck Fx	N	-1588	-1799	-1507	-2555	-1974	-2472	-2102	-2739	-2201
Neck Fz	N	1358	2359	1962	2640	2533	2721	1911	3324	2332
Neck Moc	Nm	-65	-81	-66	-88	-70	-98	-86	-117	-95.1
Cst X	mm	-35.6	-27.6	-26.8	-66.6	-33.8	-49.5	-34.0	lost data	-59.2
Cst G	g	32	60	94	170	113	107	57	98.6	93.5
V*C	m/s	0.72	0.27	0.60	4.13	0.81	2.08	0.56	lost data	2.15
Comments				no chin insert or neck wrap	V*C from chest pot only	V*C from chest pot only	V*C from chest pot only		chest pot ball ejected	

test # 043400--		39	40	41	42	43	44	45
system		B	B	B	B	B	B	B
ISO position		2	2	1	1	1	1	1
dummy S/N		273	273	273	273	273	273	273
HIC		lost data	214	228	281	234	135	151
Neck Fx	N	-2659	-2463	-1715	-2055	-1681	-1764	-1276
Neck Fz	N	2672	2560	2568	3005	2587	2383	2143
Neck Moc	Nm	-112	-101	-71	-85	-71	-80	-60
Cst X	mm	-62.4	-56.5	-33.6	-30.4	-26.6	-27.9	-24.9
Cst G	g	lost data	81	97	63	74	64	67
V*C	m/s	3.49	2.46	0.54	0.42	0.31	0.37	0.32
Comments				no chin insert or neck wrap	no chin insert		TMJ head skin	one piece neck skin

Table C.2. Passenger Static OOP Testing Results

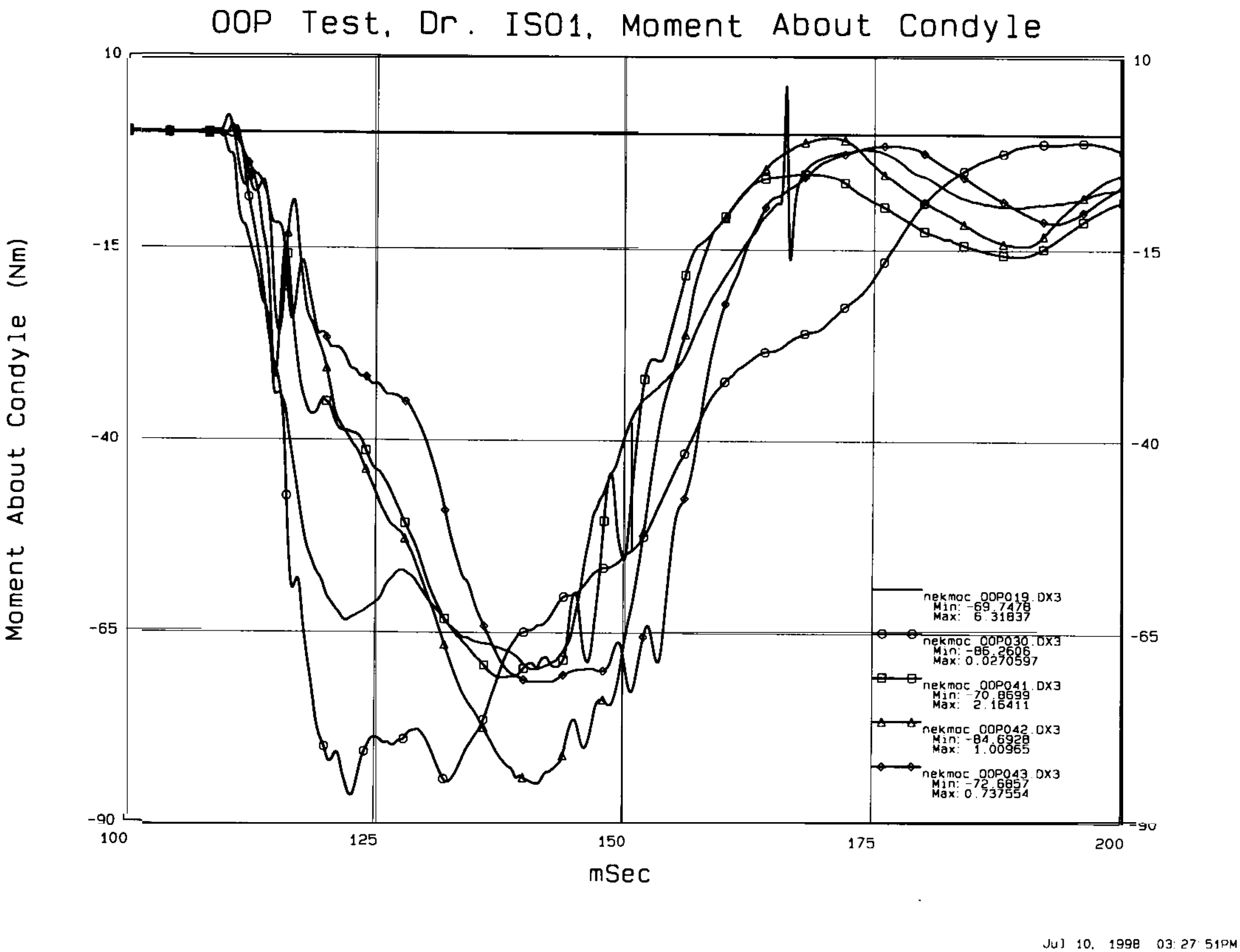
test # 043400--		16	17	28	29	46	47
system		C1	C1	D	D	C1	C2
ISO position		Pass.1	Pass.1	Pass. 1	Pass.2	Pass.1	Pass.1
dummy S/N		273	273	019	019	273	273
HIC		259	387	3319	571	490	595
Neck Fx	N	-4447	-2981	-9918	-1788	-2316	-3369
Neck Fz	N	5423	4550	9884	4497	4898	3788
Neck Moc	Nm	-136	-136	-143	-79	-119	-152
Cst X	mm	-59.5	-53.5	-19.9	lost data	-53.1	-34.3
Cst G	g	183	107	358	249	125	78
V*C	m/s	2.94	2.37	0.35	lost data	4.02	1.49
Comments					chest pot ball ejected		

Figure C.6



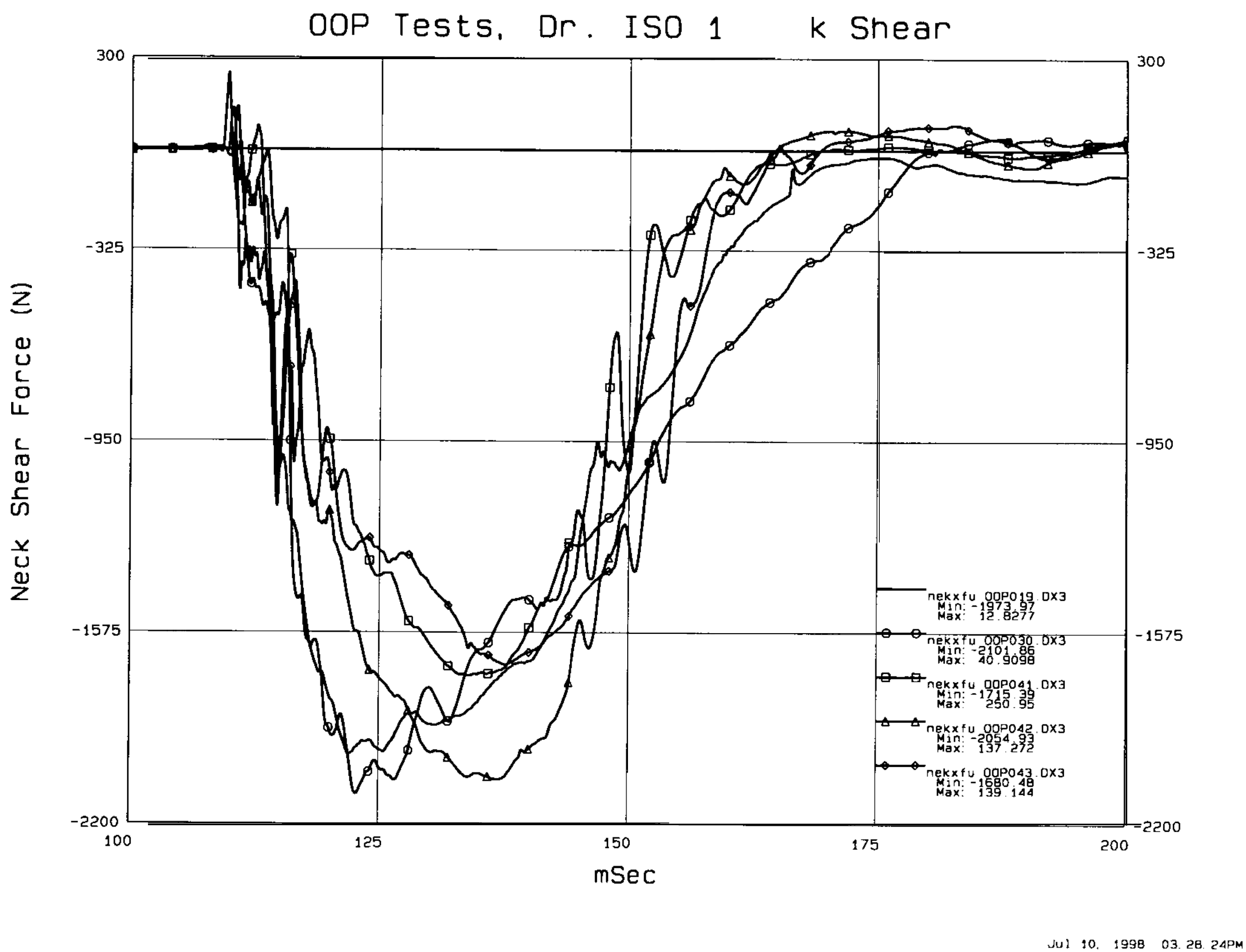
OOP Tests, Dr. ISO 1, Res. Head Accel.
hedrg OOP019.DX3
Min: 0.0135551
Max: 57.6911
hedrg OOP030.DX3
Min: 0.0099589
Max: 63.672
hedrg OOP041.DX3
Min: 0.000123826
Max: 71.8435
hedrg OOP042.DX3
Min: 0.00602584
Max: 67.2478
hedrg OOP043.DX3
Min: 0.000221389
Max: 71.5056
Resultant Head Accel. (g)
80
60
40
20
0
100.00
111.25
122.50
133.75
145.00
mSec
JUL 10, 1998 03:26:38PM

Figure C.7



OOP Test, Dr. IS01, Moment About Condyle
Moment About Condyle (Nm)
mSec
10
-15
-40
-65
-90
100
125
150
175
200
nekmoc OOP019.DX3
Min: -69.7478
Max: 6.31837
nekmoc OOP030.DX3
Min: -86.2606
Max: 0.0270597
nekmoc OOP041.DX3
Min: -70.8699
Max: 2.16411
nekmoc OOP042.DX3
Min: -84.6928
Max: 1.00965
nekmoc OOP043.DX3
Min: -72.6857
Max: 0.737554
Jul 10, 1998 03:27:51PM

Figure C.8



OOP Tests, Dr. ISO 1 k Shear
Neck Shear Force (N)
300
-325
-950
-1575
-2200
100
125
150
175
200
mSec
nekxfu OOP019.DX3
Min: -1973.97
Max: 12.8277
nekxfu OOP030.DX3
Min: -2101.86
Max: 40.9098
nekxfu OOP041.DX3
Min: -1715.39
Max: 250.95
nekxfu OOP042.DX3
Min: -2054.93
Max: 137.272
nekxfu OOP043.DX3
Min: -1680.48
Max: 139.144
Jul 10, 1998 03.28.24PM

Figure C.9

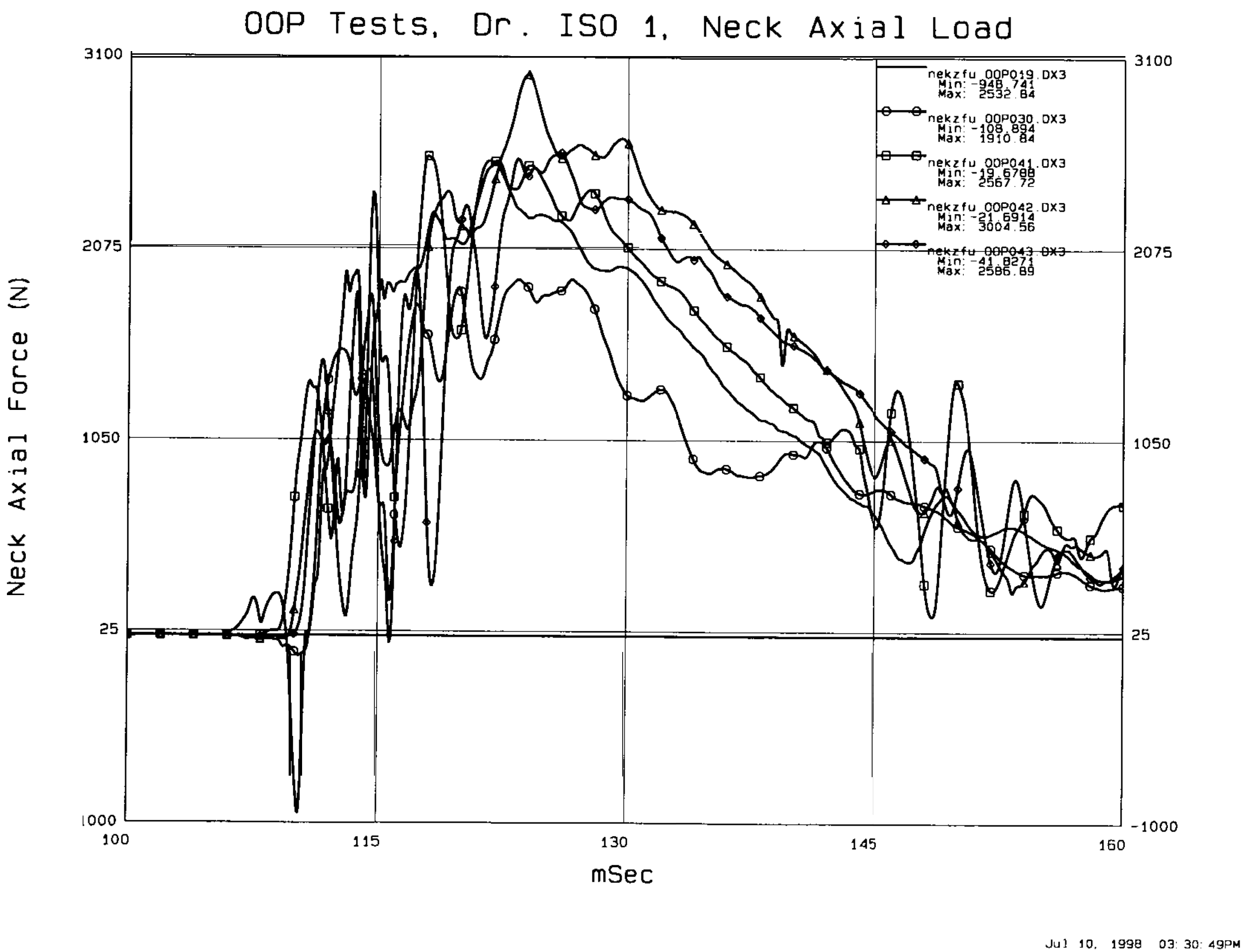

OOP Tests, Dr. ISO 1, Neck Axial Load
Neck Axial Force (N)
mSec
3100
2075
1050
25
1000
-1000
100
115
130
145
160
nekzfu 00P019.DX3
Min: -948.741
Max: 2532.84
nekzfu 00P030.DX3
Min: -108.894
Max: 1910.84
nekzfu 00P041.DX3
Min: -19.6788
Max: 2567.72
nekzfu 00P042.DX3
Min: -21.6914
Max: 3004.56
nekzfu 00P043.DX3
Min: -41.8271
Max: 2586.89
Jul 10, 1998 03:30:49PM

Figure C.10

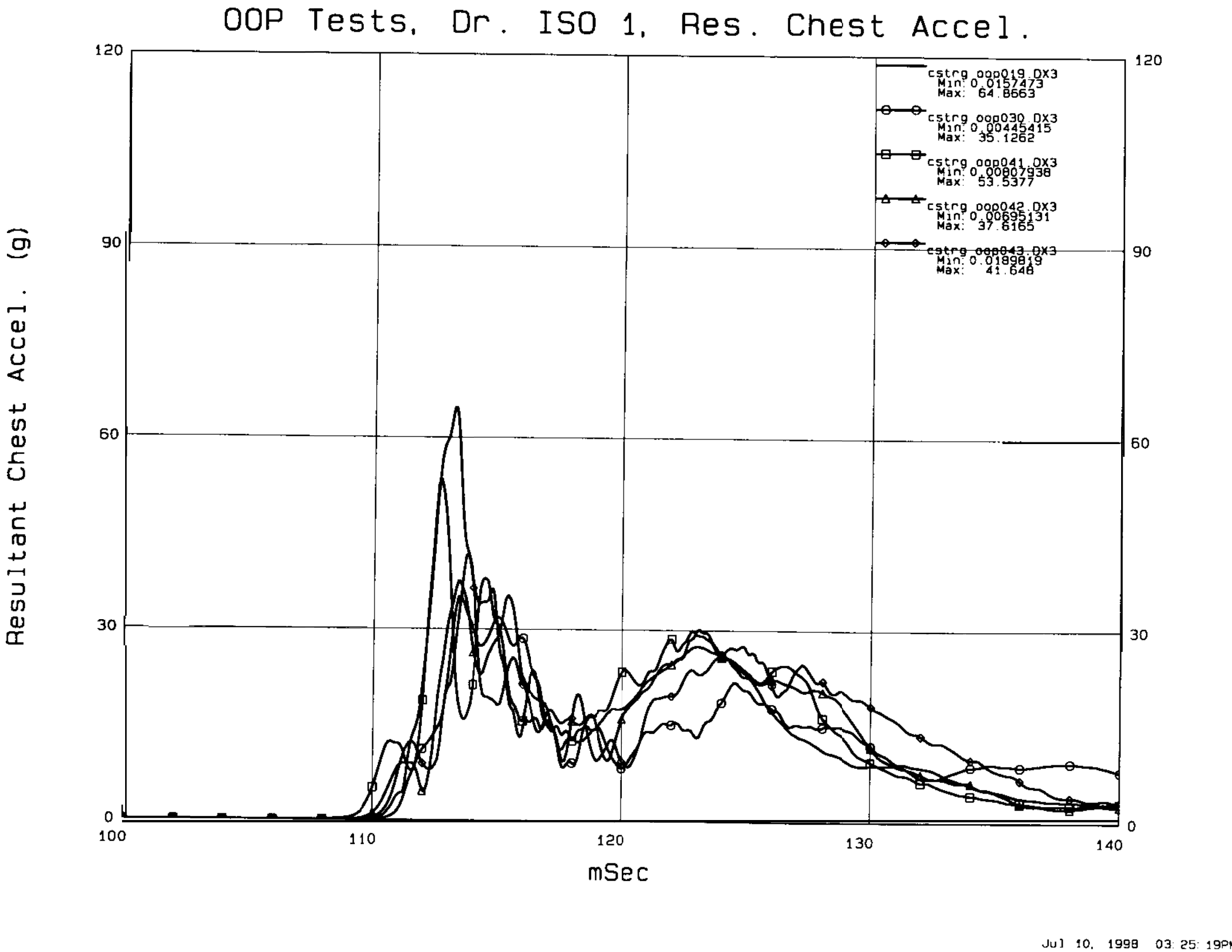

OOP Tests, Dr. ISO 1, Res. Chest Accel.
cstrg oop019.DX3
Min: 0.0157473
Max: 64.8663
cstrg oop030.DX3
Min: 0.00445415
Max: 35.1262
cstrg oop041.DX3
Min: 0.00807938
Max: 53.5377
cstrg oop042.DX3
Min: 0.00695131
Max: 37.6165
cstrg oop043.DX3
Min: 0.0189819
Max: 41.648
Resultant Chest Accel. (g)
0
30
60
90
120
100
110
120
130
140
mSec
Jul 10, 1998 03:25:19PM

Figure C.11

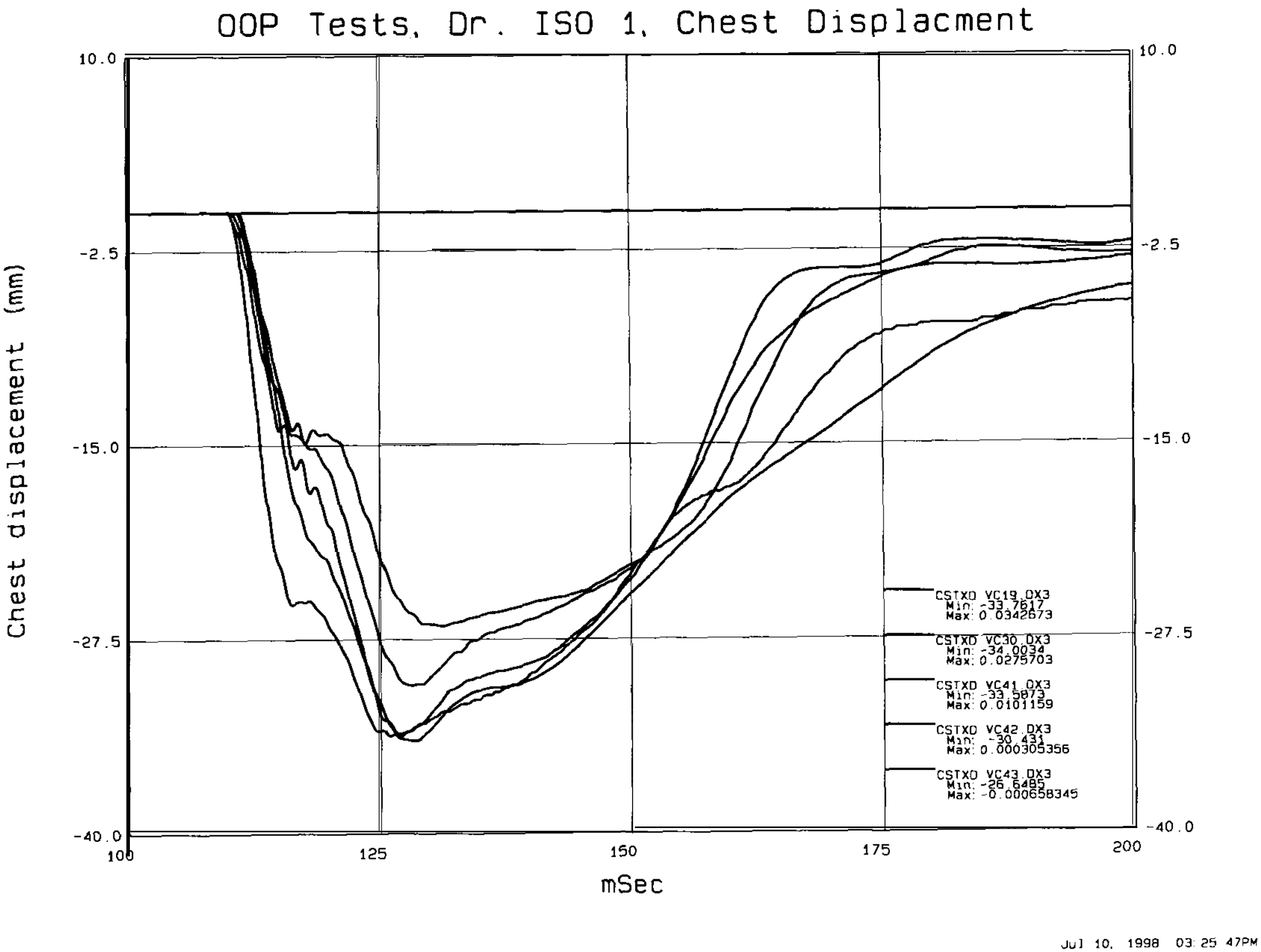
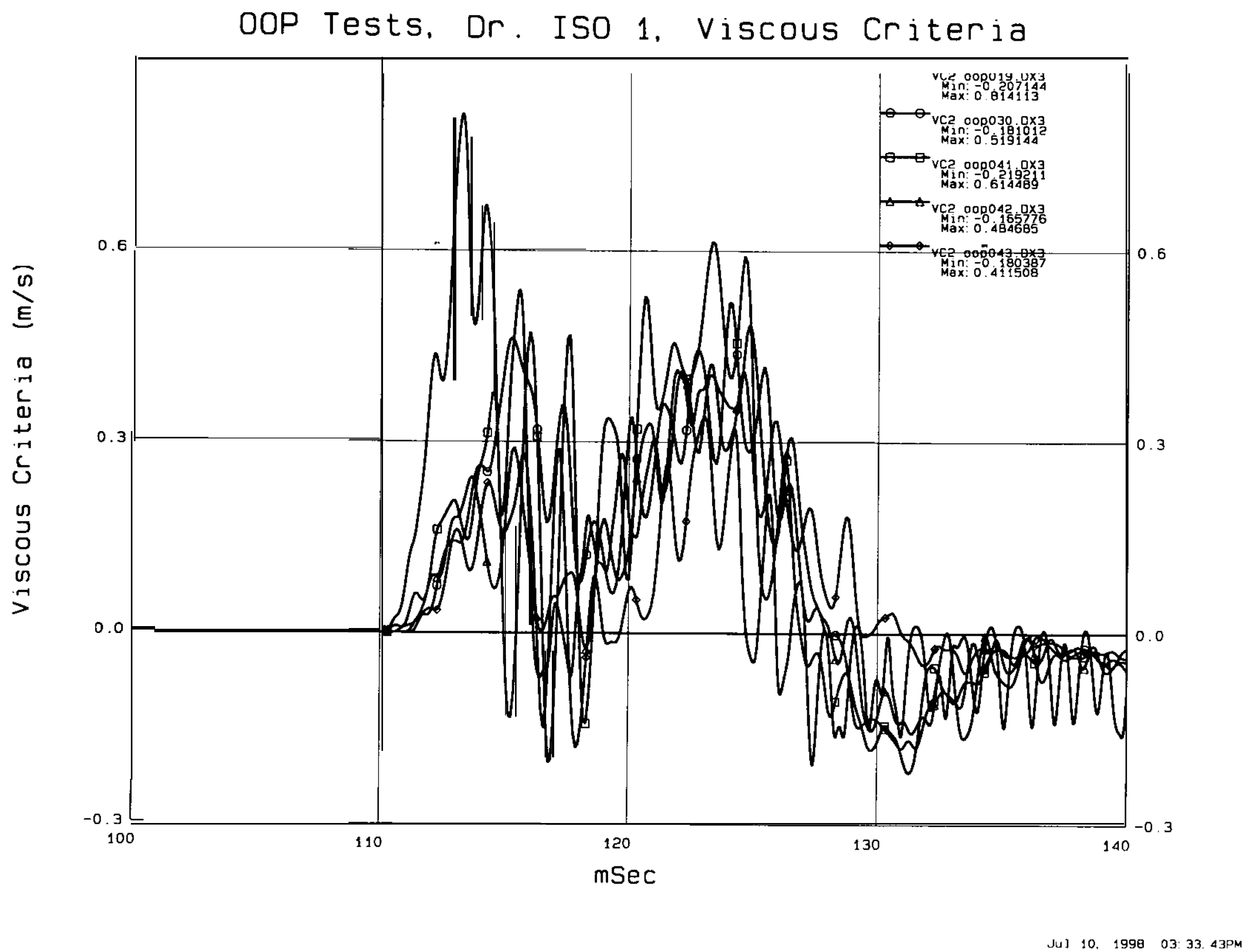
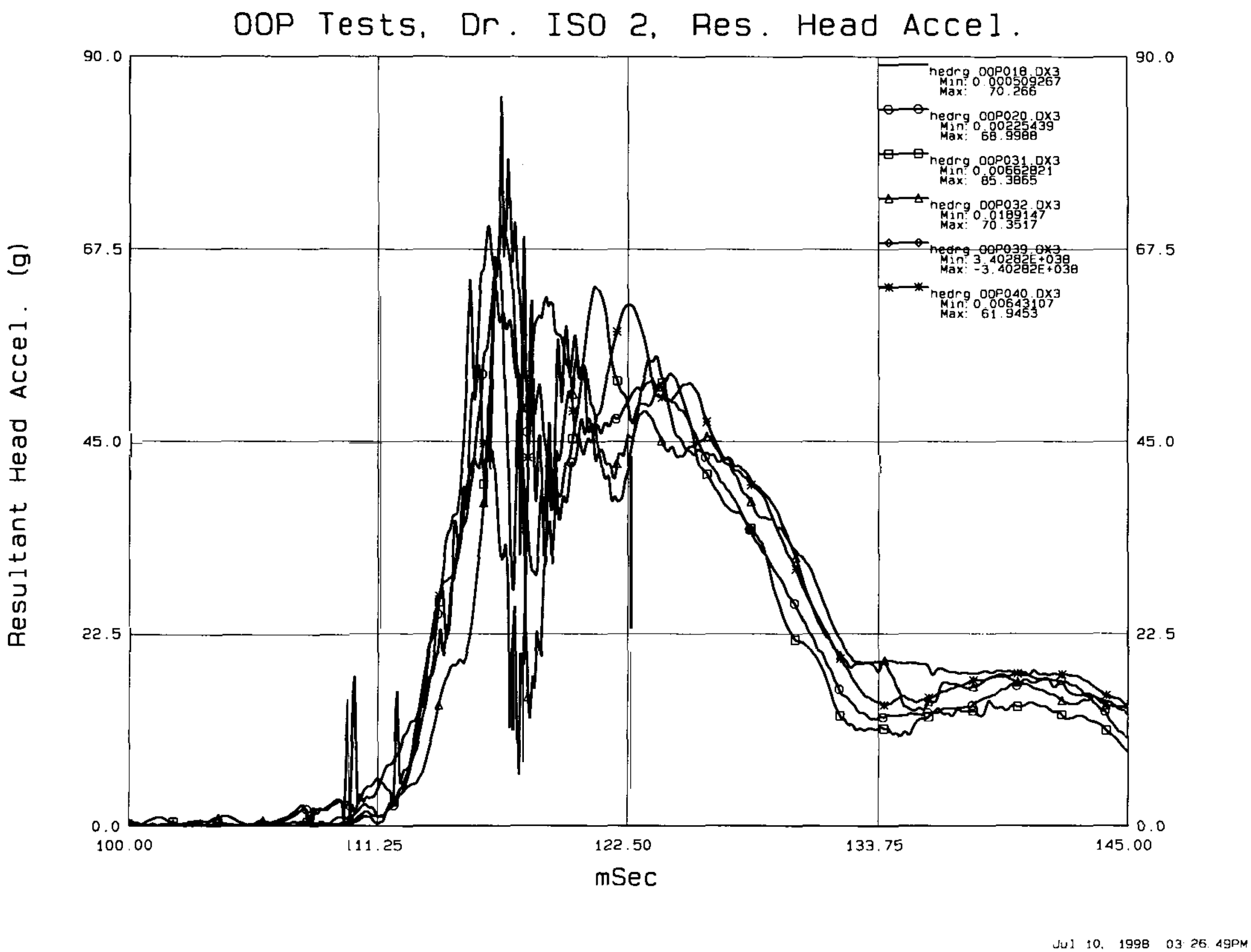

OOP Tests, Dr. ISO 1, Chest Displacment
Chest displacement (mm)
10.0
-2.5
-15.0
-27.5
-40.0
100
125
150
175
200
mSec
CSTXD VC19.DX3
Min: -33.7617
Max: 0.0342673
CSTXD VC30.DX3
Min: -34.0034
Max: 0.0275703
CSTXD VC41.DX3
Min: -33.5873
Max: 0.0101159
CSTXD VC42.DX3
Min: -30.431
Max: 0.000305356
CSTXD VC43.DX3
Min: -26.6485
Max: -0.000658345
Jul 10, 1998 03:25 47PM

Figure C.12


OOP Tests, Dr. ISO 1, Viscous Criteria
VC2 oop019.DX3
Min: -0.207144
Max: 0.814113
VC2 oop030.DX3
Min: -0.181012
Max: 0.519144
VC2 oop041.DX3
Min: -0.219211
Max: 0.614489
VC2 oop042.DX3
Min: -0.165776
Max: 0.484685
VC2 oop043.DX3
Min: -0.180387
Max: 0.411508
Viscous Criteria (m/s)
0.6
0.3
0.0
-0.3
100
110
120
130
140
mSec
Jul 10, 1998 03:33.43PM

rigure C.13



OOP Tests, Dr. ISO 2, Res. Head Accel.
hedrg OOP018.DX3
Min: 0.000509267
Max: 70.266
hedrg OOP020.DX3
Min: 0.00225439
Max: 68.9988
hedrg OOP031.DX3
Min: 0.00662821
Max: 85.3865
hedrg OOP032.DX3
Min: 0.0189147
Max: 70.3517
hedrg OOP039.DX3
Min: 3.40282E+038
Max: -3.40282E+038
hedrg OOP040.DX3
Min: 0.00643107
Max: 61.9453
90.0
67.5
45.0
22.5
0.0
100.00
111.25
122.50
133.75
145.00
mSec
Resultant Head Accel. (g)
Jul 10, 1998 03:26.49PM

Figure C.14

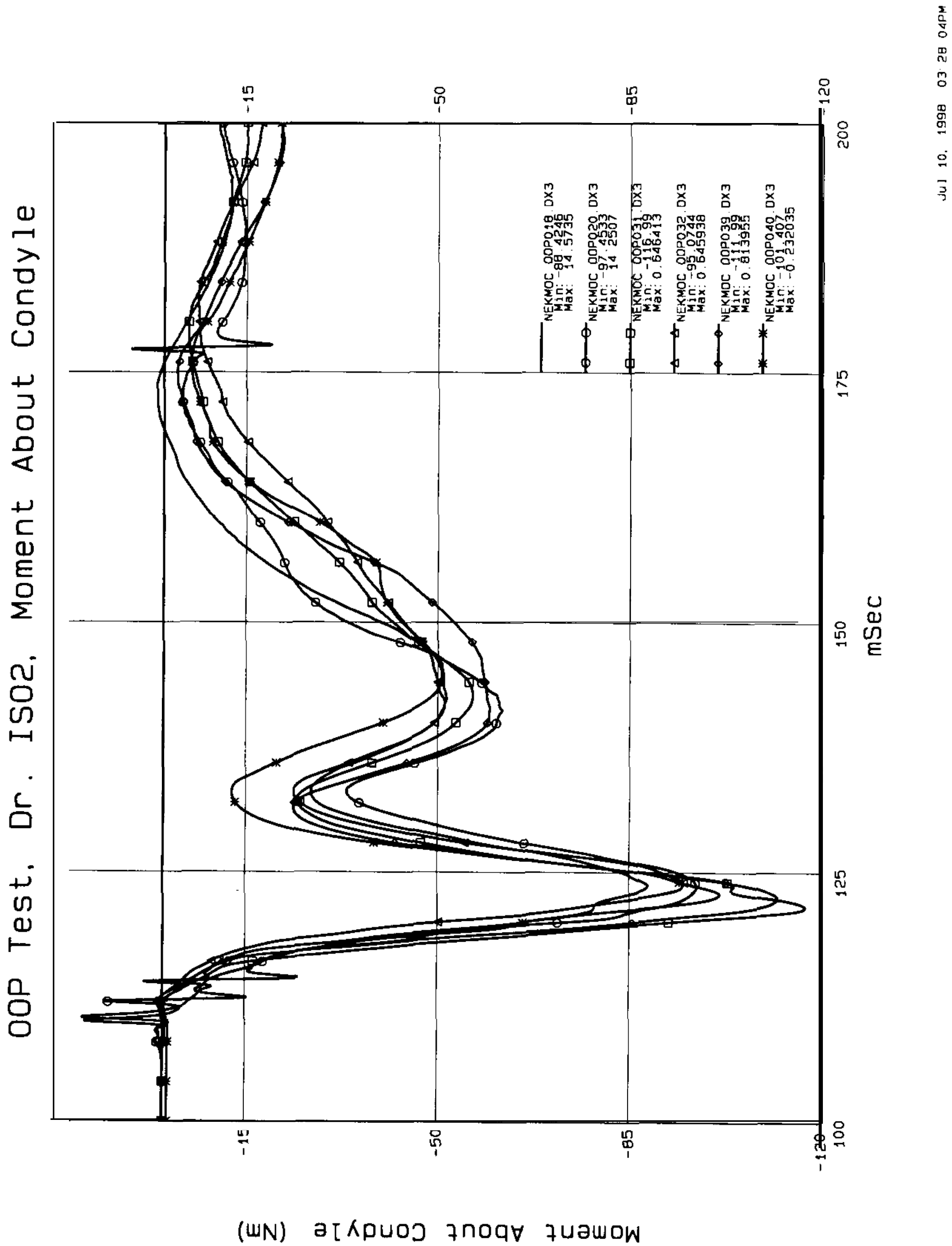
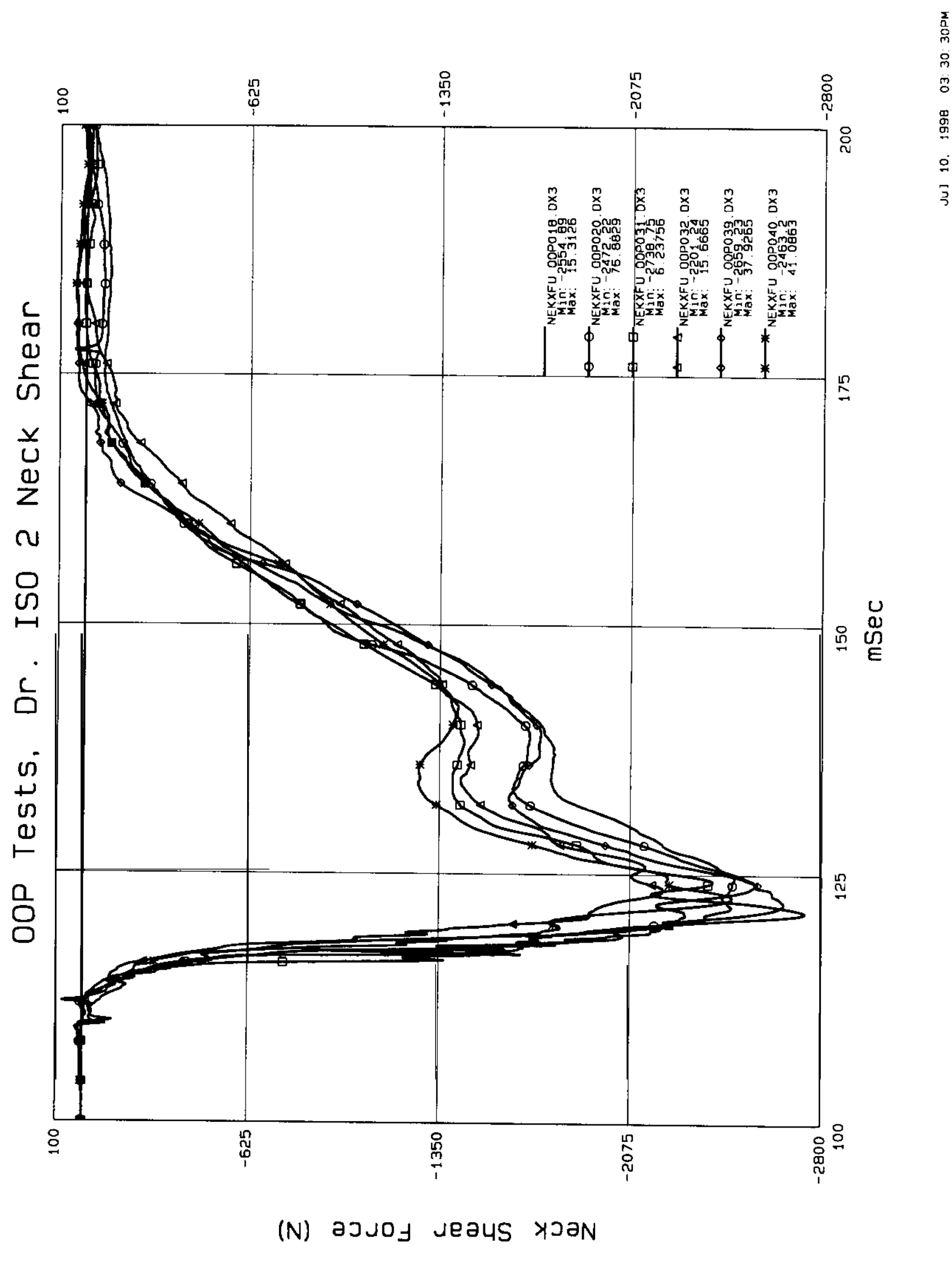
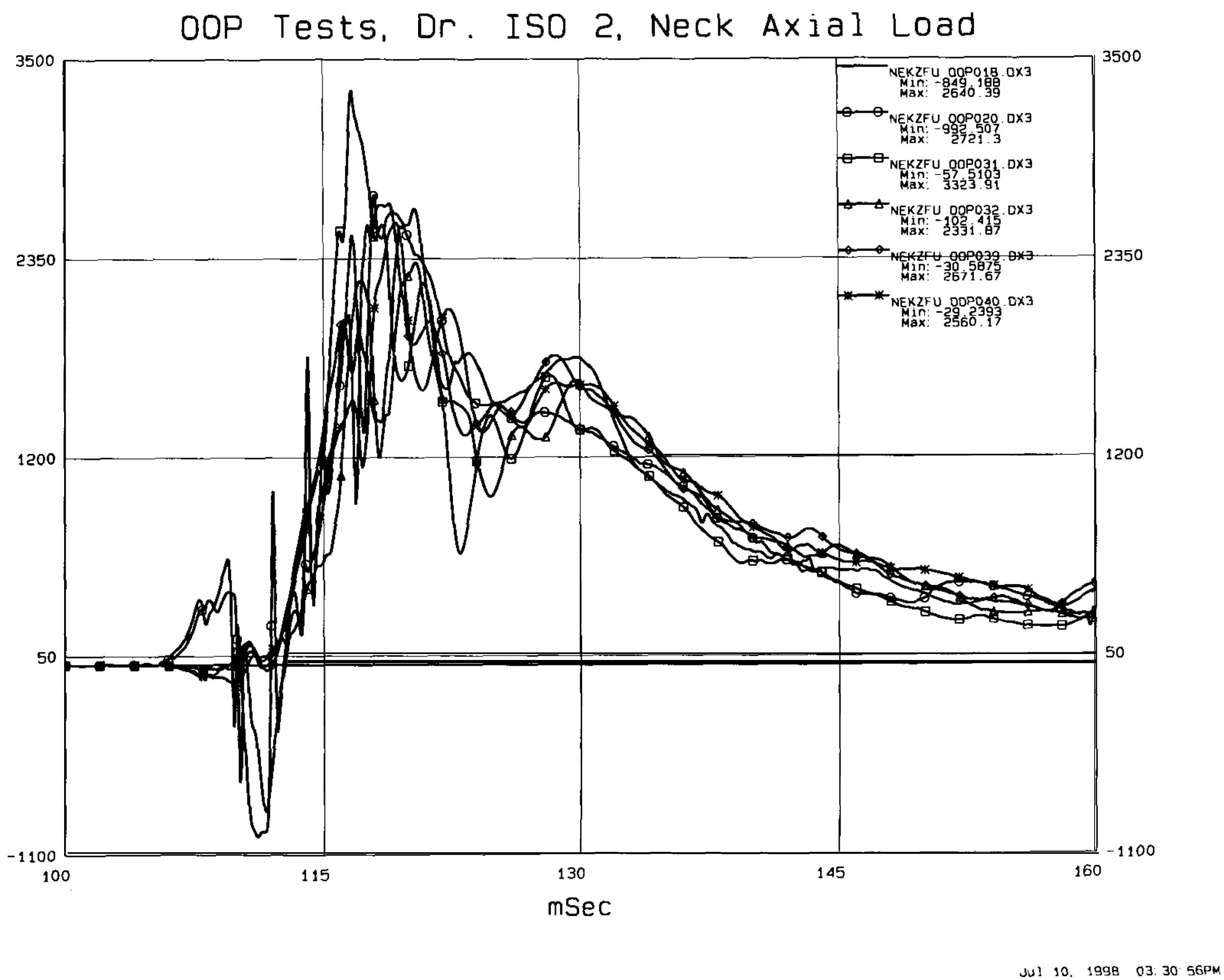

OOP Test, Dr. IS02, Moment About Condyle
Moment About Condyle (Nm)
mSec
-15
-50
-85
-120
100
125
150
175
200
NEKMOC OOP018 DX3
Min: -88.4246
Max: 14.5735
NEKMOC OOP020 DX3
Min: -97.4533
Max: 14.2507
NEKMOC OOP031 DX3
Min: -116.99
Max: 0.646413
NEKMOC OOP032 DX3
Min: -95.0744
Max: 0.645938
NEKMOC OOP039 DX3
Min: -111.99
Max: 0.813955
NEKMOC OOP040 DX3
Min: -101.407
Max: -0.232035
Jul 10, 1998 03:28 04PM

Figure C.15



OOP Tests, Dr. ISO 2 Neck Shear
Neck Shear Force (N)
mSec
100
-625
-1350
-2075
-2800
100
125
150
175
200
NEKXFU OOP018.DX3
Min: -2554.89
Max: 15.3126
NEKXFU OOP020.DX3
Min: -2472.22
Max: 76.8829
NEKXFU OOP031.DX3
Min: -2738.75
Max: 6.23756
NEKXFU OOP032.DX3
Min: -2201.24
Max: 15.6665
NEKXFU OOP039.DX3
Min: -2659.23
Max: 37.9265
NEKXFU OOP040.DX3
Min: -2463.2
Max: 41.0863
Jul 10, 1998 03:30:30PM

Figure C. 16



OOP Tests, Dr. ISO 2, Neck Axial Load
Neck Axial Force (N)
mSec
3500
2350
1200
50
-1100
100
115
130
145
160
NEKZFU OOP018.DX3 Min: -849.188 Max: 2640.39
NEKZFU OOP020.DX3 Min: -992.507 Max: 2721.3
NEKZFU OOP031.DX3 Min: -57.5103 Max: 3323.91
NEKZFU OOP032.DX3 Min: -102.415 Max: 2331.87
NEKZFU OOP039.DX3 Min: -30.5875 Max: 2671.67
NEKZFU OOP040.DX3 Min: -29.2393 Max: 2560.17
Jul 10, 1998 03:30:56PM

Figure C.17

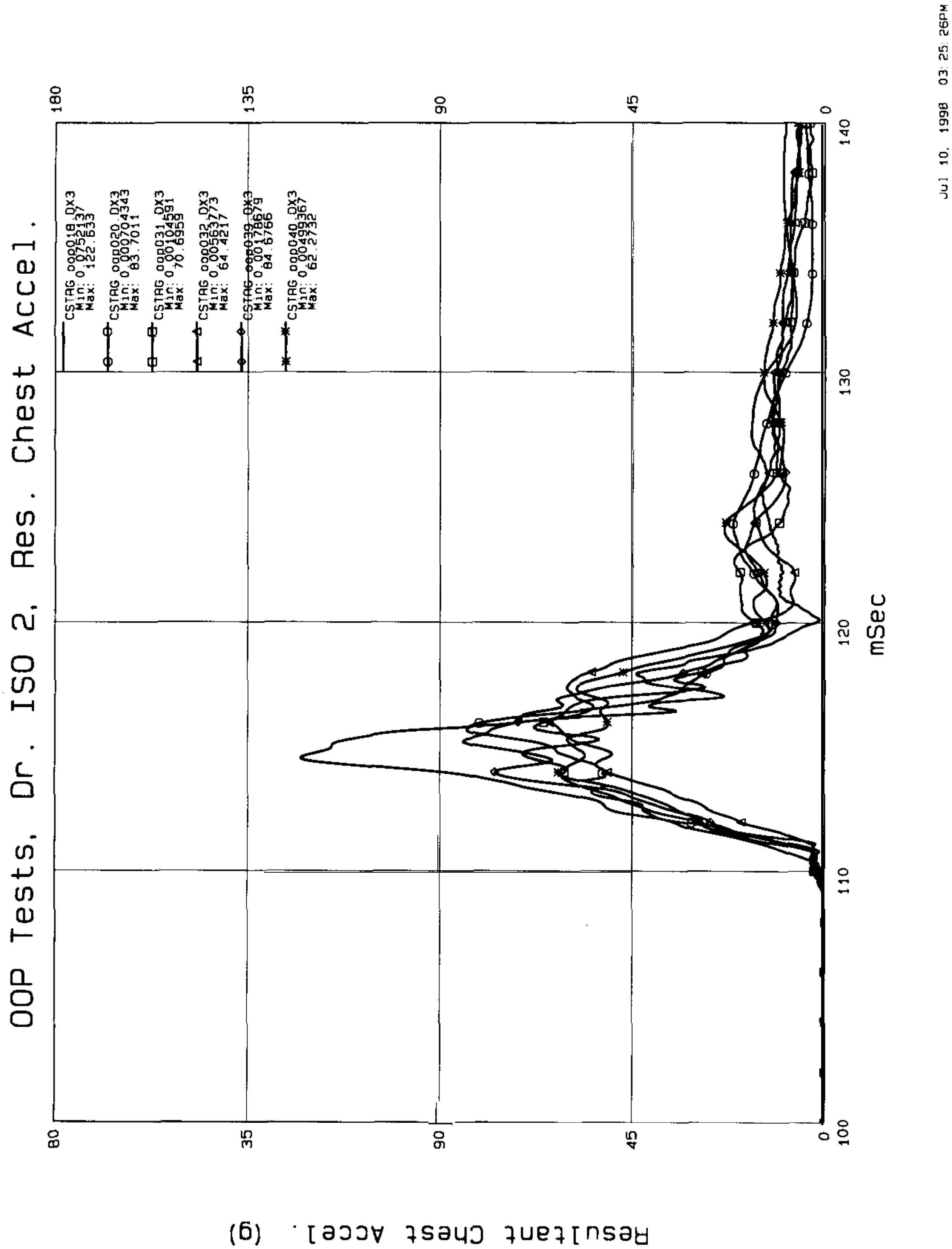

OOP Tests, Dr. ISO 2, Res. Chest Accel.
CSTRG oop018.DX3
Min: 0.0752137
Max: 122.633
CSTRG oop020.DX3
Min: 0.000704343
Max: 83.7011
CSTRG oop031.DX3
Min: 0.00104591
Max: 70.6959
CSTRG oop032.DX3
Min: 0.00563773
Max: 64.4217
CSTRG oop039.DX3
Min: 0.00178679
Max: 84.6766
CSTRG oop040.DX3
Min: 0.00499367
Max: 62.2732
Resultant Chest Accel. (g)
mSec
Jul 10, 1998 03:25:26PM

Figure C. 18

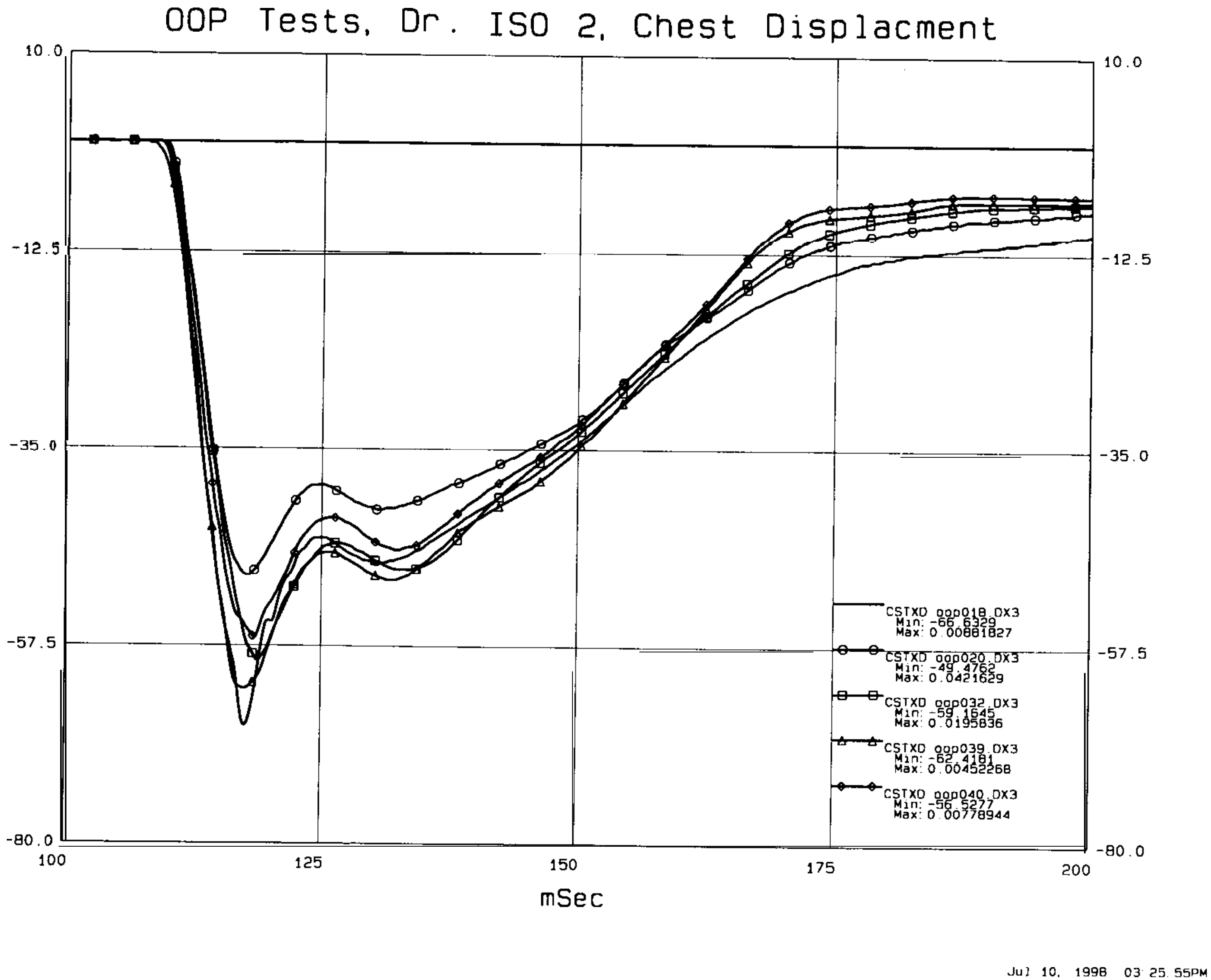
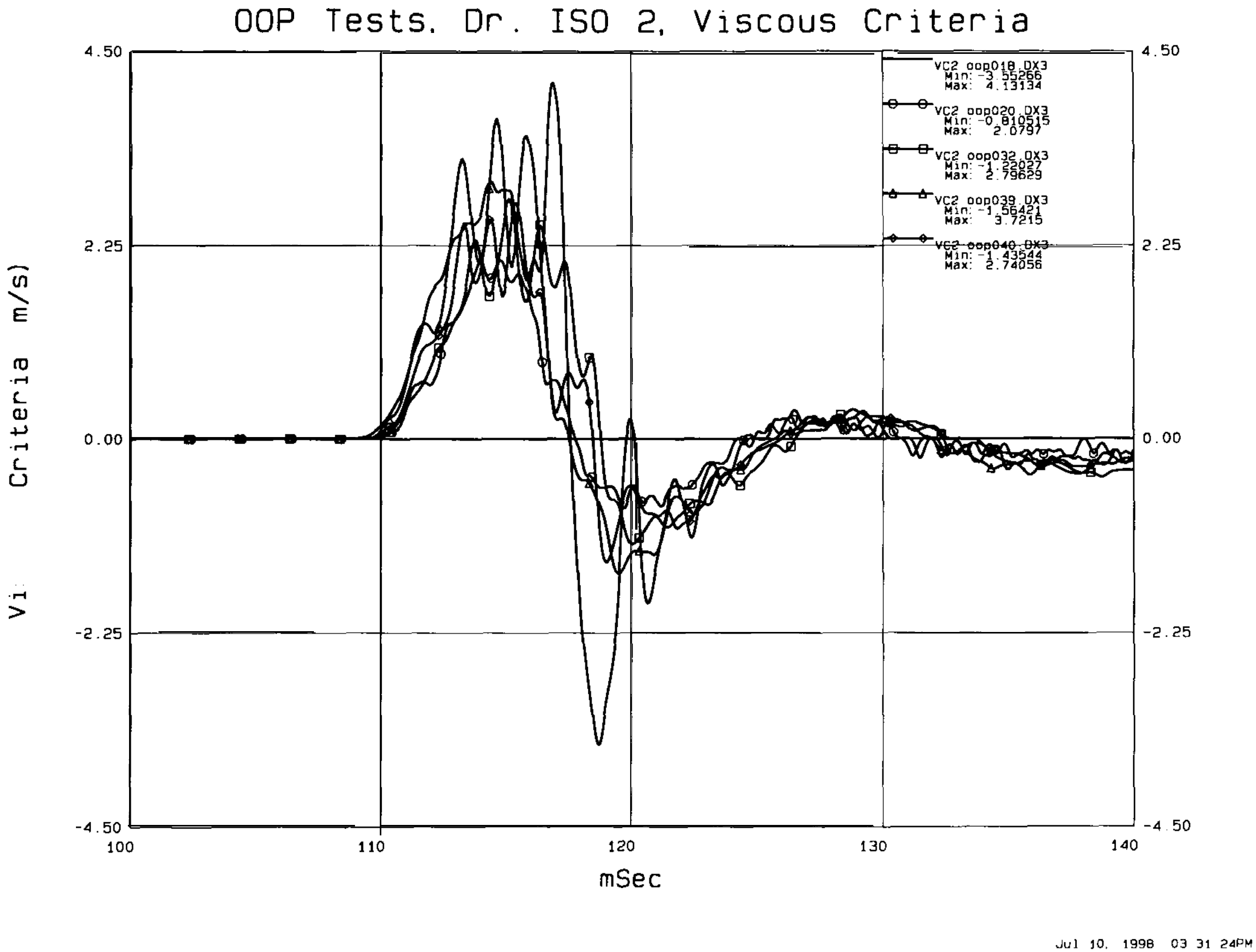

OOP Tests, Dr. ISO 2, Chest Displacment
10.0
-12.5
-35.0
-57.5
-80.0
100
125
150
175
200
mSec
Chest displacement (mm)
CSTXD oop018.DX3
Min: -66.6329
Max: 0.00881827
CSTXD oop020.DX3
Min: -49.4762
Max: 0.0421629
CSTXD oop032.DX3
Min: -59.1645
Max: 0.0195836
CSTXD oop039.DX3
Min: -62.4181
Max: 0.00452268
CSTXD oop040.DX3
Min: -56.5277
Max: 0.00778944
Jul 10, 1998 03:25.55PM

Figure C. 19



OOP Tests, Dr. ISO 2, Viscous Criteria
4.50
2.25
0.00
-2.25
-4.50
100
110
120
130
140
mSec
Vi
Criteria m/s)
VC2 oop018.DX3
Min: -3.55266
Max: 4.13134
VC2 oop020.DX3
Min: -0.810515
Max: 2.0797
VC2 oop032.DX3
Min: -1.22027
Max: 2.79629
VC2 oop039.DX3
Min: -1.56421
Max: 3.7215
VC2 oop040.DX3
Min: -1.43544
Max: 2.74056
Jul 10, 1998 03 31 24PM

Figure C.20

OOP Tests, Pass. #1, Res. Head Accel.

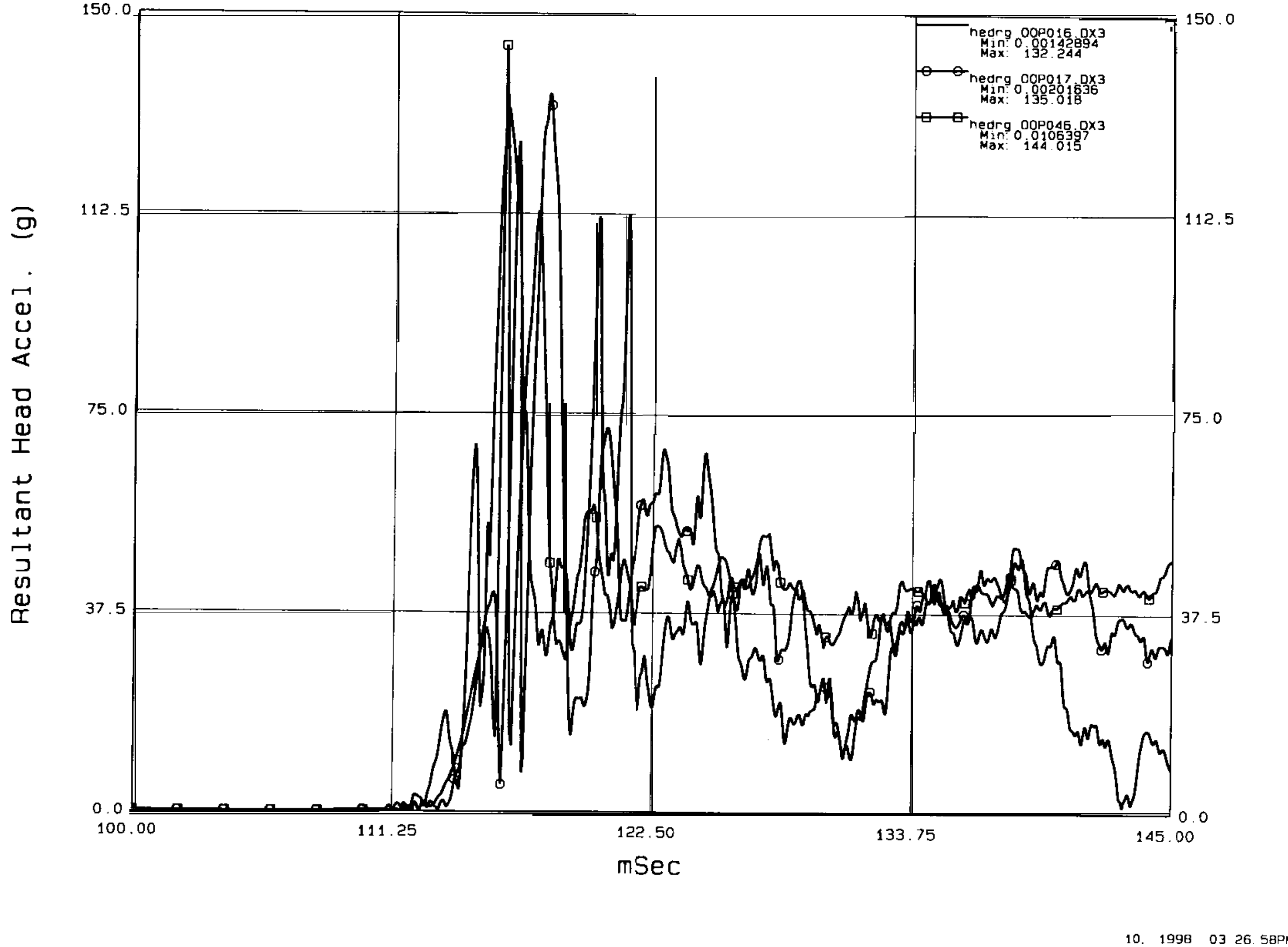
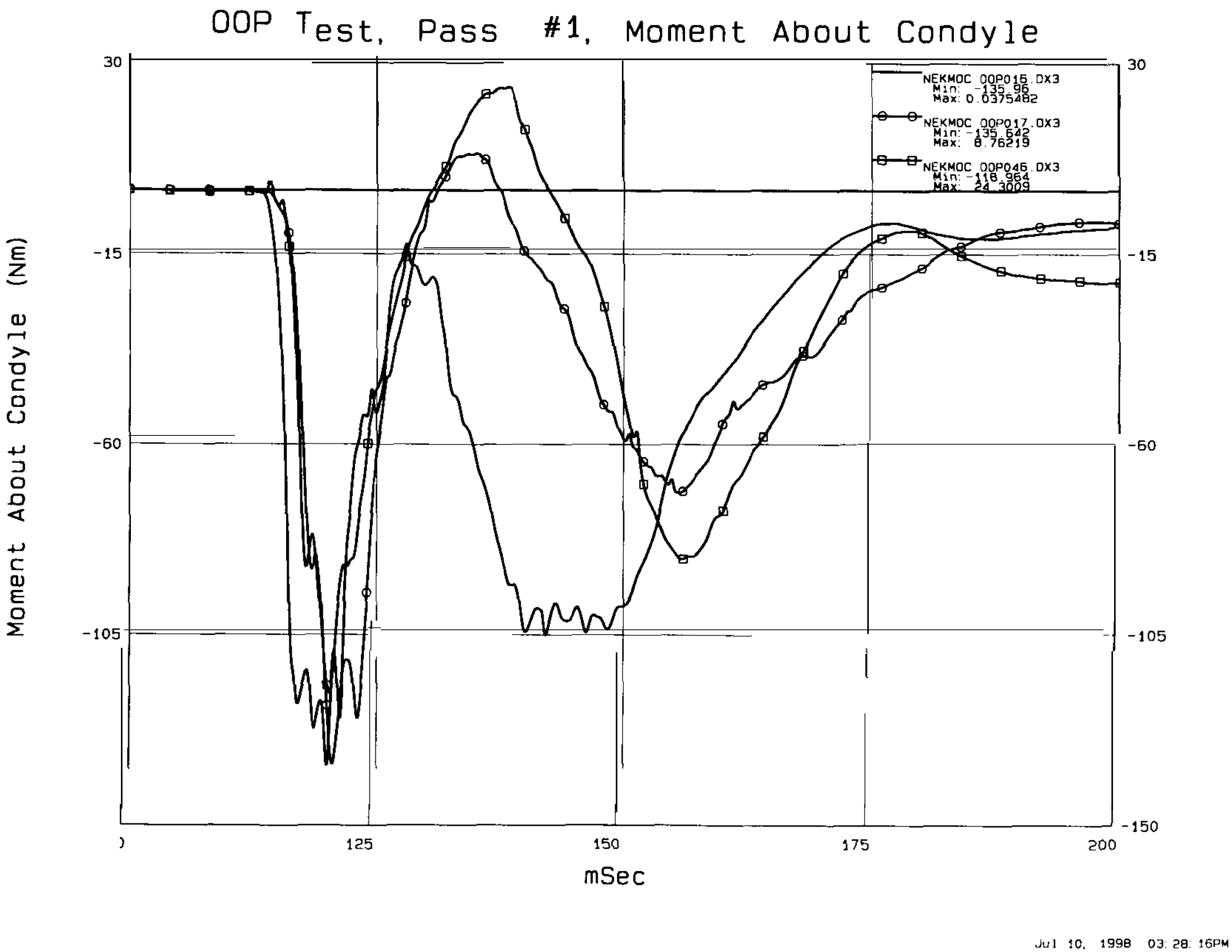
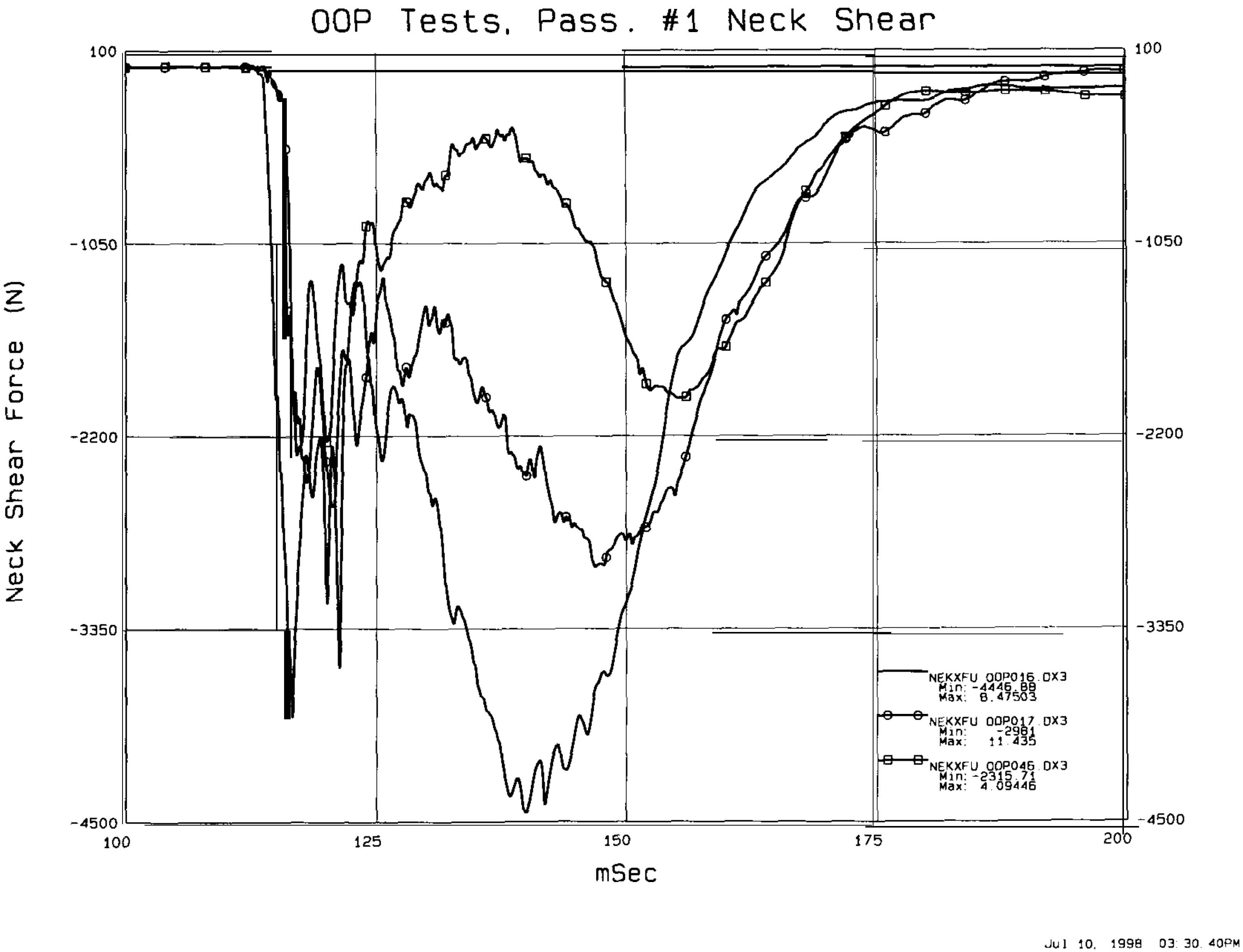


Figure C.21



OOP Test, Pass #1, Moment About Condyle
NEKMOC OOP015.DX3
Min: -135.96
Max: 0.0375482
NEKMOC OOP017.DX3
Min: -135.642
Max: 8.76219
NEKMOC OOP046.DX3
Min: -118.964
Max: 24.3009
30
-15
-60
-105
-150
125
150
175
200
mSec
Moment About Condyle (Nm)
Jul 10, 1998 03:28:16PM

Figure C.22



OOP Tests, Pass. #1 Neck Shear
Neck Shear Force (N)
mSec
100
-1050
-2200
-3350
-4500
100
125
150
175
200
NEKXFU OOP016.DX3
Min: -4446.88
Max: 8.47503
NEKXFU OOP017.DX3
Min: -2981
Max: 11.435
NEKXFU OOP046.DX3
Min: -2315.71
Max: 4.09446
Jul 10, 1998 03:30.40PM

Figure C.23

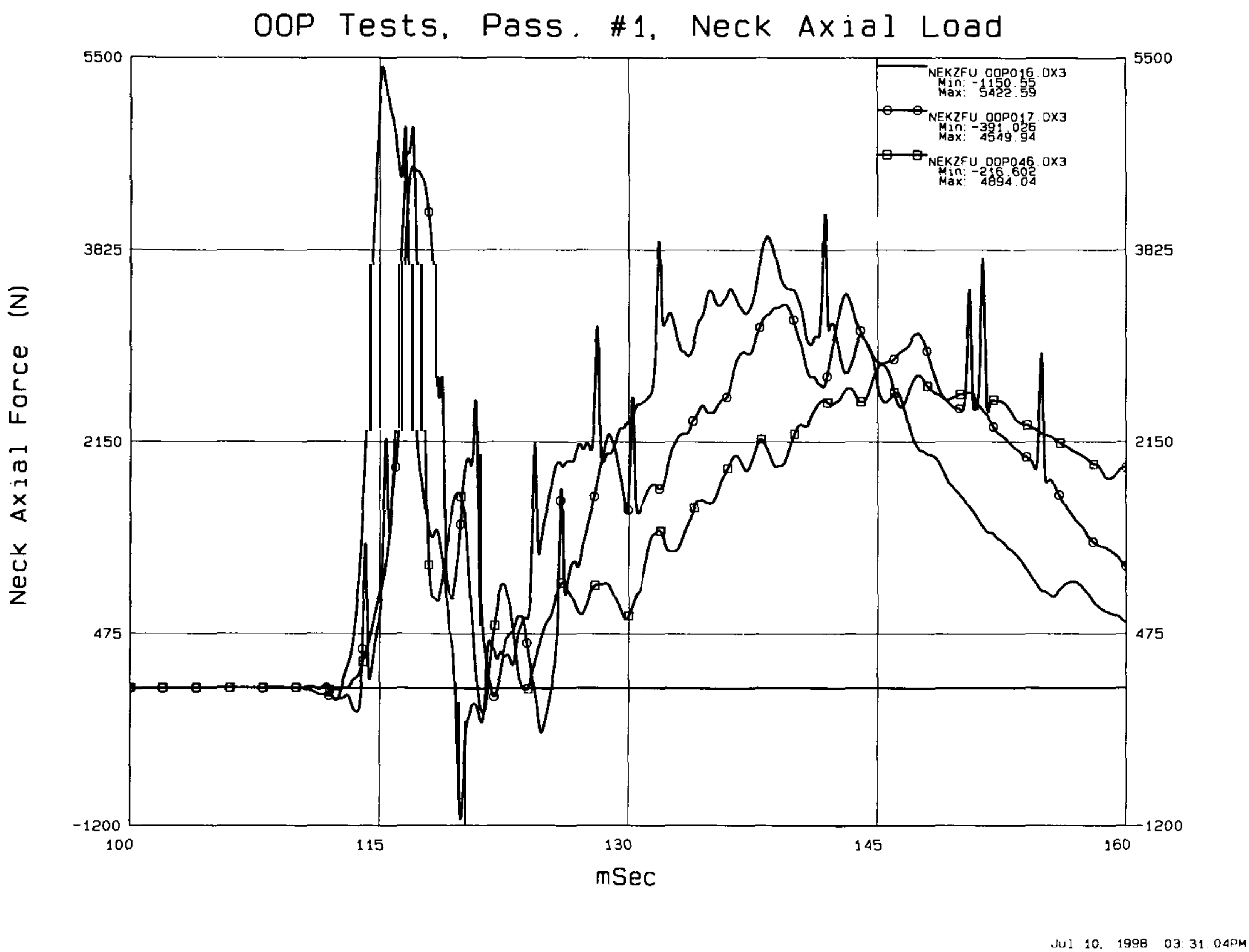
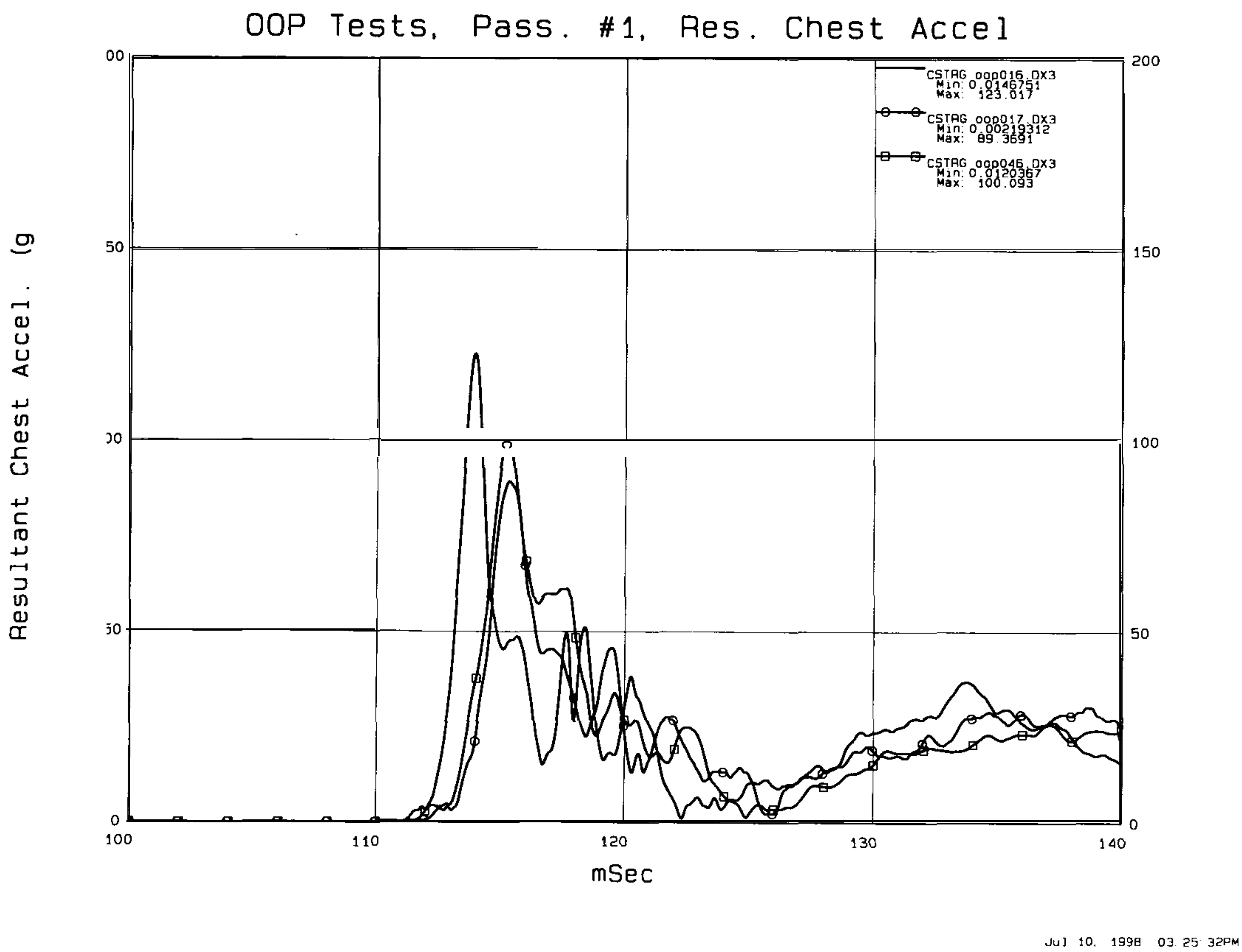
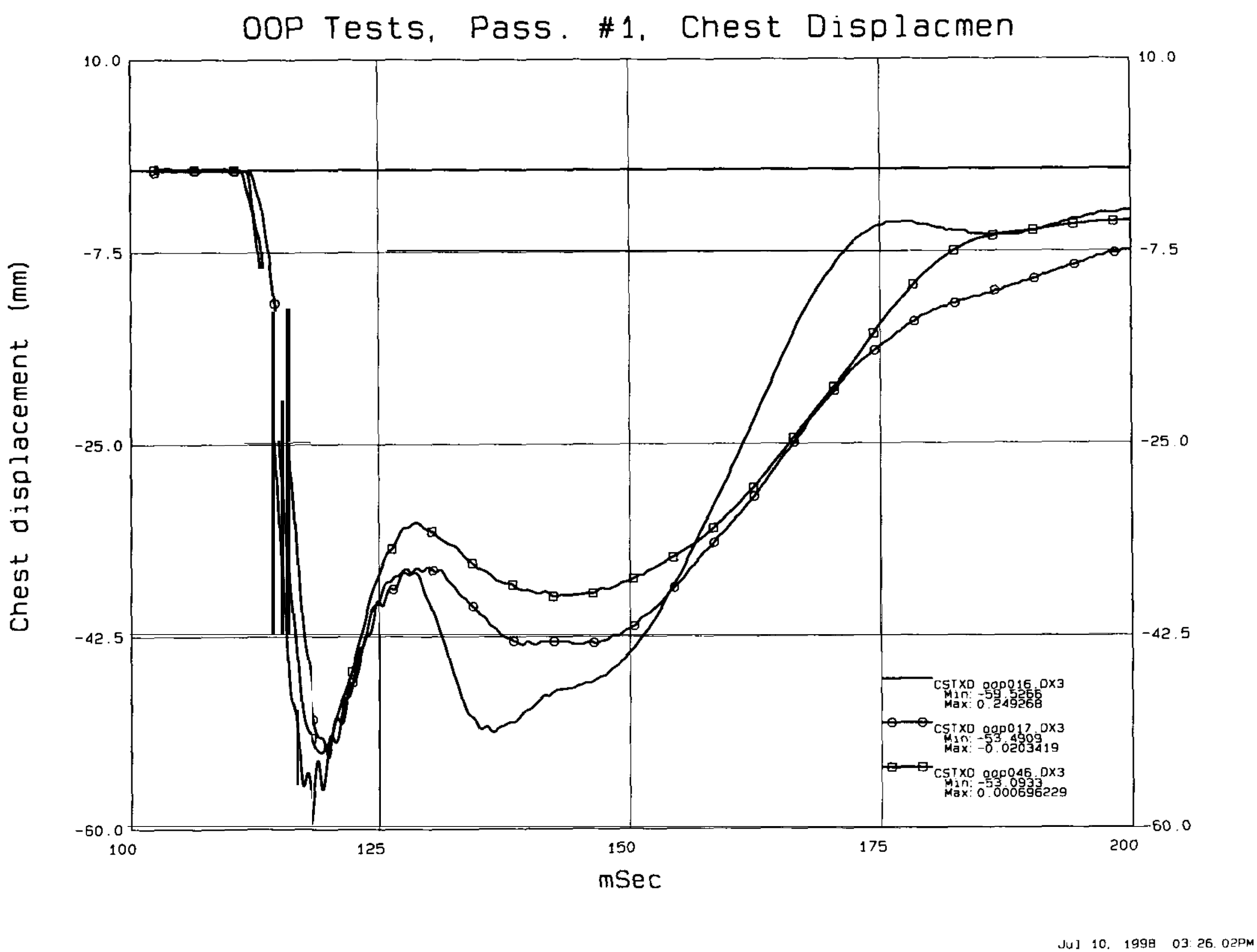

OOP Tests, Pass. #1, Neck Axial Load
Neck Axial Force (N)
mSec
5500
3825
2150
475
-1200
100
115
130
145
160
NEKZFU OOP016.DX3
Min: -1150.55
Max: 5422.59
NEKZFU OOP017.DX3
Min: -391.026
Max: 4549.94
NEKZFU OOP046.DX3
Min: -216.602
Max: 4894.04
Jul 10, 1998 03:31:04PM

Figure C.24



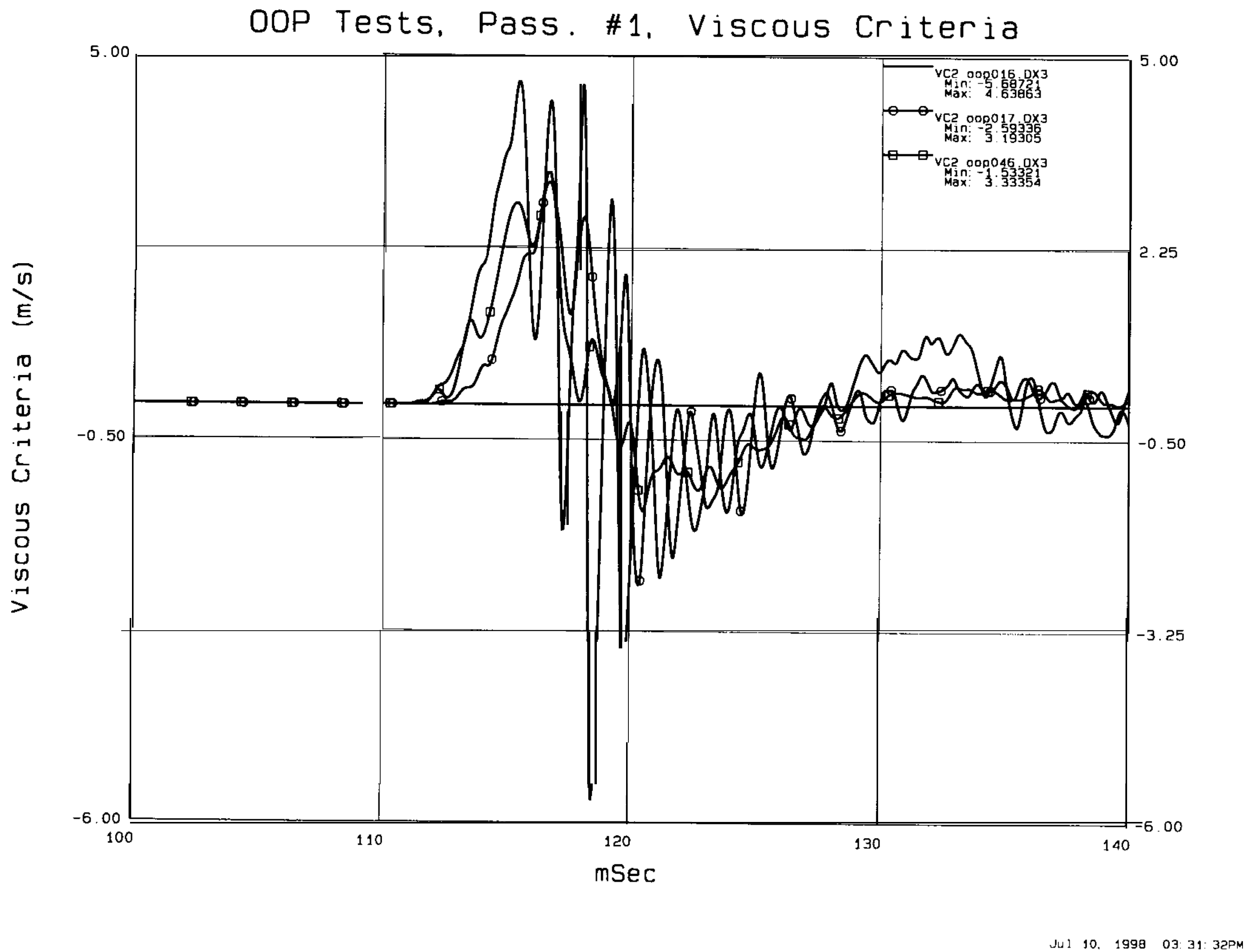
OOP Tests, Pass. #1, Res. Chest Accel
CSTRG ooo016.DX3
Min: 0.0146751
Max: 123.017
CSTRG ooo017.DX3
Min: 0.00219312
Max: 89.3691
CSTRG ooo046.DX3
Min: 0.0120367
Max: 100.093
Resultant Chest Accel. (g
mSec
100
110
120
130
140
0
50
100
150
200
Jul 10, 1998 03:25:32PM

Figure C.25



OOP Tests, Pass. #1, Chest Displacmen
10.0
-7.5
-25.0
-42.5
-60.0
100
125
150
175
200
mSec
Chest displacement (mm)
CSTXD oop016.DX3
Min: -59.5266
Max: 0.249268
CSTXD oop017.DX3
Min: -53.4909
Max: -0.0203419
CSTXD oop046.DX3
Min: -53.0933
Max: 0.000696229
Jul 10, 1998 03:26.02PM

Figure C.26


OOP Tests, Pass. #1, Viscous Criteria
5.00
2.25
-0.50
-3.25
-6.00
100
110
120
130
140
mSec
Viscous Criteria (m/s)
VC2 oop016.DX3
Min: -5.68721
Max: 4.63863
VC2 oop017.DX3
Min: -2.59336
Max: 3.19305
VC2 oop046.DX3
Min: -1.53321
Max: 3.33354
Jul 10, 1998 03:31:32PM

APPENDIX D - CALIBRATION RESULTS

Table D. 1. Head Drop Calibration Results

Test Date	Dummy S/N	Test No.	Cal Lab	Peak Resultant Acceleration (g)	Peak Lateral Acceleration (g)	Is Acceleration Curve Unimodal?
10/30/97	273	273C4HD1	TRC	278.48	2.26	YES
11/1197	273	273C5HD1	TRC	284.17	6.96	YES
12/08/97	273	273C7HD1	TRC	278.32	-3.54	YES
01/09/98	273	273C8HD1	TRC	271.23	-2.46	YES
01/29/98	273	273C9HD1	TRC	274.41	-2.87	YES
02/20/98	273	27310HD1	TRC	272.76	-3.91	YES
01/09/98	289	289C1HD1	TRC	264.68	2.67	YES
01/30/98	289	289C2HD1	TRC	272.86	-3.58	YES
02/20/98	289	289C3HD1	TRC	269.68	6.79	YES
Average	both			274.07		
Std. Dev.	both			5.36		
% CV	both			1.95		
Average	273			276.56		
Std. Dev.	273			4.32		
% CV	273			1.56		

Table D.2. Neck Flexion Calibration Results

Test Date	Dummy S/N	Test No.	Cal Lab	Impact Velocity (m/s)	Peak D-plane Rotation (deg)	Peak Moment (Nm)	Time - Positive Moment Decay to 10 Nm (ms)
10/30/97	273	273C4NF1	TRC	6.99	82.91	72.64	89.80
10/31/97	273	273C4NF2	TRC	7.06	82.77	71.51	89.00
10/31/97	273	273C4NF3	TRC	7.06	84.15	75.12	89.40
11/11/97	273	273C5NF1	TRC	6.99	82.74	71.42	89.00
11/11/97	273	273C5NF2	TRC	7.06	84.18	74.25	88.70
11/11/97	273	273C5NF3	TRC	7.06	83.34	70.76	89.70
12/05/97	273	273C7NF1	TRC	7.12	83.26	75.29	87.80
01/09/98	273	273C8NF1	TRC	7.12	85.59	74.2	90.00
01/30/98	273	273C9NF3	TRC	7.12	81.17	74.22	89.30
02/23/98	273	27310NF4	TRC	7.12	86.46	73.47	89.20
01/09/98	289	289C1NF1	TRC	7.06	87.94	76.08	89.90
01/09/98	289	289C1NF3	TRC	7.06	88.93	78.05	89.60
01/09/98	289	289C1NF4	TRC	7.12	90.26	81.14	88.00
01/30/98	289	289C2NF1	TRC	7.12	86.07	76.35	87.80
02/18/98	289	289C3NF1	TRC	7.12	89.33	79.00	89.10
02/18/98	289	289C3NF2	TRC	7.12	88.79	80.06	89.60
02/18/98	289	289C3NF4	TRC	7.12	89.48	81.14	90.70
02/18/98	289	289C3NF5	TRC	7.12	89.26	79.40	91.60
Average	both				85.92	75.78	89.34
Std. Dev.	both				2.86	3.25	0.93
% CV	both				3.33	4.29	1.04
Average	273				83.66	73.29	89.19
Std. Dev.	273				1.44	1.53	0.60
% CV	273				1.72	2.09	0.67
Average	289				88.76	78.90	89.54
Std. Dev.	289				1.19	1.83	1.19
% CV	289				1.34	2.32	1.33

Table D.3. Neck Extension Calibration Results

Test Date	Dummy S/N	Test No.	Cd Lab	Impact Velocity (m/s)	D-Plane Peak Rotation (degrees)	Peak Moment (Nm)	Time - Negative Moment Decay to -10 (ms)
10/30/97	273	273C4NE1	TRC	6.10	102.80	-58.66	104.3
11/12/97	273	273C5NE1	TRC	6.10	99.14	-59.00	103.2
11/12/97	273	273C5NE2	TRC	6.14	101.35	-66.32	100.6
12/05/97	273	273C7NE1	TRC	6.10	103.33	-60.66	102.1
01/09/98	273	273C8NE1	TRC	6.10	104.33	-61.59	103.7
01/30/98	273	273C9NE1	TRC	6.14	101.63	-58.90	102.0
02/23/98	273	27310NE1	TRC	6.10	104.02	-60.02	102.8
01/09/98	289	289C1NE1	TRC	6.10	104.64	-68.06	103.5
01/09/98	289	289C1NE2	TRC	6.00	103.29	-67.15	104.3
01/09/98	289	289C1NE3	TRC	6.05	102.00	-63.37	106.0
01/30/98	289	289C2NE1	TRC	6.05	104.38	-56.65	108.0
02/19/98	289	289C3NE2	TRC	6.05	106.38	-63.89	105.7
Average	both				103.1 I	-62.02	103.85
Std. Dev.	both				1.81	3.55	I.92
% cv	both				I.76	5.73	1.85
Average	273				102.37	-60.74	102.67
Std. Dev.	273				1.68	2.48	1.14
% cv	273				1.64	4.09	1.11
Average	289				104.14	-63.82	105.50
Std. Dev.	289				I.46	4.02	1.55
% cv	289				1.40	6.29	1.47

Table D.4. Thorax Impact Calibration Results

Test Date	Dummy S/N	Test No.	Cal. Lab	Impact Speed (m/s)	Max. Sternum Deflection (mm)	Force at Time of Max. Deflection (N)	Internal Hysteresis (%)	Peak Force during Deflection Corridor* (N)	Peak Force (N)
10/30/97	273	273C4TH1	TRC	6.68	53.9	3545	73.4	4250.9	4250.9
11/11/97	273	273C5TH1	TRC	6.68	52.0	3708	74.0	3926.9	3926.9
12/08/97	273	273C7TH1	TRC	6.74	51.4	3706	74.7	4124.0	4124.0
01/09/98	273	273C8TH1	TRC	6.77	51.5	3751	74.7	4085.2	4085.2
01/30/98	273	273C9TH1	TRC	6.76	51.3	3736	74.3	4170.8	4170.8
2/17/98	273	27310TH1	TRC	6.80	52.9	3820	74.5	4139.5	4139.5
01/09/98	289	289C1TH1	TRC	6.74	52.9	3849	77.2	4087.2	4087.2
01/30/98	289	289C2TH1	TRC	6.74	51.4	3912	76.2	4259.3	4259.3
02/13/98	289	289C3TH1	TRC	6.74	48.9	3785	75.7	4094.4	4214.9
02/13/98	289	289C3TH2	TRC	6.83	53.0	3978	75.4	4348.3	4348.3
Average	both				51.92	3779.00	75.01	4148.65	4160.70
Std. Dev.	both				1.31	114.75	1.07	111.20	111.20
% CV	both				2.53	3.04	1.42	2.68	2.67
Average	273				52.17	3710.88	74.27	4116.22	4116.22
Std. Dev.	273				0.94	83.30	0.46	98.76	98.76
% CV	273				1.81	2.24	0.62	2.40	2.40
Average	289				51.55	3881.00	76.13	4197.30	4227.43
Std. Dev.	289				1.66	71.78	0.68	111.07	94.14
% CV	289				3.21	1.85	0.90	2.65	2.23

* deflection corridor = 48 - 55 mm

Table D.5. Knee Impact Calibration Results

Test Date	Dummy S/N	Test No.	Cal Lab	Right/Left Femur	Impact Velocity (m/s)	Peak Force (N)
10/30/97	273	273C4RK1	TRC	Right	2.12	3561.3
10/30/97	273	273C4LK2	TRC	Left	2.12	4004.5
11/12/97	273	273C5RK1	TRC	Right	2.13	3635.4
11/12/97	273	273C5LK1	TRC	Left	2.12	3817.7
12/08/97	273	273C7RK1	TRC	Right	2.07	3798.0
12/08/97	273	273C7LK1	TRC	Left	2.08	3905.7
01/09/98	273	273C8RK1	TRC	Right	2.09	3420.3
01/09/98	273	273C8LK1	TRC	Left	2.09	3632.5
01/30/98	273	273C9RK1	TRC	Right	2.08	3421.3
01/30/98	273	273C9LK1	TRC	Left	2.10	3765.0
02120198	273	27310RK1	TRC	Right	2.13	361 1.9
02/20/98	273	27310LK1	TRC	Left	2.12	3986.2
01/09/98	289	289C1RK1	TRC	Right	2.09	3898.9
01/30/98	289	289C2RK1	TRC	Right	2.10	3664.4
01/30/98	289	289C2LK1	TRC	Left	2.10	3515.5
02/18/98	289	289C3RK1	TRC	Right	2.13	3894.2
02/18/98	289	289C3LK1	TRC	Left	2.13	3638.6
Average	both					3715.96
Std. Dev.	both					179.59
% cv	both					4.83
Average	273					3713.32
Std. Dev.	273					190.20
% cv	273					5.12
Average	289					3722.32
Std. Dev.	289					150.90
% cv	289					4.05

Table D.6. Torso Flexion Results (for one abdomen)

Test #	Dummy S/N	Abdomen S/N	Initial Angle (deg)	Force @ 45 deg. (lbs)	Return Angle (deg)
TF27306	273	684	14.3	78.32	n/a
TF273 12	273	684	15.3	75.03	20.11
TF27316	273	684	16.2	75.79	20.74
AVG				76.38	

Fig. D. 1. Torso Flexion Results for (2) Different Abdomens

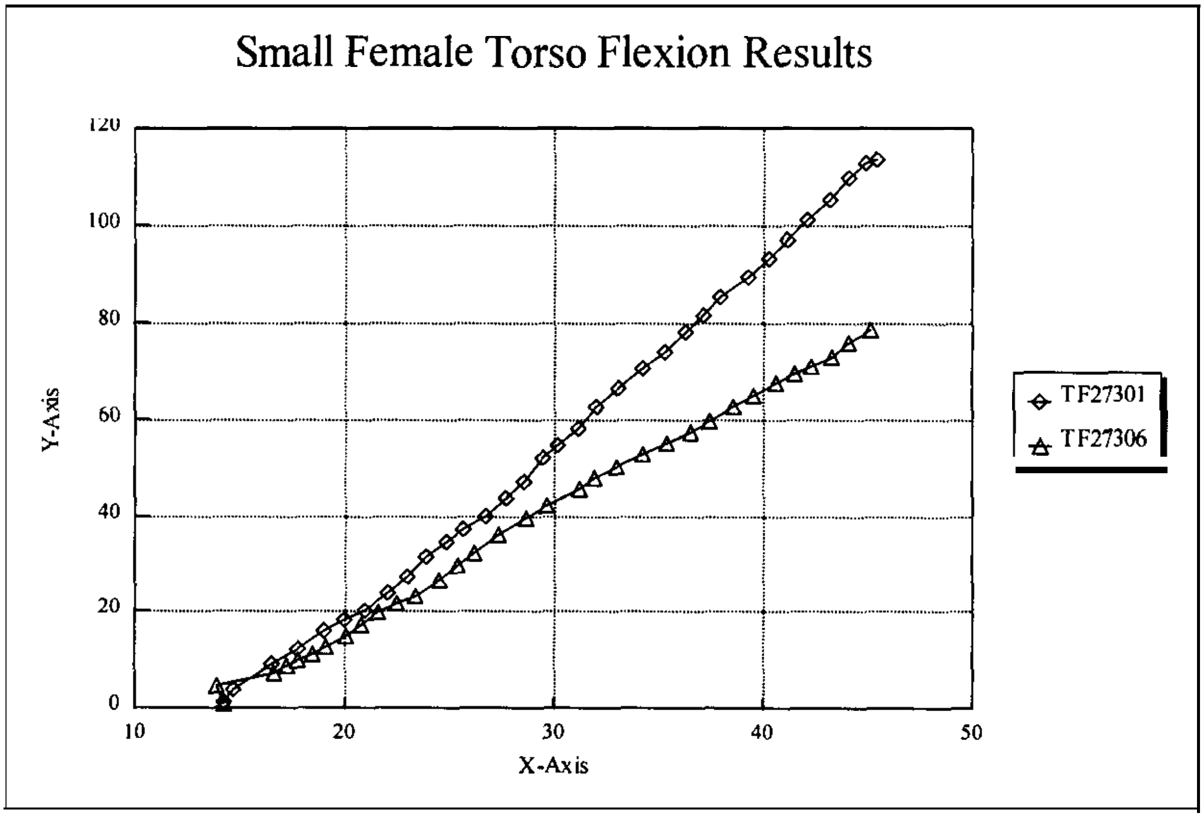
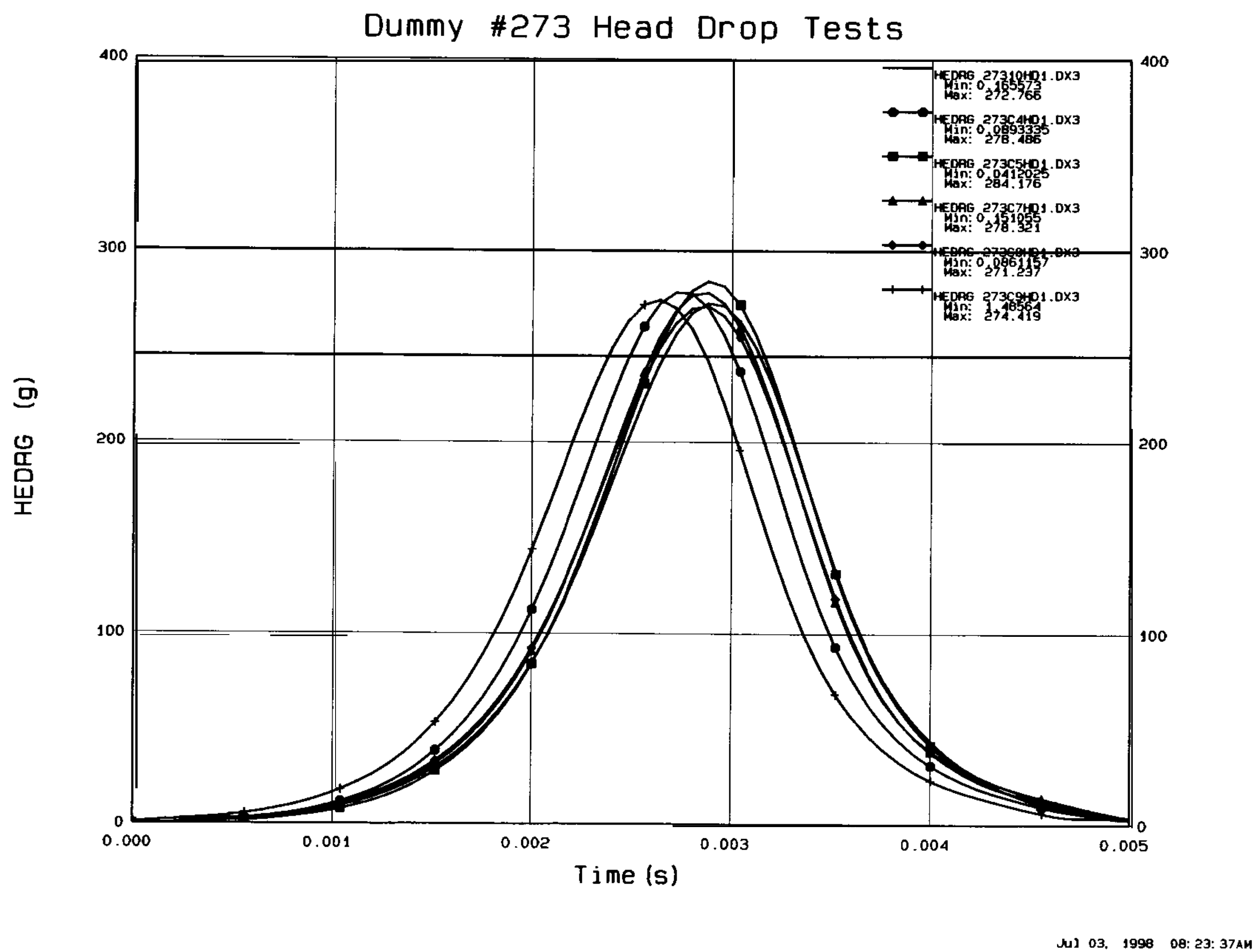
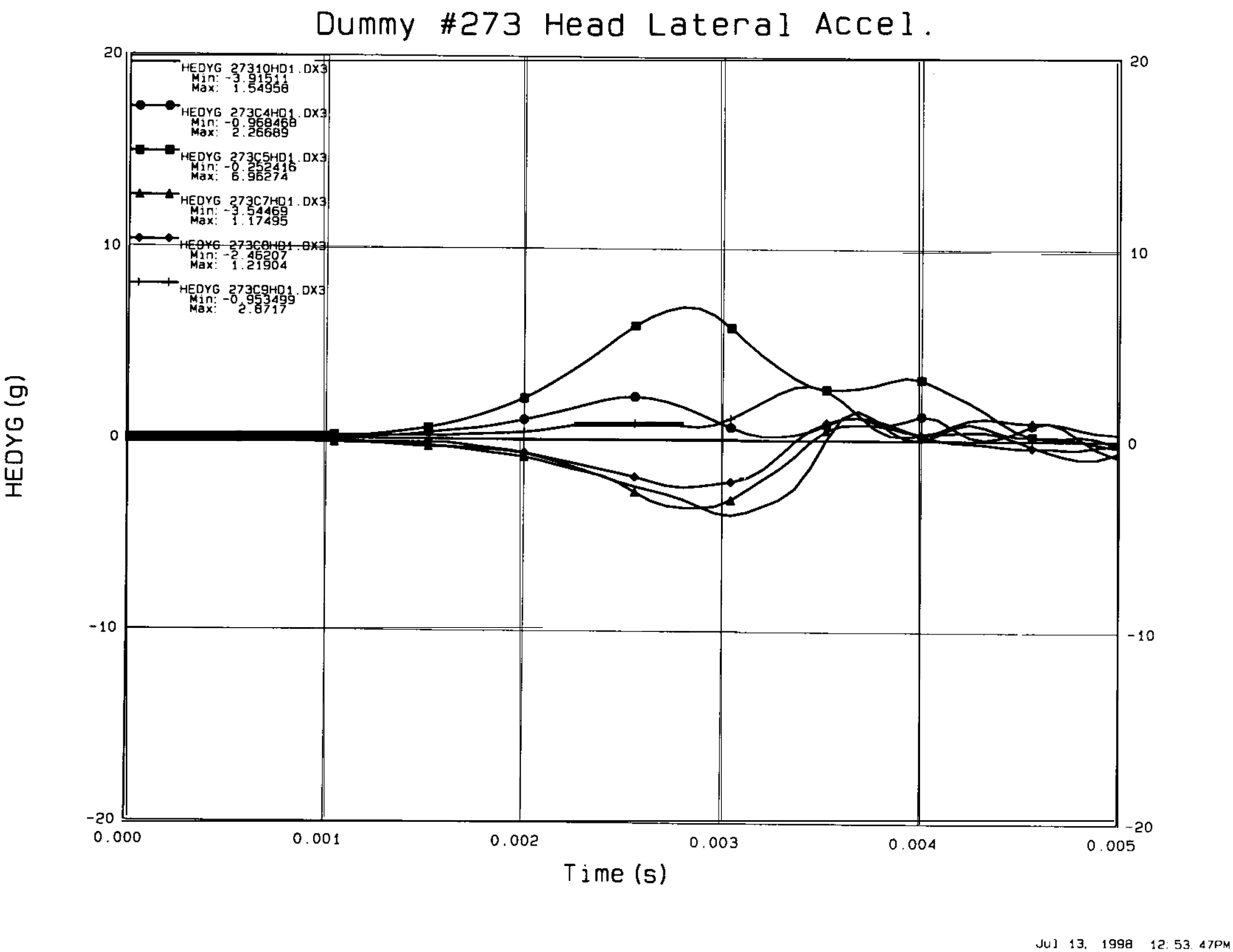


Figure D.2



Dummy #273 Head Drop Tests
HEDRG 27310HD1.DX3
Min: 0.165573
Max: 272.766
HEDRG 273C4HD1.DX3
Min: 0.0893335
Max: 278.486
HEDRG 273C5HD1.DX3
Min: 0.0412025
Max: 284.176
HEDRG 273C7HD1.DX3
Min: 0.151055
Max: 278.321
Min: 0.0861157
Max: 271.237
HEDRG 273C9HD1.DX3
Min: 1.48564
Max: 274.419
HEDRG (g)
Time (s)
0
100
200
300
400
0.000
0.001
0.002
0.003
0.004
0.005
Jul 03, 1998 08:23:37AM

Figure D.3



Dummy #273 Head Lateral Accel.
HEDYG 27310HD1.DX3
Min: -3.91511
Max: 1.54958
HEDYG 273C4HD1.DX3
Min: -0.968468
Max: 2.26689
HEDYG 273C5HD1.DX3
Min: -0.252416
Max: 6.96274
HEDYG 273C7HD1.DX3
Min: -3.54469
Max: 1.17495
HEDYG 273C8HD1.DX3
Min: -2.46207
Max: 1.21904
HEDYG 273C9HD1.DX3
Min: -0.953499
Max: 2.8717
HEDYG (g)
Time (s)
Jul 13, 1998 12:53:47PM

Figure D.4

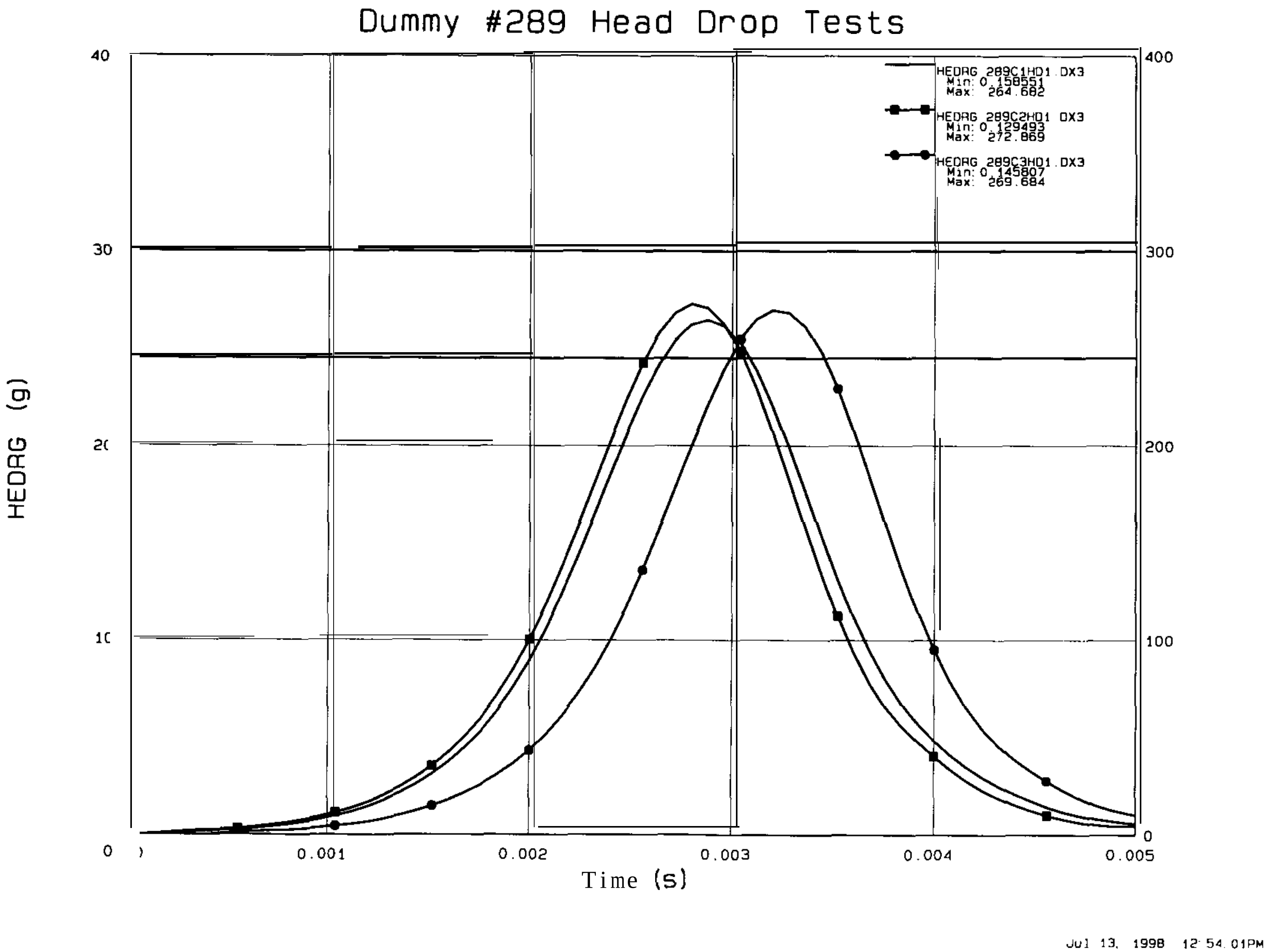
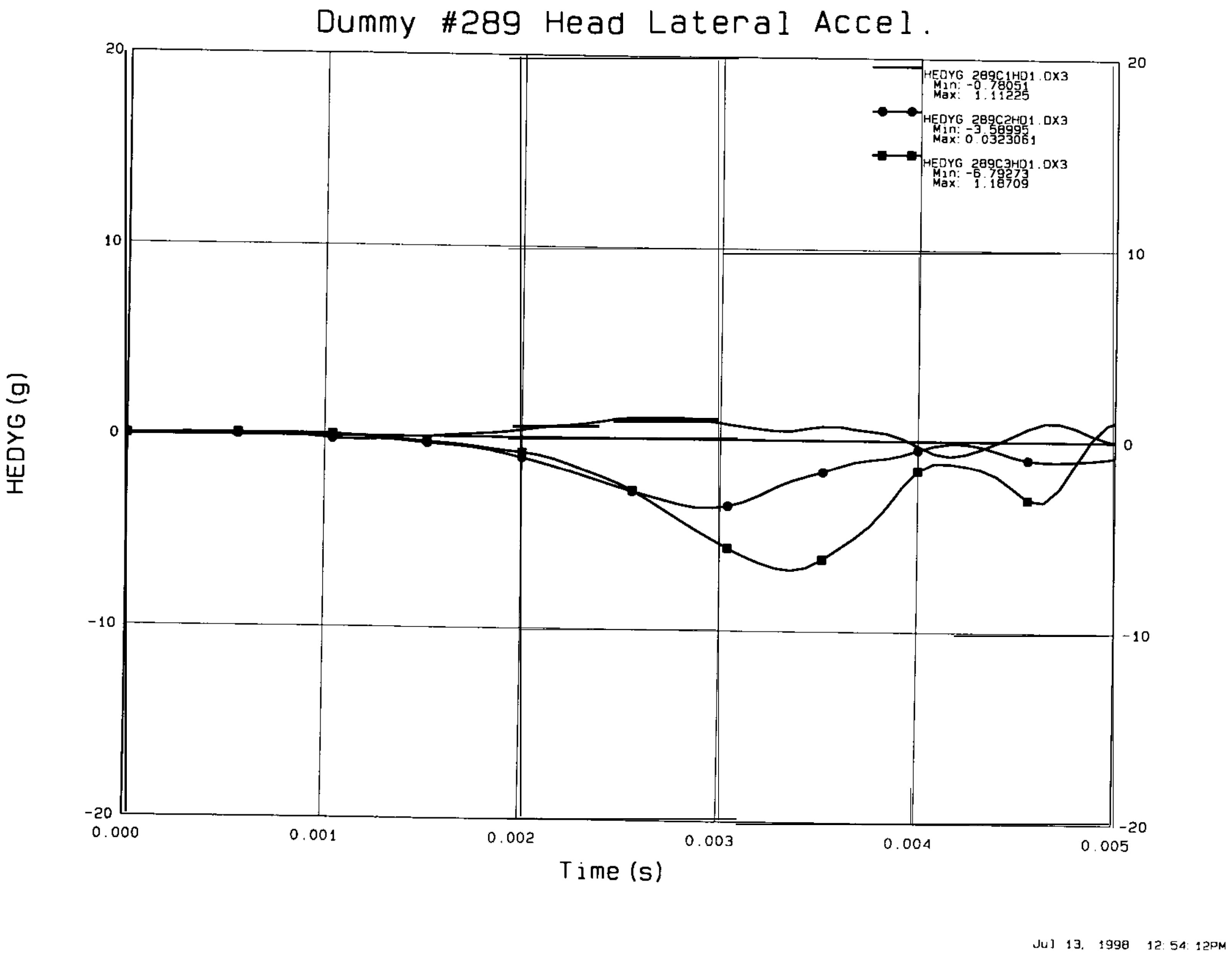

Dummy #289 Head Drop Tests
HEDRG (g)
Time (s)
HEDRG 289C1HD1.DX3
Min: 0.158551
Max: 264.682
HEDRG 289C2HD1 DX3
Min: 0.129493
Max: 272.869
HEDRG 289C3HD1.DX3
Min: 0.145807
Max: 269.684
0
10
20
30
40
100
200
300
400
0.001
0.002
0.003
0.004
0.005
JUL 13, 1998 12:54:01PM

Figure D.5



Dummy #289 Head Lateral Accel.
HEDYG 289C1HD1.DX3
Min: -0.78051
Max: 1.11225
HEDYG 289C2HD1.DX3
Min: -3.58995
Max: 0.0323061
HEDYG 289C3HD1.DX3
Min: -6.79273
Max: 1.18709
HEDYG (g)
Time (s)
20
10
0
-10
-20
0.000
0.001
0.002
0.003
0.004
0.005
Jul 13, 1998 12:54:12PM

Figure D.6

Dummy #273 Neck Flexion Tests

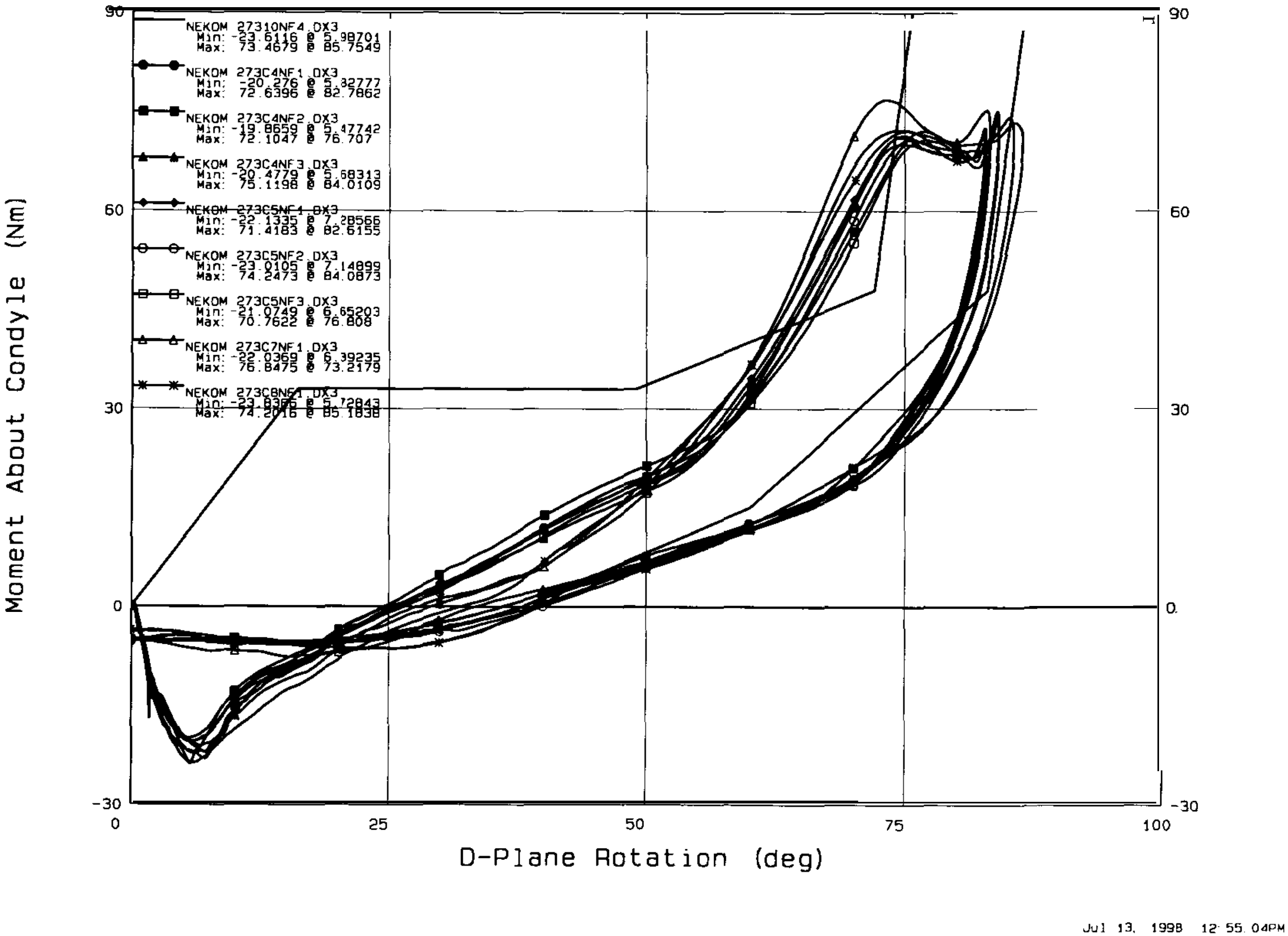


Figure D.7

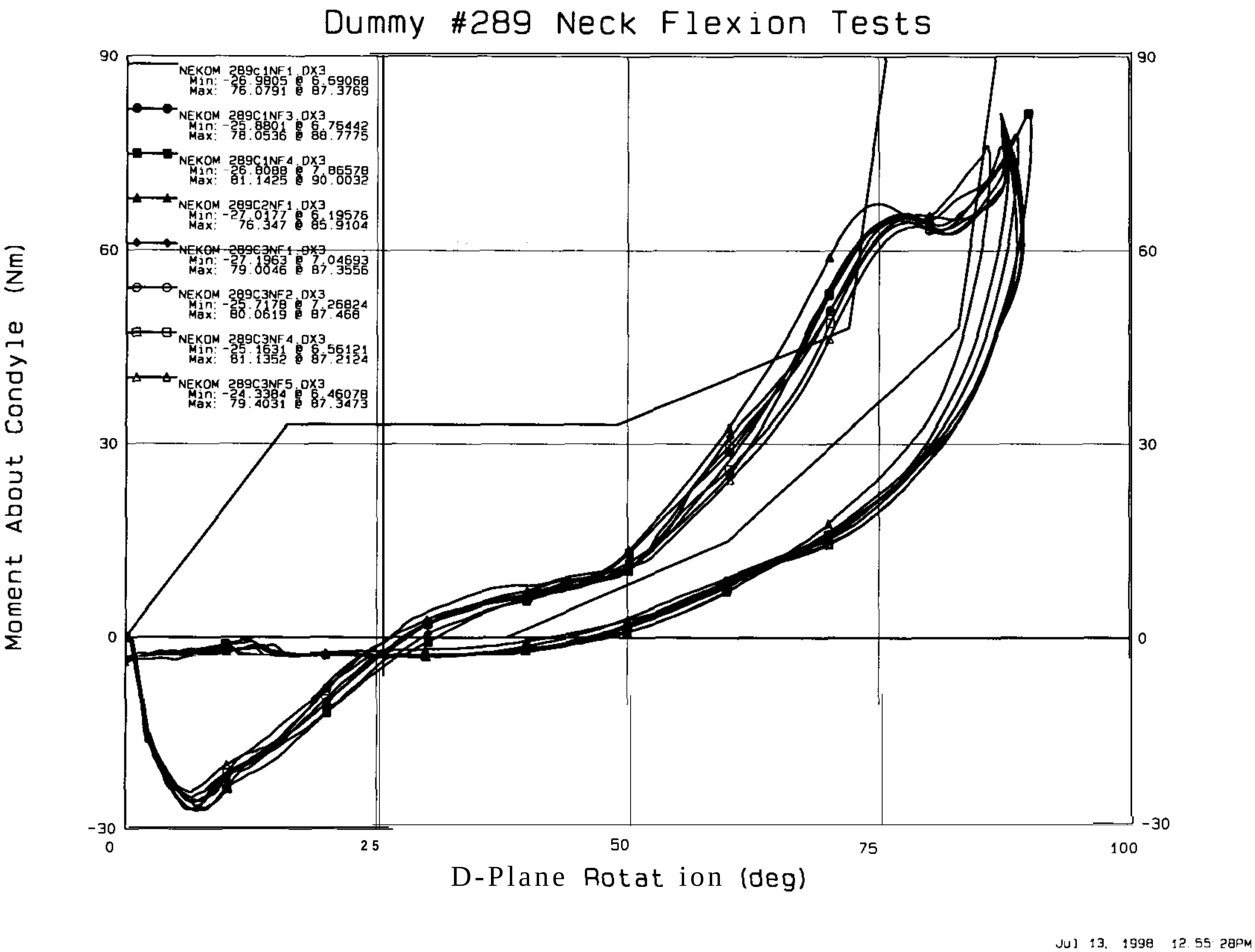
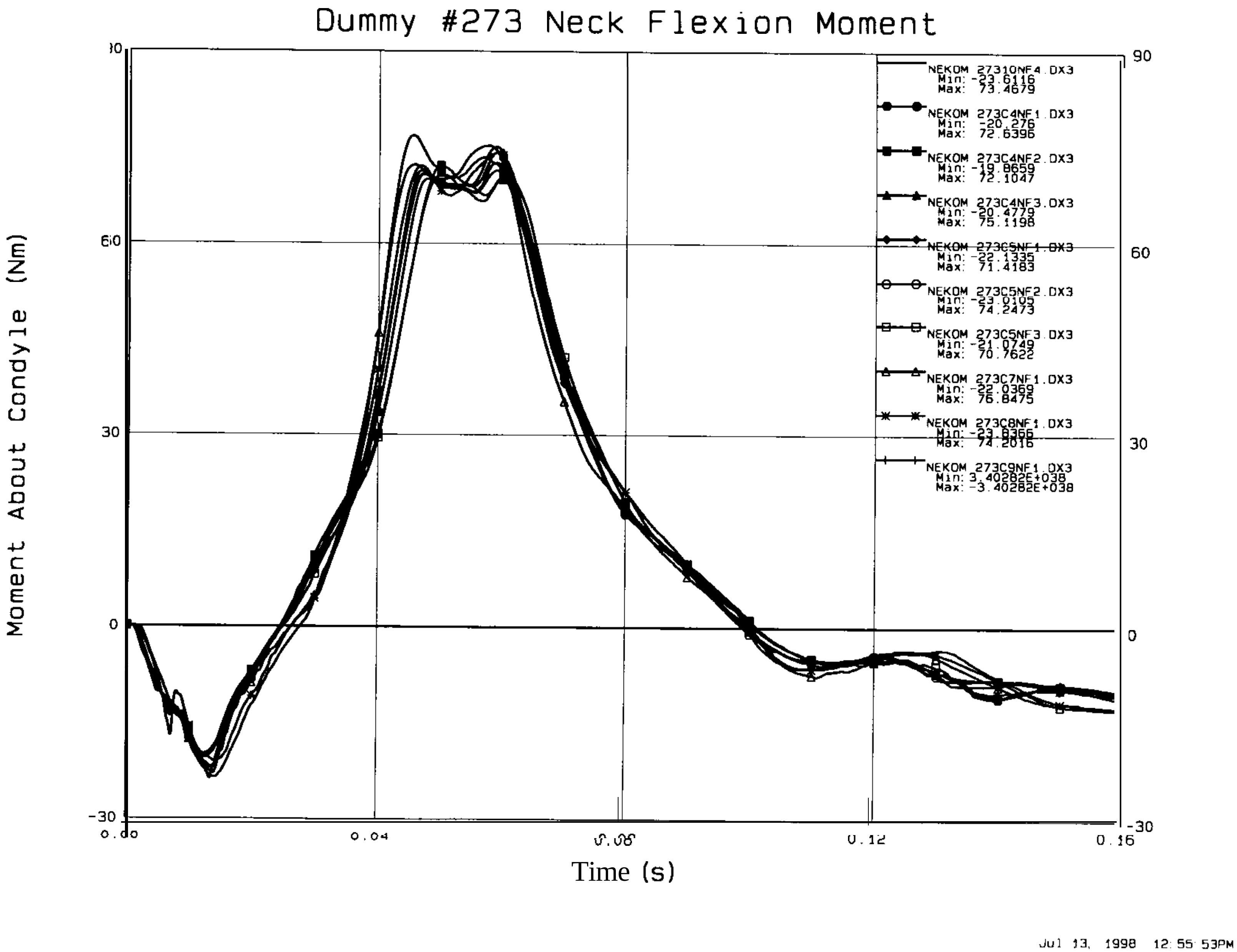
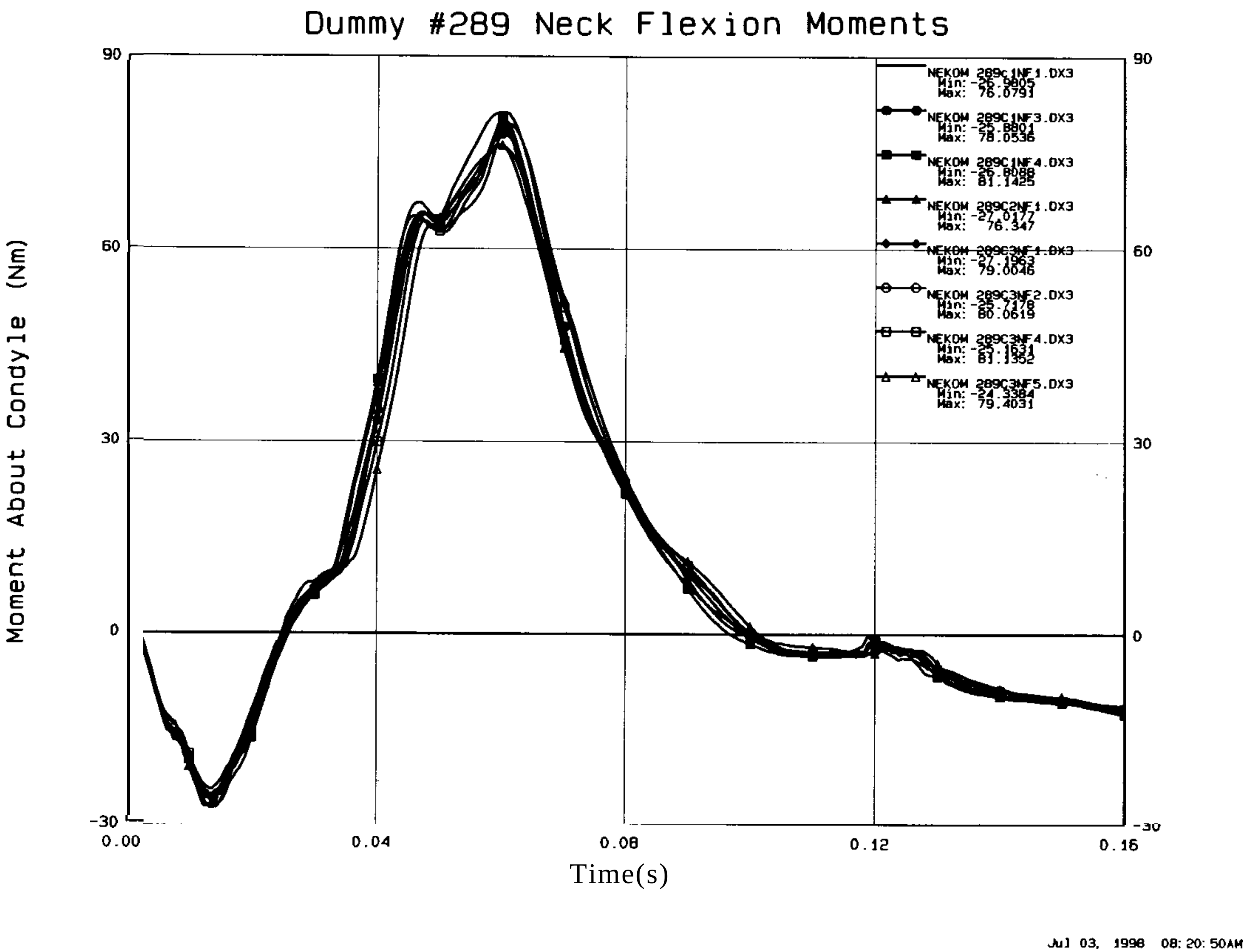

Dummy #289 Neck Flexion Tests
NEKOM 289c1NF1.DX3
Min: -26.9805 @ 6.69068
Max: 76.0791 @ 87.3769
NEKOM 289C1NF3.DX3
Min: -25.8801 @ 6.76442
Max: 78.0536 @ 88.7775
NEKOM 289C1NF4.DX3
Min: -26.8088 @ 7.86578
Max: 81.1425 @ 90.0032
NEKOM 289C2NF1.DX3
Min: -27.0177 @ 6.19576
Max: 76.347 @ 85.9104
NEKOM 289C3NF1.DX3
Min: -27.1963 @ 7.04693
Max: 79.0046 @ 87.3556
NEKOM 289C3NF2.DX3
Min: -25.7178 @ 7.26824
Max: 80.0619 @ 87.468
NEKOM 289C3NF4.DX3
Min: -25.1631 @ 6.56121
Max: 81.1352 @ 87.2124
NEKOM 289C3NF5.DX3
Min: -24.3384 @ 6.46078
Max: 79.4031 @ 87.3473
Moment About Condyle (Nm)
D-Plane Rotat ion (deg)
90
60
30
0
-30
0
25
50
75
100
Jul 13, 1998 12:55:28PM

Figure D.8



Dummy #273 Neck Flexion Moment
Moment About Condyle (Nm)
Time (s)
NEKOM 27310NF4.DX3
Min: -23.6116
Max: 73.4679
NEKOM 273C4NF1.DX3
Min: -20.276
Max: 72.6396
NEKOM 273C4NF2.DX3
Min: -19.8659
Max: 72.1047
NEKOM 273C4NF3.DX3
Min: -20.4779
Max: 75.1198
NEKOM 273C5NF1.DX3
Min: -22.1335
Max: 71.4183
NEKOM 273C5NF2.DX3
Min: -23.0105
Max: 74.2473
NEKOM 273C5NF3.DX3
Min: -21.0749
Max: 70.7622
NEKOM 273C7NF1.DX3
Min: -22.0369
Max: 76.8475
NEKOM 273C8NF1.DX3
Min: -23.8366
Max: 74.2016
NEKOM 273C9NF1.DX3
Min: 3.40282E+038
Max: -3.40282E+038
60
30
0
-30
90
0.04
0.12
0.16
Jul 13, 1998 12:55:53PM

Figure D.9



Dummy #289 Neck Flexion Moments
Moment About Condyle (Nm)
90
60
30
0
-30
0.00
0.04
0.08
0.12
0.16
Time(s)
NEKOM 289c1NF1.DX3
Min: -26.9805
Max: 76.0791
NEKOM 289C1NF3.DX3
Min: -25.8801
Max: 78.0536
NEKOM 289C1NF4.DX3
Min: -26.8088
Max: 81.1425
NEKOM 289C2NF1.DX3
Min: -27.0177
Max: 76.347
NEKOM 289C3NF1.DX3
Min: -27.1963
Max: 79.0046
NEKOM 289C3NF2.DX3
Min: -25.7178
Max: 80.0619
NEKOM 289C3NF4.DX3
Min: -25.1631
Max: 81.1352
NEKOM 289C3NF5.DX3
Min: -24.3384
Max: 79.4031
Jul 03, 1998 08:20:50AM

Figure D. 10

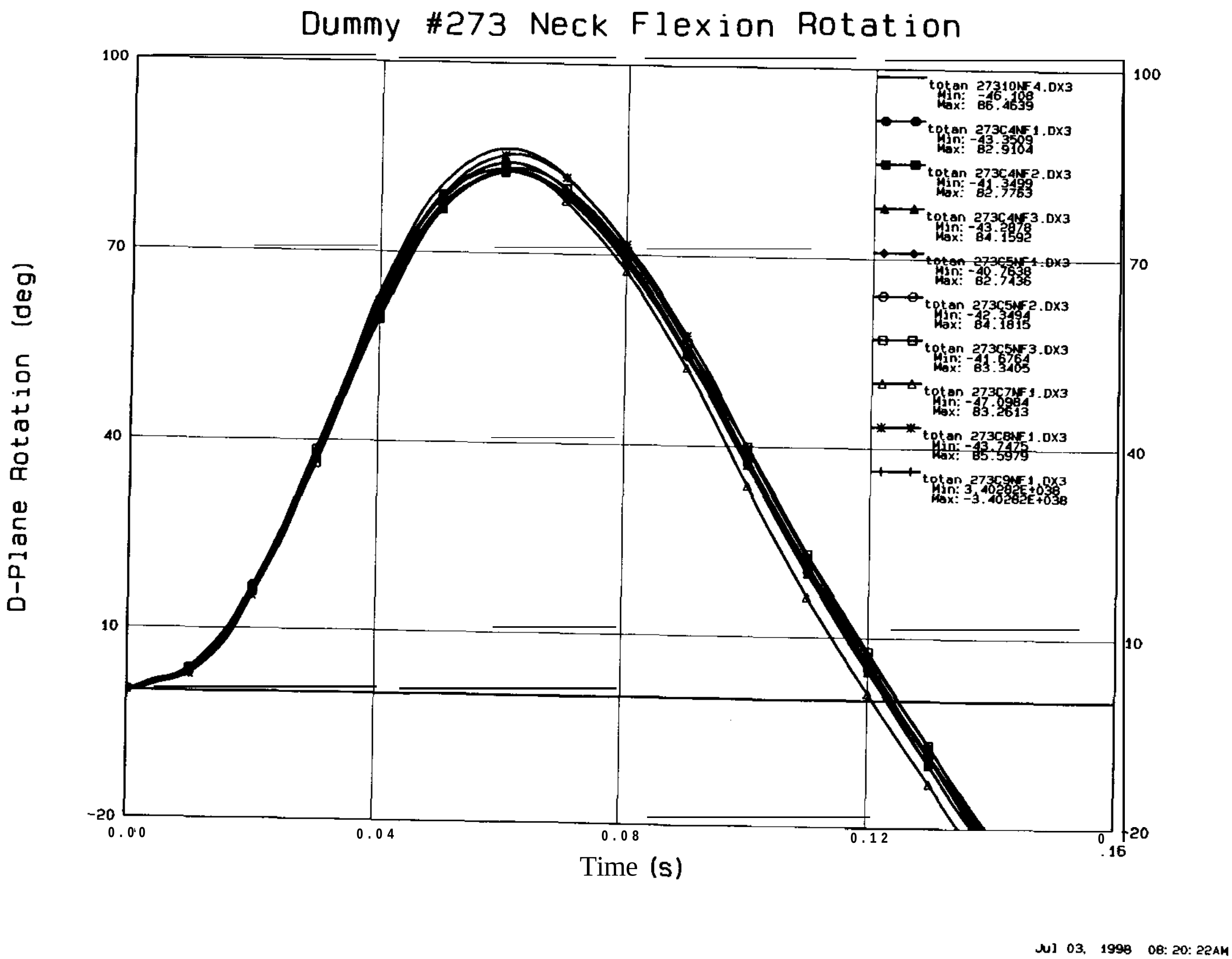
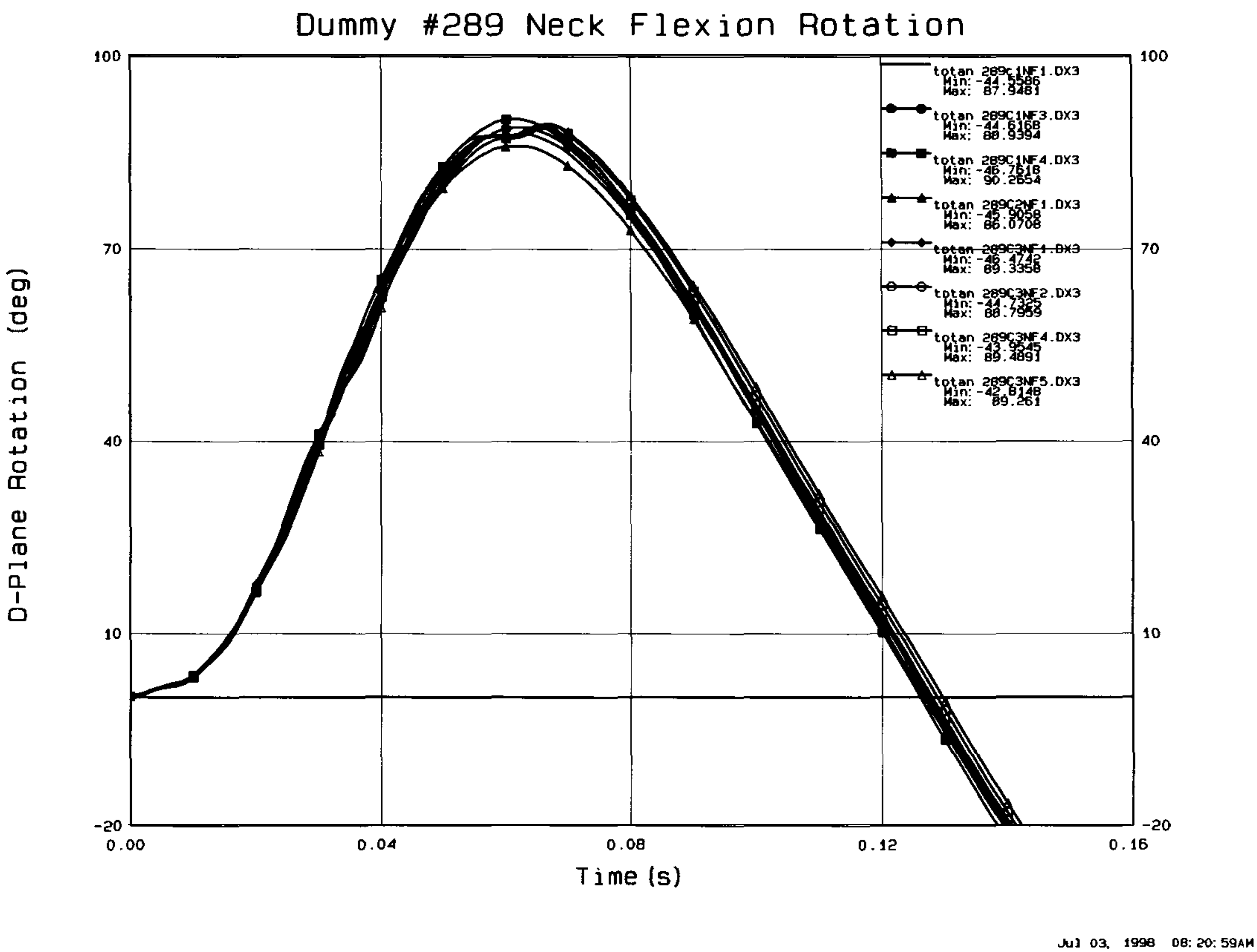
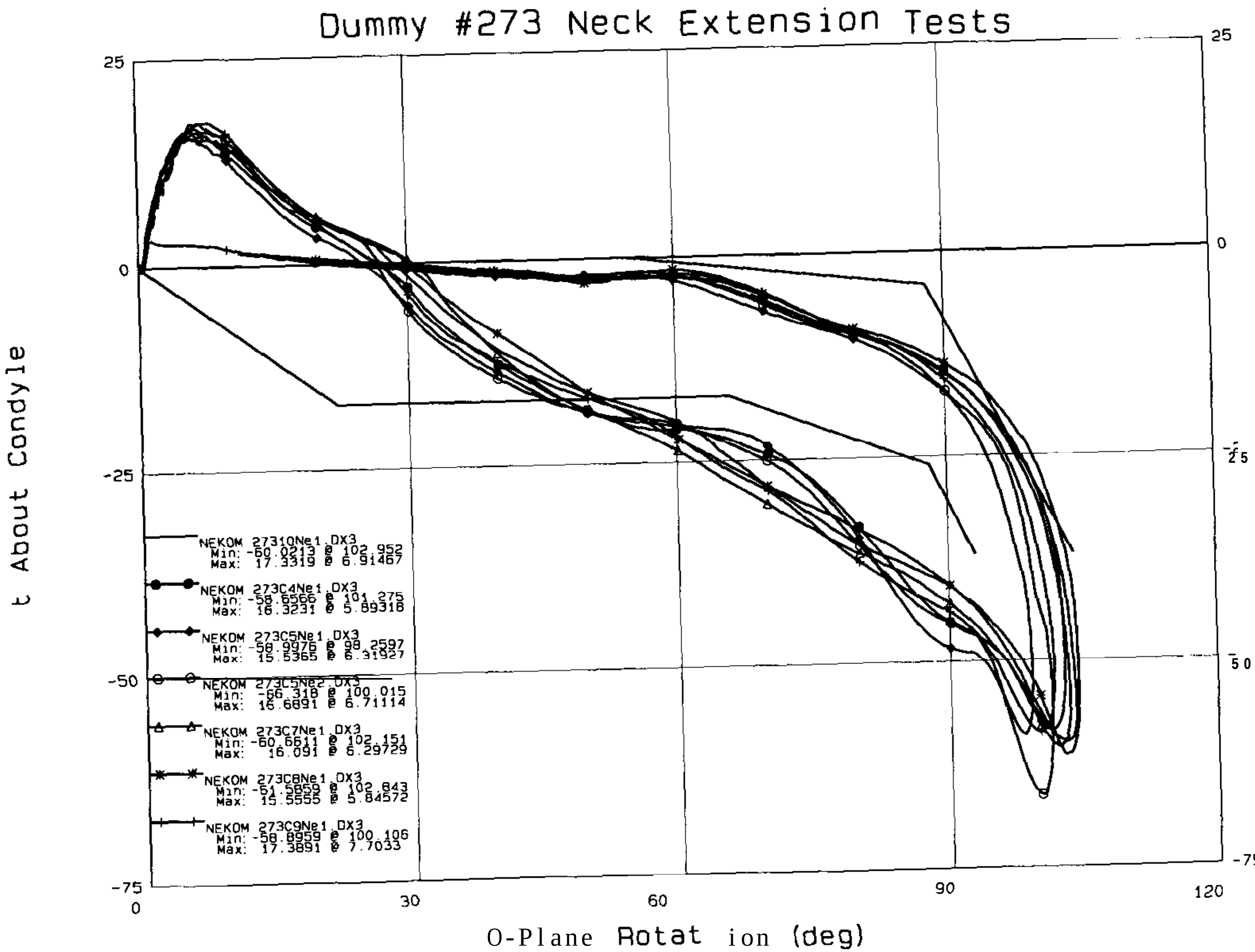

Dummy #273 Neck Flexion Rotation
D-Plane Rotation (deg)
100
70
40
10
-20
0.00
0.04
0.08
0.12
0
.16
Time (s)
totan 27310NF4.DX3
Min: -46.108
Max: 86.4639
totan 273C4NF1.DX3
Min: -43.3509
Max: 82.9104
totan 273C4NF2.DX3
Min: -41.3499
Max: 82.7763
totan 273C4NF3.DX3
Min: -43.2878
Max: 84.1592
totan 273C5NF1.DX3
Min: -40.7638
Max: 82.7436
totan 273C5NF2.DX3
Min: -42.3494
Max: 84.1815
totan 273C5NF3.DX3
Min: -41.6764
Max: 83.3405
totan 273C7NF1.DX3
Min: -47.0984
Max: 83.2613
totan 273C8NF1.DX3
Min: -43.7475
Max: 85.5979
totan 273C9NF1.DX3
Min: 3.40282E+038
Max: -3.40282E+038
Jul 03, 1998 08:20:22AM

Figure D.11



Dummy #289 Neck Flexion Rotation
D-Plane Rotation (deg)
Time (s)
100
70
40
10
-20
0.00
0.04
0.08
0.12
0.16
totan 289C1NF1.DX3 Min: -44.5586 Max: 87.9481
totan 289C1NF3.DX3 Min: -44.6168 Max: 88.9394
totan 289C1NF4.DX3 Min: -46.7618 Max: 90.2654
totan 289C2NF1.DX3 Min: -45.9058 Max: 86.0708
totan 289C3NF1.DX3 Min: -46.4742 Max: 89.3358
totan 289C3NF2.DX3 Min: -44.7325 Max: 88.7959
totan 289C3NF4.DX3 Min: -43.9545 Max: 89.4891
totan 289C3NF5.DX3 Min: -42.8148 Max: 89.261
Jul 03, 1998 08:20:59AM

Figure D.12



Jul 06. 1998 10:05:09AM

Figure D. 13

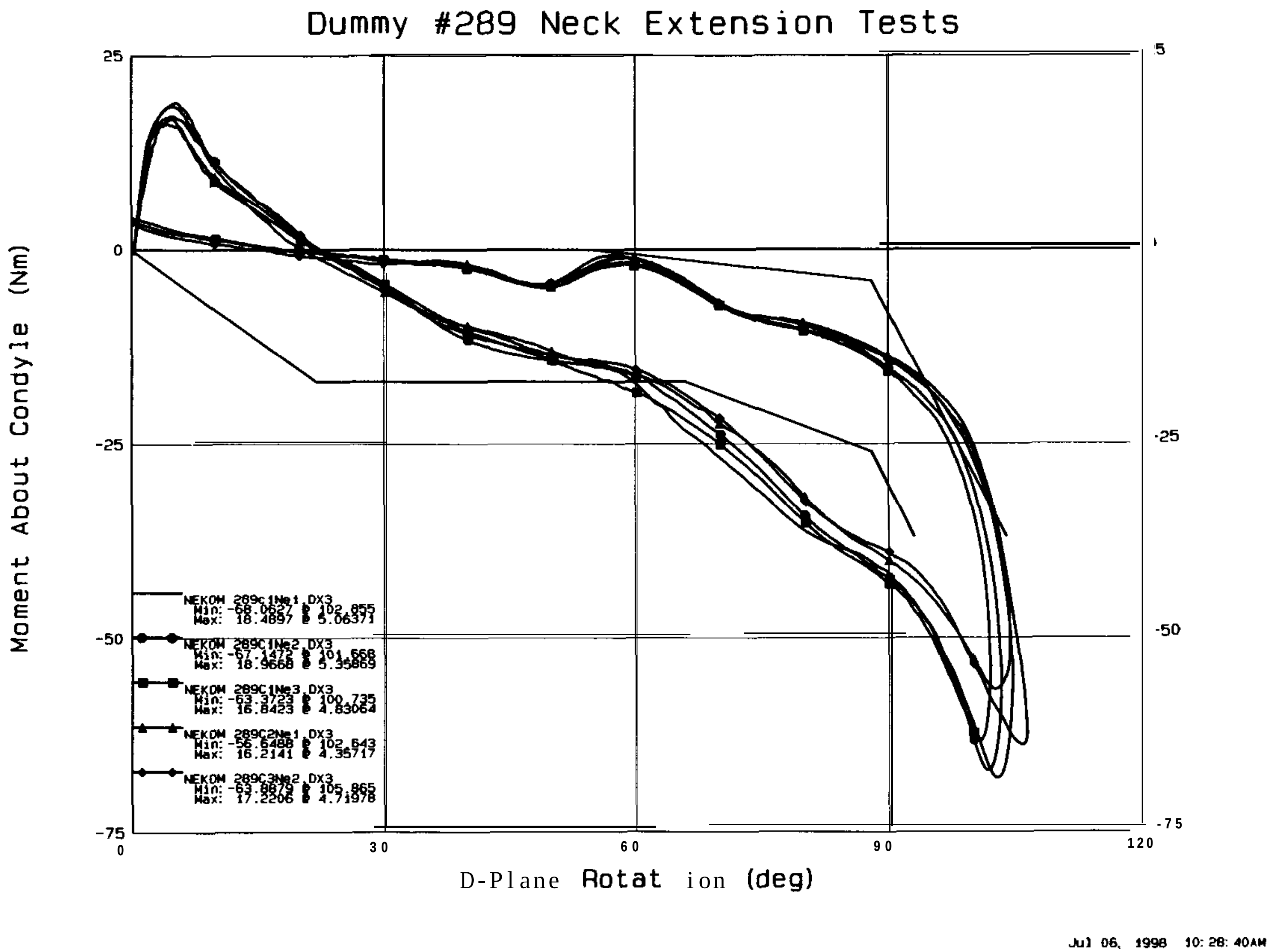
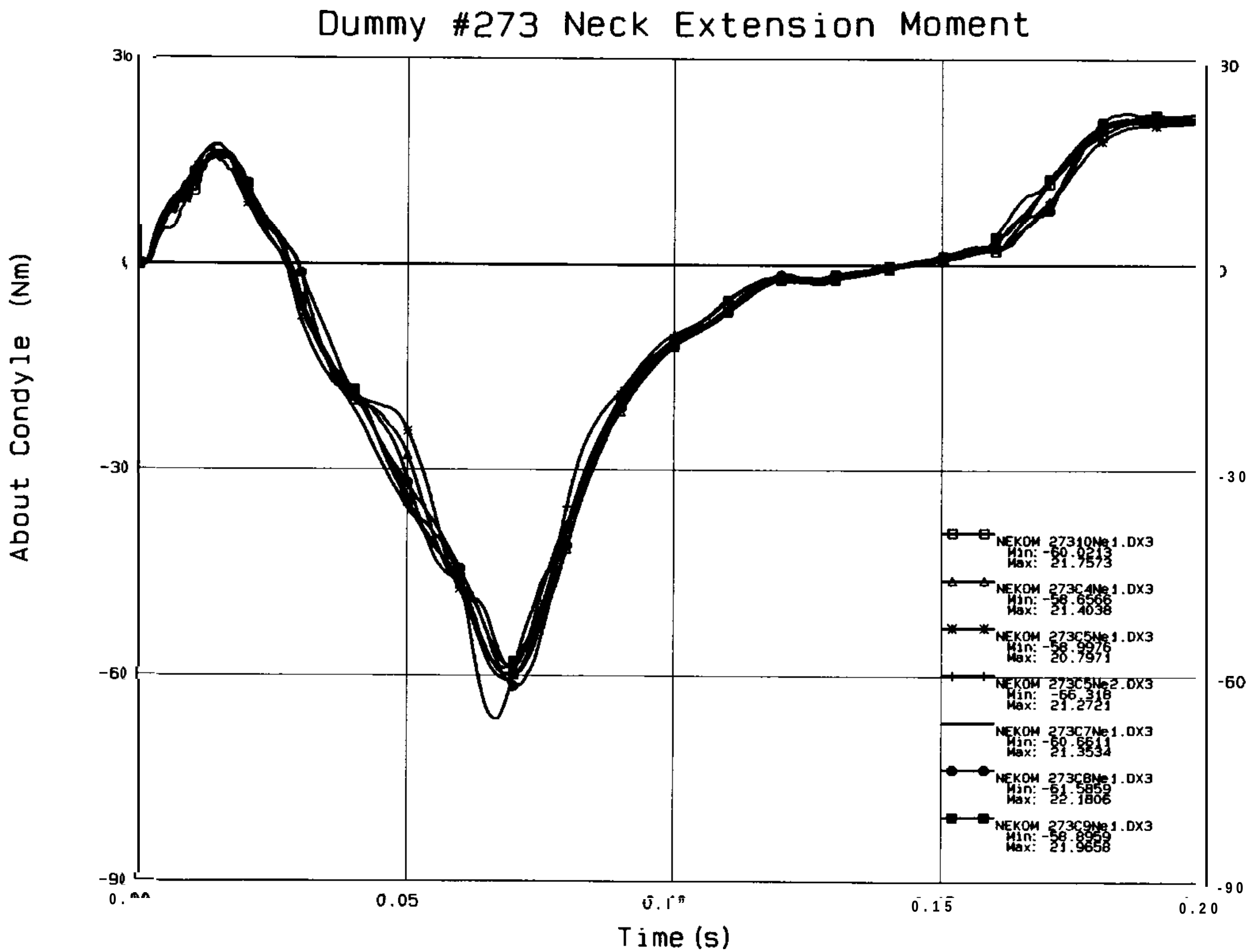
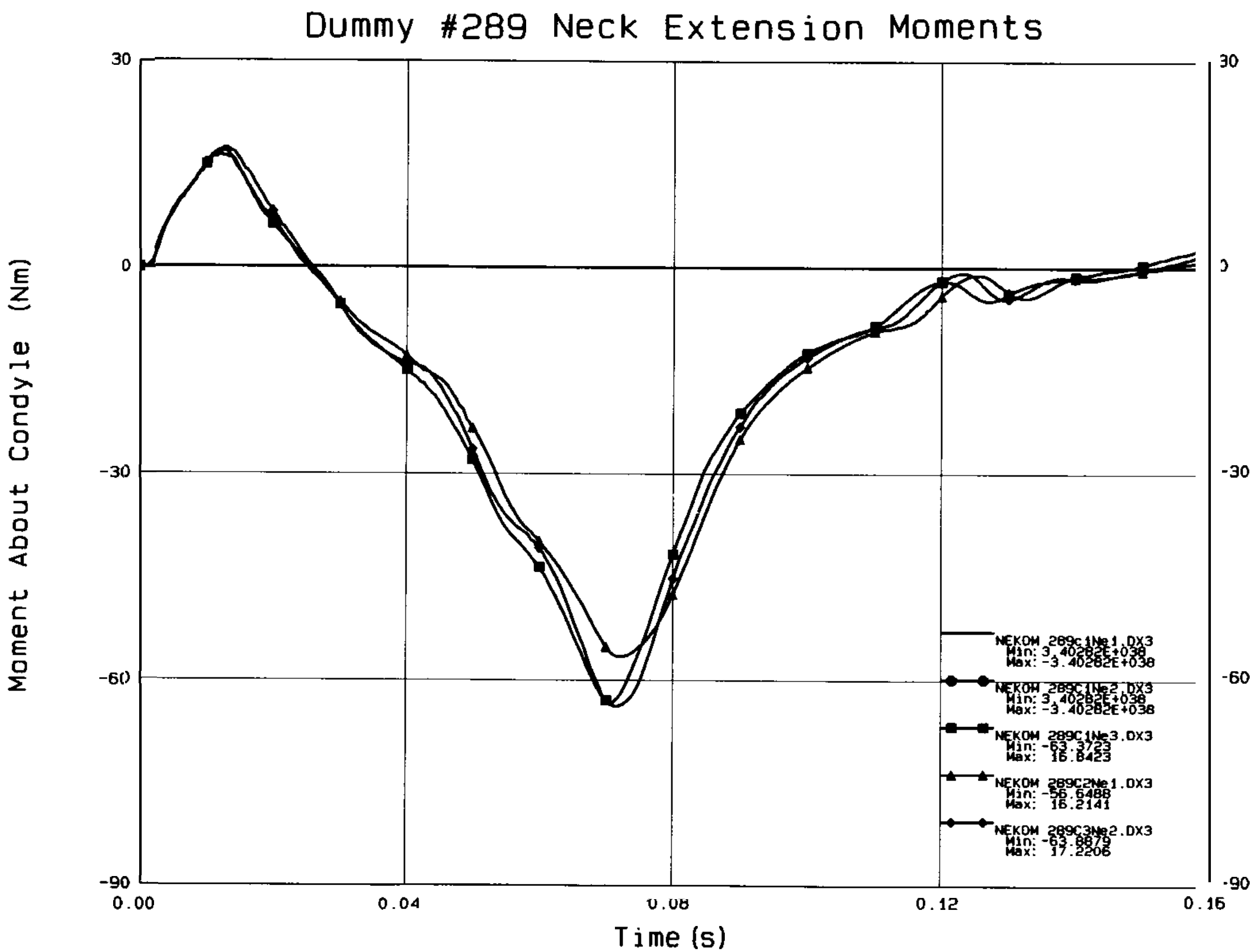

Dummy #289 Neck Extension Tests
Moment About Condyle (Nm)
25
0
-25
-50
-75
0
30
60
90
120
D-Plane Rotation (deg)
NEKOM 289c1Ne1.DX3
Min: -68.0627 @ 102.855
Max: 18.4897 @ 5.06371
NEKOM 289C1Ne2.DX3
Min: -67.1472 @ 101.668
Max: 18.9668 @ 5.35869
NEKOM 289C1Ne3.DX3
Min: -63.3723 @ 100.735
Max: 16.8423 @ 4.83064
NEKOM 289C2Ne1.DX3
Min: -56.6488 @ 102.643
Max: 16.2141 @ 4.35717
NEKOM 289C3Ne2.DX3
Min: -63.8879 @ 105.865
Max: 17.2206 @ 4.71978
Jul 06, 1998 10:28:40AM

Figure D. 14



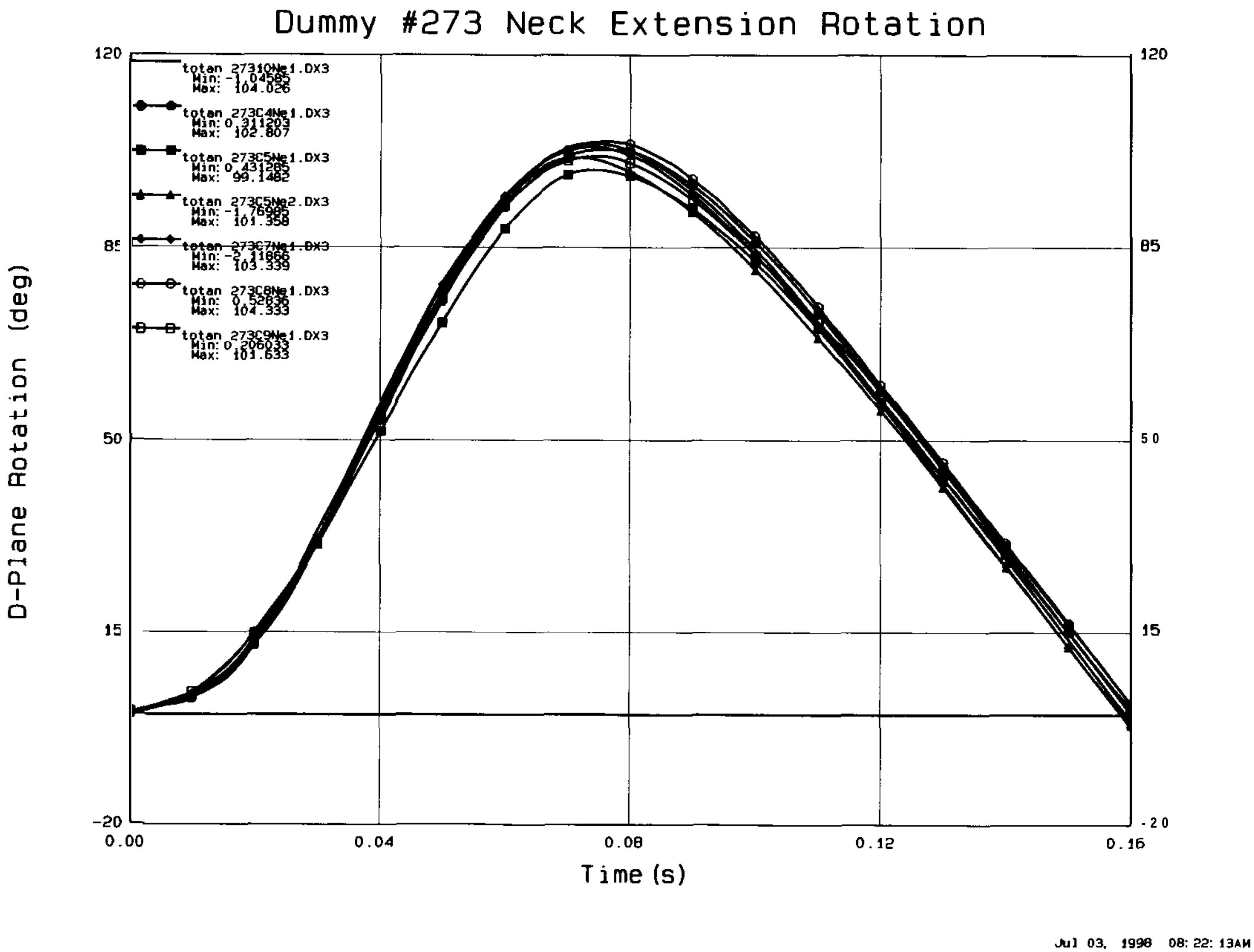
Jul 03, 1998 08:21:43AM

Figure D. 15



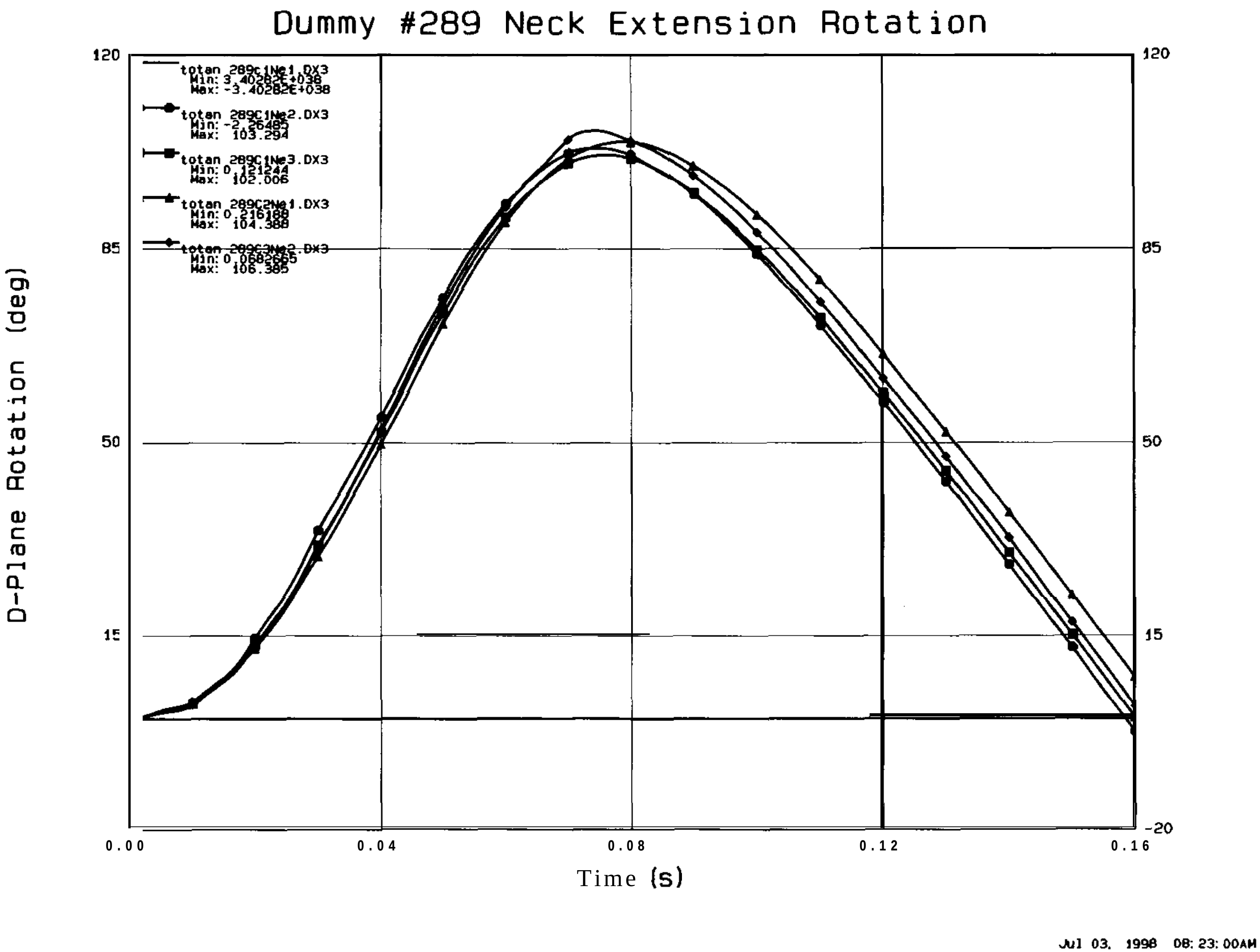
Jul 03, 1998 08:22:52AM

Figure D. 16



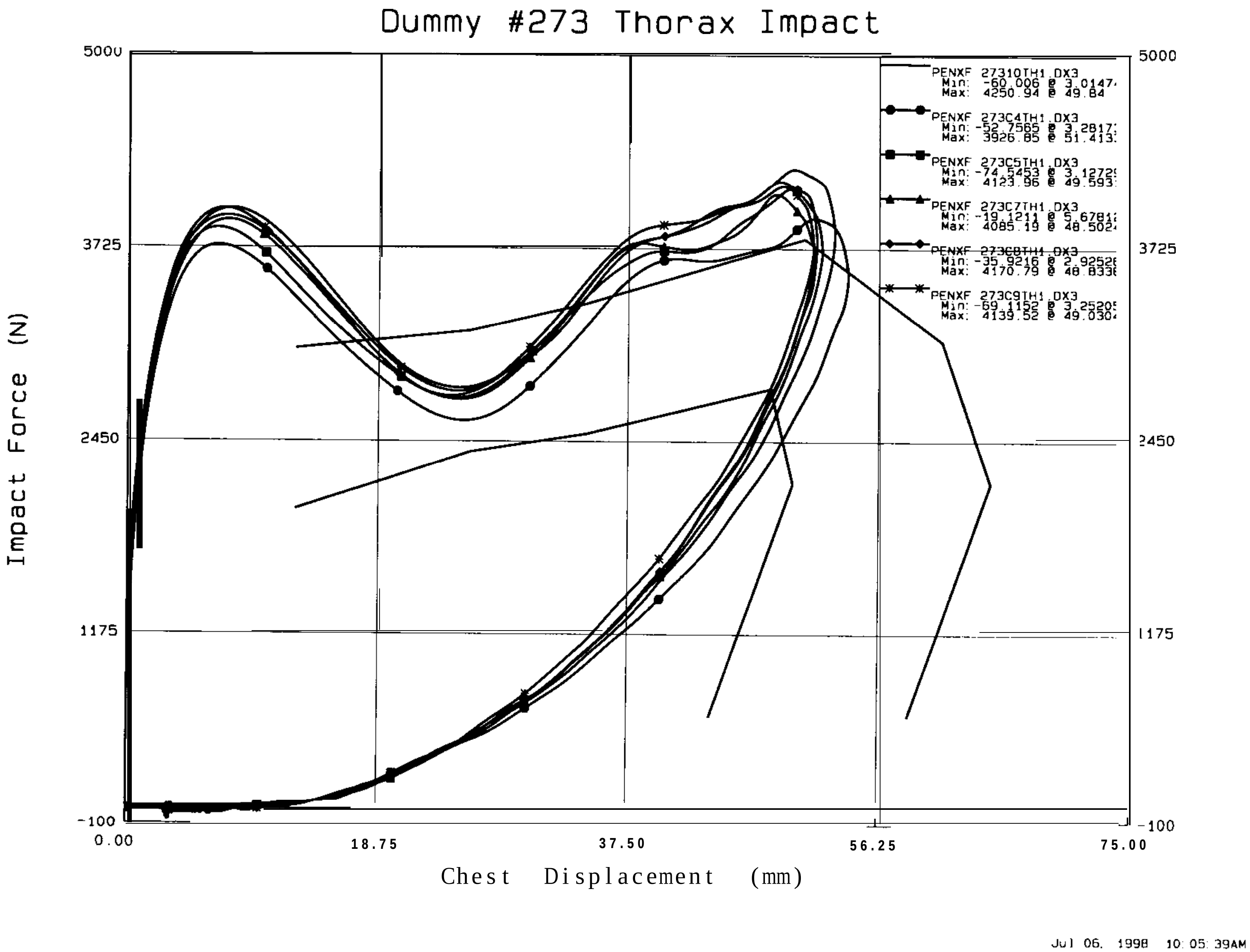
Dummy #273 Neck Extension Rotation
totan 27310Ne1.DX3
Min: -1.04585
Max: 104.026
totan 273C4Ne1.DX3
Min: 0.311203
Max: 102.807
totan 273C5Ne1.DX3
Min: 0.431285
Max: 99.1482
totan 273C5Ne2.DX3
Min: -1.76985
Max: 101.358
totan 273C7Ne1.DX3
Min: -2.11866
Max: 103.339
totan 273C8Ne1.DX3
Min: 0.52836
Max: 104.333
totan 273C9Ne1.DX3
Min: 0.206033
Max: 101.633
120
85
50
15
-20
0.00
0.04
0.08
0.12
0.16
Time (s)
D-Plane Rotation (deg)
Jul 03, 1998 08:22:13AM

Figure D. 17



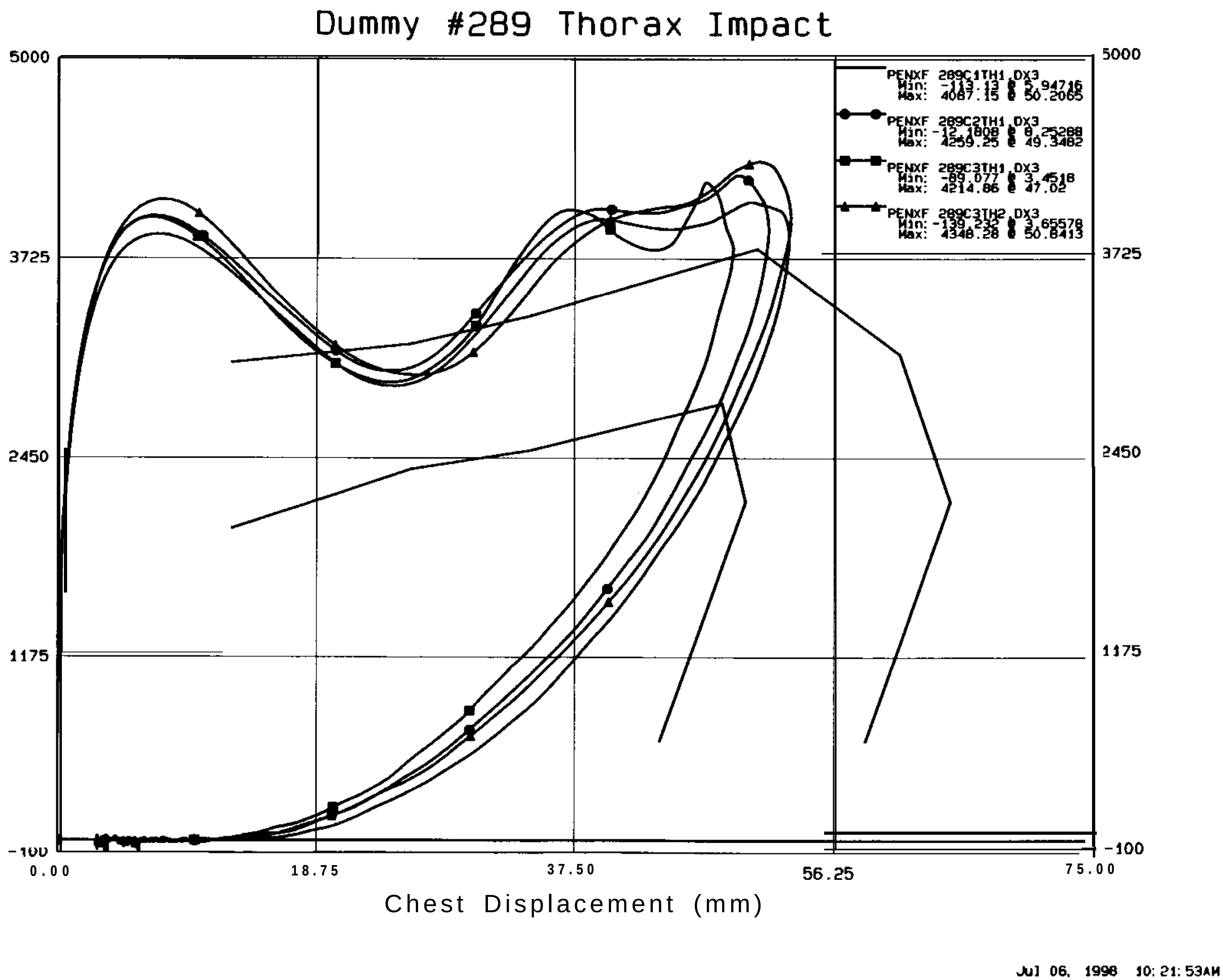
Dummy #289 Neck Extension Rotation
totan 289c1Ne1.DX3
Min: 3.40282E+038
Max: -3.40282E+038
totan 289C1Ne2.DX3
Min: -2.26485
Max: 103.294
totan 289C1Ne3.DX3
Min: 0.121244
Max: 102.006
totan 289C2Ne1.DX3
Min: 0.216188
Max: 104.388
totan 289C3Ne2.DX3
Min: 0.0682665
Max: 106.385
120
85
50
15
-20
0.00
0.04
0.08
0.12
0.16
D-Plane Rotation (deg)
Time (s)
Jul 03, 1998 08:23:00AM

Figure D. 18



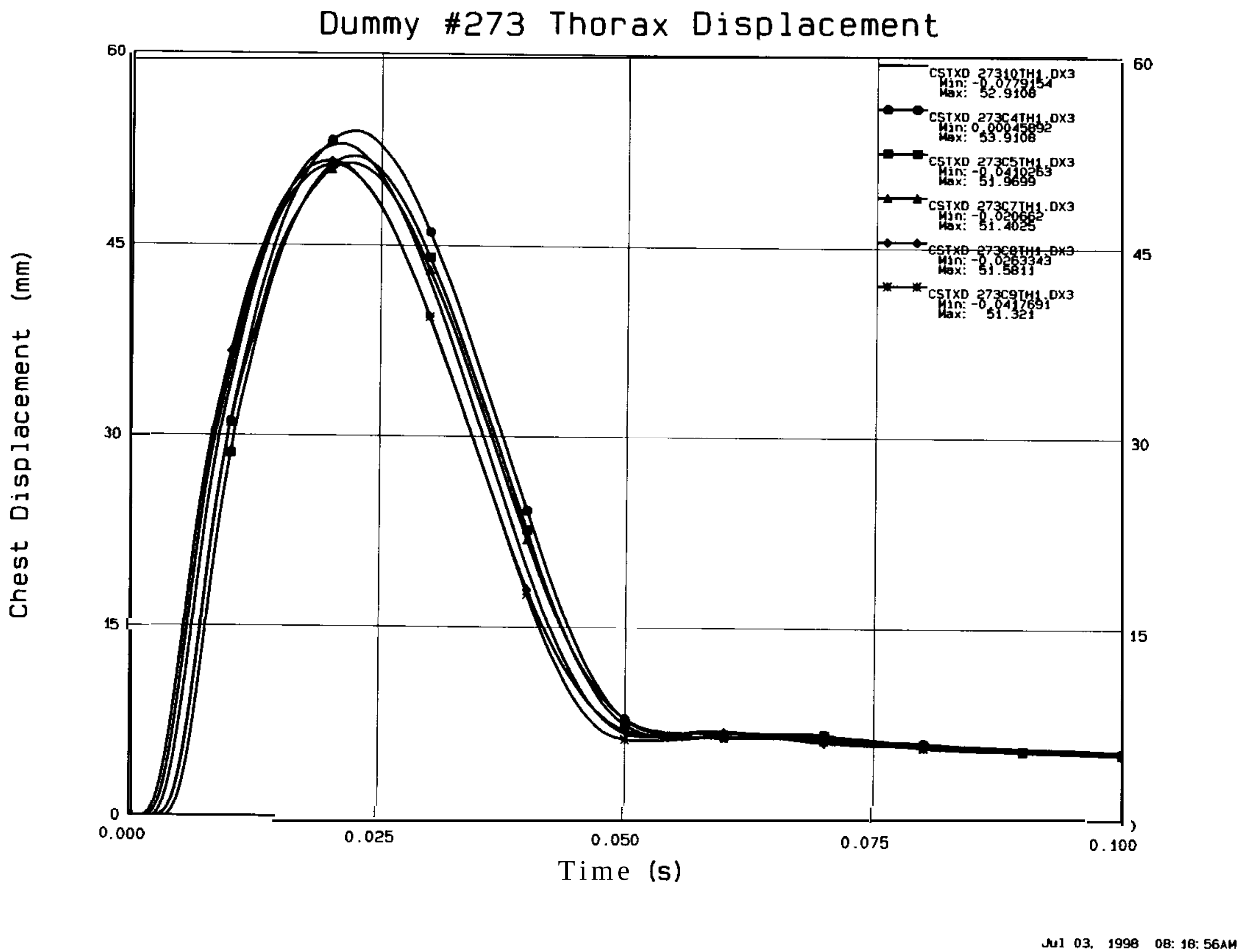
Dummy #273 Thorax Impact
Impact Force (N)
Chest Displacement (mm)
5000
3725
2450
1175
-100
0.00
18.75
37.50
56.25
75.00
PENXF 27310TH1.DX3
Min: -60.006 @ 3.0147
Max: 4250.94 @ 49.84
PENXF 273C4TH1.DX3
Min: -52.7565 @ 3.2817
Max: 3926.85 @ 51.413
PENXF 273C5TH1.DX3
Min: -74.5453 @ 3.1272
Max: 4123.96 @ 49.593
PENXF 273C7TH1.DX3
Min: -19.1211 @ 5.6781
Max: 4085.19 @ 48.502
PENXF 273C8TH1.DX3
Min: -35.9216 @ 2.9252
Max: 4170.79 @ 48.833
PENXF 273C9TH1.DX3
Min: -69.1152 @ 3.2520
Max: 4139.52 @ 49.030
Jul 06, 1998 10:05:39AM

Figure D. 19



Dummy #289 Thorax Impact
5000
3725
2450
1175
-100
Impact Force (N)
0.00
18.75
37.50
56.25
75.00
Chest Displacement (mm)
PENXF 289C1TH1.DX3
Min: -113.13 @ 5.94716
Max: 4087.15 @ 50.2065
PENXF 289C2TH1.DX3
Min: -12.1808 @ 0.25288
Max: 4259.25 @ 49.3482
PENXF 289C3TH1.DX3
Min: -89.077 @ 3.4518
Max: 4214.86 @ 47.02
PENXF 289C3TH2.DX3
Min: -139.232 @ 3.65578
Max: 4348.28 @ 50.8413
Jul 06, 1998 10:21:53AM

Figure D.20



Dummy #273 Thorax Displacement
Chest Displacement (mm)
Time (s)
0
15
30
45
60
0.000
0.025
0.050
0.075
0.100
CSTXD 27310TH1.DX3
Min: -0.0779154
Max: 52.9108
CSTXD 273C4TH1.DX3
Min: 0.00045892
Max: 53.9108
CSTXD 273C5TH1.DX3
Min: -0.0410263
Max: 51.9699
CSTXD 273C7TH1.DX3
Min: -0.020662
Max: 51.4025
CSTXD 273C8TH1.DX3
Min: -0.0263343
Max: 51.5811
CSTXD 273C9TH1.DX3
Min: -0.0417691
Max: 51.321
Jul 03, 1998 08:16:56AM

Figure D.21

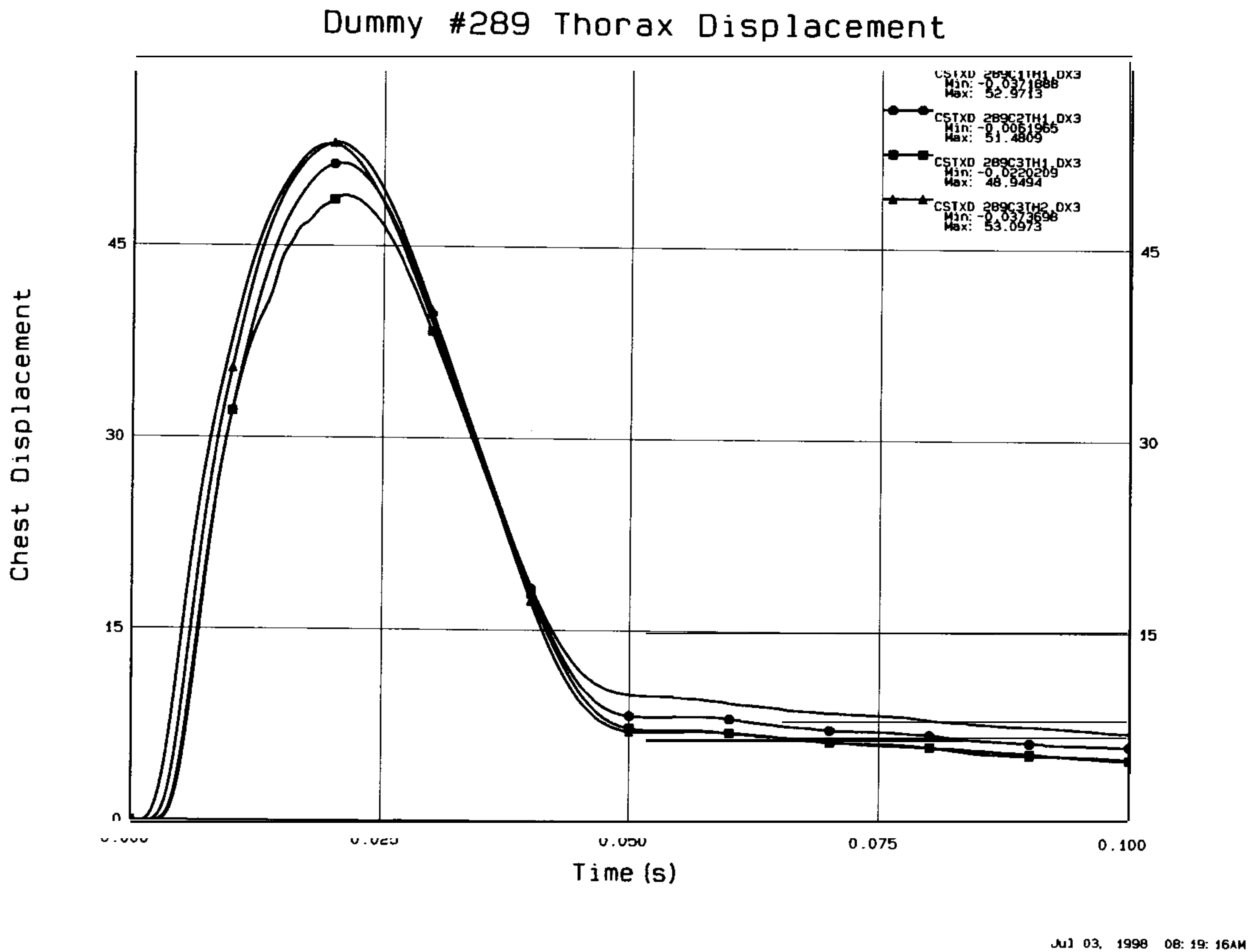

Dummy #289 Thorax Displacement
CSTXD 289C1TH1.DX3
Min: -0.0371888
Max: 52.9713
CSTXD 289C2TH1.DX3
Min: -0.0061965
Max: 51.4809
CSTXD 289C3TH1.DX3
Min: -0.0220209
Max: 48.9494
CSTXD 289C3TH2.DX3
Min: -0.0373698
Max: 53.0973
Chest Displacement
0
15
30
45
0.075
0.100
Time (s)
Jul 03, 1998 08:19:16AM

Figure D.22

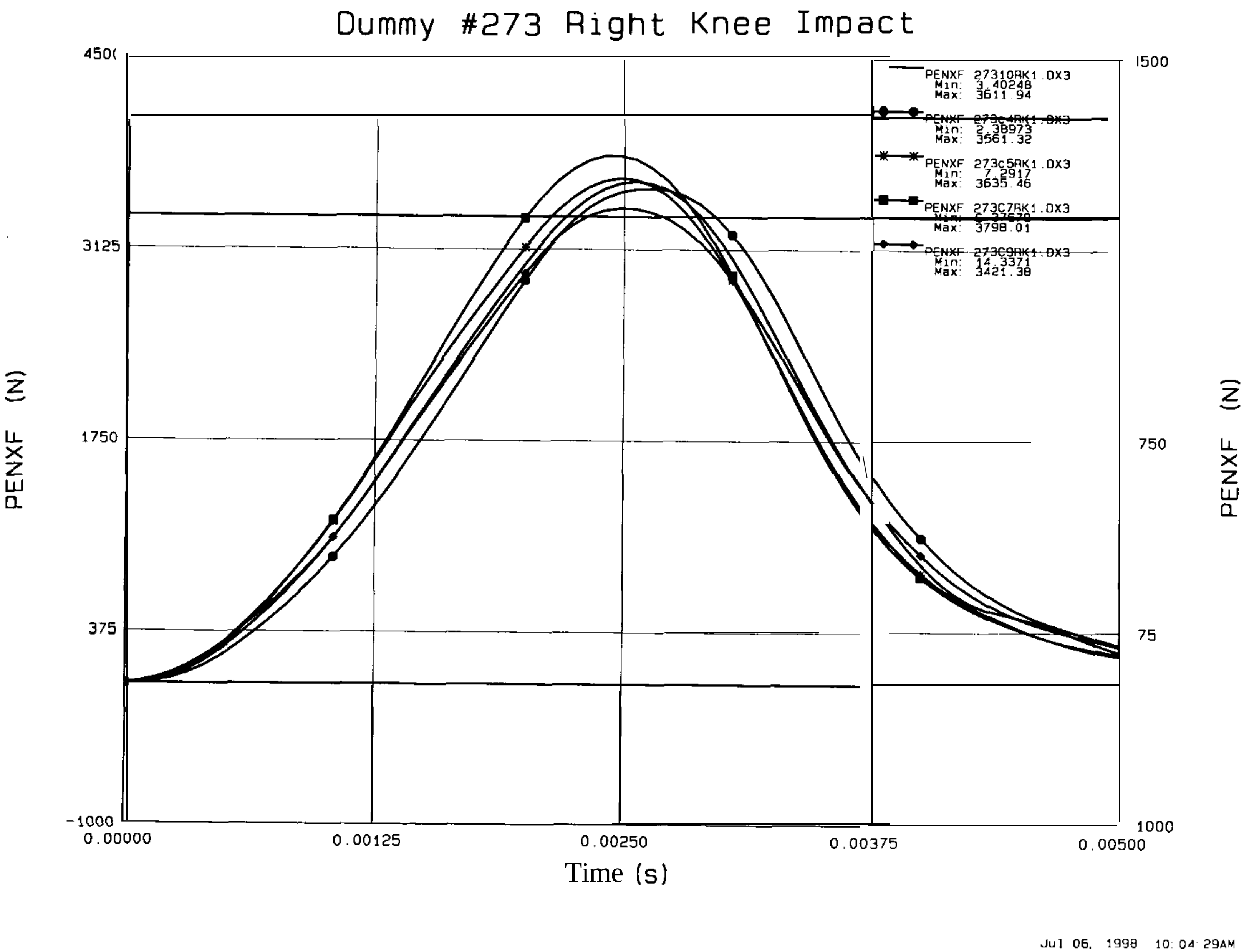
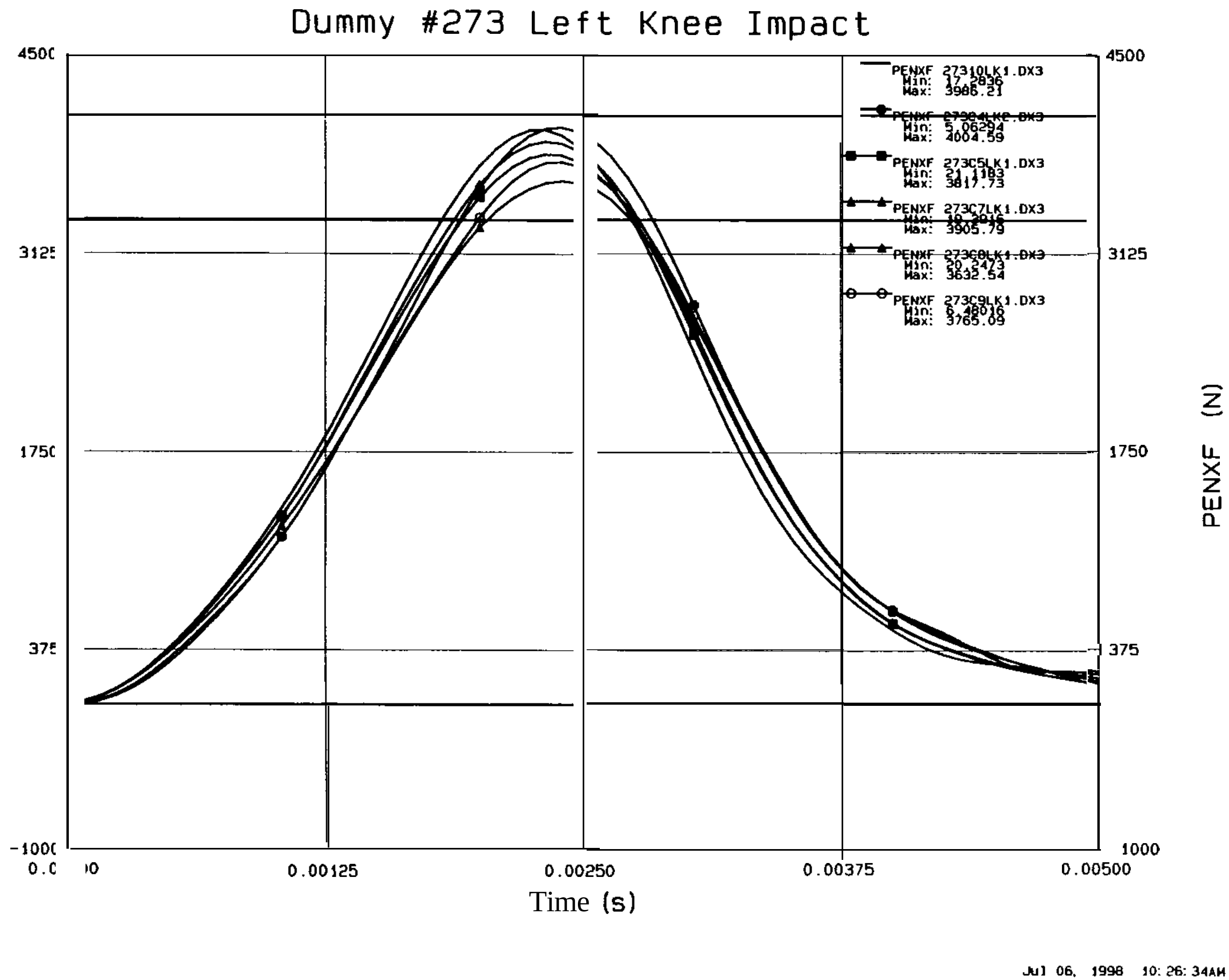
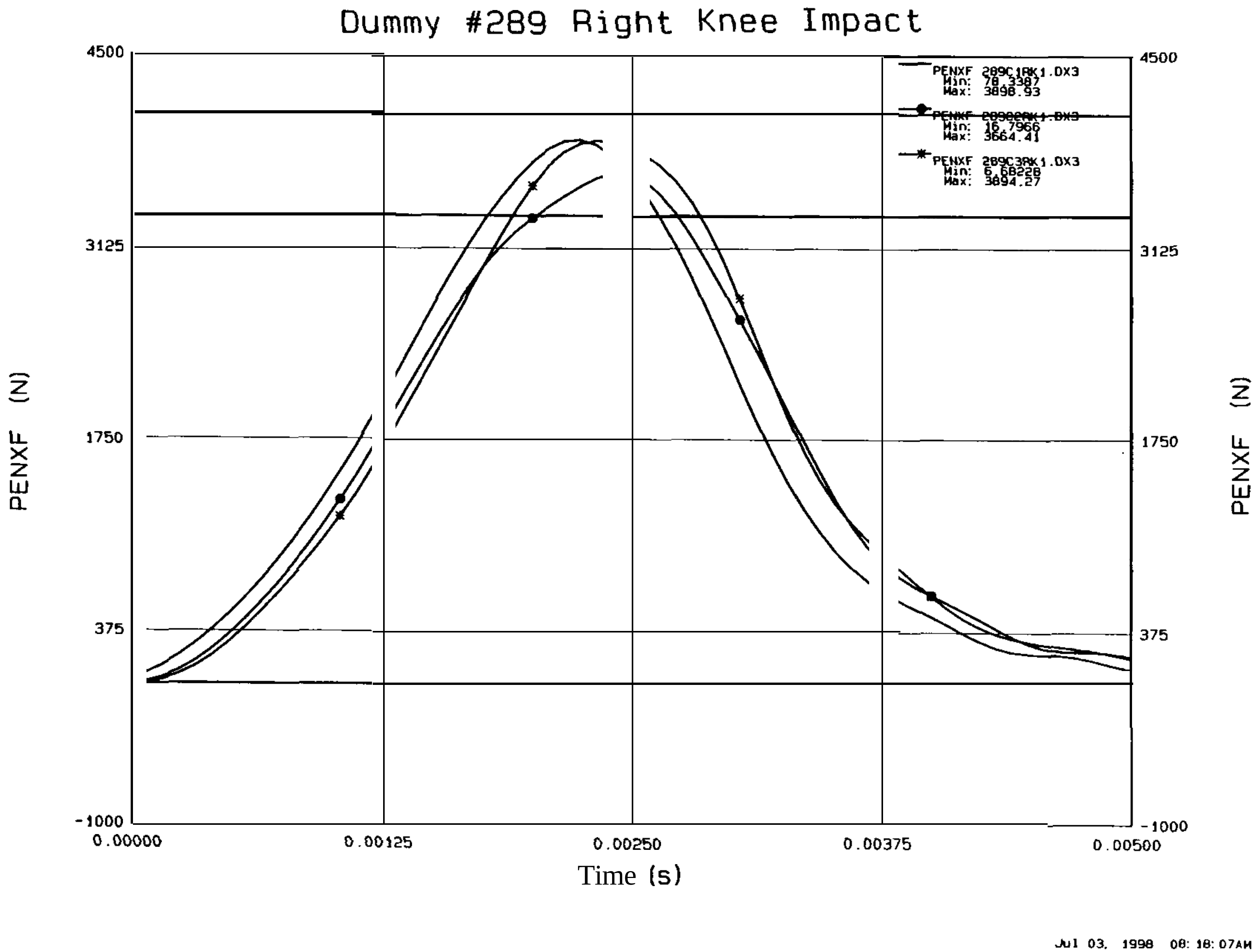

Dummy #273 Right Knee Impact
PENXF 27310RK1.DX3
Min: 3.40248
Max: 3611.94
PENXF 273c4RK1.DX3
Min: 2.38973
Max: 3561.32
PENXF 273c5RK1.DX3
Min: 7.2917
Max: 3635.46
PENXF 273C7RK1.DX3
Max: 3798.01
PENXF 273C9RK1.DX3
Min: 14.3371
Max: 3421.38
PENXF (N)
4500
3125
1750
375
-1000
1500
750
75
1000
0.00000
0.00125
0.00250
0.00375
0.00500
Time (s)
Jul 06, 1998 10:04:29AM

Figure D.23



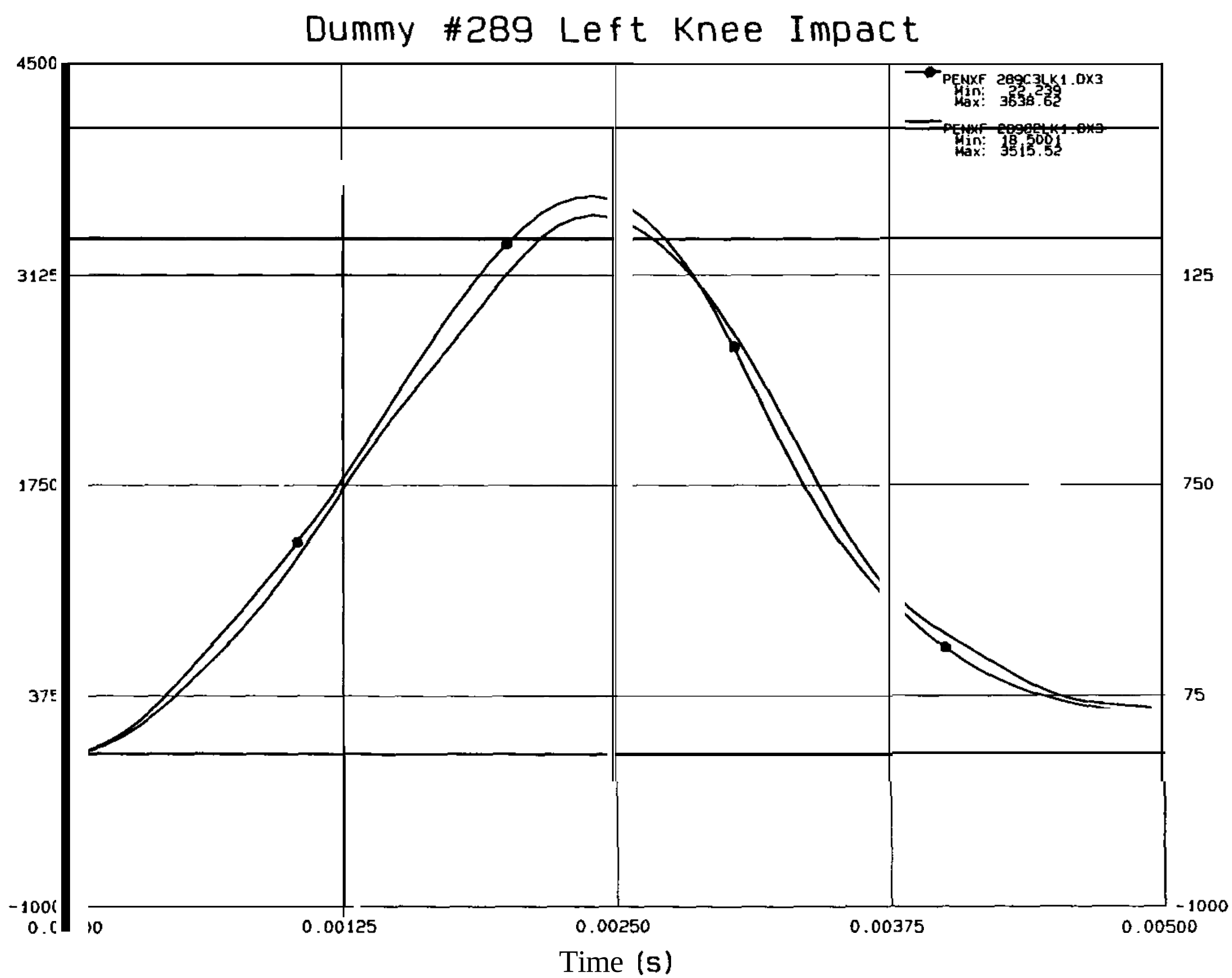
Dummy #273 Left Knee Impact
PENXF 27310LK1.DX3
Min: 17.2836
Max: 3986.21
PENXF 27304LK2.DX3
Min: 5.06294
Max: 4004.59
PENXF 273C5LK1.DX3
Min: 21.1183
Max: 3817.73
PENXF 273C7LK1.DX3
Max: 3905.79
PENXF 273C8LK1.DX3
Min: 20.2473
Max: 3632.54
PENXF 273C9LK1.DX3
Min: 6.48016
Max: 3765.09
4500
3125
1750
375
-1000
4500
3125
1750
375
1000
0.00125
0.00250
0.00375
0.00500
PENXF (N)
PENXF (N)
Time (s)
Jul 06, 1998 10:26:34AM

Figure D.24



Dummy #289 Right Knee Impact
4500
3125
1750
375
-1000
PENXF (N)
PENXF 289C1RK1.DX3
Min: 78.3387
Max: 3898.93
PENXF 289C2RK1.DX3
Min: 16.7966
Max: 3664.41
PENXF 289C3RK1.DX3
Min: 6.68228
Max: 3894.27
0.00000
0.00125
0.00250
0.00375
0.00500
Time (s)
Jul 03, 1998 08:18:07AM

Figure D.25



Jul 03, 1998 08:18:15AM

APPENDIX E - SLED TESTING

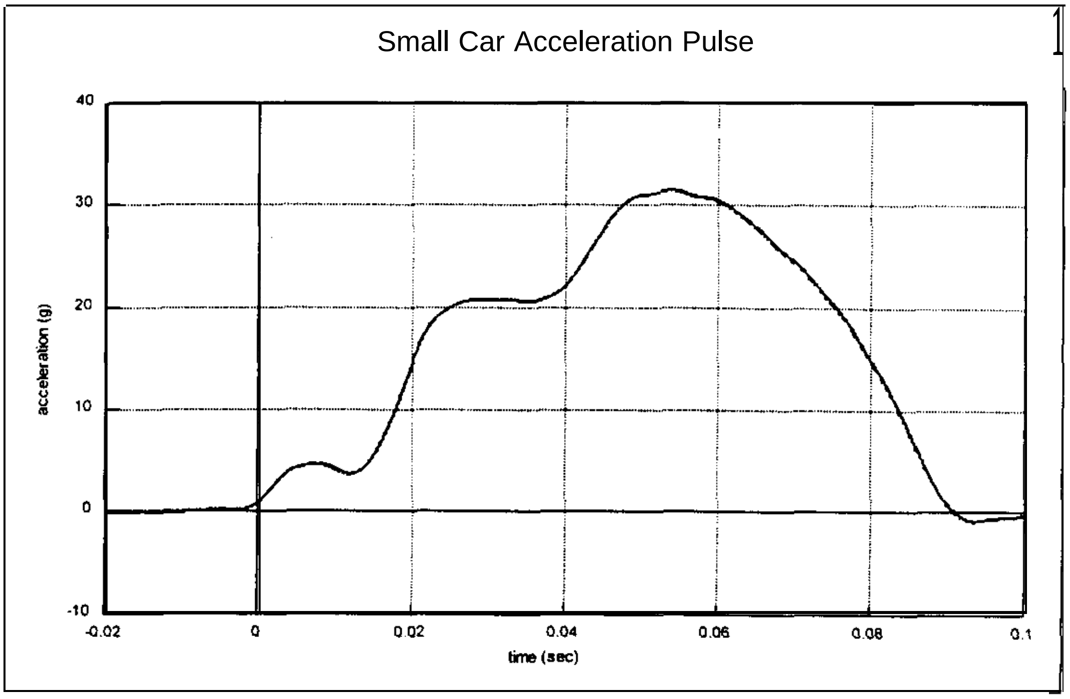


Fig. E. 1. Small Car Sled Pulse with 59 kph Impact Velocity

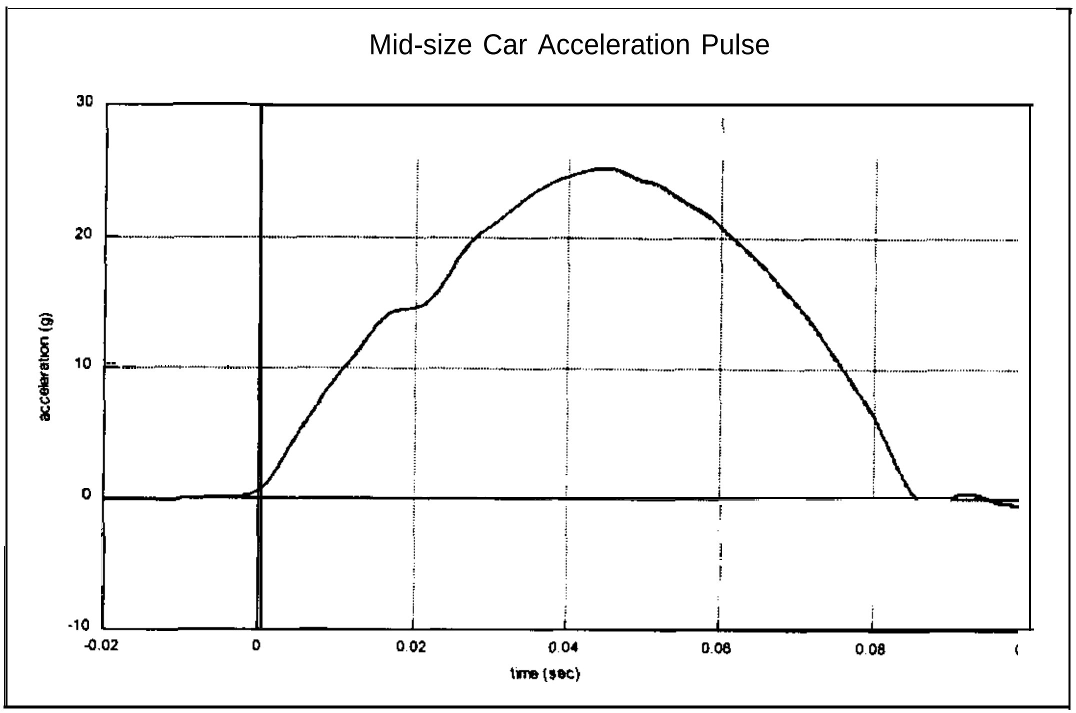


Fig. E.2. Mid-size Car Sled Pulse with 49 kph Impact Velocity

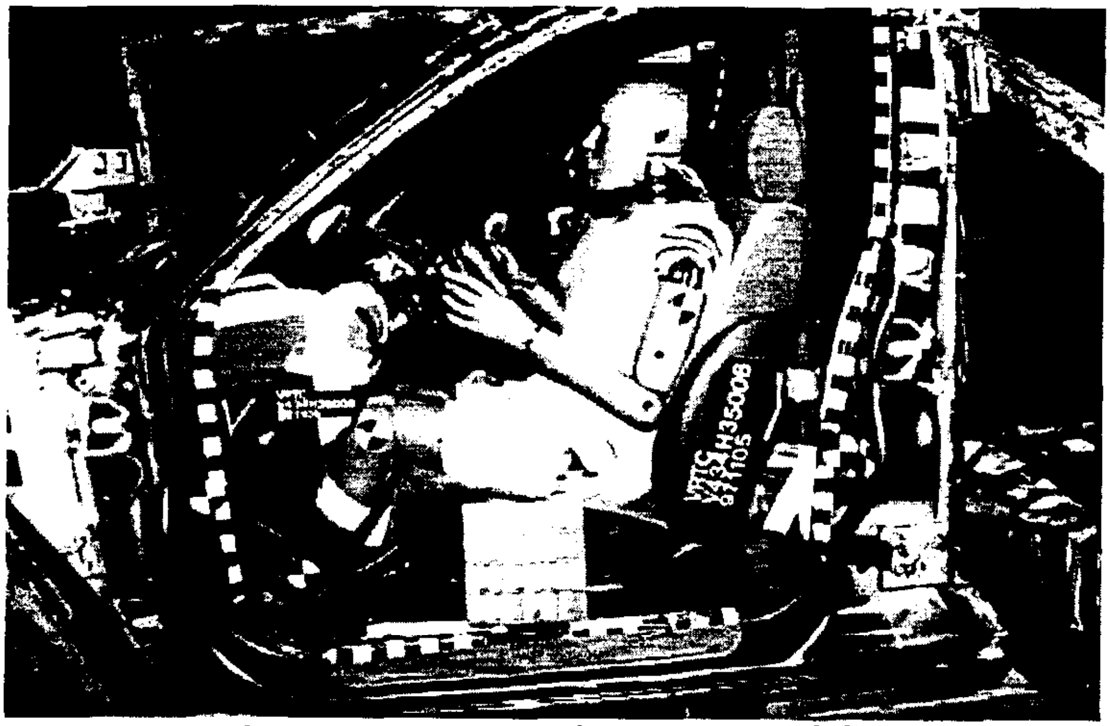


Figure E.3. Typical Driver Seating Position for Compact Car Sled Tests

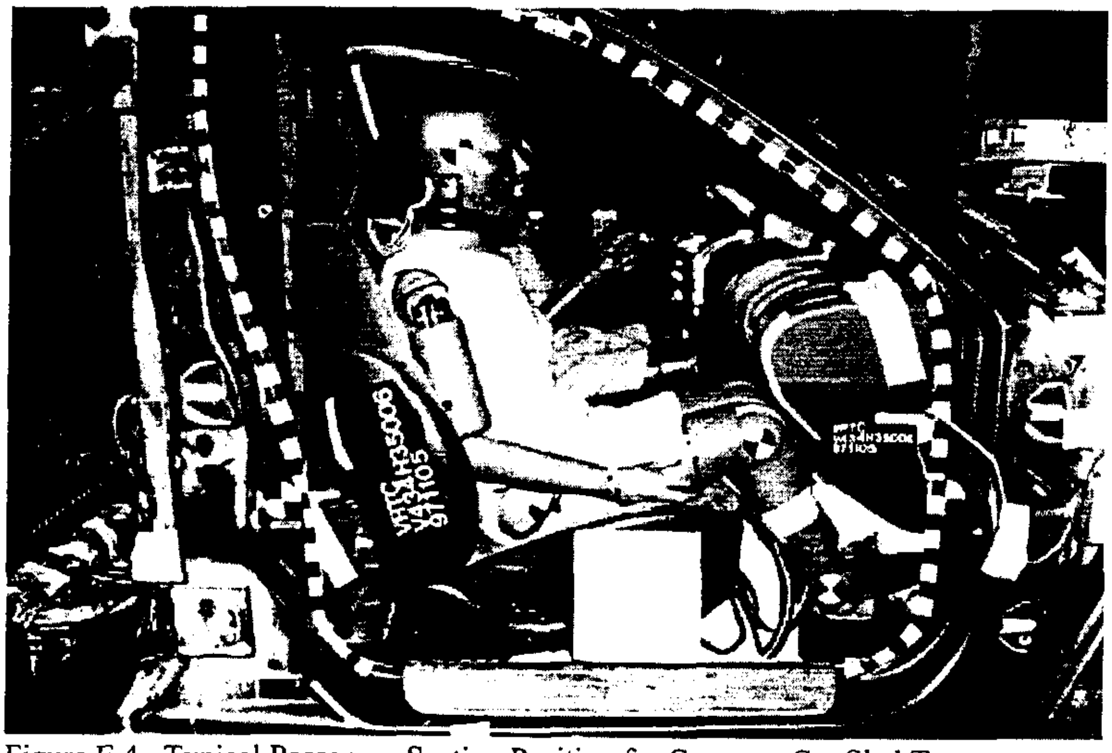


Figure E.4. Typical Passenger Seating Position for Compact Car Sled Tests

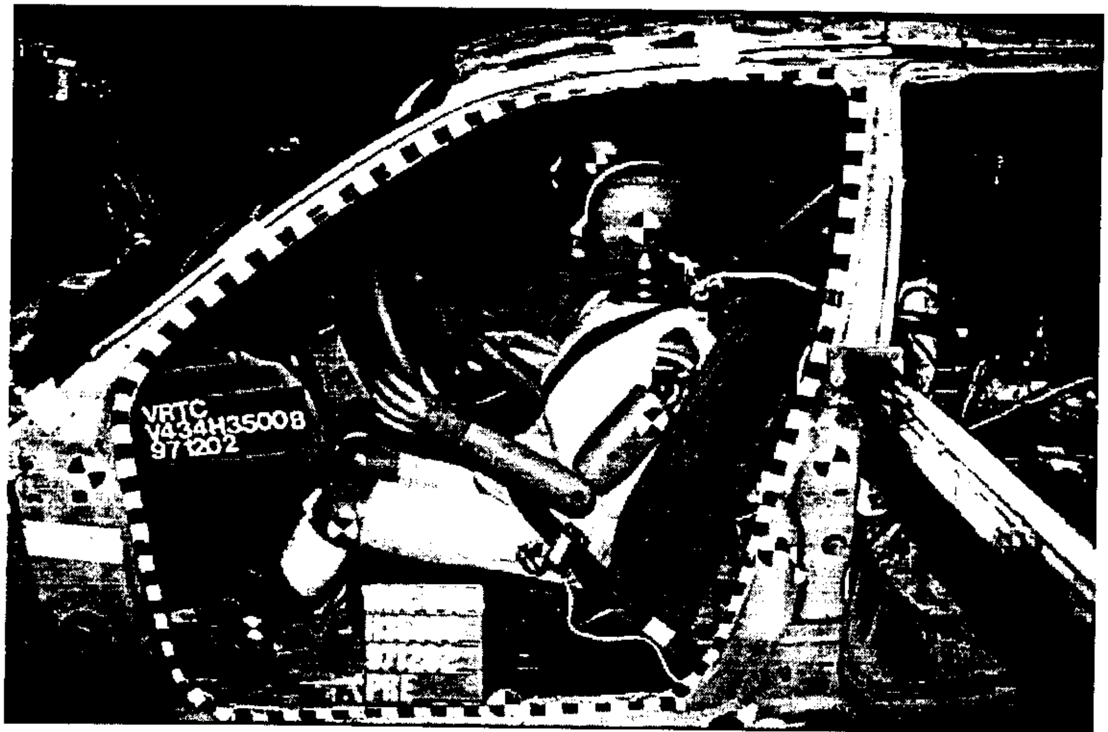


Figure E.5. Typical Driver Seating Position for Mid-size Car Sled Tests

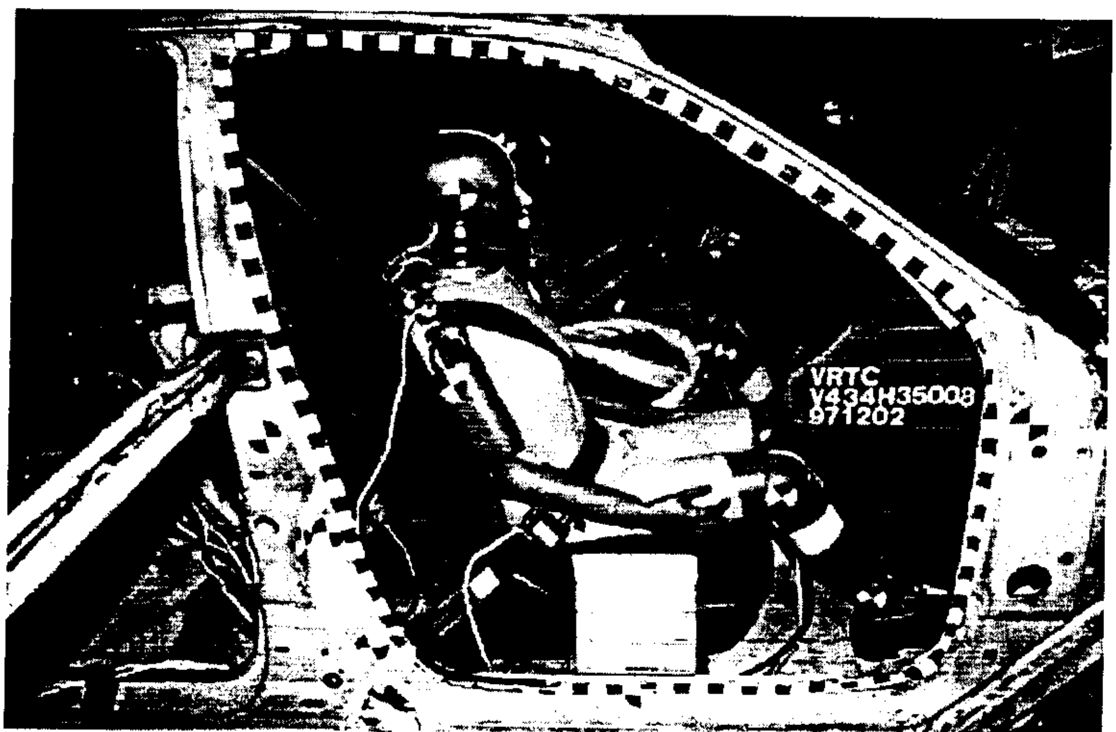


Figure E.6. Typical Passenger Seating Position for Mid-size Car Sled Tests

Table E. 1. Dynamic Sled Test Results -Driver

Test #V434H350--		01	02	03	04	05	06
dummy s/n		019	273	019	019	019	273
buck		small	small	small	small	small	small
condition		belted	belted	belted	belted	airbag	unrestrained
HIC		527	1295	1193	1199	148	816
Head X-accl	G	100	-101	85	89	47	-93
Head Y-accl	G	-6	-21	11	4	-8	-17
Head Z-accl	G	-42	-50	-43	-41	29	-44
Head Res.	G	101	102	85	89	47	93
Neck Fx	N	-927	-1253	-1289	-1244	533	735
Neck Fz	N	2016	2572	2380	2459	1244	1994
Neck Moc+	Nm	34	13	15	14	33	34
Neck Moc-	Nm	-37	-44	-51	-50	-25	-39
Chest X-accl	G	-62	-67	-67	-67	-61	-57
Chest Y-accl	G	-7	14	6	5	-3	10
Chest Z-accl	G	17	-9	-11	-13	17	58
Chest Res.	G	62	68	67	68	61	66
Chest X	mm	-45	-46	-47	-41	-50	-56
V*C	m/s	0.57	0.56	0.54	0.50	0.42	1.45
Pelvis X-accl	G	50	50	51	54	60	66
Pelvis Y-accl	G	7	10	7	8	21	14
Pelvis Z-accl	G	26	23	21	25	14	26
Pelvis Res.	G	52	53	55	57	64	69
Lumbar Fx	N	1988	2072	2173	2257	1683	1070
Lumbar Fz	N	1390	1239	1550	1872	331	1371
Lumbar My	Nm	121	144	129	134	44	45
Illiac, Rt. Fx	N	1109	2150	1184	1248	95	109
Illiac, Lt. Fx	N	2217	1974	2231	2161	256	88
L. Femur Fz	N	-2265	-1749	-1629	-1785	-3849	-3737
R. Femur Fz	N	-756	-713	-292	-895	-4723	-5672
comments		d-ring bolt failed					

Table E. 1. Dynamic Sled Test Results - Driver (cont.)

Test #V434H350--		07	08	09	10	11	12
dummy s/n		019	273	273	273	273	019
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	airbag	unrestrained
HIC		1644	2382	968	1239	189	1206
Head X-accl	G	266	-319	-213	-195	-43	186
Head Y-accl	G	22	-45	-18	-21	16	-8
Head Z-accl	G	-43	-39	-52	-39	-41	57
Head Res.	G	267	322	214	196	58	195
Neck Fx	N	772	836	-882	-779	-695	-804
Neck Fz	N	3555	3040	3115	3299	1570	4582
Neck Moc+	Nm	50	15	48	40	31	23
Neck Moc-	Nm	-24	-23	-34	-33	-74	-33
Chest X-accl	G	-55	-52	-67	-55	-61	-73
Chest Y-accl	G	-5	8	7	9	8	4
Chest Z-accl	G	24	24	19	19	15	24
Chest Res.	G	57	53	67	56	63	77
Chest X	mm	-40	-36	-49	lost data	-36	-54
V*C	m/s	0.40	0.54	1.10	lost data	0.55	2.02
Pelvis X-accl	G	47	53	67	51	53	101
Pelvis Y-accl	G	-11	-10	12	7	19	42
Pelvis Z-accl	G	38	41	39	33	16	52
Pelvis Res.	G	53	57	71	57	57	114
Lumbar Fx	N	1816	3086	2674	2658	2095	1883
Lumbar Fz	N	1651	2857	1919	1808	936	1212
Lumbar My	Nm	127.5	219	167	183	78	134
Illiac, Rt. Fx	N	3164	4232	2512	3669	34	270
Illiac, Lt. Fx	N	2581	4226	2501	3118	46	7
L. Femur Fz	N	-2026	1517	-2004	-922	-3693	-3883
R. Femur Fz	N	1456	1572	888	2037	-3741	-8780
comments					lost chest pot data		

Table E.1. Dynamic Sled Test Results - Driver (cont.)

Test #V434H350--		13	14	15	16	17	18
dummy s/n		273	019	273	273	019	019
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	belted	belted
HIC		1399	1121	953	1040	1747	1368
Head X-accl	G	-229	216	-161	-198	281	200
Head Y-accl	G	-18	18	-17	-28	9	-17
Head Z-accl	G	-40	-44	-43	-45	-43	-39
Head Res.	G	230	216	162	200	281	200
Neck Fx	N	-831	-907	-761	-856	-775	-841
Neck Fz	N	3070	3391	2755	3290	3179	3008
Neck Moc+	Nm	57	36	23	29	46	43
Neck Moc-	Nm	-33	-36	-33	-36	-34	-35
Chest X-accl	G	-59	-55	-58	-58	-51	-56
Chest Y-accl	G	5	5	6	7	6	6
Chest Z-accl	G	22	20	22	17	21	23
Chest Res.	G	59	55	59	58	51	56
Chest X	mm	-36	-38	-40	-40	-36	-36
V*C	m/s	0.39	0.39	0.63	0.52	0.35	0.33
Pelvis X-accl	G	50	48	64	54	48	48
Pelvis Y-accl	G	9	8	12	11	8	7
Pelvis Z-accl	G	32	49	30	30	42	26
Pelvis Res.	G	56	68	69	61	63	54
Lumbar Fx	N	2718	2493	2756	2662	2557	2631
Lumbar Fz	N	1958	2698	1869	1938	2219	1277
Lumbar My	Nm	183	162	167	179	165	169
Illiac, Rt, Fx	N	3747	3234	3698	3043	3382	3280
Illiac, Lt. Fx	N	3198	2719	2955	3184	2881	2871
L. Femur Fz	N	-1491	-1857	-1684	-1674	-1982	-2298
R. Femur Fz	N	1847	1717	1849	2071	1825	1753
comments							

Table E. 1. Dynamic Sled Test Results - Driver (cont.)

Test #V434H350--		19	20	21	22	23	24
dummy s/n		273	273	289	289	289	289
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	belted	belted
HIC		1140	1292	1050	919	1079	1259
Head X-accl	G	-138	-165	127	162	206	127
Head Y-accl	G	-15	17	10	8	10	-15
Head Z-accl	G	-42	-41	-46	-48	-46	-46
Head Res.	G	140	167	128	163	208	129
Neck Fx	N	-722	-759	-765	-752	-741	-768
Neck Fz	N	1982	2084	2296	2480	3039	2477
Neck Moc+	Nm	21	32	33	32	66	29
Neck Moc-	Nm	-29	-31	-34	-34	-31	-35
Chest X-accl	G	-58	-54	-55	-56	-51	-52
Chest Y-accl	G	7	5	4	4	4	5
Chest Z-accl	G	20	18	21	20	26	19
Chest Res.	G	59	54	55	57	52	53
Chest X	mm	-39	-37	-41	-43	-40	-43
V*C	m/s	0.38	0.35	0.38	0.47	0.35	0.50
Pelvis X-	G	63	50	48	52	47	49
Pelvis Y-	G	12	8	5	8	9	6
Pelvis Z-	G	30	27	26	23	24	23
Pelvis Res.	G	67	52	51	56	49	50
Lumbar Fx	N	2469	2738	2554	2421	2394	2365
Lumbar Fz	N	1744	1324	1324	1647	1391	1649
Lumbar My	Nm	160	174	176	157	160	149
Illiac. Rt. Fx	N	2842	3417	3562	3282	3461	3134
Illiac. Lt. Fx	N	2682	3073	3103	2815	2806	3023
L. Femur Fz	N	-1510	-1226	-1364	-1854	-1726	-1907
R. Femur Fz	N	1597	1848	1667	1697	1720	1610
comments							

Table E.l. Dynamic Sled Test Results - Driver (cont.)

Test #V434H350--		25	26	27	28
dummy s/n		273	289	273	273
buck		mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted
HIC		859	981	1436	1392
Head X-accl	G	-118	176	-235	-168
Head Y-accl	G	-12	8	-29	-11
Head Z-accl	G	-47	-45	-47	-41
Head Res.	G	121	177	237	169
Neck Fx	N	-824	-706	-814	-888
Neck Fz	N	2128	2257	2440	2909
Neck Moc+	Nm	23	46	42	35
Neck Moc-	Nm	-31	-36	-36	-39
Chest X-accl	G	-55	-52	-51	-58
Chest Y-accl	G	8	5	5	7
Chest Z-accl	G	16	20	19	19
Chest Res.	G	55	52	51	58
Chest X	mm	-40	-37	-33	-39
V*C	m/s	0.36	0.26	0.26	0.43
Pelvis X-accl	G	56	47	54	55
Pelvis Y-accl	G	10	7	10	8
Pelvis Z-accl	G	29	23	31	23
Pelvis Res.	G	59	49	61	56
Lumbar Fx	N	2391	lost data	lost data	lost data
Lumbar Fz	N	1957	lost data	lost data	lost data
Lumbar My	Nm	159	lost data	lost data	lost data
Illiac, Rt, Fx	N	3198	3122	2989	3336
Illiac, Lt. Fx	N	2362	2992	2657	2987
L. Femur Fz	N	-2107	-1504	-1472	-1648
R. Femur Fz	N	1898	1600	1737	1898
comments					

Table E.2. Dynamic Sled Test Results - Passenger

Test #V434H350--		01	02	03	04	05	06
dummy s/n		273	019	273	273	273	019
buck		small	small	small	small	small	small
condition		belted	belted	belted	belted	airbag	unrestrained
HIC		1759	1950	1937	1937	283	2646
Head X-accl	G	-100	135	-130	-128	-48	129
Head Y-accl	G	13	-32	18	13	9	-26
Head Z-accl	G	-67	-77	-68	-65	-12	155
Head Res.	G	105	142	136	137	48	194
Neck Fx	N	-1051	-1341	-1443	-1383	1248	2629
Neck Fz	N	2488	2576	2438	2334	404	1092
Neck Moc+	Nm	21	15	22	25	95	20
Neck Moc-	Nm	-40	-42	-39	-38	-20	-390
Chest X-accl	G	-53	-53	-56	-58	-78	-102
Chest Y-accl	G	-15	-12	-9	-11	4	-22
Chest Z-accl	G	-15	11	-12	12	15	-63
Chest Res.	G	53	53	56	56	79	113
Chest X	mm	-37	-47	-39	-39	-13	-27
V*C	m/s	0.32	0.32	0.32	0.29	0.09	0.94
Pelvis X-accl	G	51	55	60	59	52	62
Pelvis Y-accl	G	7	-9	-9	11	-9	-23
Pelvis Z-accl	G	18	27	21	23	25	40
Pelvis Res.	G	53	58	61	62	57	70
Lumbar Fx	N	2210	2633	2979	3052	2163	2369
Lumbar Fz	N	1206	2074	1322	1739	613	2865
Lumbar My	Nm	133	171	195	205	114	118
Illiac, Rt. Fx	N	1181	1180	2270	3215	202	777
Illiac, Lt. Fx	N	2099	2636	2921	3025	129	4622
L. Femur Fz	N	-2277	-1570	-1199	-1933	-3236	-4767
R. Femur Fz	N	-2864	-490	-2114	-897	-4063	-4065
comments							

Table E.2. Dynamic Sled Test Results - Passenger (cont.)

Test #V434H350--		07	08	09	10	11	12
dummy s/n		273	019	019	019	019	273
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	airbag	unrestrained
HIC		761	829	876	947	270	984
Head X-accl	G	-51	-53	-60	60	-94	-112
Head Y-accl	G	7	14	14	16	12	-16
Head Z-accl	G	-53	-65	-65	-67	-32	63
Head Res.	G	65	73	73	75	96	113
Neck Fx	N	-1588	-1661	-1792	-1979	720	-1312
Neck Fz	N	2167	2422	2270	2375	2888	994
Neck Moc+	Nm	77	45	50	47	29	25
Neck Moc-	Nm	-20	-22	-22	-24	-94	-150
Chest X-accl	G	-54	-44	-45	-53	-68	-72
Chest Y-accl	G	6	3	6	-4	3	-17
Chest Z-accl	G	14	16	11	19	-23	-39
Chest Res.	G	54	46	47	53	69	76
Chest X	mm	-37	-43	-39	-35	-12	-46
V*C	m/s	0.32	0.26	0.39	0.24	0.10	1.92
Pelvis X-accl	G	57	36	39	45	50	56
Pelvis Y-accl	G	10	-8	11	12	10	-18
Pelvis Z-accl	G	30	34	32	35	25	55
Pelvis Res.	G	61	44	50	50	55	63
Lumbar Fx	N	2741	2172	1862	3012	2087	962
Lumbar Fz	N	2139	2813	2712	2757	522	4013
Lumbar My	Nm	203	145	125	198	143	77
Illiac, Rt, Fx	N	3998	3573	2203	3804	275	335
Illiac, Lt. Fx	N	3849	lost data	lost data	lost data	13	1284
L. Femur Fz	N	1586	831	1073	1323	-3721	-5460
R. Femur Fz	N	1438	-958	-2048	-1200	-3275	-3780
comments							

Table E.2. Dynamic Sled Test Results - Passenger (cont.)

Test #V434H350--		13	14	15	16	17	18
dummy s/n		019	273	019	019	273	273
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	belted	belted
HIC		839	713	1001	960	862	915
Head X-accl	G	68	-49	72	75	-61	-61
Head Y-accl	G	-10	-3	-13	13	11	6
Head Z-accl	G	-52	-56	-61	-54	-53	-55
Head Res.	G	70	65	75	78	63	67
Neck Fx	N	-1991	-1478	-2016	-2027	-1747	-1674
Neck Fz	N	2420	2000	2758	3001	2310	2385
Neck Moc+	Nm	48	60	53	46	72	68
Neck Moc-	Nm	-39	-46	-46	-36	-40	-42
Chest X-accl	G	-56	-55	-56	-58	-55	-51
Chest Y-accl	G	-3	8	5	6	-6	4
Chest Z-accl	G	16	-15	19	17	15	-14
Chest Res.	G	56	56	56	58	55	51
Chest X	mm	-33.1	-30.4	-33.6	-35.2	-37.4	-32.1
V*C	m/s	0.24	0.36	0.26	0.25	0.38	0.33
Pelvis X-accl	G	52	53	49	51	49	45
Pelvis Y-accl	G	-7	14	-10	-11	-9	6
Pelvis Z-accl	G	25	33	31	29	22	25
Pelvis Res.	G	57	56	58	55	53	49
Lumbar Fx	N	3237	2839	3215	3220	2982	2844
Lumbar Fz	N	2202	2493	2458	1970	2320	2174
Lumbar My	Nm	216	197	221	218	224	199
Illiac, Rt. Fx	N	3875	3696	4050	3876	4491	4045
Illiac, Lt. Fx	N	4536	4121	3863	4192	4204	4059
L. Femur Fz	N	1623	1455	1439	1524	1489	1487
R. Femur Fz	N	599	756	1145	938	1656	1405
comments							

Table E.2. Dynamic Sled Test Results - Passeneer (cont.)

Test #V434H350--		19	20	21	22	23	24
dummy s/n		289	289	289	289	289	289
buck		mid-size	mid-size	mid-size	mid-size	mid-size	mid-size
condition		belted	belted	belted	belted	belted	belted
HIC		963	924	780	824	780	693
Head X-accl	G	-60	64	-58	-63	-60	-57
Head Y-accl	G	7	12	5	5	-5	4
Head Z-accl	G	-54	-53	-50	-50	-48	-47
Head Res.	G	75	67	64	65	63	61
Neck Fx	N	-1631	-1561	-1633	-1666	-1523	-1433
Neck Fz	N	2348	2525	2204	2316	2177	2177
Neck Moc+	Nm	83	67	69	70	74	59
Neck Moc-	Nm	-43	-38	-42	-38	-43	-43
Chest X-accl	G	-55	-53	-54	-52	-55	-57
Chest Y-accl	G	-5	2	4	3	4	7
Chest Z-accl	G	-16	18	17	15	17	-16
Chest Res.	G	55	53	54	53	55	57
Chest X	mm	lost data	-34	-33	-31	-32	-33
V*C	m/s	lost data	0.27	0.26	0.24	0.25	0.30
Pelvis X-	G	57	48	56	49	50	57
Pelvis Y-	G	-8	-6	6	7	-10	-8
Pelvis Z-	G	40	21	24	27	30	35
Pelvis Res.	G	70	51	58	52	55	61
Lumbar Fx	N	3244	3114	3277	3166	2854	2886
Lumbar Fz	N	2934	2065	2380	2235	2820	2630
Lumbar My	Nm	244	224	217	215	213	200
Illiac. Rt. Fx	N	4307	4550	4101	4218	4421	4030
Illiac. Lt. Fx	N	4498	4223	4415	4334	4432	3993
L. Femur Fz	N	1517	1463	1561	1471	1435	1622
R. Femur Fz	N	1210	1329	1378	1276	1193	937
comments		lost chest pot data					

Table E.3. Peak Sternum and Spine Accelerometer Measurements

		V434H35001		V434H35002		V434H35003	
		compact car		compact car		compact car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	107	209	79	38	95	11
	sternum middle	118	170	92	15	109	13
	sternum bottom	138	171	111	13	127	29
	spine top	7	63	7	70	7	71
	spine middle	6	61	5	63	5	64
	spine bottom	5	60	1	56	3	58
passenger	sternum top	143	73	56	10	70	27
	sternum middle	106	72	62	8	68	12
	sternum bottom	123	79	72	10	69	12
	spine top	5	52	6	53	6	55
	spine middle	4	56	5	55	4	58
	spine bottom	2	58	5	57	3	60

		V434H35004		V434H35005		V434H35006	
		compact car		compact car		compact car	
		belted		airbag		unrestrained	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	84	9	126	55	129	54
	sternum middle	94	6	91	33	134	37
	sternum bottom	107	7	117	58	240	71
	spine top	7	72	9	61	3	60
	spine middle	4	62	8	62	3	55
	spine bottom	3	62	8	66	0	54
passenger	sternum top	63	29	81	27	254	169
	sternum middle	65	8	64	3	205	54
	sternum bottom	75	8	66	3	293	69
	spine top	7	57	3	43	11	125
	spine middle	4	59	2	62	19	98
	spine bottom	2	61	4	76	28	94

Table E.3. Peak Sternum and Spine Accelerometer Measurements (cont.)

		V434H35007		V434H35008		V434H35009	
		mid-size car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	82	15	67	37	83	15
	sternum middle	82	19	73	21	77	10
	sternum bottom	85	21	79	24	81	11
	spine top	7	61	7	50	7	63
	spine middle	5	48	6	55	5	71
	spine bottom	4	51	3	60	0	75
passenger	sternum top	63	32	67	14	90	27
	sternum middle	67	15	62	19	98	38
	sternum bottom	71	16	66	27	106	52
	spine top	6	52	13	42	12	44
	spine middle	4	59	8	48	8	47
	spine bottom	6	65	7	56	7	54

		V434H35010		V434H35011		V434H35012	
		mid-size car		mid-size car		mid-size car	
		belted		airbag		unrestrained	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	91	29	206	126	174	266
	sternum middle	57	16	89	50	128	71
	sternum bottom	69	14	158	63	123	60
	spine top	12	53	12	41	17	83
	spine middle	8	58	9	50	14	70
	spine bottom	1	62	9	59	11	75
passenger	sternum top	95	77	57	26	432	271
	sternum middle	83	75	67	25	223	177
	sternum bottom	89	66	73	41	222	215
	spine top	10	51	16	44	7	77
	spine middle	6	58	10	51	4	68
	spine bottom	5	64	12	59	5	59

Table E.3. Peak Sternum and Spine Accelerometer Measurements (cont.)

		V434H35013		V434H35014		V434H35015	
		mid-size car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	68	10	56	9	101	24
	sternum middle	68	10	56	7	72	24
	sternum bottom	68	12	59	10	84	36
	spine top	8	57	7	55	7	56
	spine middle	5	63	5	57	5	62
	spine bottom	lost data	lost data	3	60	4	64
passenger	sternum top	60	10	97	48	55	49
	sternum middle	64	9	72	48	53	21
	sternum bottom	68	9	79	53	60	23
	spine top	6	54	9	51	8	54
	spine middle	4	60	5	59	5	59
	spine bottom	6	67	14	65	7	65

		V434H35016		V434H35017		V434H35018	
		mid-size car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	71	16	58	13	60	20
	sternum middle	56	8	62	13	61	8
	sternum bottom	64	11	64	17	73	13
	spine top	7	56	8	50	11	55
	spine middle	5	60	5	53	7	59
	spine bottom	4	68	4	57	4	62
passenger	sternum top	56	8	53	36	66	27
	sternum middle	61	9	56	18	64	15
	sternum bottom	72	10	64	24	64	20
	spine top	7	57	6	52	7	48
	spine middle	4	60	4	58	5	54
	spine bottom	9	65	4	61	6	58

Table E.3. Peak Sternum and Spine Accelerometer Measurements (cont.)

		V434H35019		V434H35020		V434H35021	
		mid-six car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
[redacted]	sternum top	79	9	91	10	88	12
	sternum middle	64	6	67	8	64	12
	sternum bottom	68	15	83	12	64	22
	spine top	8	56	9	52	10	53
	spine middle	5	62	6	58	6	58
	spine bottom	0	65	lost data	lost data	lost data	lost data
[redacted]	sternum top	58	21	60	20	63	27
	sternum middle	56	13	65	12	65	14
	sternum bottom	65	12	68	10	66	16
	spine top	9	55	7	52	6	52
	spine middle	8	61	5	55	4	59
	spine bottom	6	67	6	61	4	40

		V434H35022		V434H35023		V434H35024	
		mid-size car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	105	59	53	12	91	18
	sternum middle	75	43	59	8	78	11
	sternum bottom	78	46	63	11	87	17
	spine top	6	55	9	52	10	52
	spine middle	5	60	6	53	7	56
	spine bottom	lost data	lost data	lost data	lost data	lost data	lost data
passenger	sternum top	70	25	51	22	63	14
	sternum middle	68	12	52	10	66	8
	sternum bottom	68	15	58	12	70	10
	spine top	7	50	7	53	5	54
	spine middle	5	57	4	58	3	50
	spine bottom	3	41	3	36	3	39

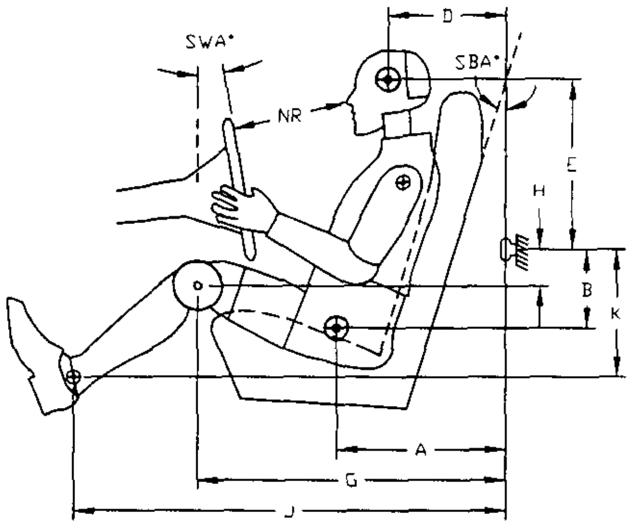
Table E.3. Peak Sternum and Spine Accelerometer Measurements (cont.)

		V434H35025		V434H35026		V434H35027	
		mid-size car		mid-size car		mid-size car	
		belted		belted		belted	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	85	21	56	11	73	42
	sternum middle	73	11	66	9	75	21
	sternum bottom	71	21	78	12	76	18
	spine top	8	53	7	51	10	50
	spine middle	6	57	6	57	7	56
	spine bottom	lost data	lost data	5	65	0	62
passenger	sternum top	70	17	49	18	54	18
	sternum middle	75	12	53	9	54	12
	sternum bottom	78	12	58	7	57	10
	spine top	6	54	6	49	6	52
	spine middle	4	57	4	57	4	55
	spine bottom	6	63	10	63	6	60

		V434H35028		V434H35029		V434H35030	
		mid-size car		mid-size car		mid-size car	
		belted		bag and belt		airbag	
		peak negative	peak positive	peak negative	peak positive	peak negative	peak positive
driver	sternum top	75	22	n/a	n/a	n/a	n/a
	sternum middle	50	19	n/a	n/a	n/a	n/a
	sternum bottom	58	20	n/a	n/a	n/a	n/a
	spine top	10	57	n/a	n/a	n/a	n/a
	spine middle	7	59	n/a	n/a	n/a	n/a
	spine bottom	lost data	lost data	n/a	n/a	n/a	n/a
passenger	sternum top	63	15	138	26	66	26
	sternum middle	70	9	78	6	63	20
	sternum bottom	75	9	86	7	85	18
	spine top	6	52	10	56	5	55
	spine middle	4	56	8	59	5	75
	spine bottom	5	62	5	64	8	90

Table E.4. Seating Position for Dynamic Sled Tests

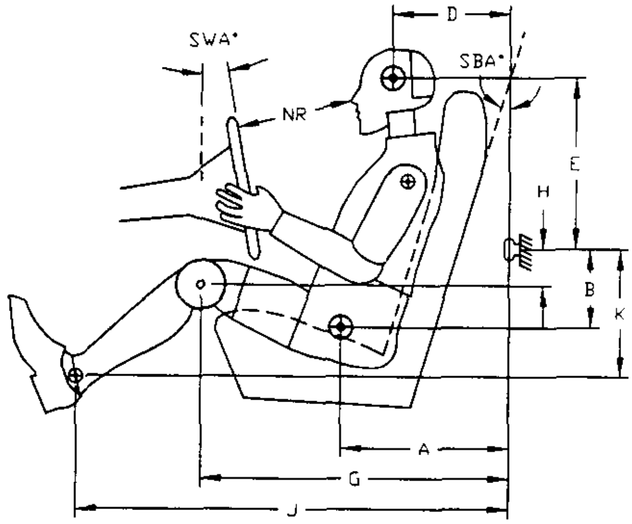
Test # V343H35001
Date: 11/3/97
Buck: Compact Car
Driver Condition: Belted
Pass. Condition: Belted



Dim	Description		units	Driver	Passenger
A	H-Point	X	in	14.0	14.2
B		Y	in	9.7	10.9
C		Z	in	-2.7	-2.4
D	Head CG	X	in	8.2	8.3
E		Y	in	13.3	13.0
F		Z	in	19.4	19.5
G	Knee Bolt	X	in	26.6	27.5
H		Y	in	9.5	10.2
I		Z	in	0.9	0.9
J	Ankle Bolt	X	in	33.0	32.8
K		Y	in	8.5	10.3
L		Z	in	9.7	8.6
PA	Pelvic Angle		deg	20.7	24.2
KK	Knee Spacing		in	9.5	7.0
SWA	Steering Wheel Angle		deg	22.5	n/a
SBA	Seat Back Angle		deg	17.9	18.0
NR	Nose to Rim		in	10.1	n/a
CS	Chest to S/W		in	6.7	n/a
CD	Chest to Dash		in	n/a	12.6
KDL	Left Knee to Bolster		in	0.1	0.4
KDR	Right Knee to Bolster		in	0.1	0.5

Table E.5. Seating Position for Dynamic Sled Tests

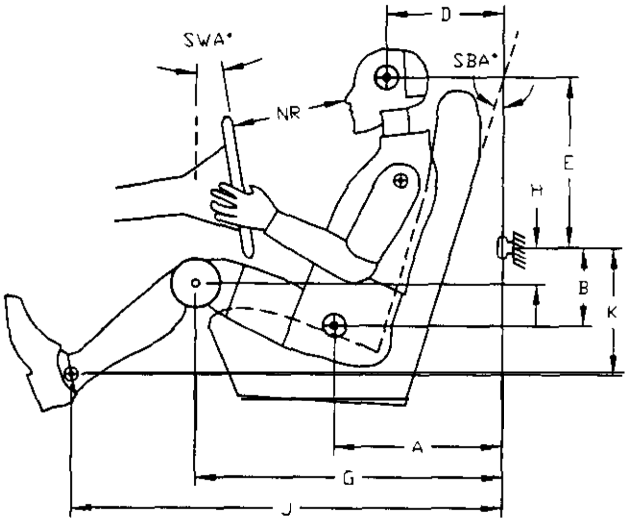
Test # V343H35005
Date: 11/5/97
Buck: Compact Car
Driver Condition: Airbag
Pass. Condition: Airbag



Dim	Description		units	Driver	Passenger
A	H-Point	X	in	14.0	14.2
B		Y	in	9.8	10.5
C		Z	in	-2.9	-3.2
D	Head CG	X	in	8.2	8.3
E		Y	in	13.3	13.0
F		Z	in	19.2	19.2
G	Knee Bolt	X	in	26.7	27.2
H		Y	in	9.4	10.1
I		Z	in	0.9	0.9
J	Ankle Bolt	X	in	32.8	32.0
K		Y	in	8.5	10.2
L		Z	in	8.6	9.1
PA	Pelvic Angle		deg	20.6	23.9
KK	Knee Spacing		in	9.5	7.0
SWA	Steering Wheel Angle		deg	22.6	n/a
SBA	Seat Back Angle		deg	18.3	18.1
NR	Nose to Rim		in	9.9	n/a
CS	Chest to S/W		in	6.8	n/a
CD	Chest to Dash		in	n/a	12.8
KDL	Left Knee to Bolster		in	0.4	0.8
KDR	Right Knee to Bolster		in	0.6	1.0

Table E.6. Seating Position for Dynamic Sled Tests

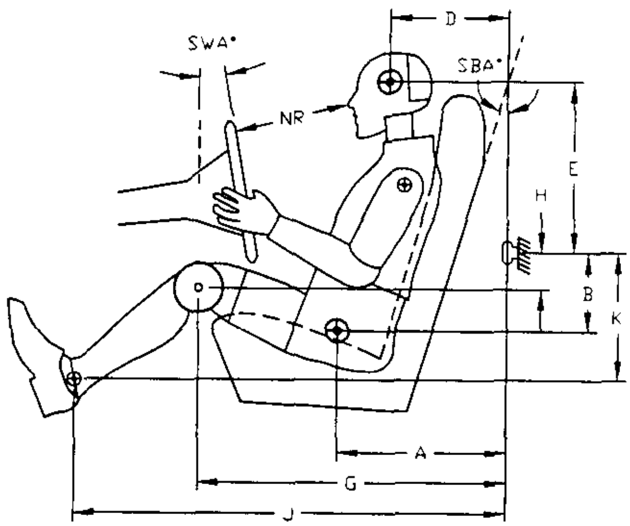
Test # V343H35020
Date: 1/12/98
Buck: Mid-size Car
Driver Condition: Belted
Pass. Condition: Belted



Dim	Description		units	Driver	Passenger
A	H-Point	X	in	14.1	14.6
B		Y	in	9.5	9.5
C		Z	in	4.9	5.7
D	Head CG	X	in	8.8	9.1
E		Y	in	12.2	12.5
F		Z	in	17.4	16.9
G	Knee Bolt	X	in	27.6	27.8
H		Y	in	9.5	10.1
I		Z	in	1.6	1.6
J	Ankle Bolt	X	in	33.4	32.6
K		Y	in	10.1	10.8
L		Z	in	11.0	11.2
PA	Pelvic Angle		deg	22.0	20.9
KK	Knee Spacing		in	8.6	7.3
SWA	Steering Wheel Angle		deg	22.5	n/a
SBA	Seat Back Angle		deg	19.4	18.4
NR	Nose to Rim		in	9.6	n/a
CS	Chest to S/W		in	3.4	n/a
CD	Chest to Dash		in	n/a	13.9
KDL	Left Knee to Bolster		in	1.0	2.7
KDR	Right Knee to Bolster		in	0.9	2.6

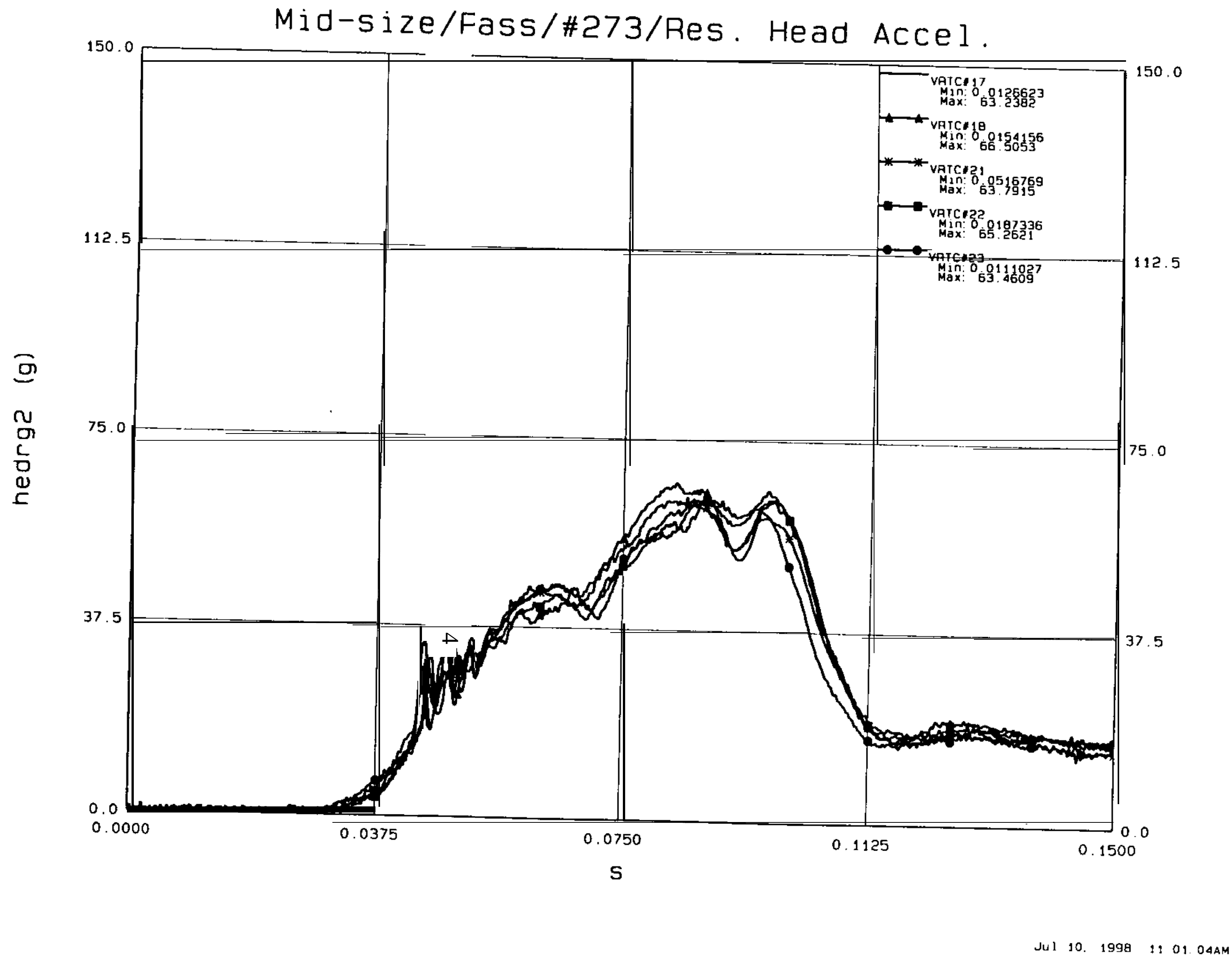
Table E.7. Seating Position for Dynamic Sled Tests

Test # V343H35021
Date: 1/13/98
Buck: Mid-size Car
Driver Condition: Belted
Pass. Condition: Belted



Dim	Description		units	Driver	Passenger
A	H-Point	X	in	14.4	14.9
B		Y	in	9.3	9.8
C		Z	in	5.3	5.2
D	Head CG	X	in	9.1	9.4
E		Y	in	12.3	12.3
F		Z	in	16.8	16.6
G	Knee Bolt	X	in	27.6	28.0
H		Y	in	9.0	9.9
I		Z	in	1.6	1.6
J	Ankle Bolt	X	in	32.8	33.8
K		Y	in	9.5	10.5
L		Z	in	11.2	10.9
PA	Pelvic Angle		deg	21.9	21.3
KK	Knee Spacing		in	8.5	7.5
SWA	Steering Wheel Angle		deg	23.0	n/a
SBA	Seat Back Angle		deg	20.0	19.7
NR	Nose to Rim		in	9.4	n/a
CS	Chest to S/W		in	2.9	n/a
CD	Chest to Dash		in	n/a	14.3
KDL	Left Knee to Bolster		in	0.8	2.7
KDR	Right Knee to Bolster		in	0.9	2.5

Figure E.7



Mid-size/Fass/#273/Res. Head Accel.
150.0
112.5
75.0
37.5
0.0
0.0000
0.0375
0.0750
0.1125
0.1500
S
hedrg2 (g)
VRTC#17 Min: 0.0126623 Max: 63.2382
VRTC#18 Min: 0.0154156 Max: 66.5053
VRTC#21 Min: 0.0516769 Max: 63.7915
VRTC#22 Min: 0.0187336 Max: 65.2621
VRTC#23 Min: 0.0111027 Max: 63.4609
4
Jul 10. 1998 11 01 04AM

Figure E.8

Mid-size/Pass/#273/Res. Chest Accel

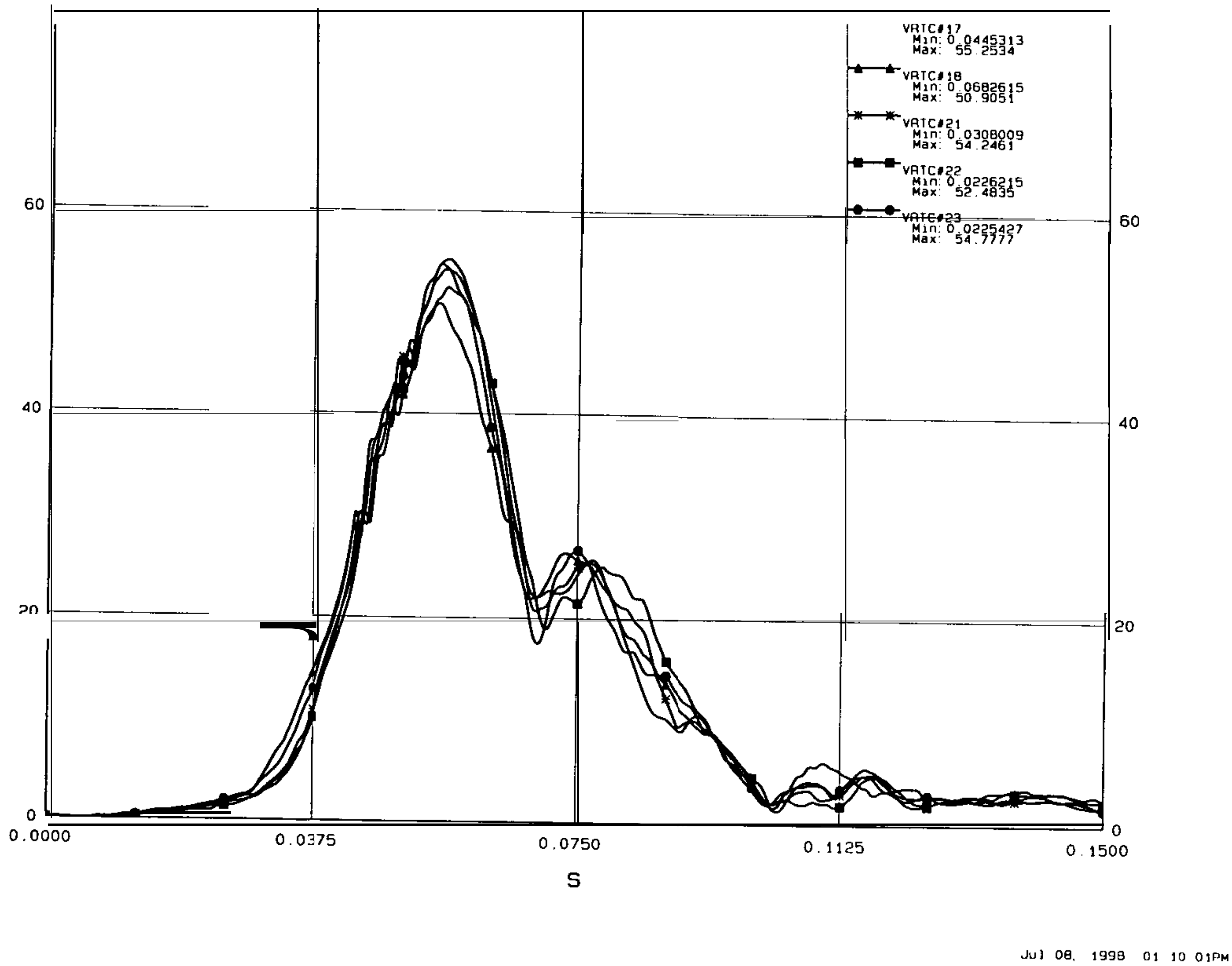
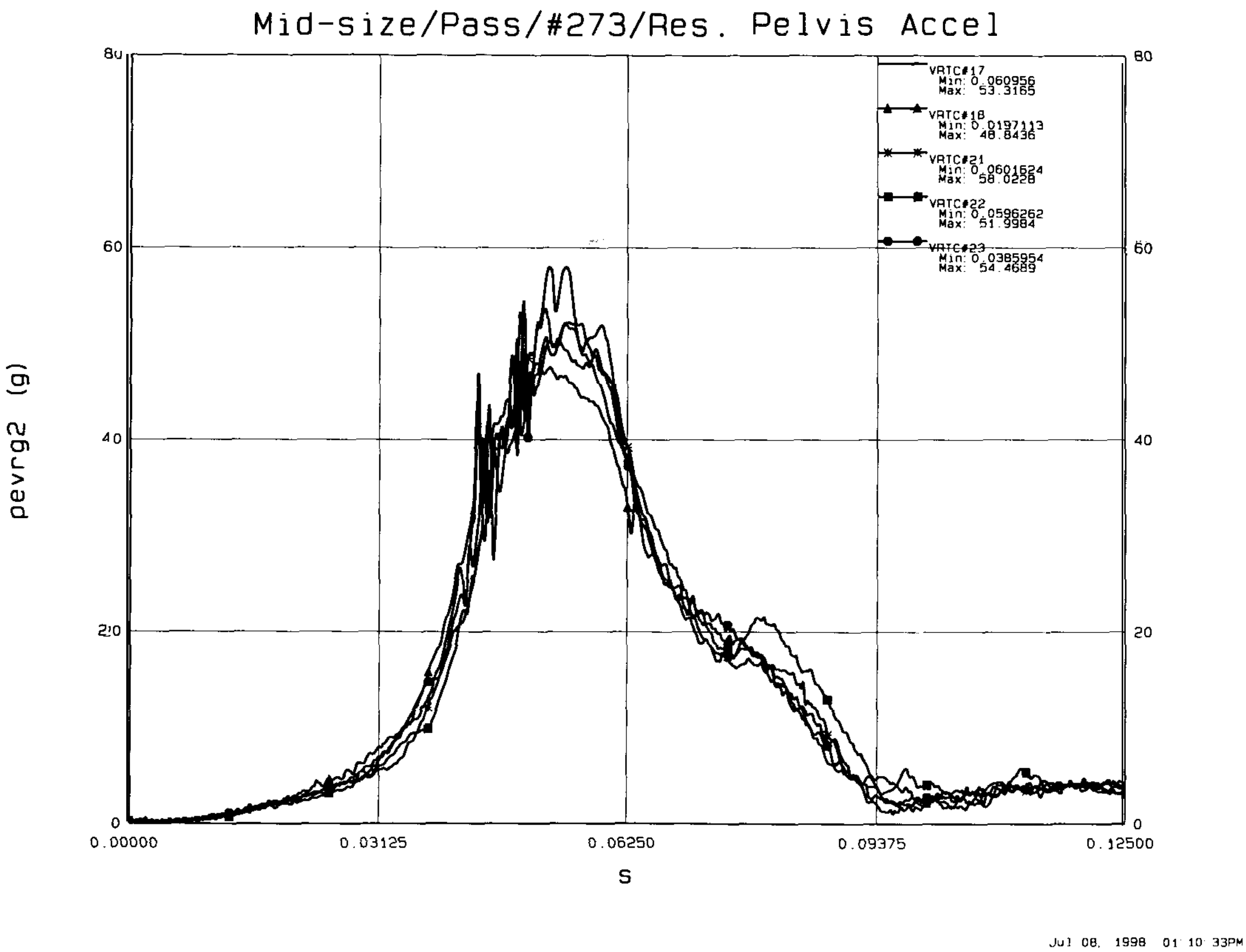
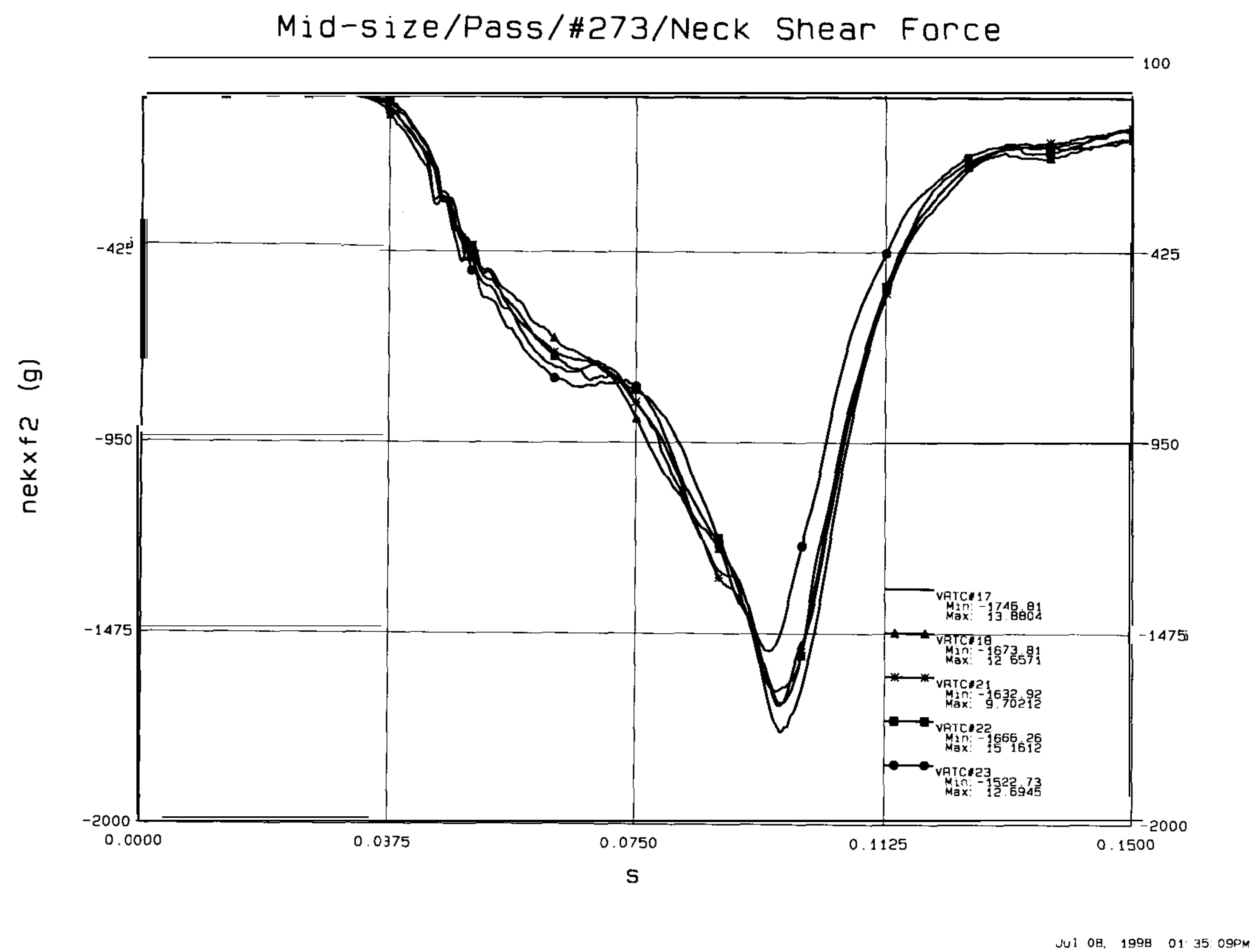


Figure E.9



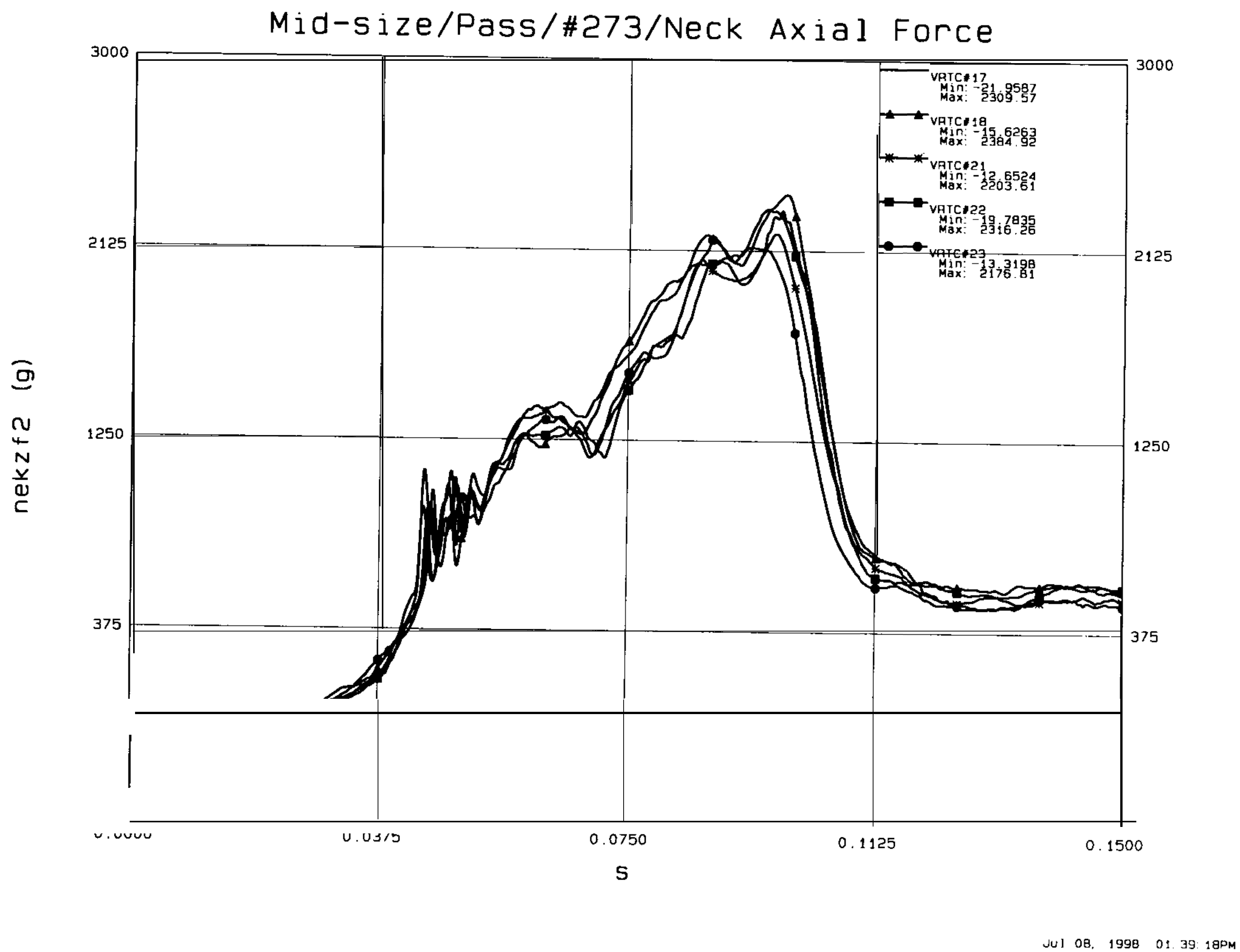
Mid-size/Pass/#273/Res. Pelvis Accel
VRTC#17 Min: 0.060956 Max: 53.3165
VRTC#18 Min: 0.0197113 Max: 48.8436
VRTC#21 Min: 0.0601624 Max: 58.0228
VRTC#22 Min: 0.0596262 Max: 51.9984
VRTC#23 Min: 0.0385954 Max: 54.4689
pevrg2 (g)
s
0.00000
0.03125
0.06250
0.09375
0.12500
0
20
40
60
80
Jul 08, 1998 01:10:33PM

Figure E.10



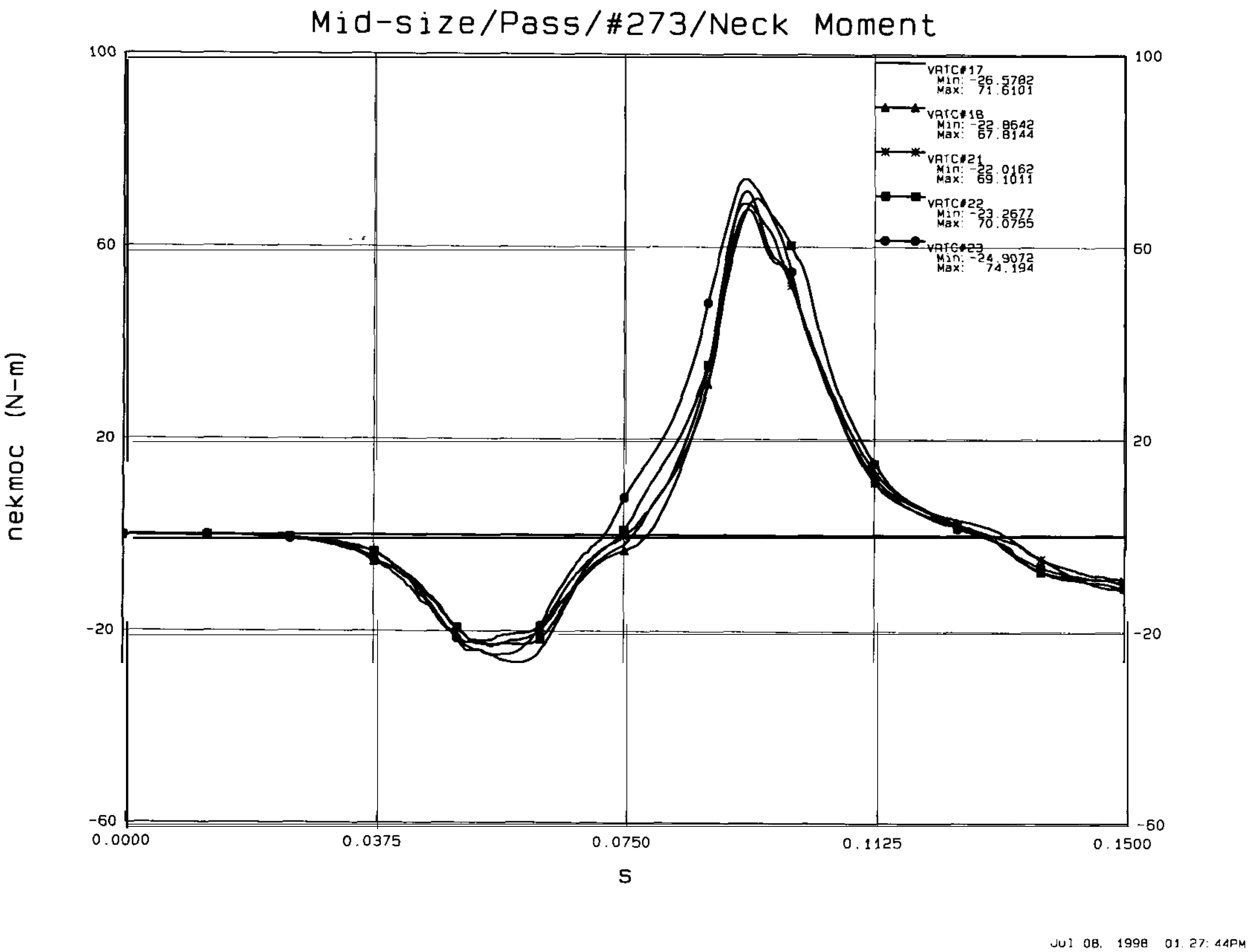
Mid-size/Pass/#273/Neck Shear Force
nekxf2 (g)
s
100
-425
-950
-1475
-2000
425
950
-1475
-2000
0.0000
0.0375
0.0750
0.1125
0.1500
VRTC#17 Min: -1746.81 Max: 13.8804
VRTC#18 Min: -1673.81 Max: 12.6571
VRTC#21 Min: -1632.92 Max: 9.70212
VRTC#22 Min: -1666.26 Max: 15.1612
VRTC#23 Min: -1522.73 Max: 12.6945
Jul 08, 1998 01:35:09PM

Figure E.11



Mid-size/Pass/#273/Neck Axial Force
3000
2125
1250
375
VRTC#17 Min: -21.9587 Max: 2309.57
VRTC#18 Min: -15.6263 Max: 2384.92
VRTC#21 Min: -12.6524 Max: 2203.61
VRTC#22 Min: -19.7835 Max: 2316.26
VRTC#23 Min: -13.3198 Max: 2176.81
nekzf2 (g)
0.0000
0.0375
0.0750
0.1125
0.1500
s
JUL 08, 1998 01:39:18PM

Figure E.12



Mid-size/Pass/#273/Neck Moment
VRTC#17
Min: -26.5782
Max: 71.6101
VRTC#18
Min: -22.8642
Max: 67.8144
VRTC#21
Min: -22.0162
Max: 69.1011
VRTC#22
Min: -23.2677
Max: 70.0755
VRTC#23
Min: -24.9072
Max: 74.194
100
60
20
-20
-60
0.0000
0.0375
0.0750
0.1125
0.1500
s
nekmoc (N-m)
Jul 08, 1998 01:27:44PM

Figure E.13

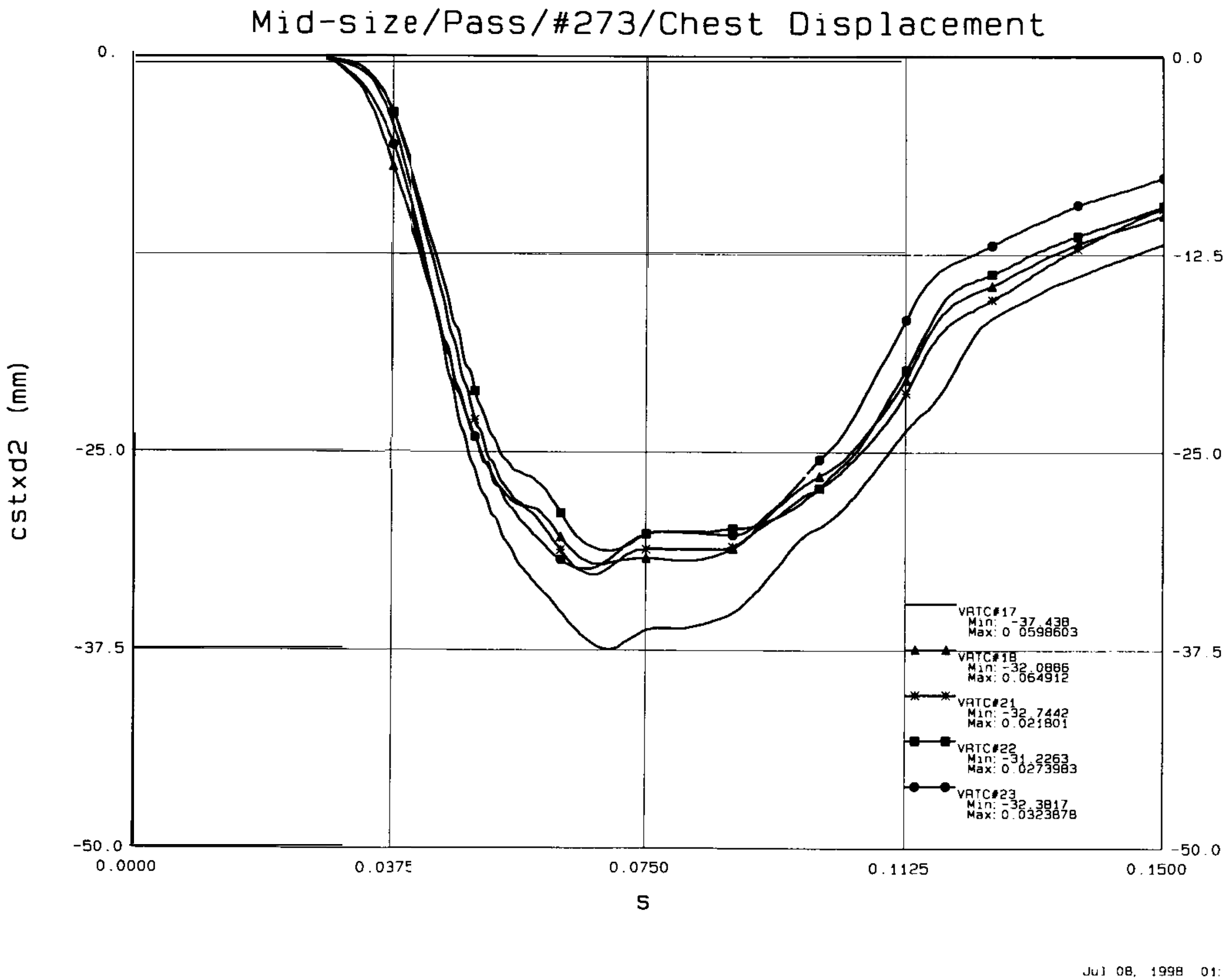

Mid-size/Pass/#273/Chest Displacement
cstxd2 (mm)
s
0.
-25.0
-37.5
-50.0
0.0
-12.5
-25.0
-37.5
-50.0
0.0000
0.0375
0.0750
0.1125
0.1500
VRTC#17
Min: -37.438
Max: 0.0598603
VRTC#18
Min: -32.0886
Max: 0.064912
VRTC#21
Min: -32.7442
Max: 0.021801
VRTC#22
Min: -31.2263
Max: 0.0273983
VRTC#23
Min: -32.3817
Max: 0.0323878
Jul 08, 1998 01:

Figure E.14

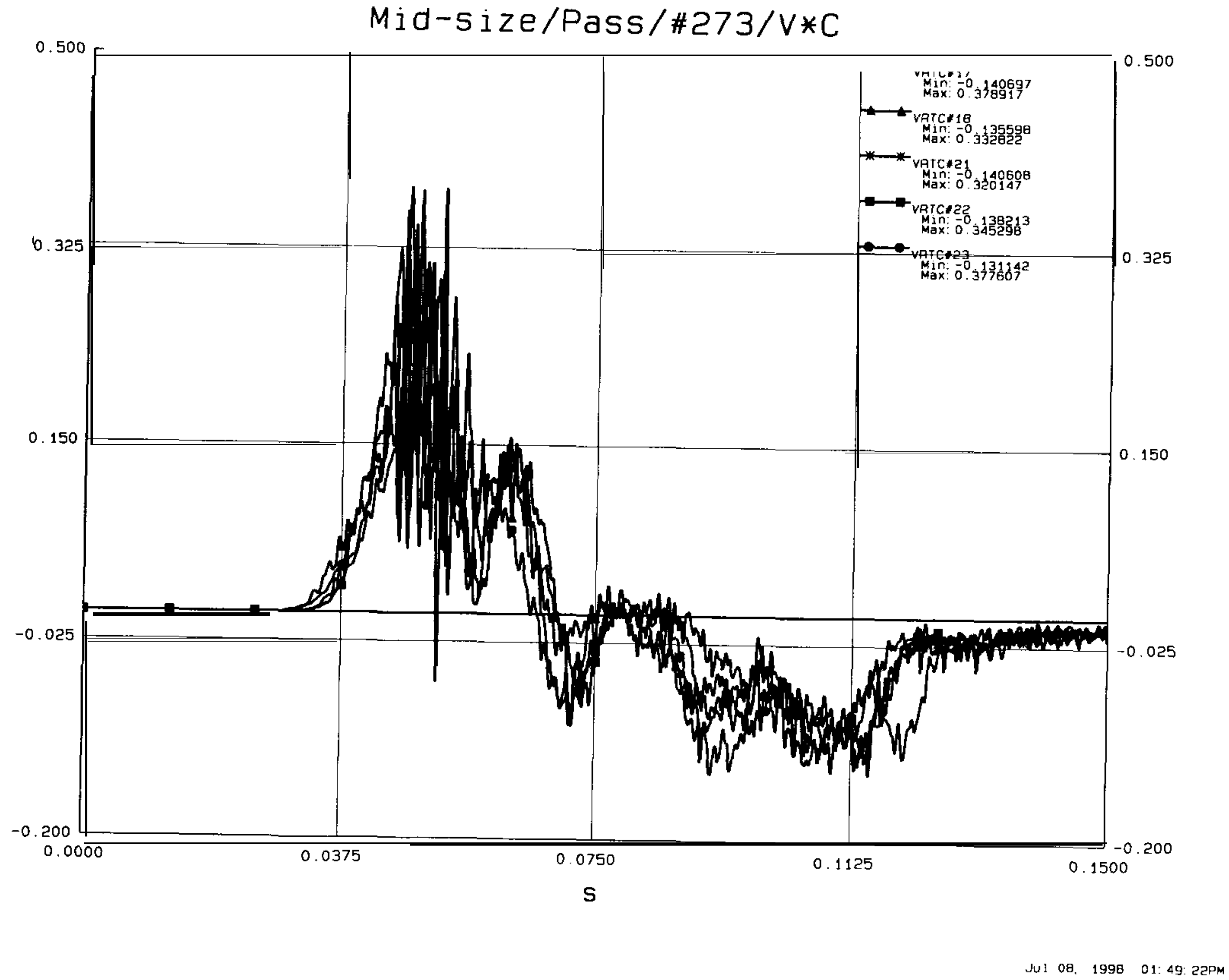
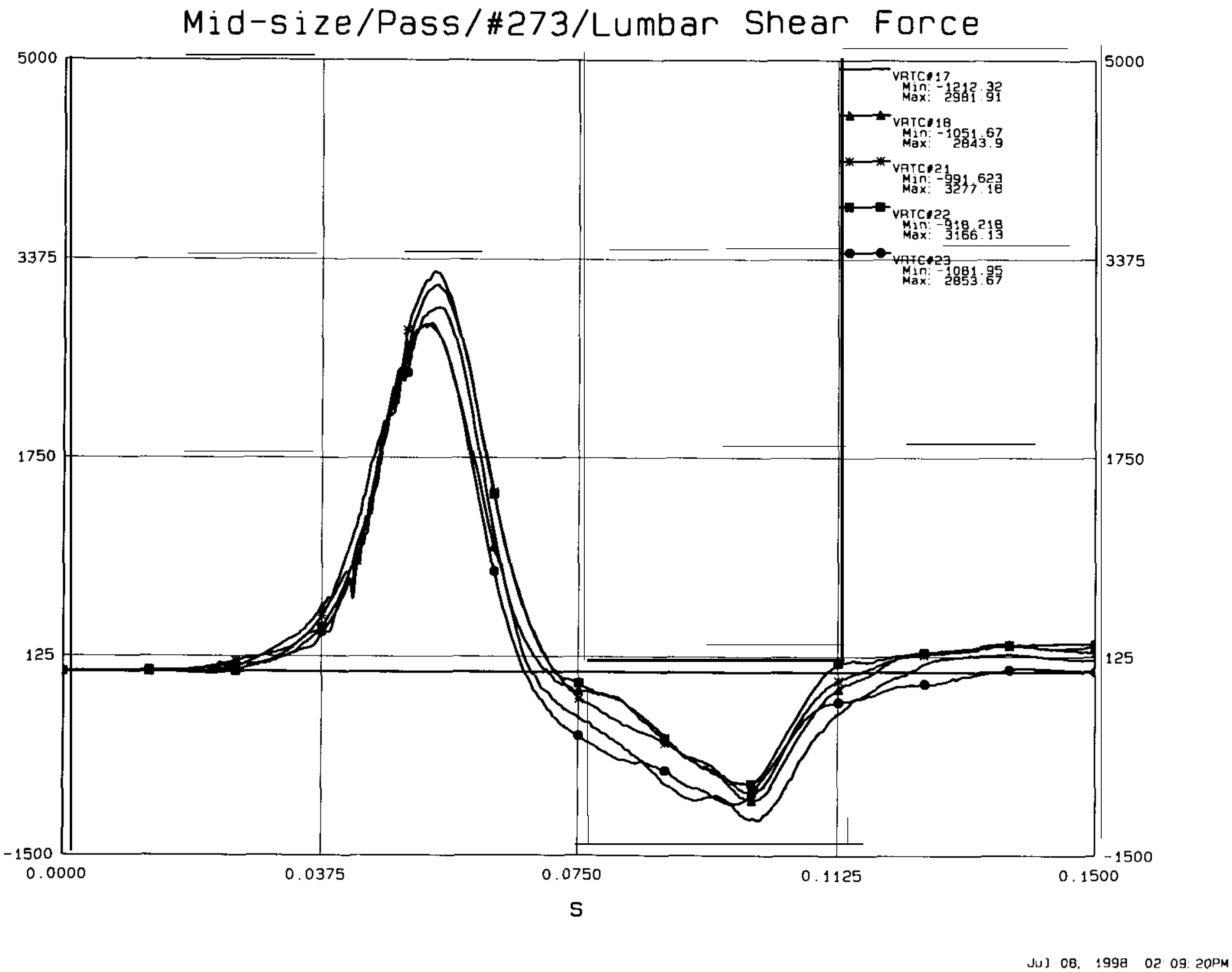

Mid-size/Pass/#273/V*C
VRTC#17
Min: -0.140697
Max: 0.378917
VRTC#18
Min: -0.135598
Max: 0.332822
VRTC#21
Min: -0.140608
Max: 0.320147
VRTC#22
Min: -0.138213
Max: 0.345298
VRTC#23
Min: -0.131142
Max: 0.377607
vc2p ()
s
0.500
0.325
0.150
-0.025
-0.200
0.0000
0.0375
0.0750
0.1125
0.1500
Jul 08, 1998 01:49:22PM

Figure E. 15



Mid-size/Pass/#273/Lumbar Shear Force
5000
3375
1750
125
-1500
0.0000
0.0375
0.0750
0.1125
0.1500
S
t12xf2 ()
VRTC#17 Min: -1212.32 Max: 2981.91
VRTC#18 Min: -1051.67 Max: 2843.9
VRTC#21 Min: -991.623 Max: 3277.18
VRTC#22 Min: -918.218 Max: 3166.13
VRTC#23 Min: -1081.95 Max: 2853.67
Jul 08, 1998 02:09:20PM

Figure E.16

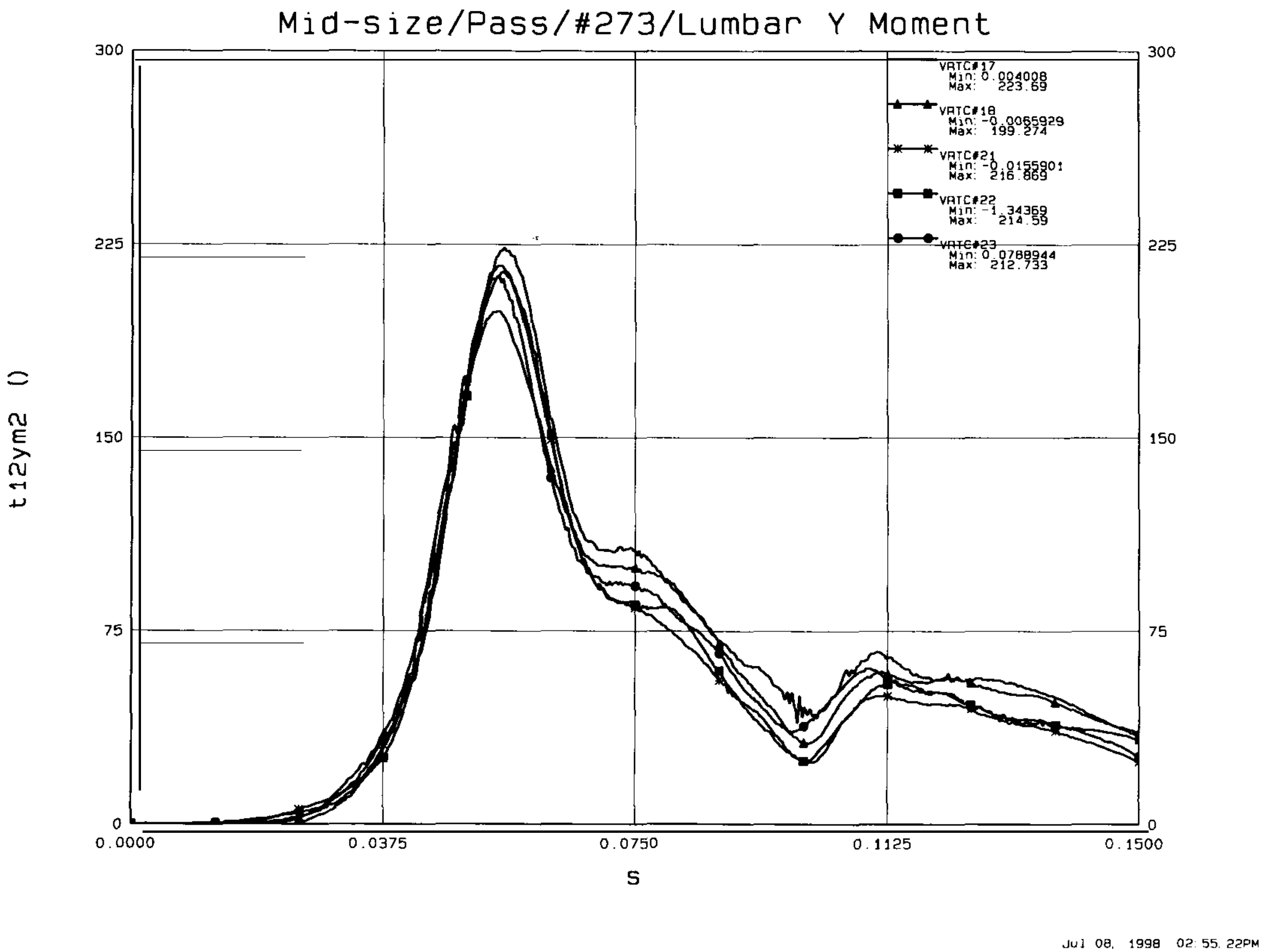

Mid-size/Pass/#273/Lumbar Y Moment
VRTC#17
Min: 0.004008
Max: 223.69
VRTC#18
Min: -0.0065929
Max: 199.274
VRTC#21
Min: -0.0155901
Max: 216.869
VRTC#22
Min: -1.34369
Max: 214.59
VRTC#23
Min: 0.0788944
Max: 212.733
300
225
150
75
0
0.0000
0.0375
0.0750
0.1125
0.1500
s
t12ym2 ()
Jul 08, 1998 02:55.22PM

Figure E. 17

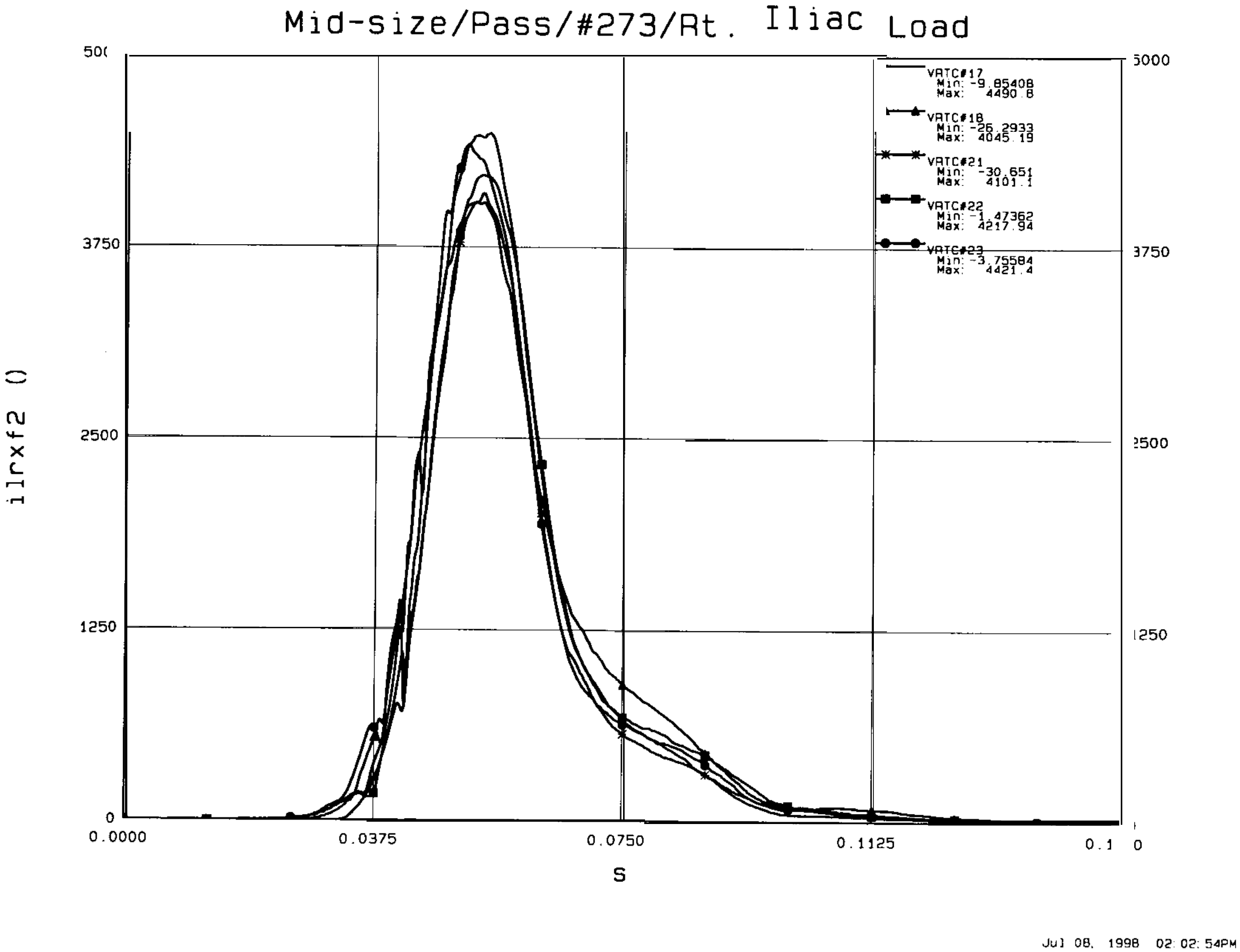
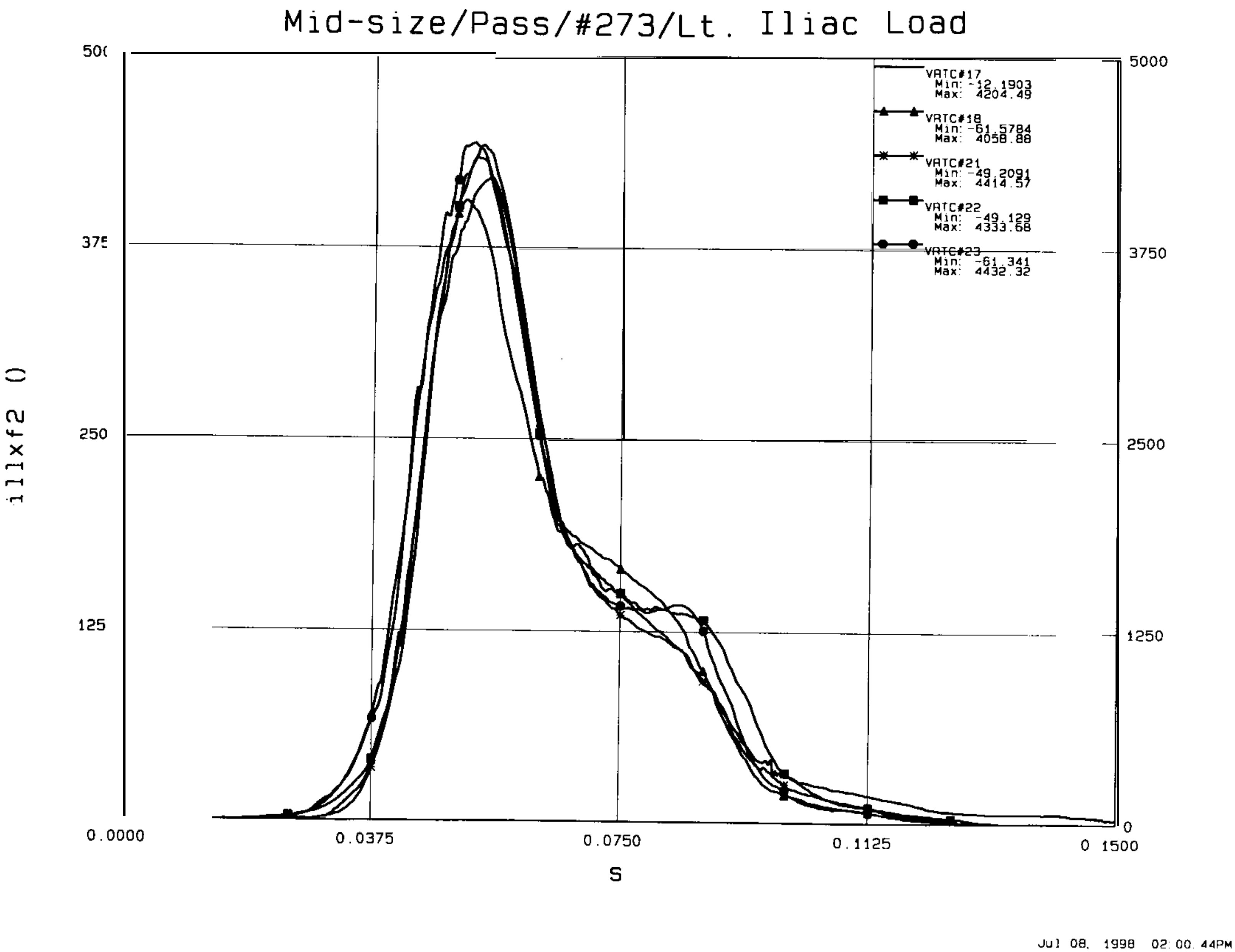
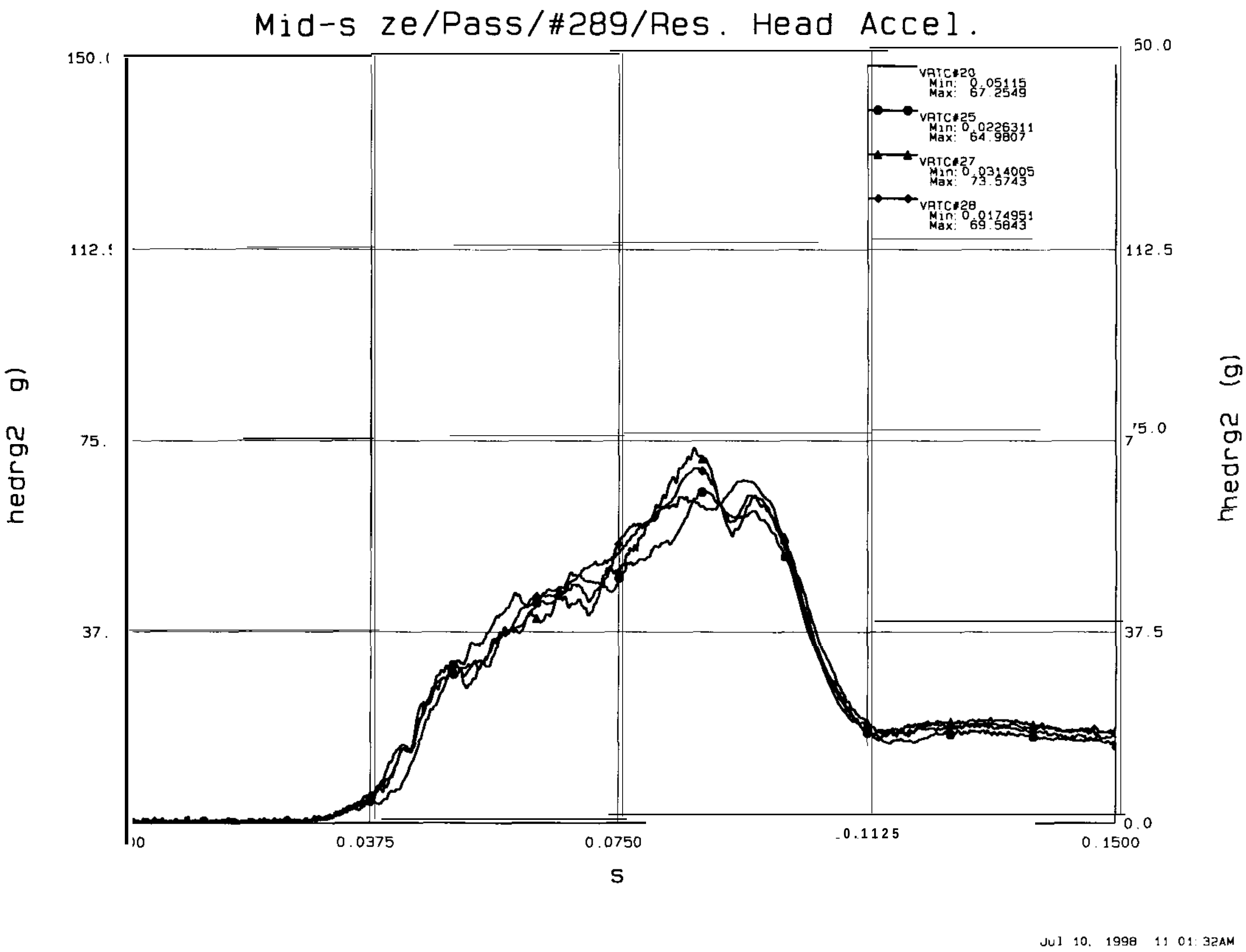

Mid-size/Pass/#273/Rt. Iliac Load
VATC#17
Min: -9.85408
Max: 4490.8
VATC#18
Min: -26.2933
Max: 4045.19
VATC#21
Min: -30.651
Max: 4101.1
VATC#22
Min: -1.47362
Max: 4217.94
VATC#23
Min: -3.75584
Max: 4421.4
ilrxf2 ()
5000
3750
2500
1250
0
0.0000
0.0375
0.0750
0.1125
S
Jul 08, 1998 02:02:54PM

Figure E. 18



Mid-size/Pass/#273/Lt. Iliac Load
VATC#17
Min: -12.1903
Max: 4204.49
VATC#18
Min: -61.5784
Max: 4058.88
VATC#21
Min: -49.2091
Max: 4414.57
VATC#22
Min: -49.129
Max: 4333.68
VATC#23
Min: -61.341
Max: 4432.32
500
375
250
125
5000
3750
2500
1250
0
0.0000
0.0375
0.0750
0.1125
0 1500
S
ill×f2 ()
Jul 08, 1998 02:00:44PM

Figure E. 19



Mid-s ze/Pass/#289/Res. Head Accel.
VRTC#20
Min: 0.05115
Max: 67.2549
VRTC#25
Min: 0.0226311
Max: 64.9807
VRTC#27
Min: 0.0314005
Max: 73.5743
VRTC#28
Min: 0.0174951
Max: 69.5843
150.
112.5
75.
37.
0.0
37.5
75.0
112.5
50.0
0.0375
0.0750
0.1125
0.1500
s
hedrg2 (g)
hedrg2 (g)
Jul 10, 1998 11:01:32AM

Figure E.20

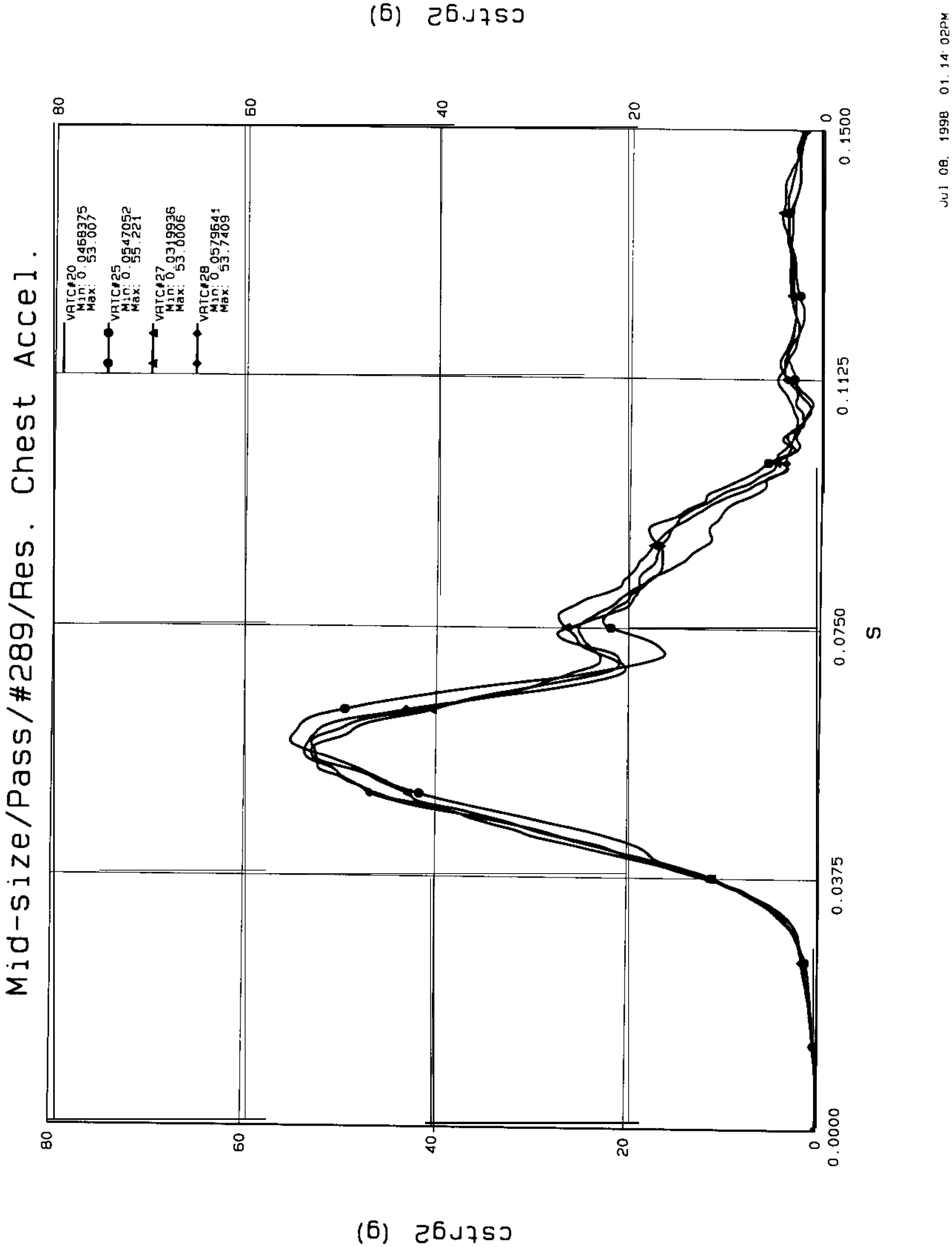
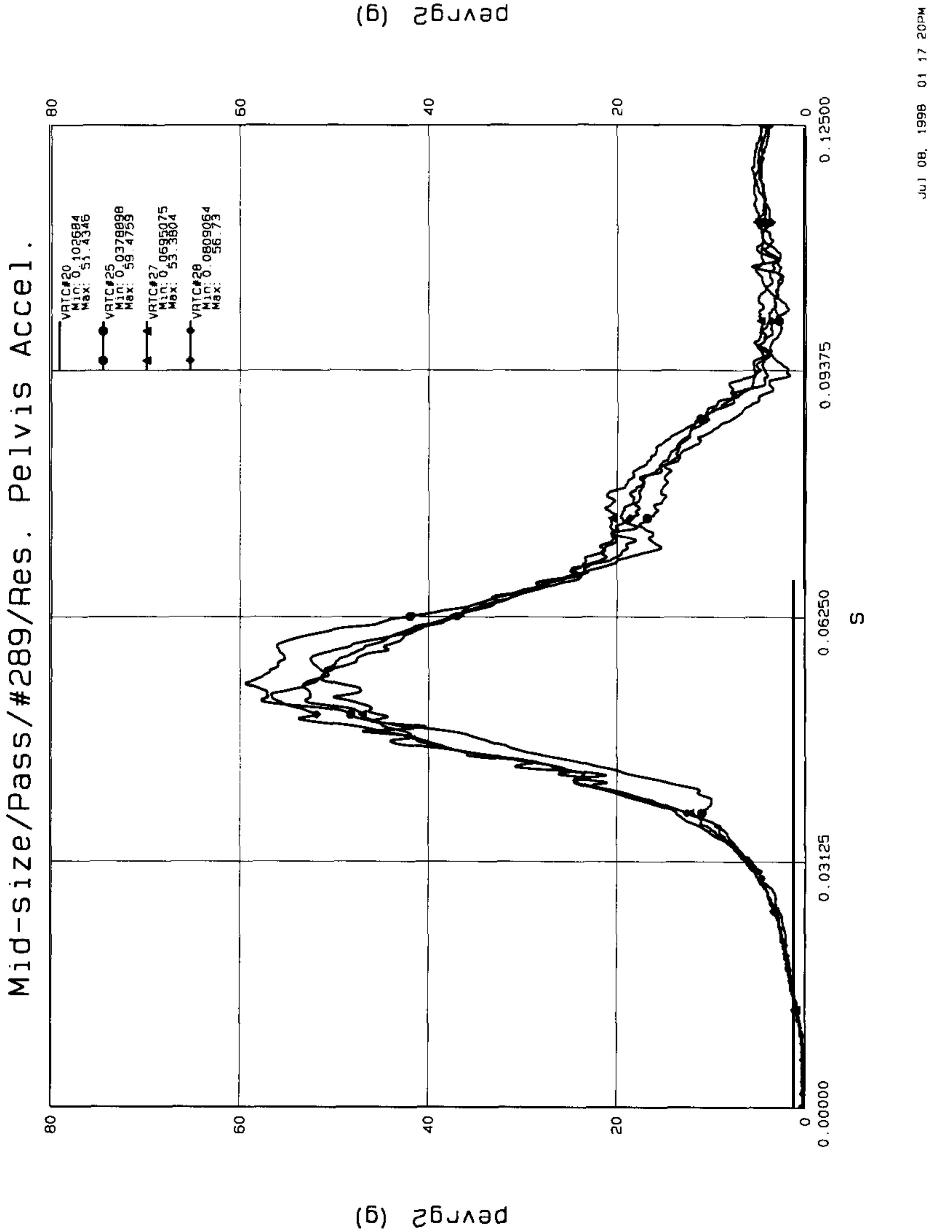
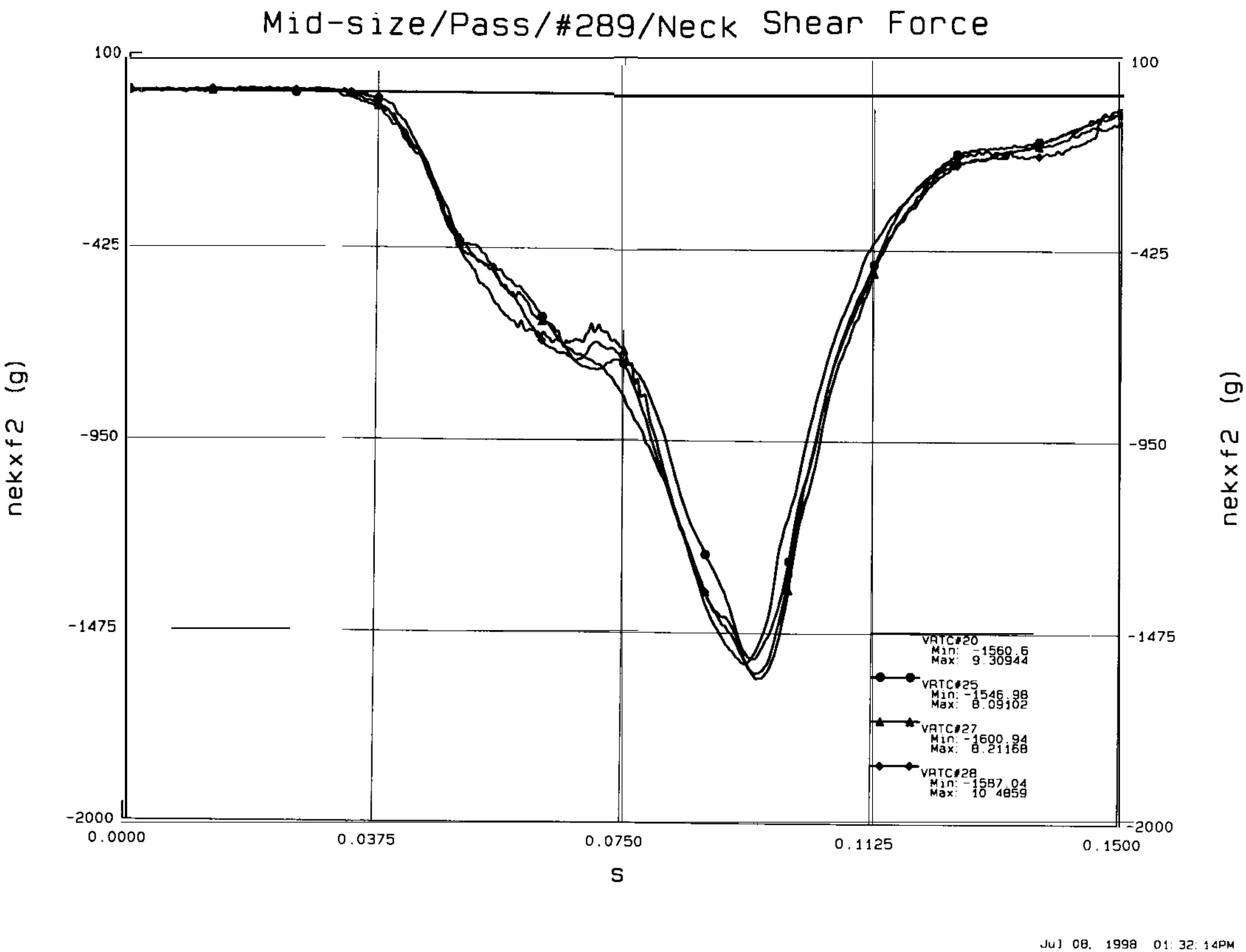

Mid-size/Pass/#289/Res. Chest Accel.
VRTC#20 Min: 0.0468375 Max: 53.007
VRTC#25 Min: 0.0547052 Max: 55.221
VRTC#27 Min: 0.0319936 Max: 53.0006
VRTC#28 Min: 0.0579641 Max: 53.7409
cstrg2 (g)
0
20
40
60
80
s
0.0000
0.0375
0.0750
0.1125
0.1500
Jul 08, 1998 01:14:02PM

Figure E.21



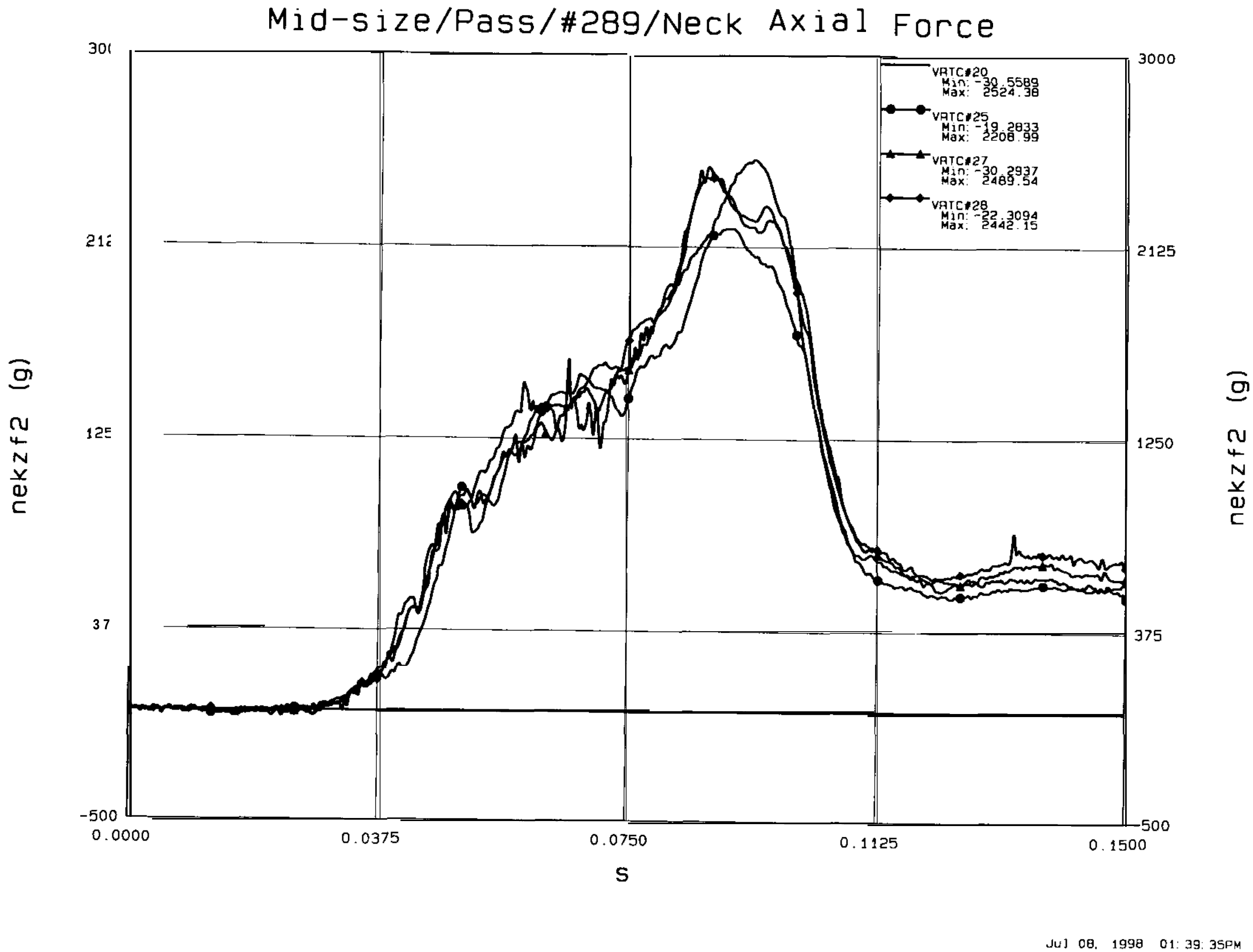
Mid-size/Pass/#289/Res. Pelvis Accel.
VRTC#20 Min: 0.102684 Max: 51.4346
VRTC#25 Min: 0.0378098 Max: 59.4759
VRTC#27 Min: 0.0695075 Max: 53.3804
VRTC#28 Min: 0.0809064 Max: 56.73
80
60
40
20
0
0.00000
0.03125
0.06250
0.09375
0.12500
S
Jul 08, 1998 01 17 20PM

Figure E.22



Mid-size/Pass/#289/Neck Shear Force
100
-425
-950
-1475
-2000
0.0000
0.0375
0.0750
0.1125
0.1500
S
nekxf2 (g)
VRTC#20
Min: -1560.6
Max: 9.30944
VRTC#25
Min: -1546.98
Max: 8.09102
VRTC#27
Min: -1600.94
Max: 8.21168
VRTC#28
Min: -1587.04
Max: 10.4859
Jul 08, 1998 01:32:14PM

Figure E.23



Mid-size/Pass/#289/Neck Axial Force
VRTC#20
Min: -30.5589
Max: 2524.38
VRTC#25
Min: -19.2833
Max: 2208.99
VRTC#27
Min: -30.2937
Max: 2489.54
VRTC#28
Min: -22.3094
Max: 2442.15
nekzf2 (g)
S
0.0000
0.0375
0.0750
0.1125
0.1500
3000
2125
1250
375
-500
Jul 08, 1998 01:39:35PM

Figure E.24

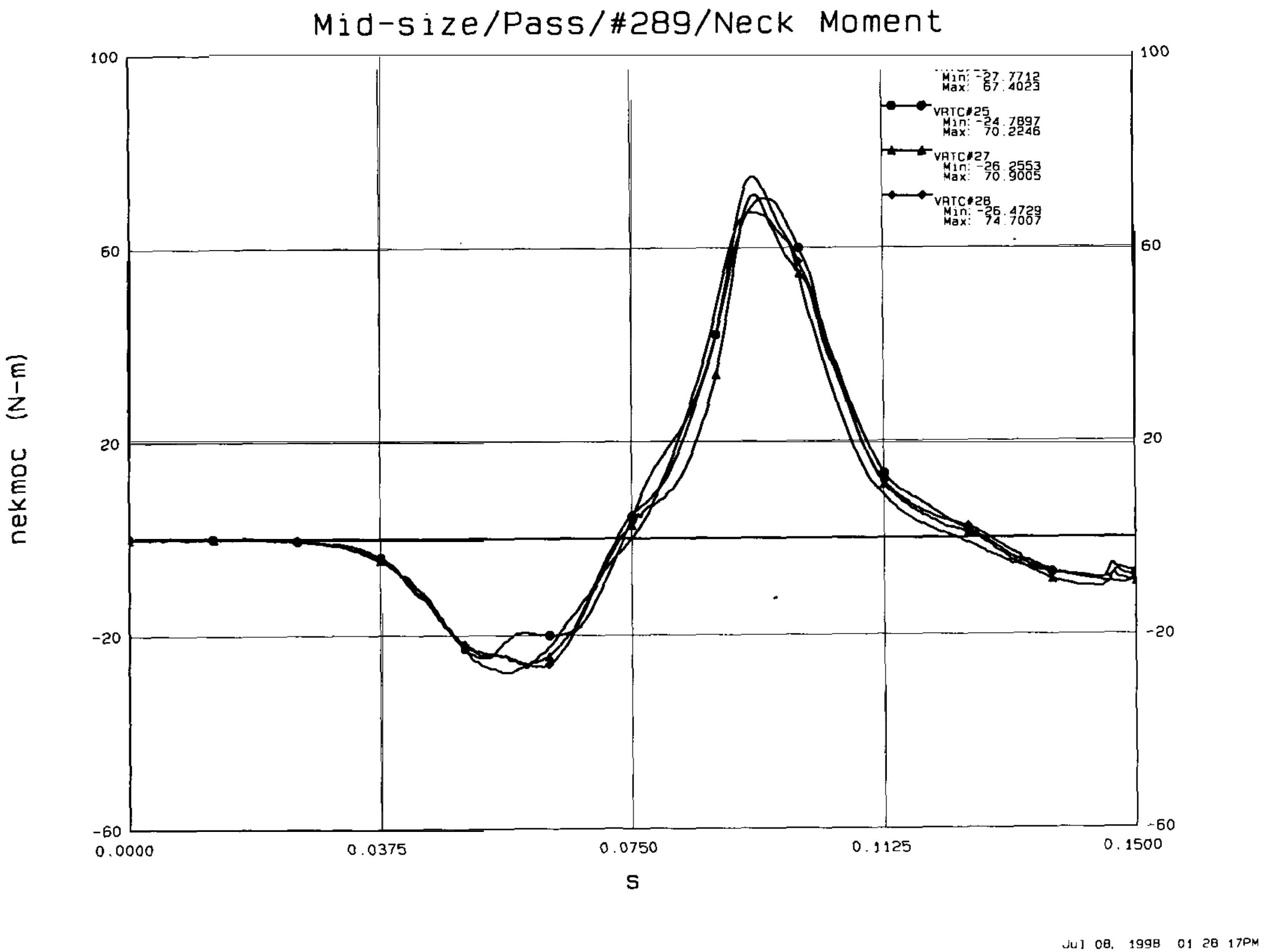

Mid-size/Pass/#289/Neck Moment
Min: -27.7712
Max: 67.4023
VRTC#25
Min: -24.7897
Max: 70.2246
VRTC#27
Min: -26.2553
Max: 70.9005
VRTC#28
Min: -26.4729
Max: 74.7007
100
60
20
-20
-60
0.0000
0.0375
0.0750
0.1125
0.1500
s
nekmoc (N-m)
Jul 08, 1998 01 28 17PM

Figure E.25

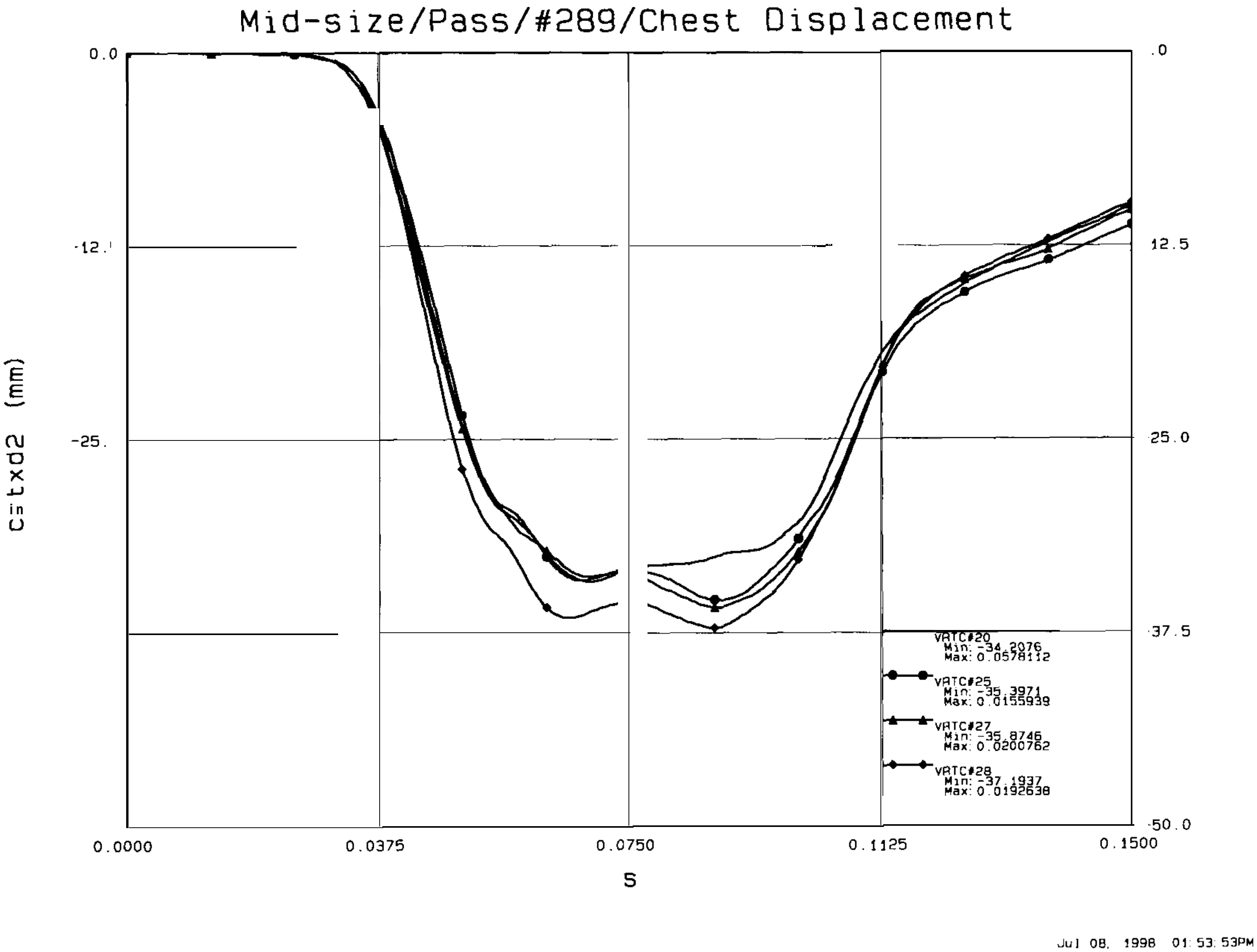
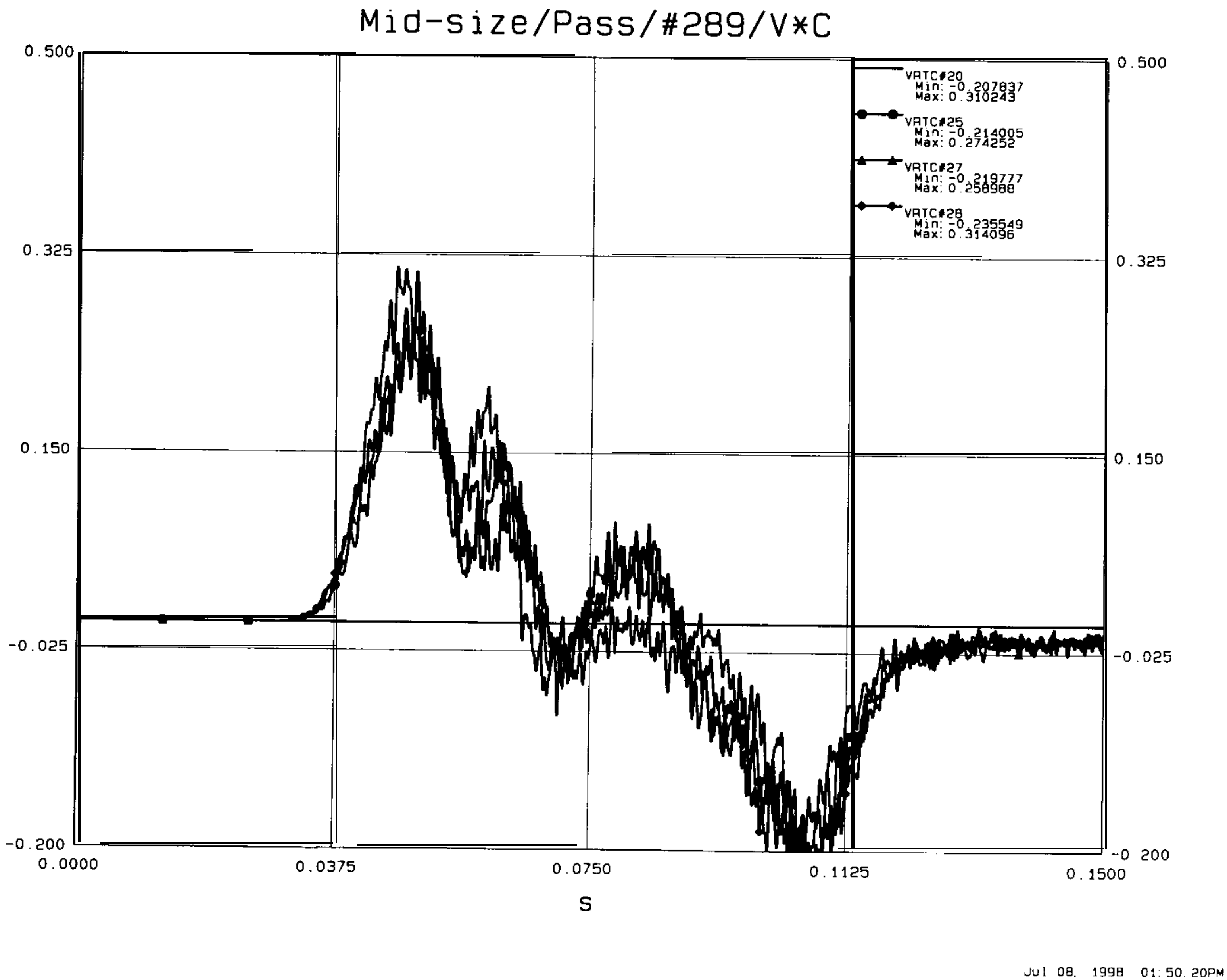
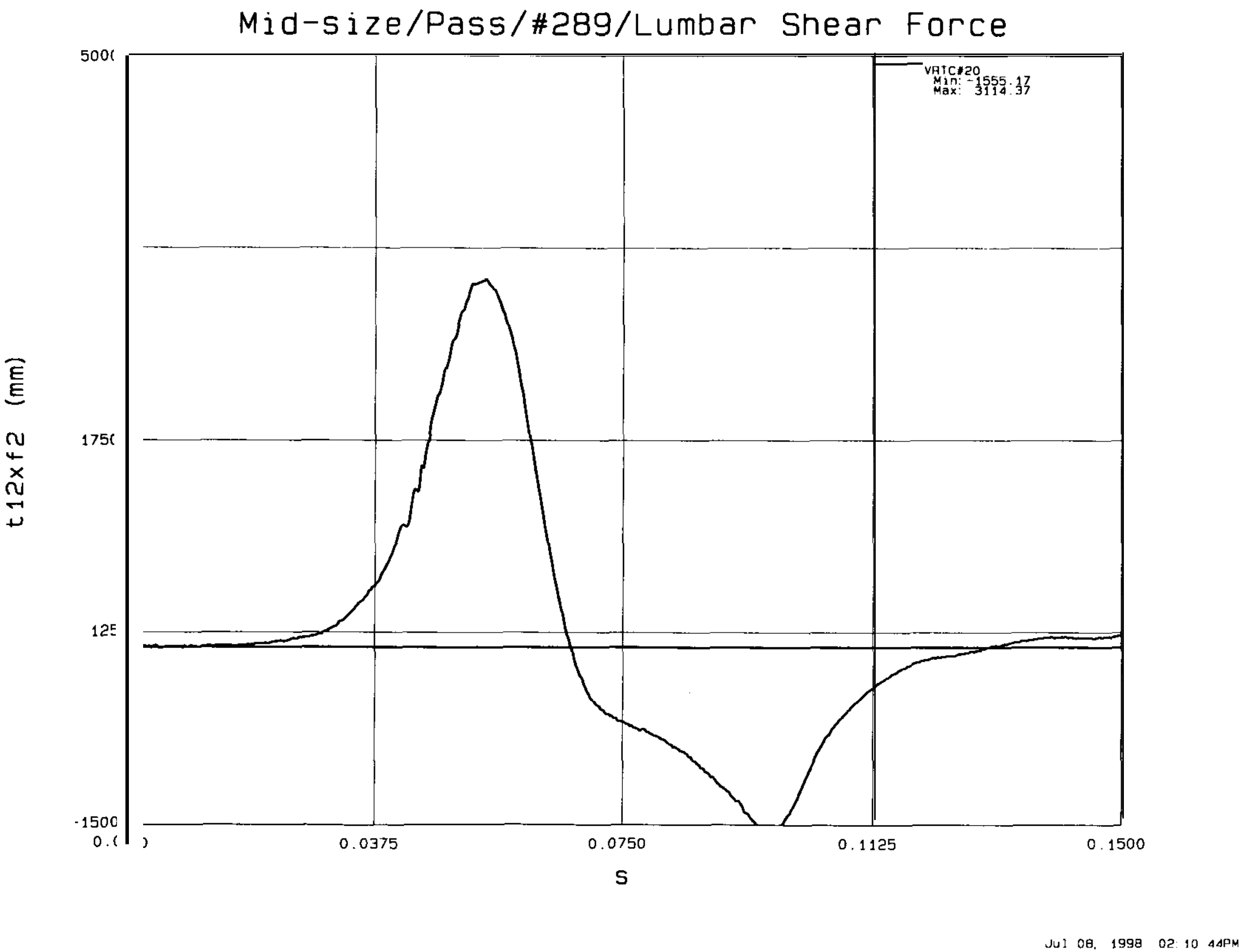

Mid-size/Pass/#289/Chest Displacement
0.0
-12.5
-25.
.0
12.5
25.0
37.5
50.0
VRTC#20
Min: -34.2076
Max: 0.0578112
VRTC#25
Min: -35.3971
Max: 0.0155939
VRTC#27
Min: -35.8746
Max: 0.0200762
VRTC#28
Min: -37.1937
Max: 0.0192638
0.0000
0.0375
0.0750
0.1125
0.1500
S
C=txd2 (mm)
Jul 08, 1998 01:53:53PM

Figure E.26



Mid-size/Pass/#289/V*C
0.500
0.325
0.150
-0.025
-0.200
0.0000
0.0375
0.0750
0.1125
0.1500
s
vc2p (mm)
VRTC#20
Min: -0.207837
Max: 0.310243
VRTC#25
Min: -0.214005
Max: 0.274252
VRTC#27
Min: -0.219777
Max: 0.258988
VRTC#28
Min: -0.235549
Max: 0.314096
Jul 08, 1998 01:50.20PM

Figure E.27



Mid-size/Pass/#289/Lumbar Shear Force
VRTC#20
Min: -1555.17
Max: 3114.37
t12xf2 (mm)
S
0.0375
0.0750
0.1125
0.1500
1750
125
-1500
Jul 08, 1998 02:10 44PM

Figure E.28

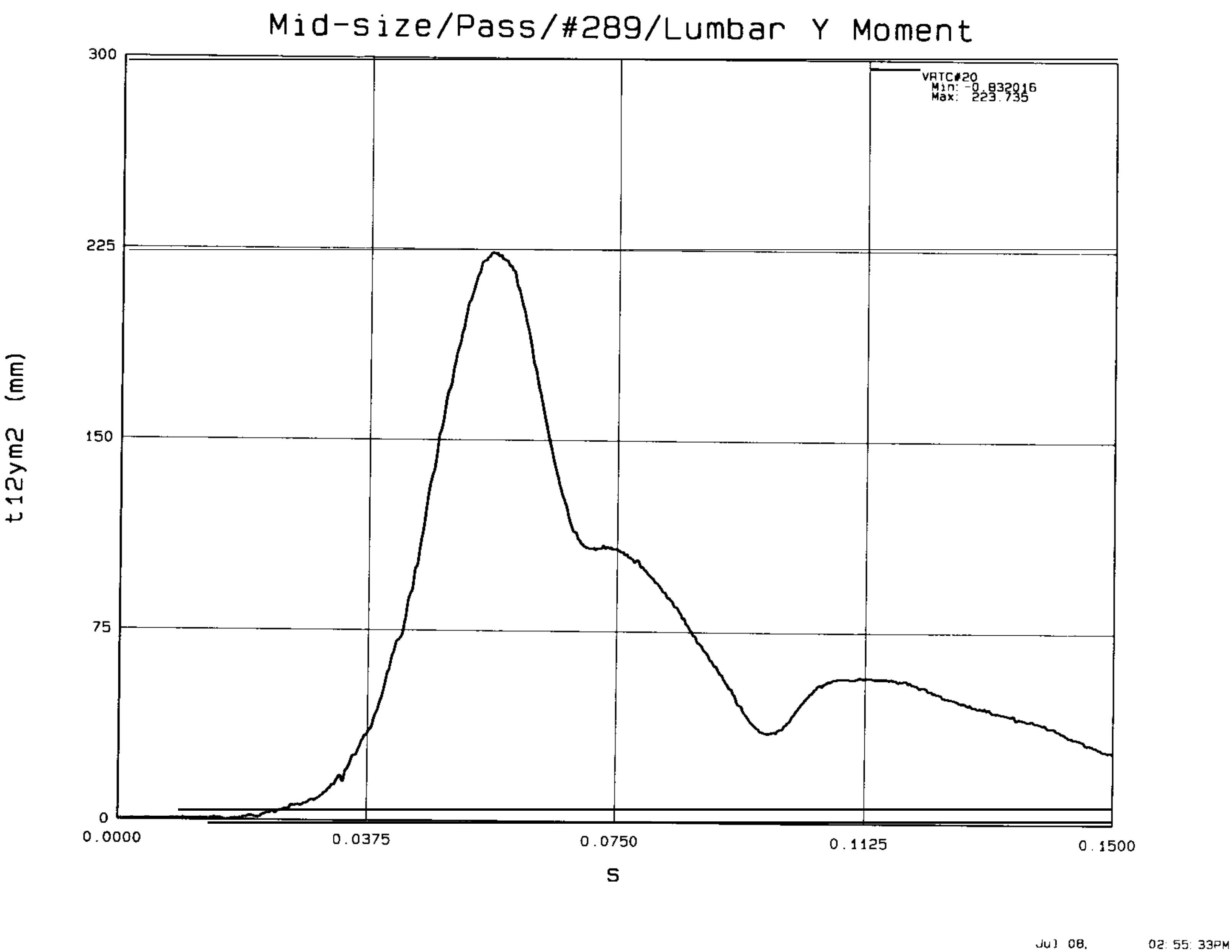
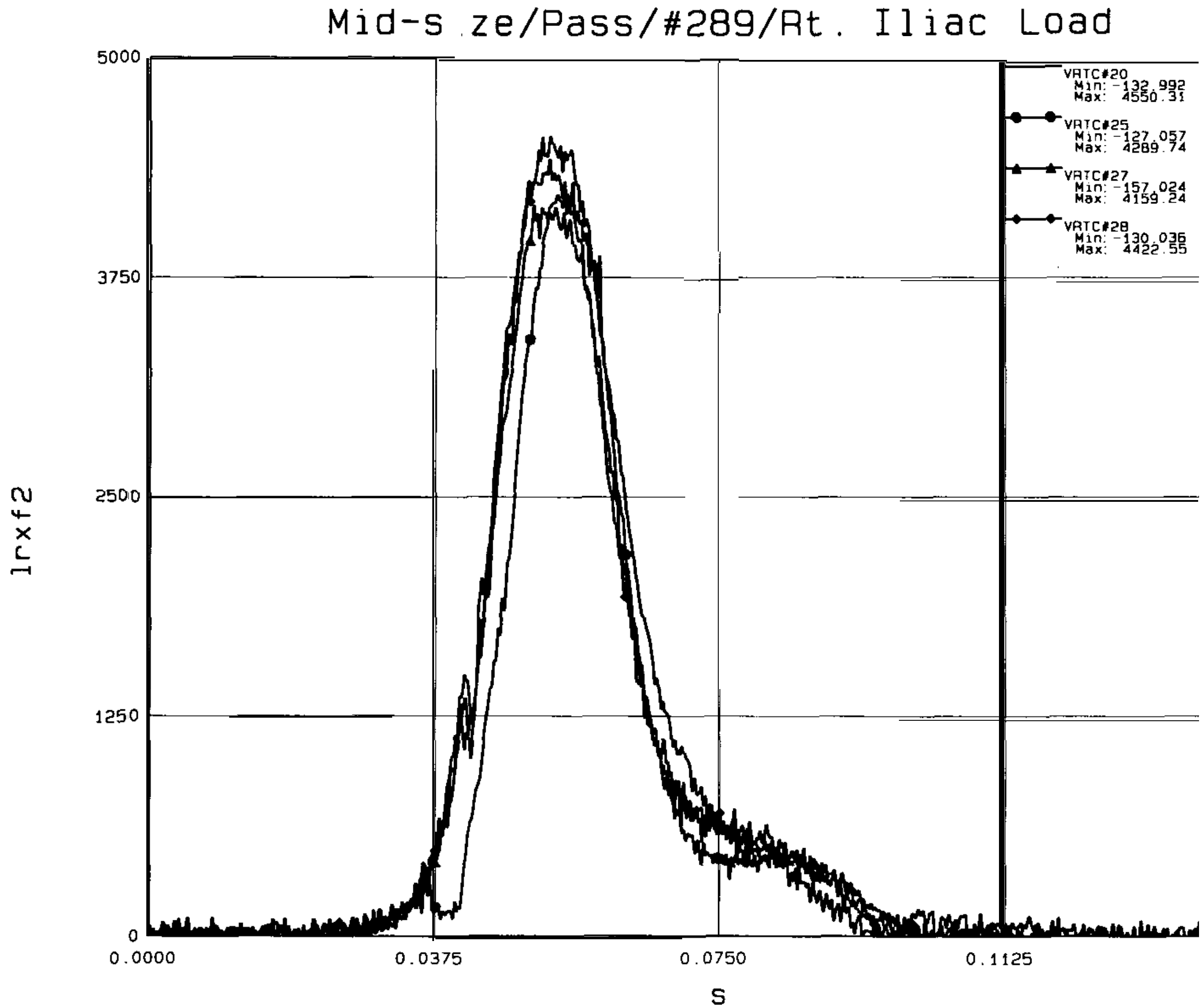

Mid-size/Pass/#289/Lumbar Y Moment
300
225
150
75
0
0.0000
0.0375
0.0750
0.1125
0.1500
s
t12ym2 (mm)
VRTC#20
Min: -0.832016
Max: 223.735
Jul 08,
02:55:33PM

Figure E.29



Mid-s ze/Pass/#289/Rt. Iliac Load
5000
3750
2500
1250
0
0.0000
0.0375
0.0750
0.1125
S
lrxf2
VRTC#20
Min: -132.992
Max: 4550.31
VRTC#25
Min: -127.057
Max: 4289.74
VRTC#27
Min: -157.024
Max: 4159.24
VRTC#28
Min: -130.036
Max: 4422.55

Figure E.30

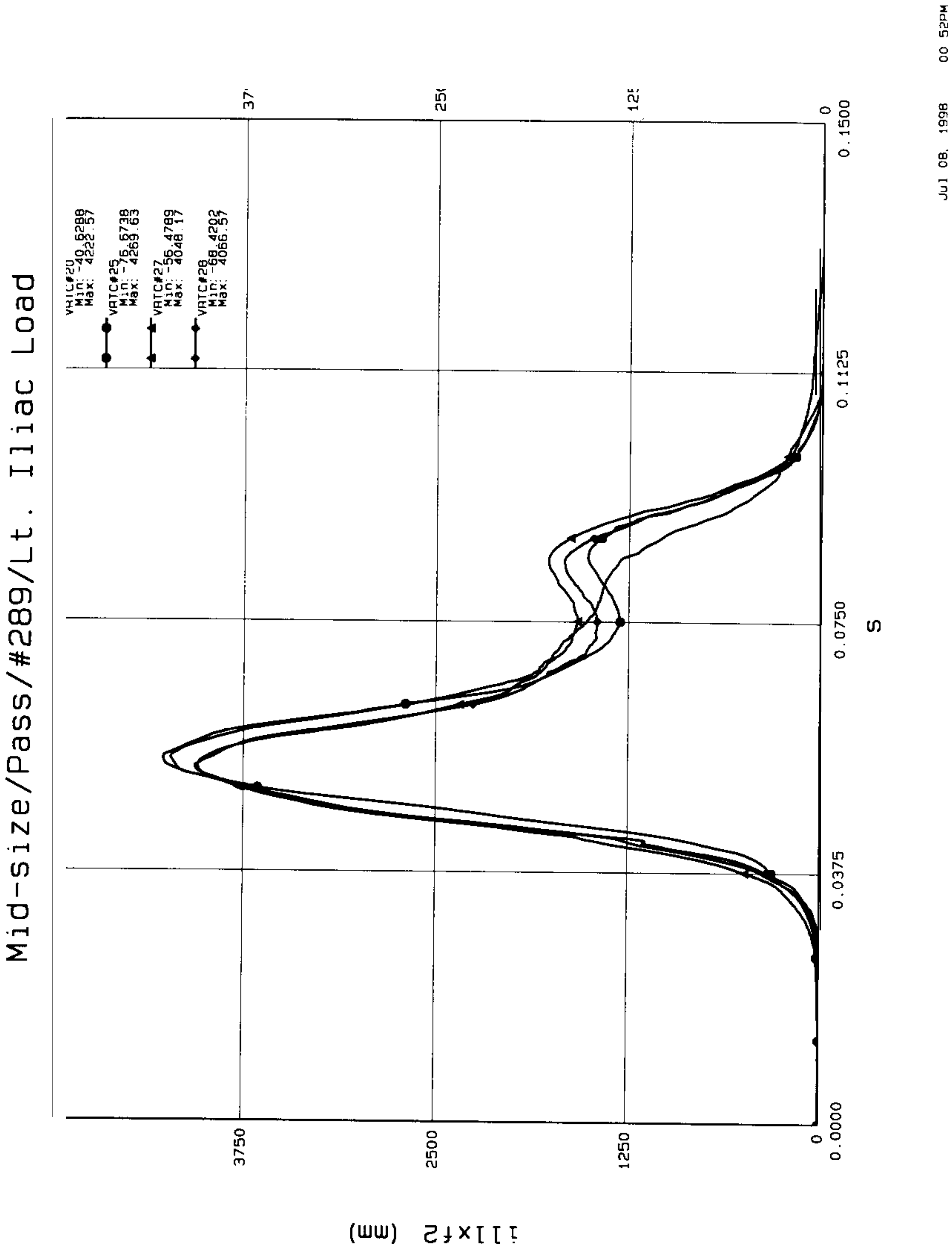
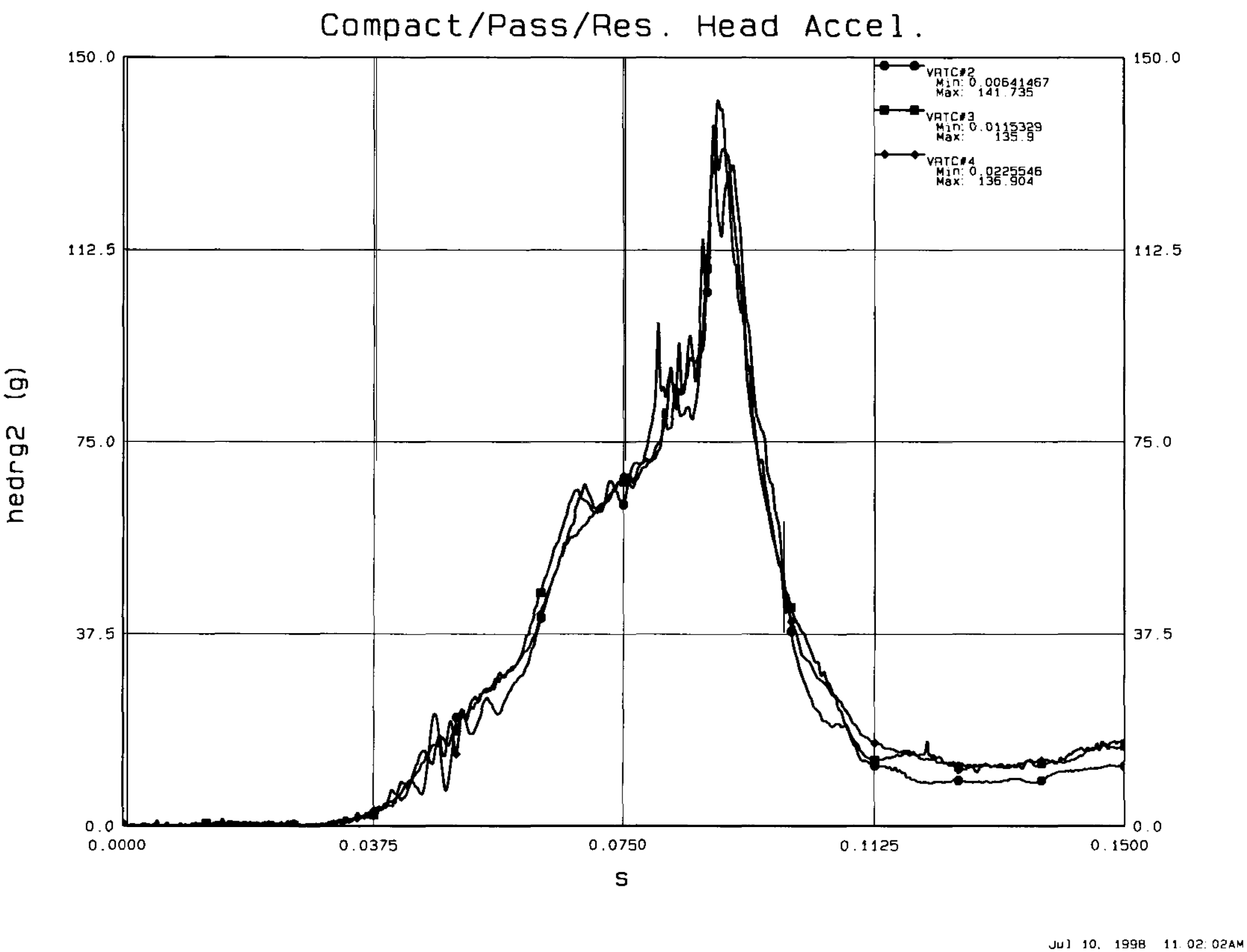
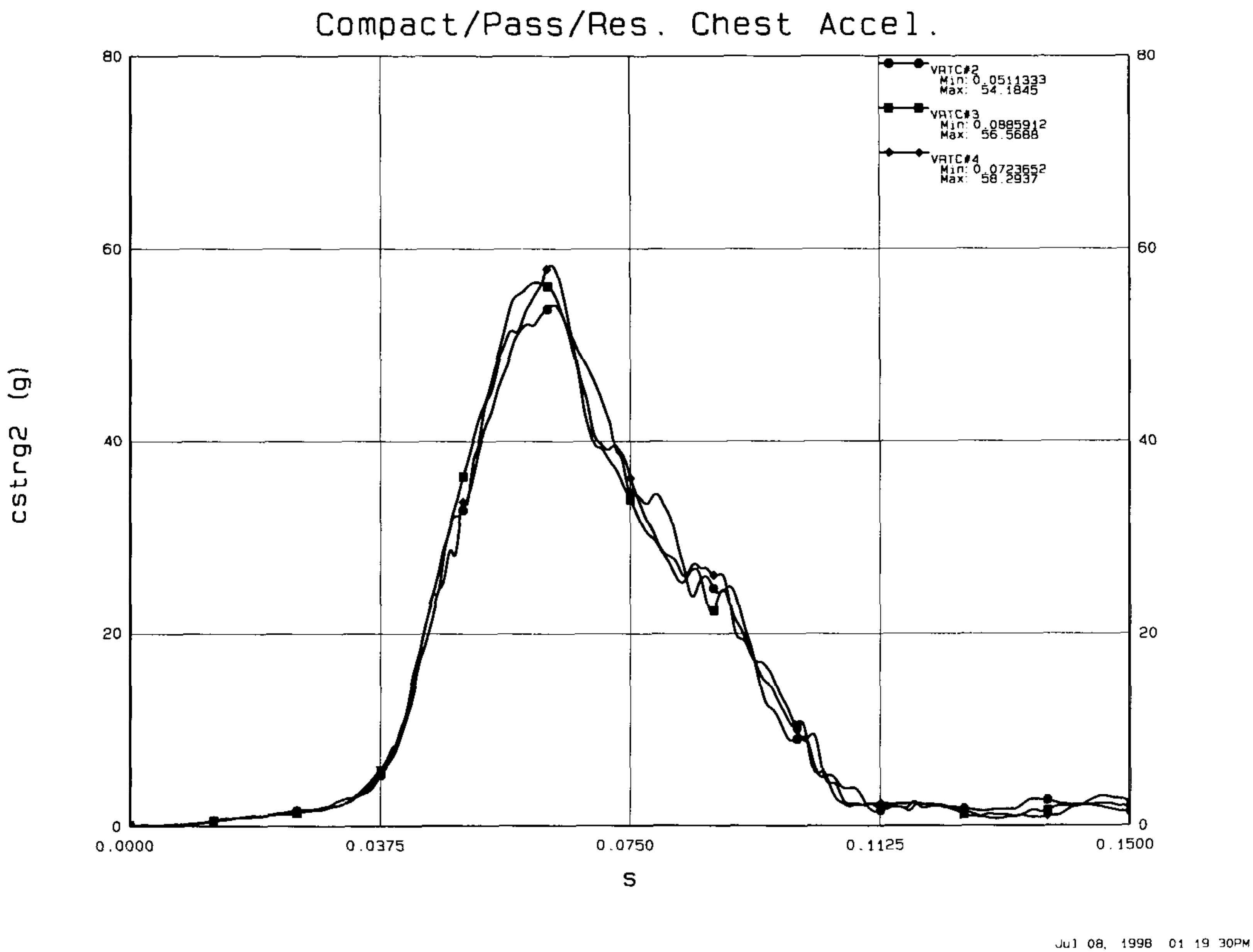

Mid-size/Pass/#289/Lt. Iliac Load
VRTC#20 Min: -40.6288 Max: 4222.57
VRTC#25 Min: -75.6738 Max: 4269.63
VRTC#27 Min: -56.4789 Max: 4048.17
VRTC#28 Min: -68.4202 Max: 4066.57
0
1250
2500
3750
0.0000
0.0375
0.0750
0.1125
0.1500
S
(mm)
Jul 08, 1998

Figure E.31



Compact/Pass/Res. Head Accel.
VRTC#2
Min: 0.00641467
Max: 141.735
VRTC#3
Min: 0.0115329
Max: 135.9
VRTC#4
Min: 0.0225546
Max: 136.904
150.0
112.5
75.0
37.5
0.0
0.0000
0.0375
0.0750
0.1125
0.1500
s
hedrg2 (g)
Jul 10, 1998 11:02:02AM

Figure E.32



Compact/Pass/Res. Chest Accel.
VRTC#2
Min: 0.0511333
Max: 54.1845
VRTC#3
Min: 0.0885912
Max: 56.5688
VRTC#4
Min: 0.0723652
Max: 58.2937
cstrg2 (g)
s
0
20
40
60
80
0.0000
0.0375
0.0750
0.1125
0.1500
Jul 08, 1998 01 19 30PM

Figure E.33

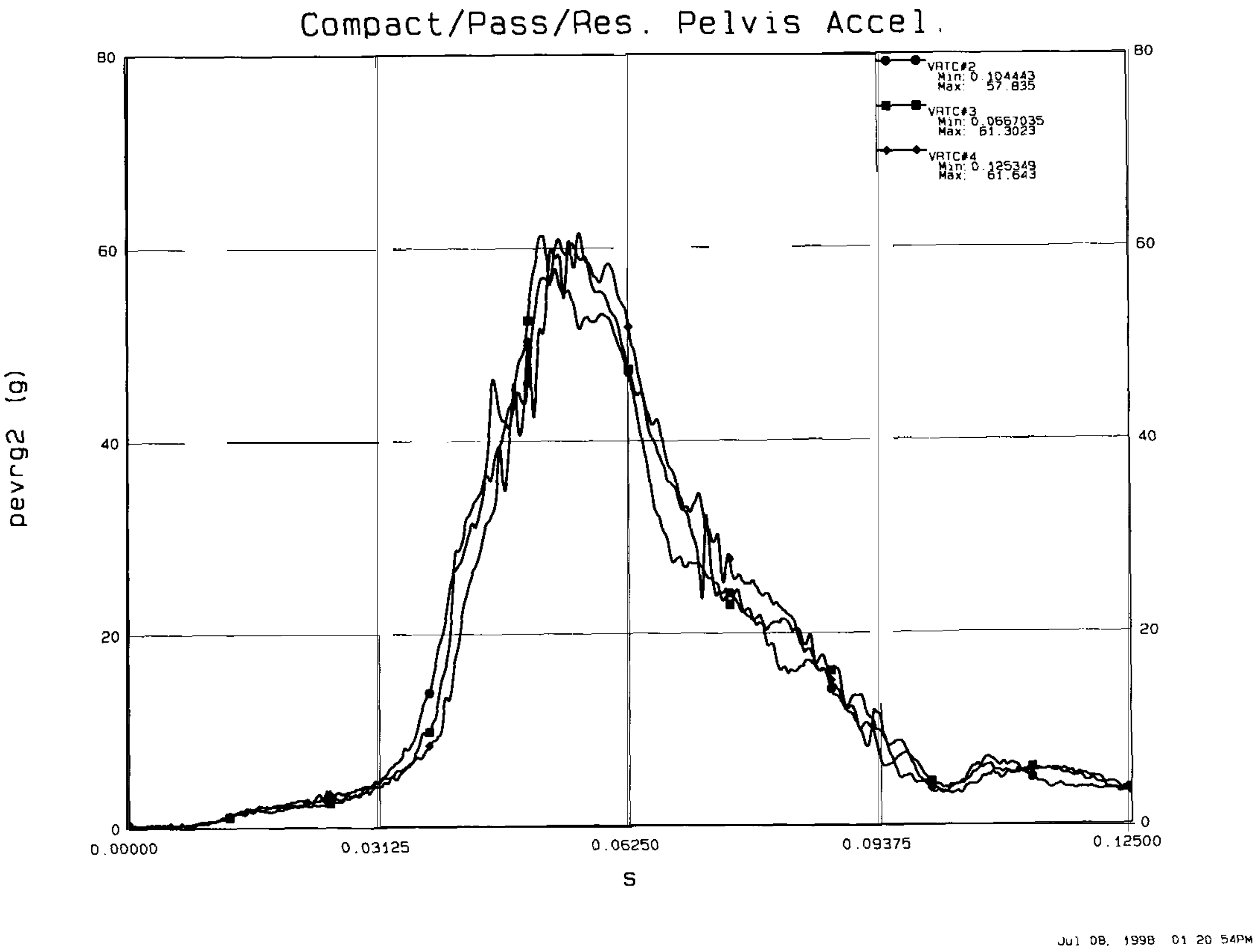
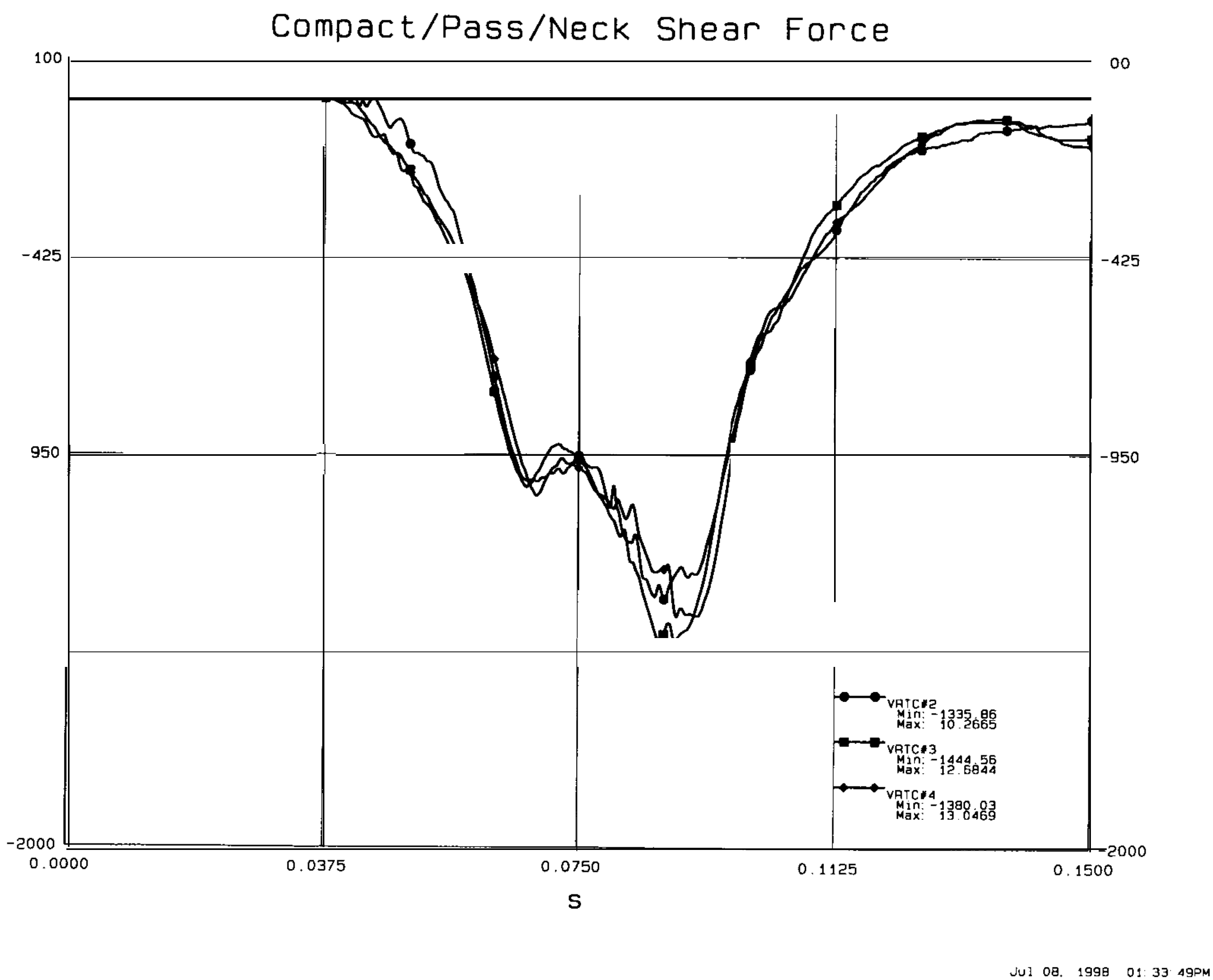
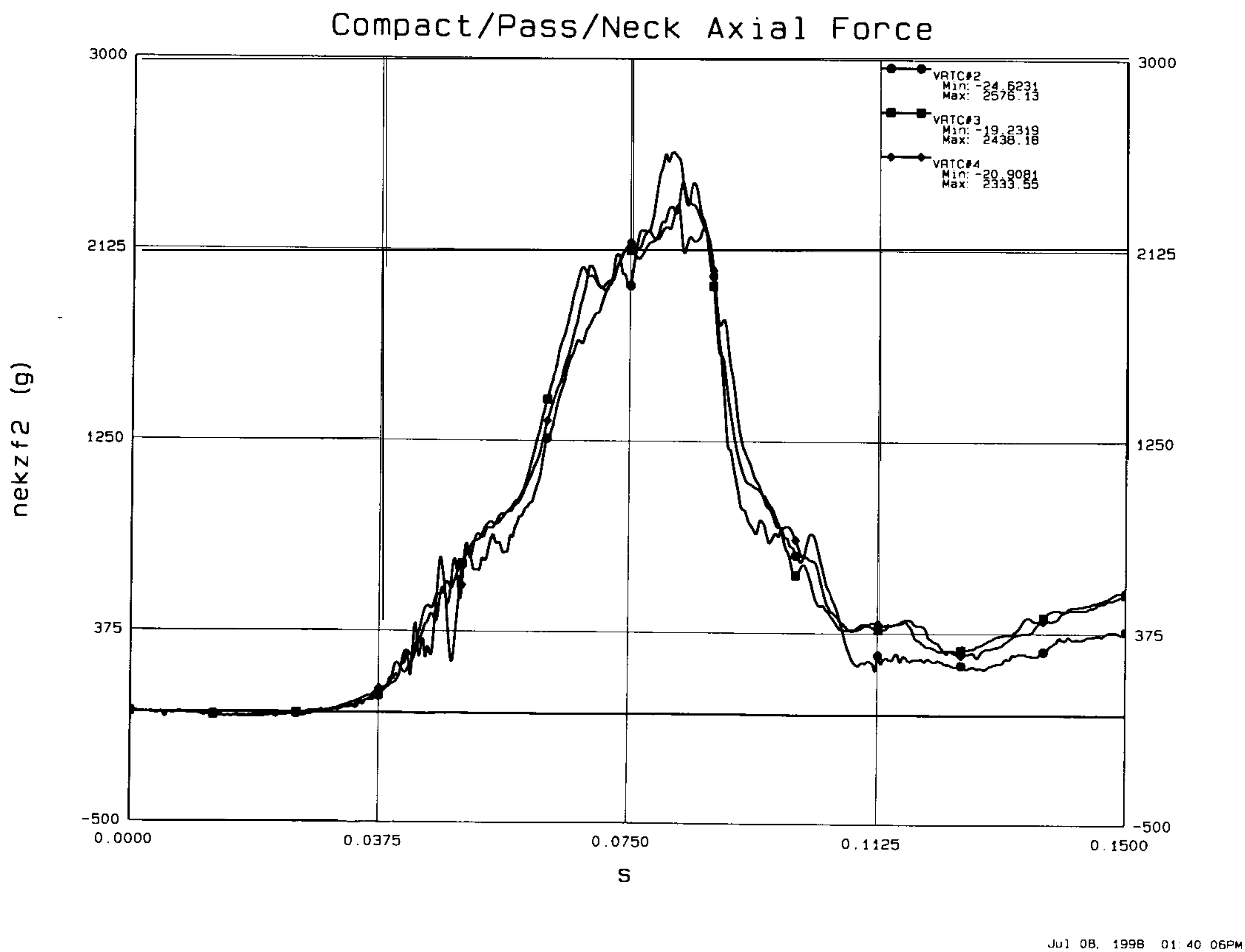

Compact/Pass/Res. Pelvis Accel.
VRTC#2
Min: 0.104443
Max: 57.835
VRTC#3
Min: 0.0667035
Max: 61.3023
VRTC#4
Min: 0.125349
Max: 61.643
pevrg2 (g)
80
60
40
20
0
0.00000
0.03125
0.06250
0.09375
0.12500
S
Jul 08, 1998 01 20 54PM

Figure E.34



Compact/Pass/Neck Shear Force
100
-425
950
-2000
00
-425
-950
-2000
0.0000
0.0375
0.0750
0.1125
0.1500
s
nekxf2 (g)
VRTC#2
Min: -1335.86
Max: 10.2665
VRTC#3
Min: -1444.56
Max: 12.6844
VRTC#4
Min: -1380.03
Max: 13.0469
Jul 08, 1998 01:33:49PM

Figure E.35



Compact/Pass/Neck Axial Force
VRTC#2
Min: -24.6231
Max: 2576.13
VRTC#3
Min: -19.2319
Max: 2438.18
VRTC#4
Min: -20.9081
Max: 2333.55
3000
2125
1250
375
-500
0.0000
0.0375
0.0750
0.1125
0.1500
s
nekzf2 (g)
Jul 08, 1998 01:40 06PM

Figure E.36

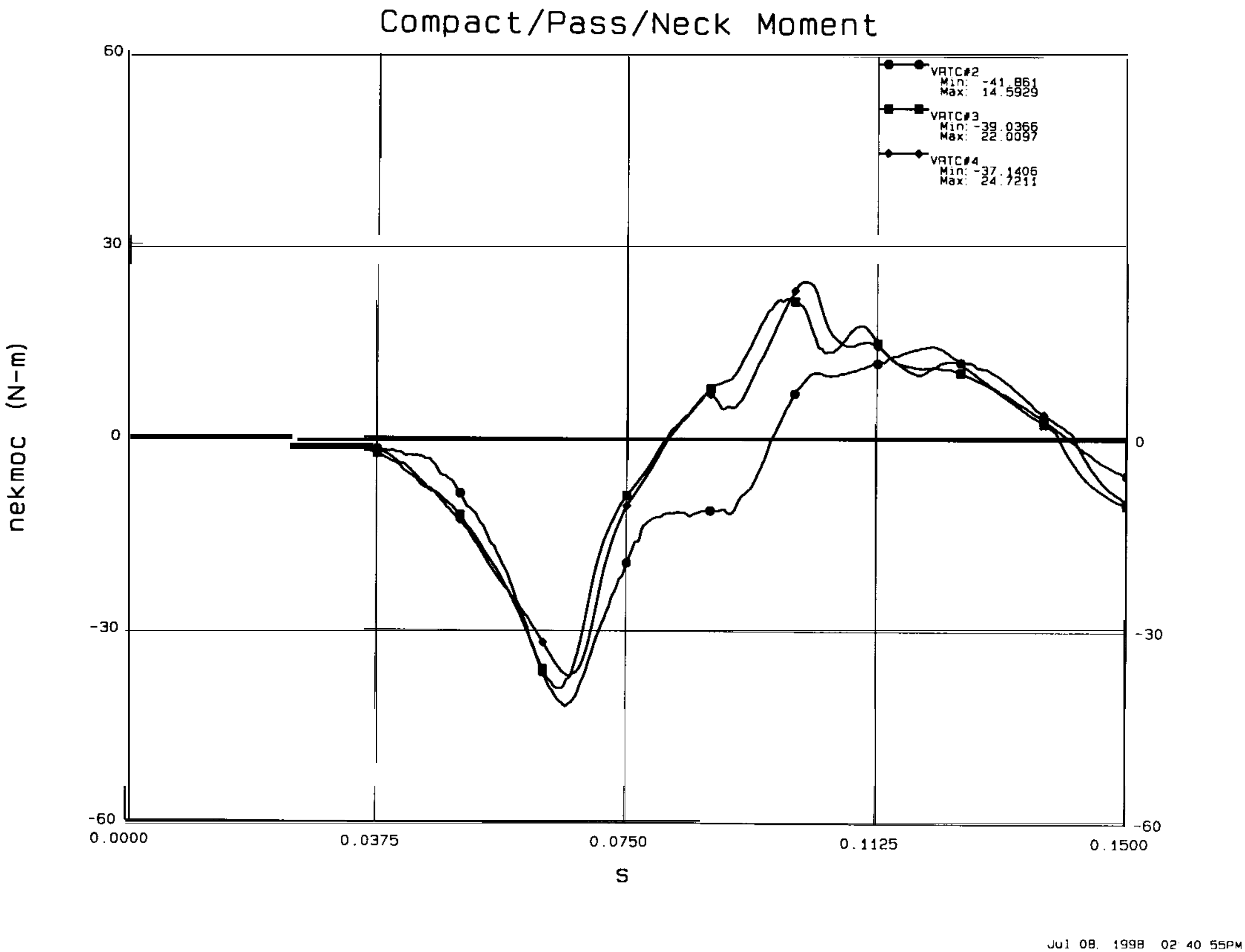

Compact/Pass/Neck Moment
VRTC#2
Min: -41.861
Max: 14.5929
VRTC#3
Min: -39.0366
Max: 22.0097
VRTC#4
Min: -37.1406
Max: 24.7211
60
30
0
-30
-60
0.0000
0.0375
0.0750
0.1125
0.1500
s
nekmoc (N-m)
Jul 08, 1998 02 40 55PM

Figure E.37

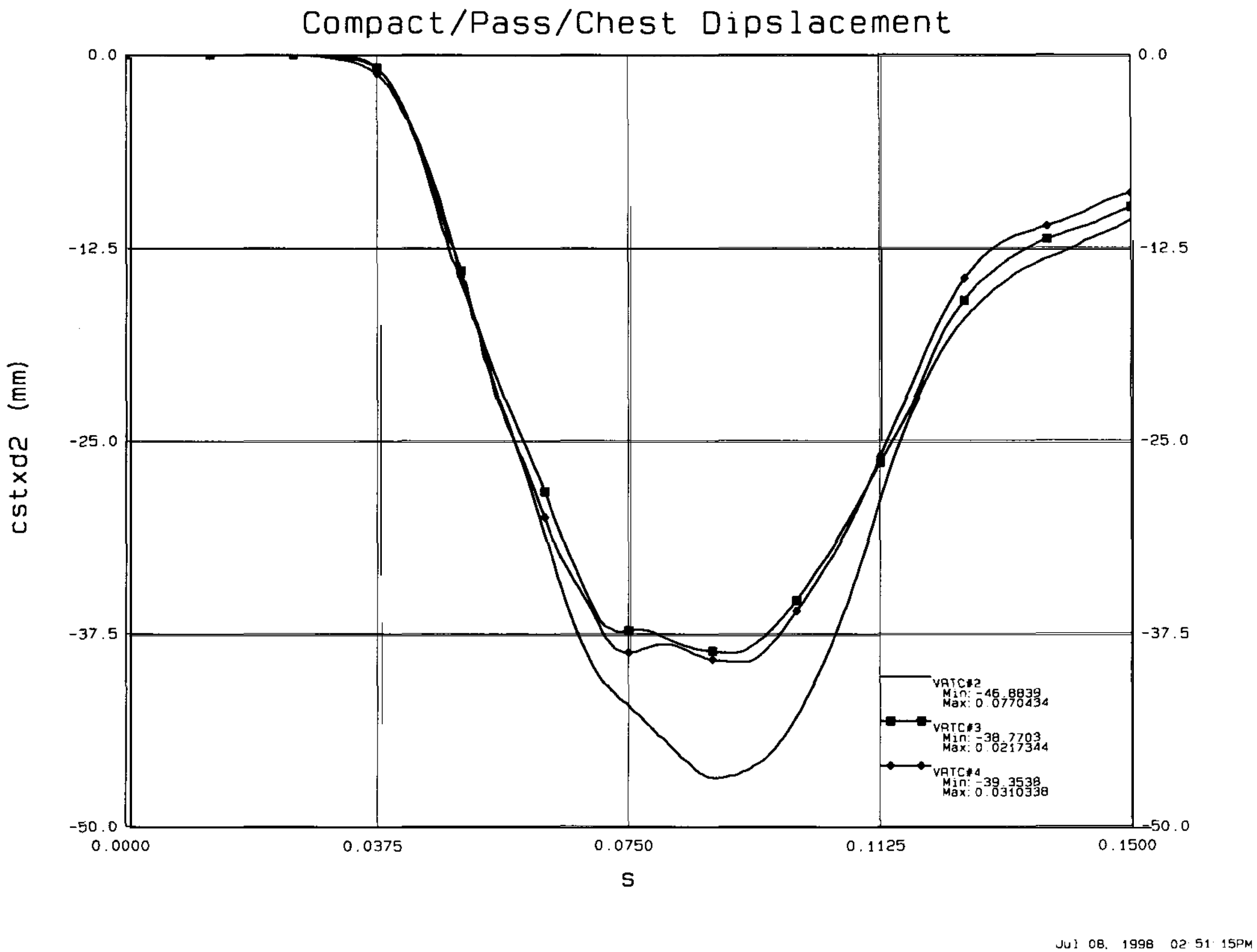
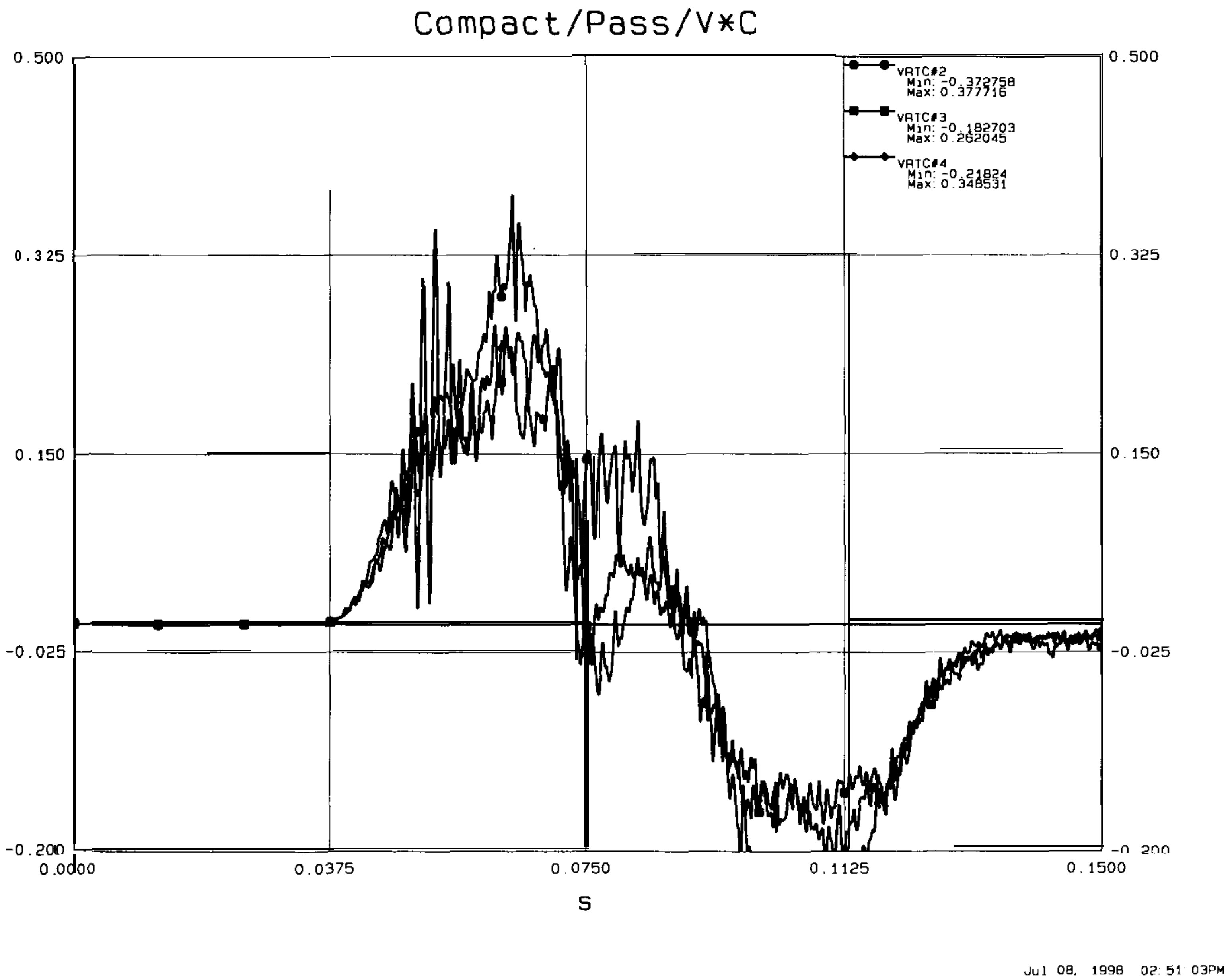
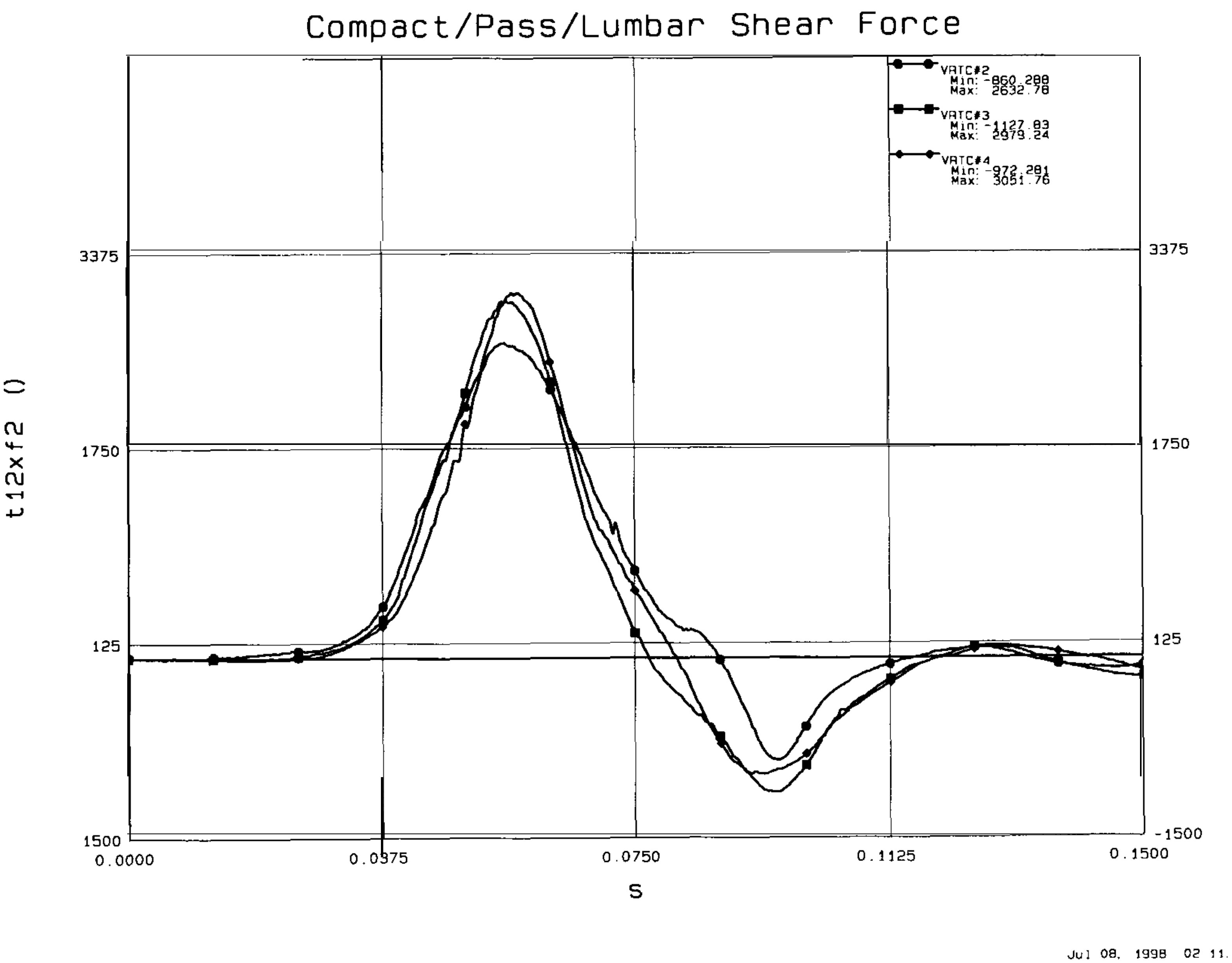

Compact/Pass/Chest Dipslacement
cstxd2 (mm)
0.0
-12.5
-25.0
-37.5
-50.0
0.0000
0.0375
0.0750
0.1125
0.1500
S
VRTC#2
Min: -46.8839
Max: 0.0770434
VRTC#3
Min: -38.7703
Max: 0.0217344
VRTC#4
Min: -39.3538
Max: 0.0310338
Jul 08, 1998 02:51:15PM

Figure E.38



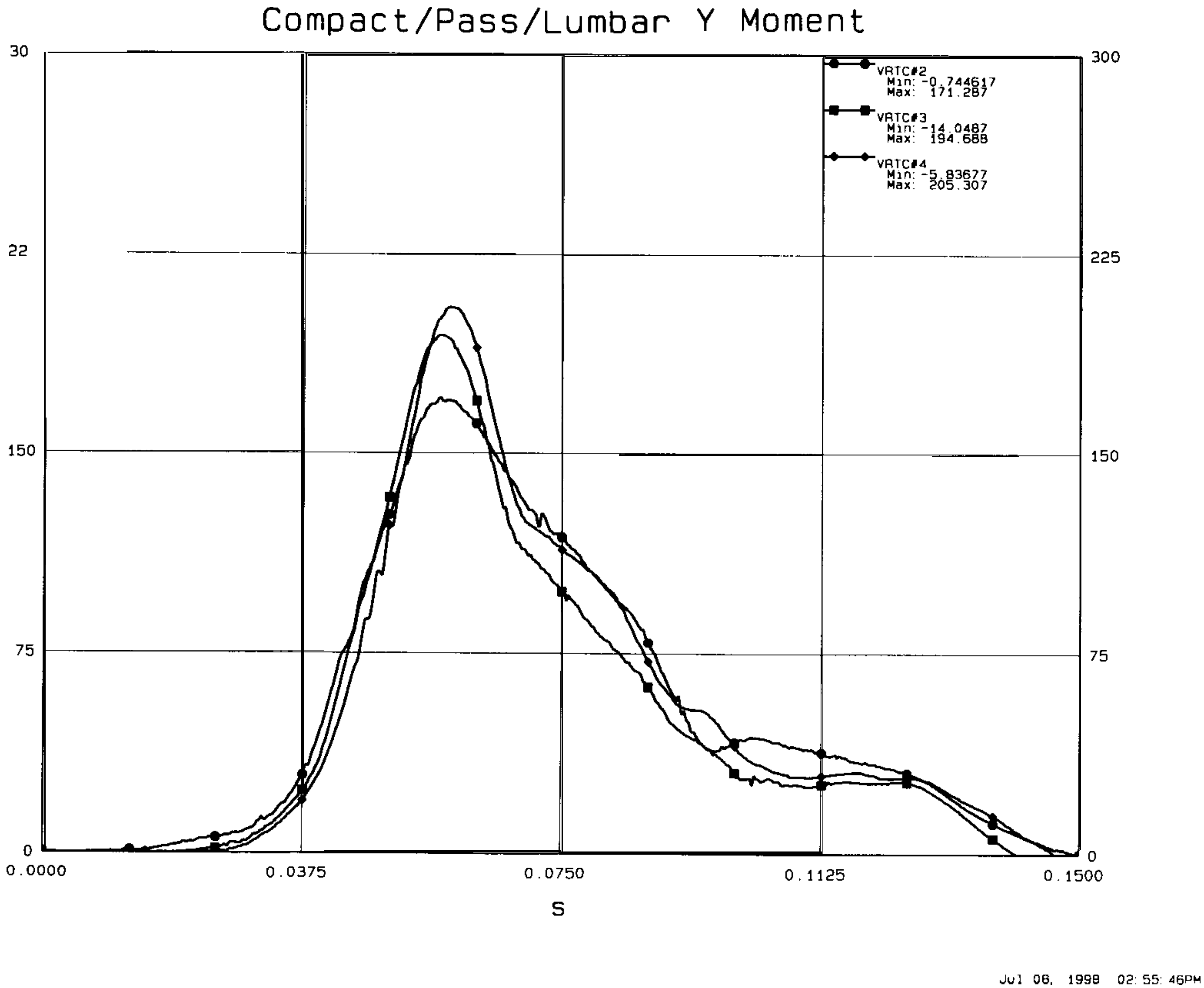
Compact/Pass/V*C
VRTC#2
Min: -0.372758
Max: 0.377716
VRTC#3
Min: -0.182703
Max: 0.262045
VRTC#4
Min: -0.21824
Max: 0.348531
vc2p ()
s
0.500
0.325
0.150
-0.025
-0.200
0.0000
0.0375
0.0750
0.1125
0.1500
Jul 08, 1998 02:51:03PM

Figure E.39



Compact/Pass/Lumbar Shear Force
VRTC#2
Min: -860.288
Max: 2632.78
VRTC#3
Min: -1127.83
Max: 2979.24
VRTC#4
Min: -972.281
Max: 3051.76
3375
1750
125
1500
-1500
0.0000
0.0375
0.0750
0.1125
0.1500
s
t12xf2 ()
Jul 08, 1998 02 11.

Figure E.40



Compact/Pass/Lumbar Y Moment
VRTC#2
Min: -0.744617
Max: 171.287
VRTC#3
Min: -14.0487
Max: 194.688
VRTC#4
Min: -5.83677
Max: 205.307
t12ym2 ()
s
30
22
150
75
0
300
225
150
75
0
0.0000
0.0375
0.0750
0.1125
0.1500
Jul 08, 1998 02:55:46PM

Figure E.41

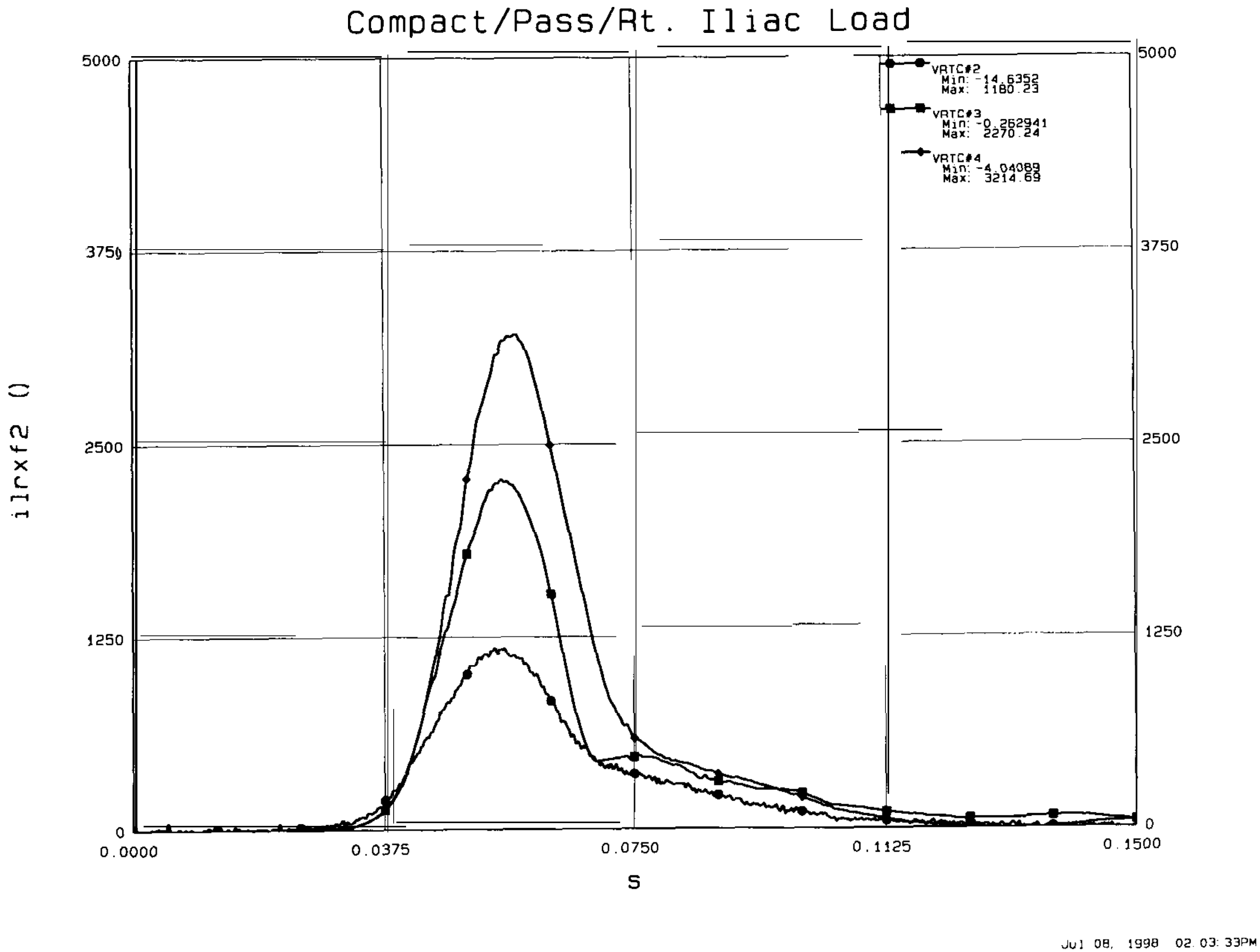
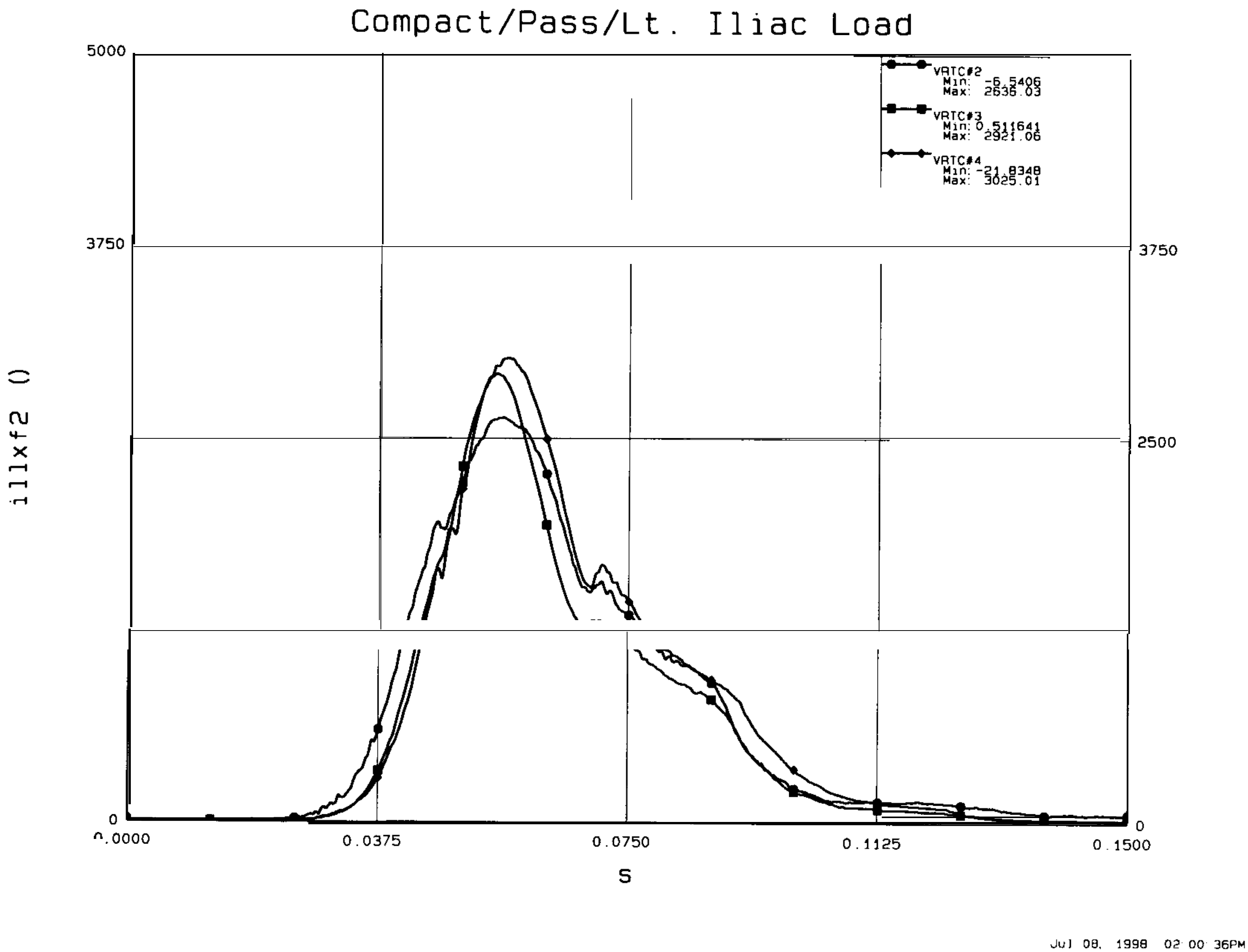

Compact/Pass/Rt. Iliac Load
5000
3750
2500
1250
0
0.0000
0.0375
0.0750
0.1125
0.1500
s
ilrxf2 ()
VRTC#2
Min: -14.6352
Max: 1180.23
VRTC#3
Min: -0.262941
Max: 2270.24
VRTC#4
Min: -4.04089
Max: 3214.69
Jul 08, 1998 02:03:33PM

Figure E.42



Compact/Pass/Lt. Iliac Load
5000
3750
2500
0
VRTC#2
Min: -6.5406
Max: 2636.03
VRTC#3
Min: 0.511641
Max: 2921.06
VRTC#4
Min: -21.8348
Max: 3025.01
ill×f2 ()
0.0375
0.0750
0.1125
0.1500
s
Jul 08, 1998 02:00:36PM

APPENDIX F. NECK WRAP AND HEAD SKIN EVALUATION

Table F. 1 .a. Neck Extension Pendulum Tests With SAE-Proposed Neck Skin

performance criteria	ext #1	ext #2	ext #3	avg	std.dev.	% cv
peak D-plane rotation	102.7	103.0	101.6	102.4	0.74	0.72
rotation angle at -10 Nm	80.8	80.6	78.9	80.1	1.04	1.30
peak moment about condyle	-59. l	-60.8	-62.2	-60.7	1.55	2.56
moment decay time from peak to -10Nm	34.6	34.0	35.0	34.5	0.5	1.46
time to peak rotation after peak moment	7.6	7.9	5.1	6.9	1.54	22.39

Table F.l .b. Neck Extension Pendulum Tests Without Neck Skin

performance criteria	ext #4	ext #5	ext #6	avg	std.dev.	% cv
peak D-plane rotation	102.2	103.4	104.0	103.2	0.92	0.89
rotation angle at -10 Nm	83.1	82.1	80.4	81.9	1.37	1.67
peak moment about condyle	-54.8	-62.2	-65.4	-60.8	5.44	8.94
moment decay time from peak to -10Nm	33.9	33.6	35.6	33.9	1.62	4.77
time to peak rotation after peak moment	9.5	9.8	6.3	8.5	1.94	22.73

Table F.2.a. Neck Flexion Pendulum Tests With SAE-Proposed Neck Skin

performance criteria	flx #1	flx #2	flx #3	avg.	std.dev.	% cv
peak D-plane rotation	82.5	84.8	86.8	84.7	2.15	2.54
rotation angle decay time from peak to 0	60.7	60.7	63.7	61.7	1.73	2.81
peak moment about condyle	72.5	74.7	73.8	73.7	1.11	1.50
moment decay time from peak to 0 Nm	41.8	42.5	39.6	41.3	1.51	3.66
time to peak rotation after peak moment	4.1	3.2	2.6	3.3	0.75	22.88

Table F.2.b. Neck Flexion Pendulum Tests Without Neck Skin

performance criteria	flx #4	flx #5	flx #6	avg.	std.dev.	% cv
peak D-plane rotation	86.3	86.9	86.9	86.7	0.35	0.40
rotation angle decay time from peak to 0	63.3	62.1	62.2	62.5	0.67	1.06
peak moment about condyle	73.7	75.2	75.7	74.9	1.04	1.39
moment decay time from peak to 0 Nm	40.2	39.8	40.1	40.0	0.21	0.52
time to peak rotation after peak moment	2.8	3.4	3.6	3.3	0.42	12.74

Table F.3. OOP Test Results for Standard Head Skin without Neck Wrap

test # 043400--		48	50	52	58	AVG	STDEV	%CV
Neck Fx	N	-741.6	-599.9	-733.0	-731.0	-701.4	67.8	9.7
Neck Fz	N	995.3	1008.7	956.6	1137.3	1024.5	78.4	7.7
Neck Moc	Nm	-40.6	-28.2	-34.1	-31.9	-33.7	5.2	15.4
Head Res	g	18.7	22.0	21.4	27.7	22.5	3.8	16.9
Chest Res	g	20.1	25.5	24.6	23.6	23.5	2.4	10.1

Table F.4. OOP Test Results for TMJ Head Skin with SAE-Proposed Neck Wrap

test # 043400--		49	51	53	AVG	STDEV	%CV
Neck Fx	N	-629.9	-810.6	-829.4	-777.6	74.0	9.5
Neck Fz	N	946.8	1079.2	1061.4	1029.1	71.9	7.0
Neck Moc	Nm	-40.3	-43.9	-45.1	-43.1	2.5	5.8
Head Res	g	17.3	17.4	26.7	20.5	5.4	26.4
Chest Res	g	16.6	18.7	32.9	22.7	8.9	39.0

Table F.5. OOP Test Results for TMJ Head Skin without Neck Wrap

test # 043400--		54	55	56	AVG	STDEV	%CV
Neck Fx	N	-611.8	-557.0	-641.2	-603.3	42.7	7.1
Neck Fz	N	1159.0	1017.0	950.9	1042.3	106.3	10.2
Neck Moc	Nm	-26.4	-25.6	-29.6	-27.2	2.1	7.8
Head Res	g	27.9	28.4	25.5	27.3	1.6	5.7
Chest Res	g	22.8	39.1	36.6	32.8	8.8	26.7

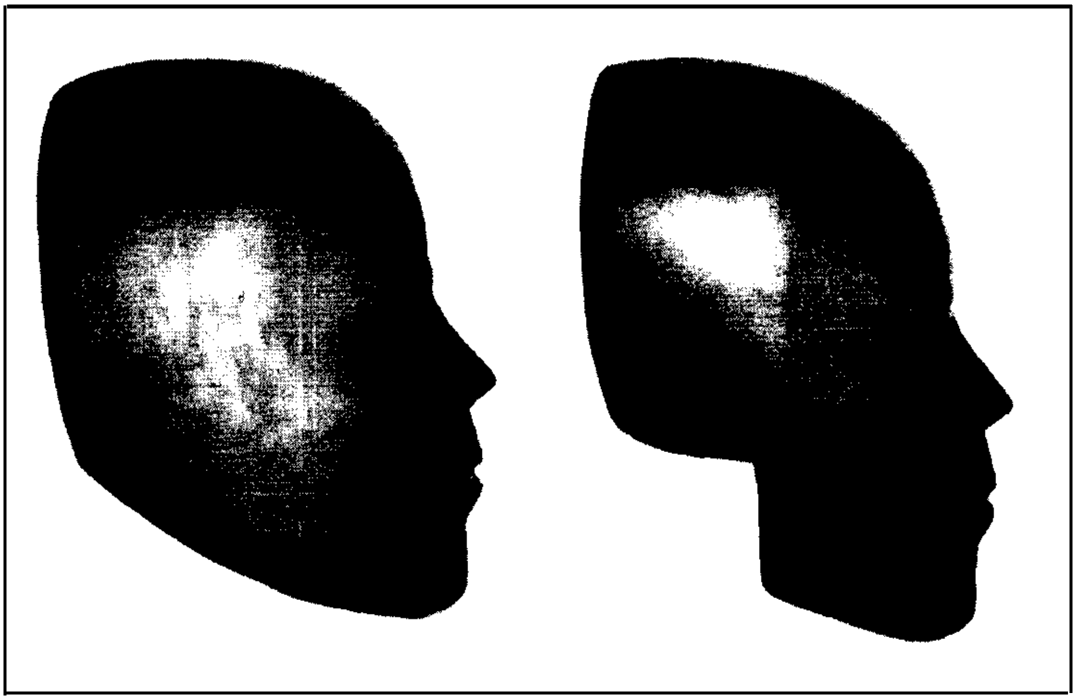


Fig. F. 1. TMJ Head Skin (left and Standard Skin (right)

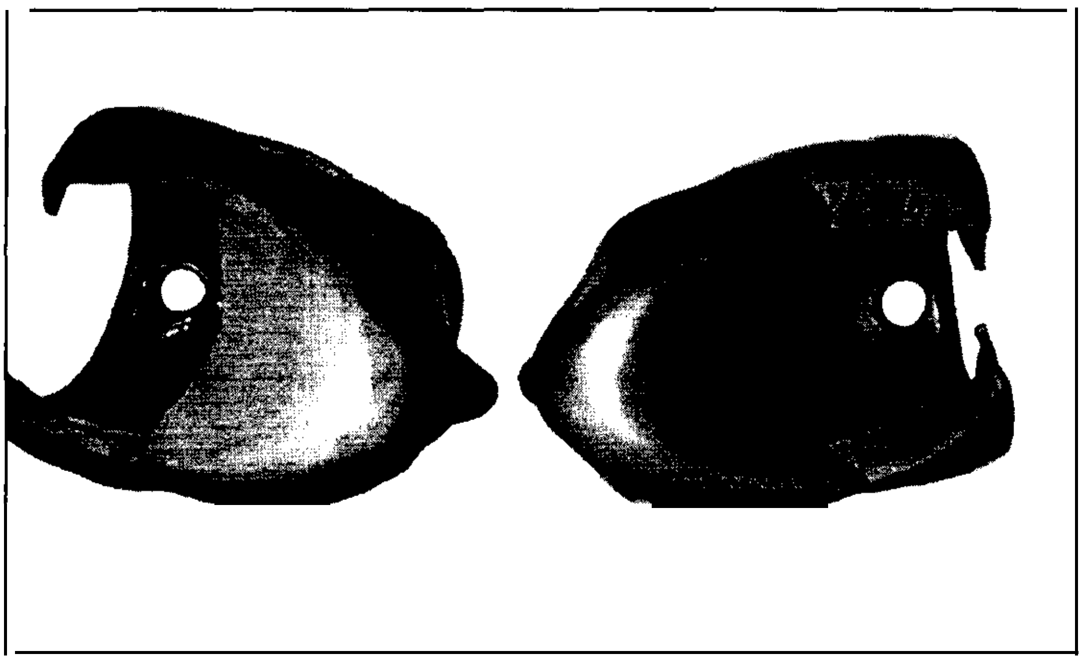


Fig. F.2. TMJ Head Skin (left) and Standard Skin (right)

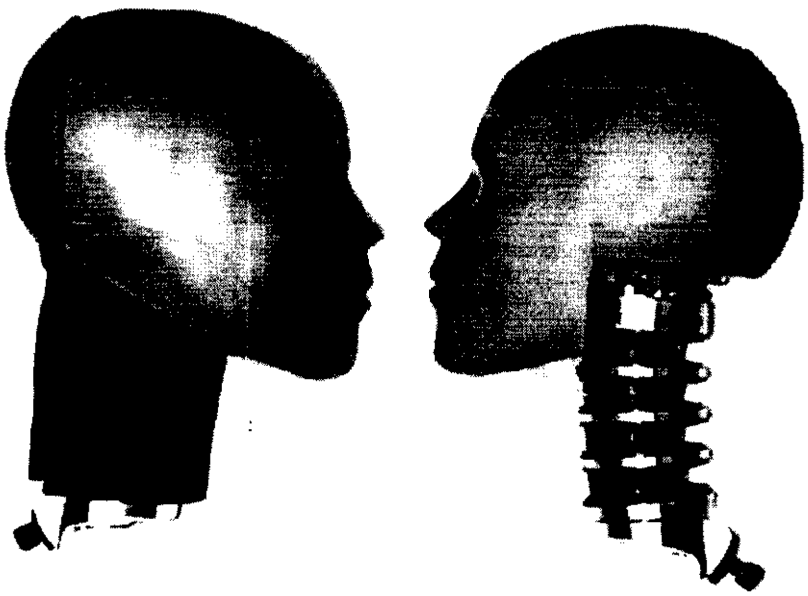
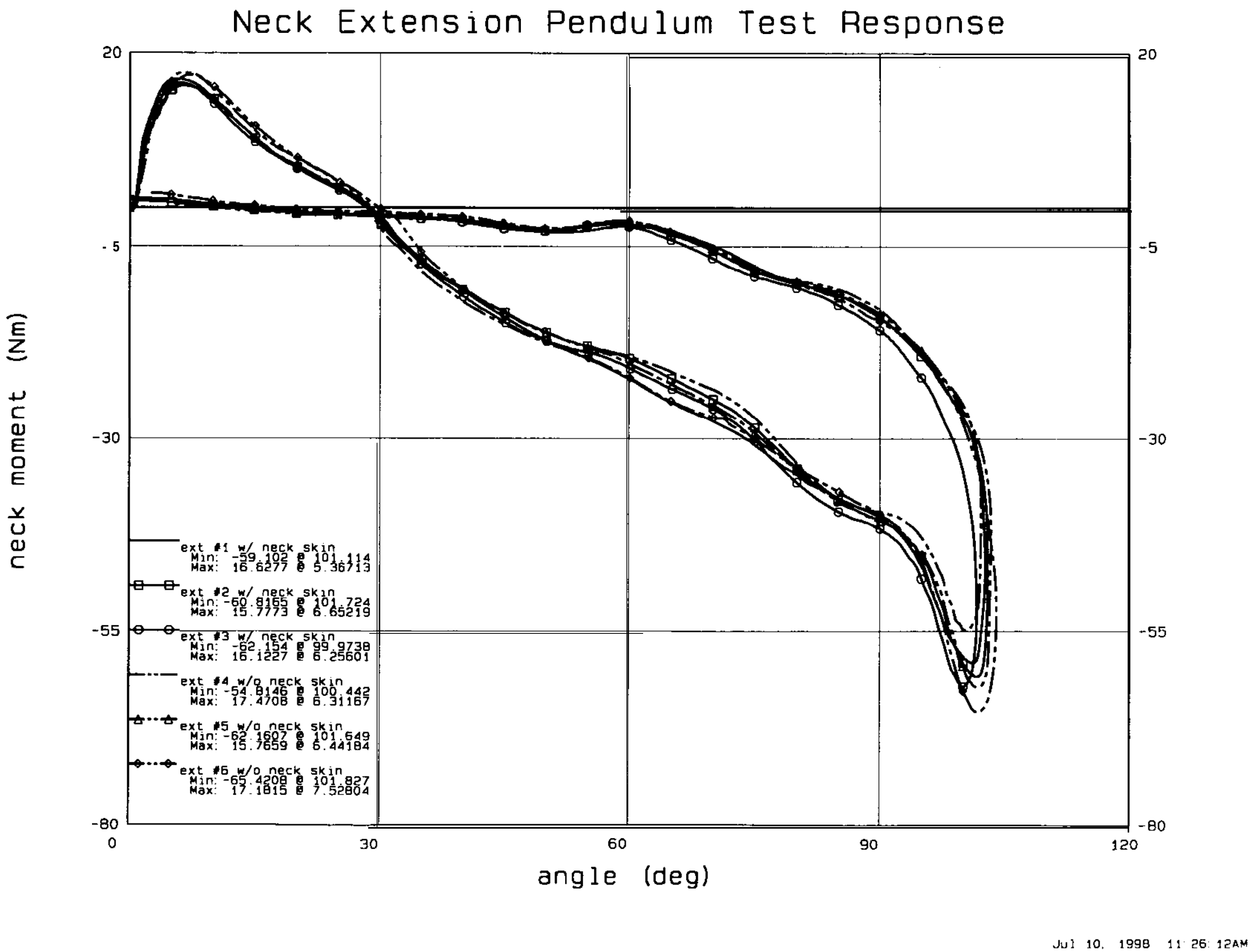


Fig. F.3. TMJ Head Skin with SAE-proposed Neck Wrap (left) and Standard Skin without Neck Wrap (right)

Figure F.4. Static OOP Test Setup (TMJ head skin and SAE-proposed Neck Wrap)

Figure F. 5



Neck Extension Pendulum Test Response
20
-5
-30
-55
-80
0
30
60
90
120
neck moment (Nm)
angle (deg)
ext #1 w/ neck skin
Min: -59.102 @ 101.114
Max: 16.6277 @ 5.36713
ext #2 w/ neck skin
Min: -60.8165 @ 101.724
Max: 15.7773 @ 6.65219
ext #3 w/ neck skin
Min: -62.154 @ 99.9738
Max: 16.1227 @ 6.25601
ext #4 w/o neck skin
Min: -54.8146 @ 100.442
Max: 17.4708 @ 6.31167
ext #5 w/o neck skin
Min: -62.1607 @ 101.649
Max: 15.7659 @ 6.44184
ext #6 w/o neck skin
Min: -65.4208 @ 101.827
Max: 17.1815 @ 7.52804
Jul 10, 1998 11:26:12AM

Figure F.6

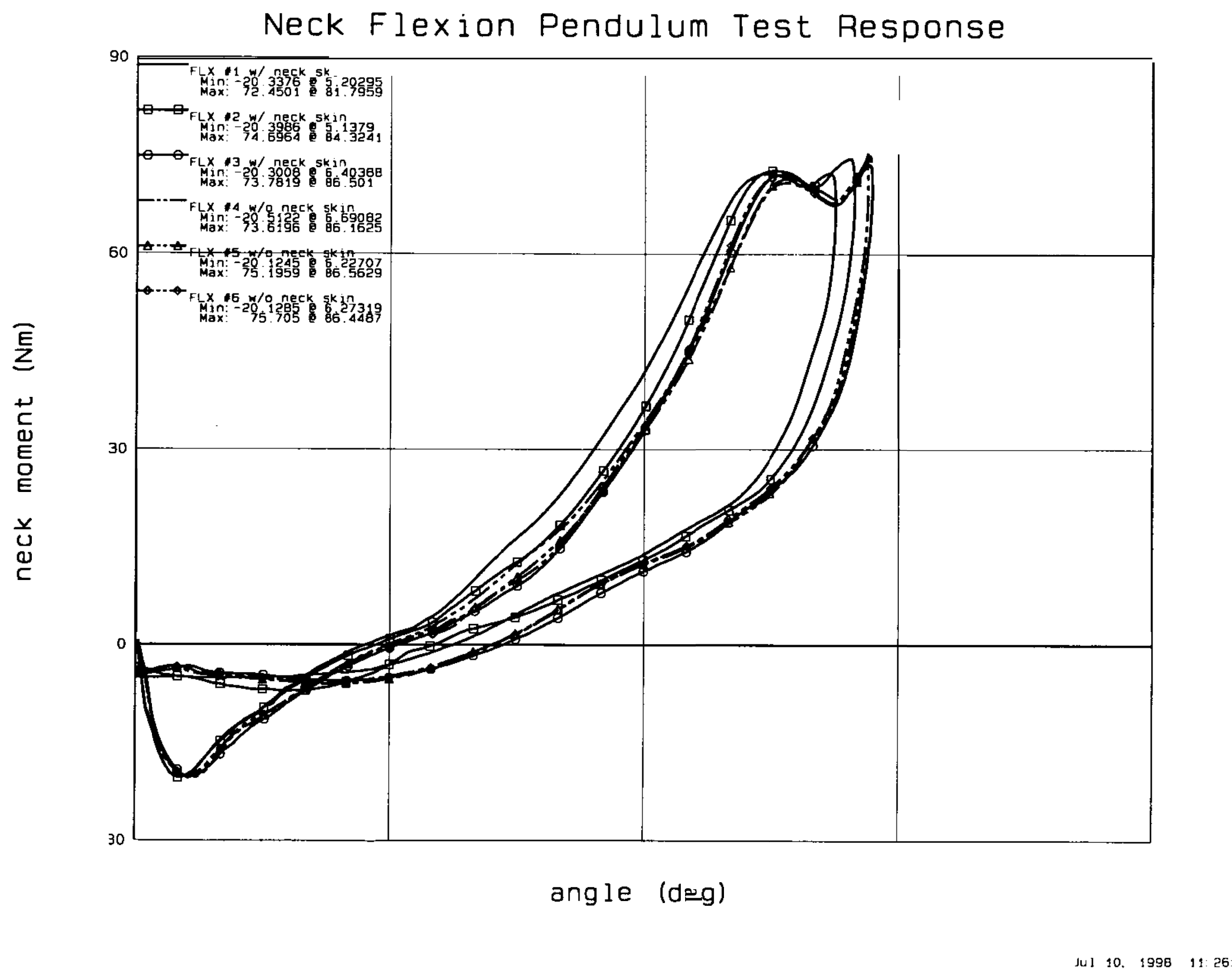
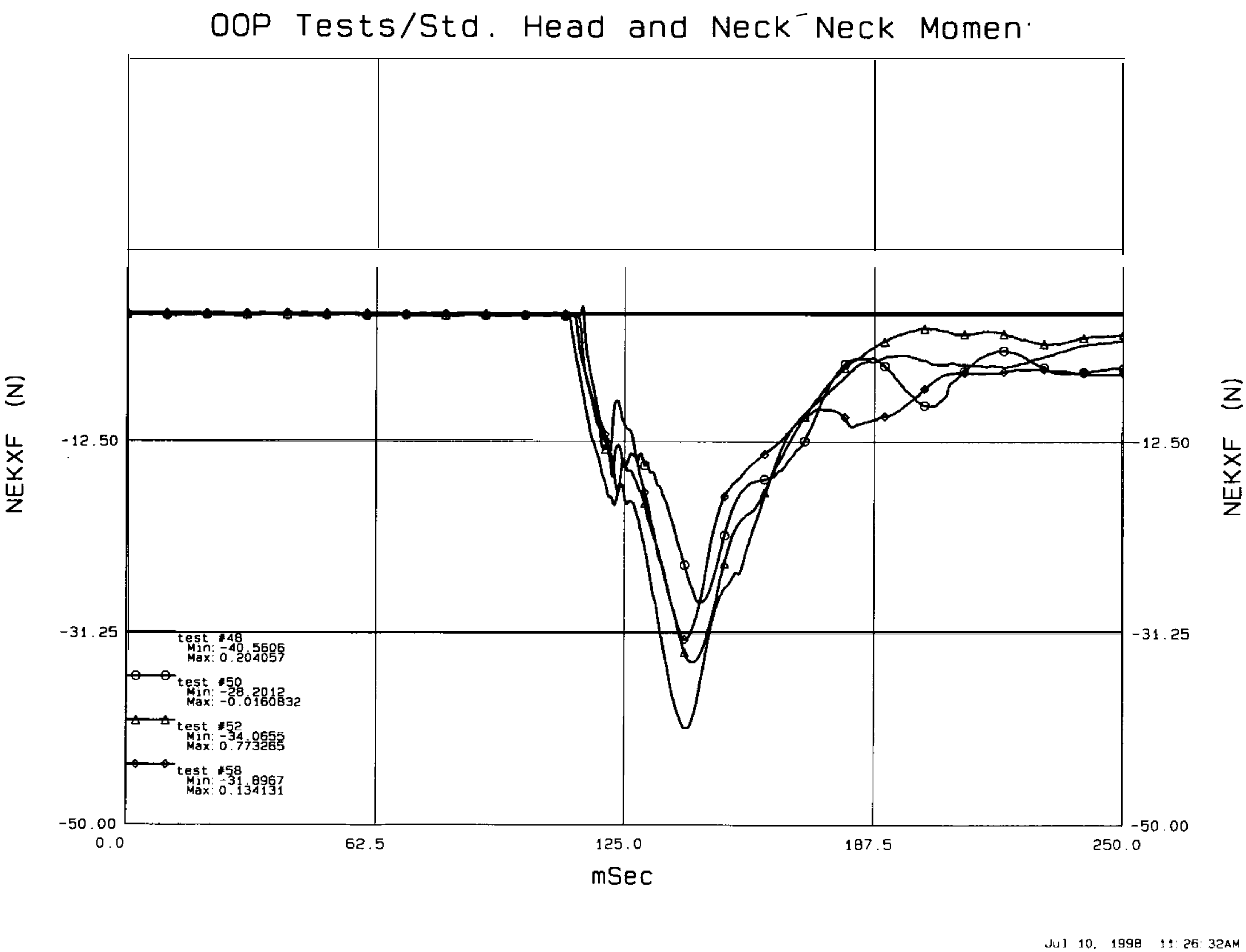
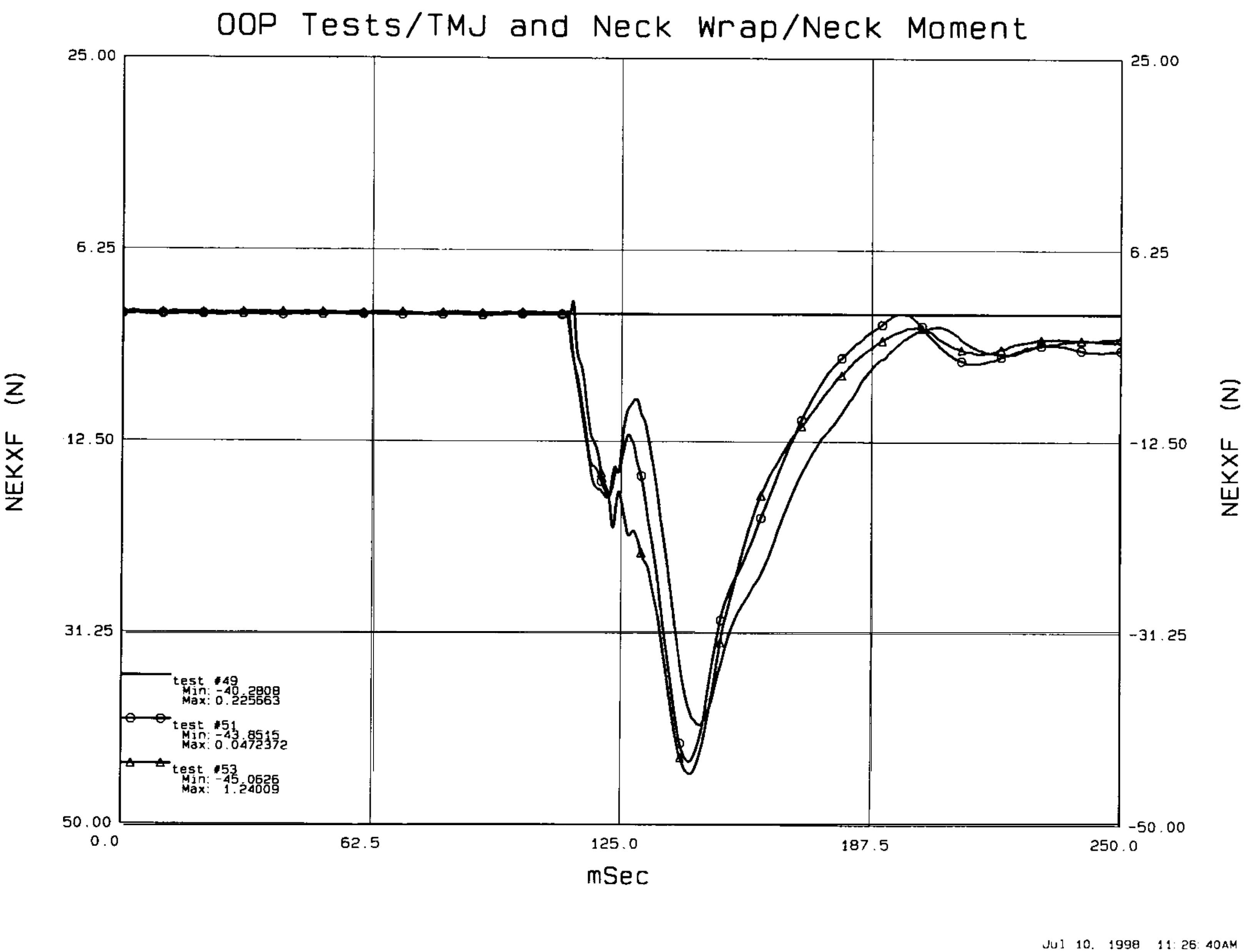

Neck Flexion Pendulum Test Response
FLX #1 w/ neck sk
Min: -20.3376 @ 5.20295
Max: 72.4501 @ 81.7959
FLX #2 w/ neck skin
Min: -20.3986 @ 5.1379
Max: 74.6964 @ 84.3241
FLX #3 w/ neck skin
Min: -20.3008 @ 6.40368
Max: 73.7819 @ 86.501
FLX #4 w/o neck skin
Min: -20.5122 @ 6.69082
Max: 73.6196 @ 86.1625
FLX #5 w/o neck skin
Min: -20.1245 @ 6.22707
Max: 75.1959 @ 86.5629
FLX #6 w/o neck skin
Min: -20.1285 @ 6.27319
Max: 75.705 @ 86.4487
90
60
30
0
30
neck moment (Nm)
angle (deg)
Jul 10, 1998 11:26

Figure F.7



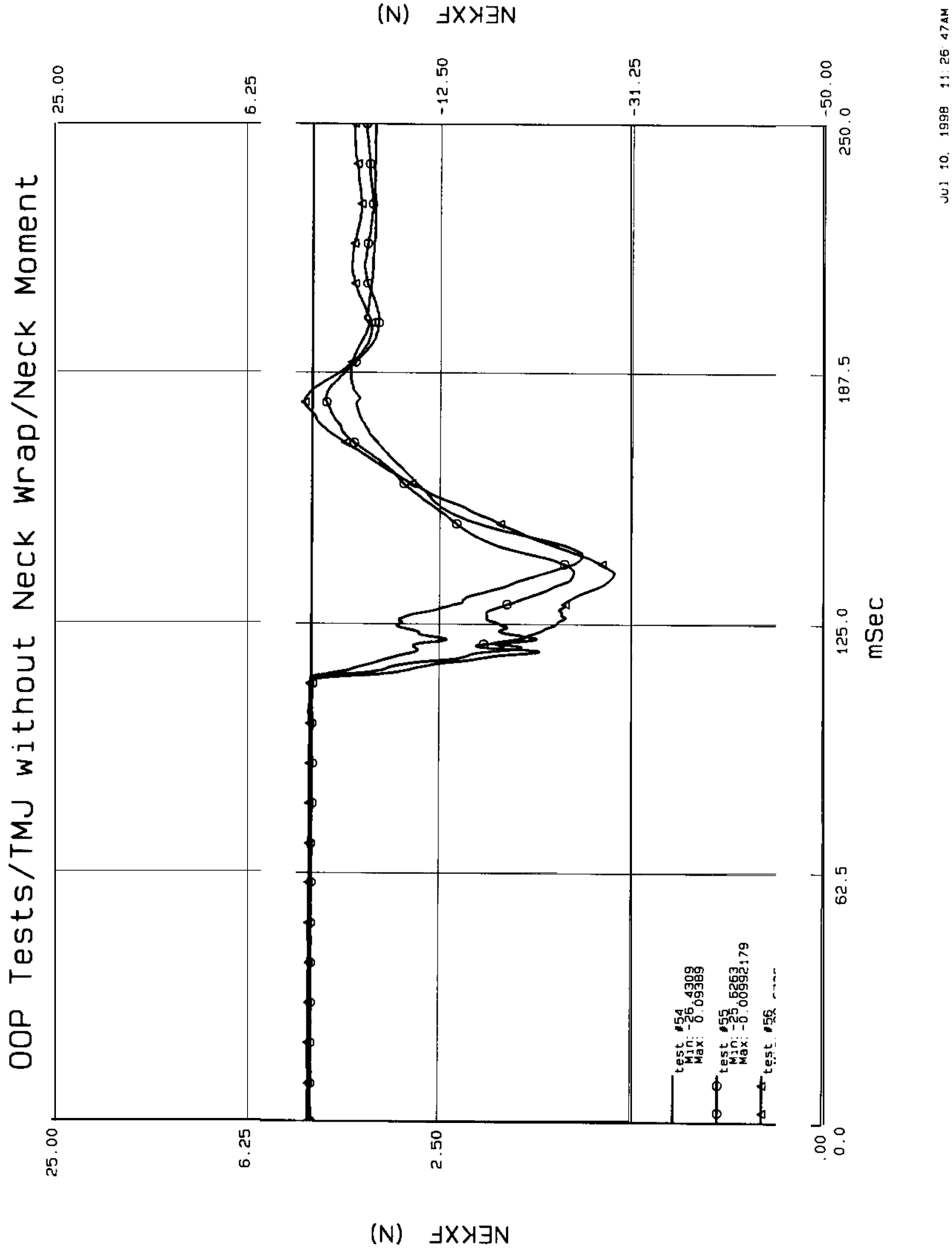
OOP Tests/Std. Head and Neck¯Neck Momen·
NEKXF (N)
-12.50
-31.25
-50.00
0.0
62.5
125.0
187.5
250.0
mSec
test #48
Min: -40.5606
Max: 0.204057
test #50
Min: -28.2012
Max: -0.0160832
test #52
Min: -34.0655
Max: 0.773265
test #58
Min: -31.8967
Max: 0.134131
Jul 10, 1998 11:26:32AM

Figure F.8



OOP Tests/TMJ and Neck Wrap/Neck Moment
25.00
6.25
12.50
31.25
50.00
-12.50
-31.25
-50.00
NEKXF (N)
0.0
62.5
125.0
187.5
250.0
mSec
test #49
Min: -40.2808
Max: 0.225663
test #51
Min: -43.8515
Max: 0.0472372
test #53
Min: -45.0626
Max: 1.24009
Jul 10, 1998 11:26:40AM

Figure F.9



OOP Tests/TMJ without Neck Wrap/Neck Moment
NEKXF (N)
25.00
6.25
-12.50
-31.25
-50.00
2.50
0.0
62.5
125.0
187.5
250.0
mSec
test #54
Min: -26.4309
Max: 0.09389
test #55
Min: -25.5263
Max: -0.00992179
test #56
Jul 10, 1998 11:26 47AM

Figure F.10

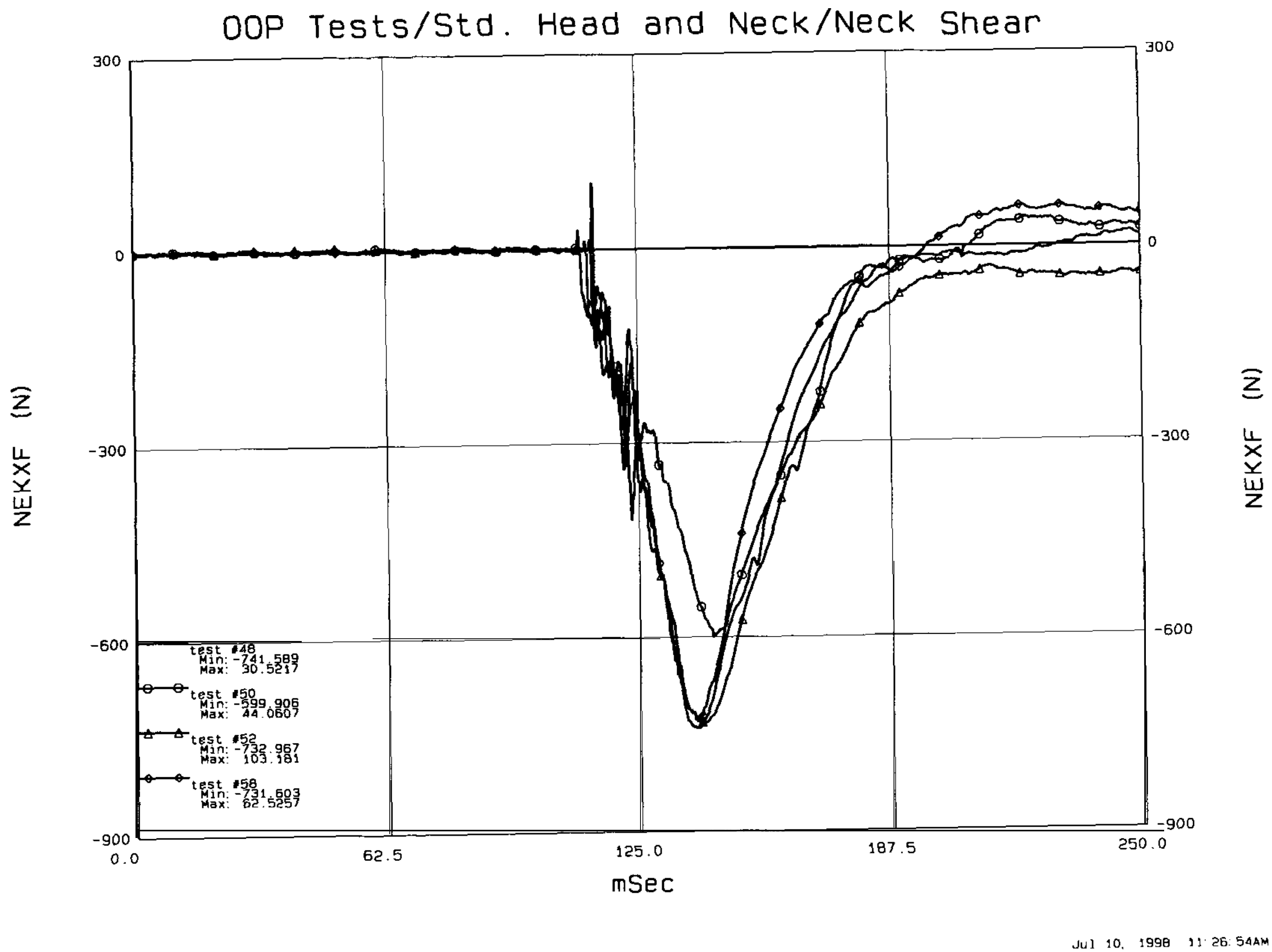
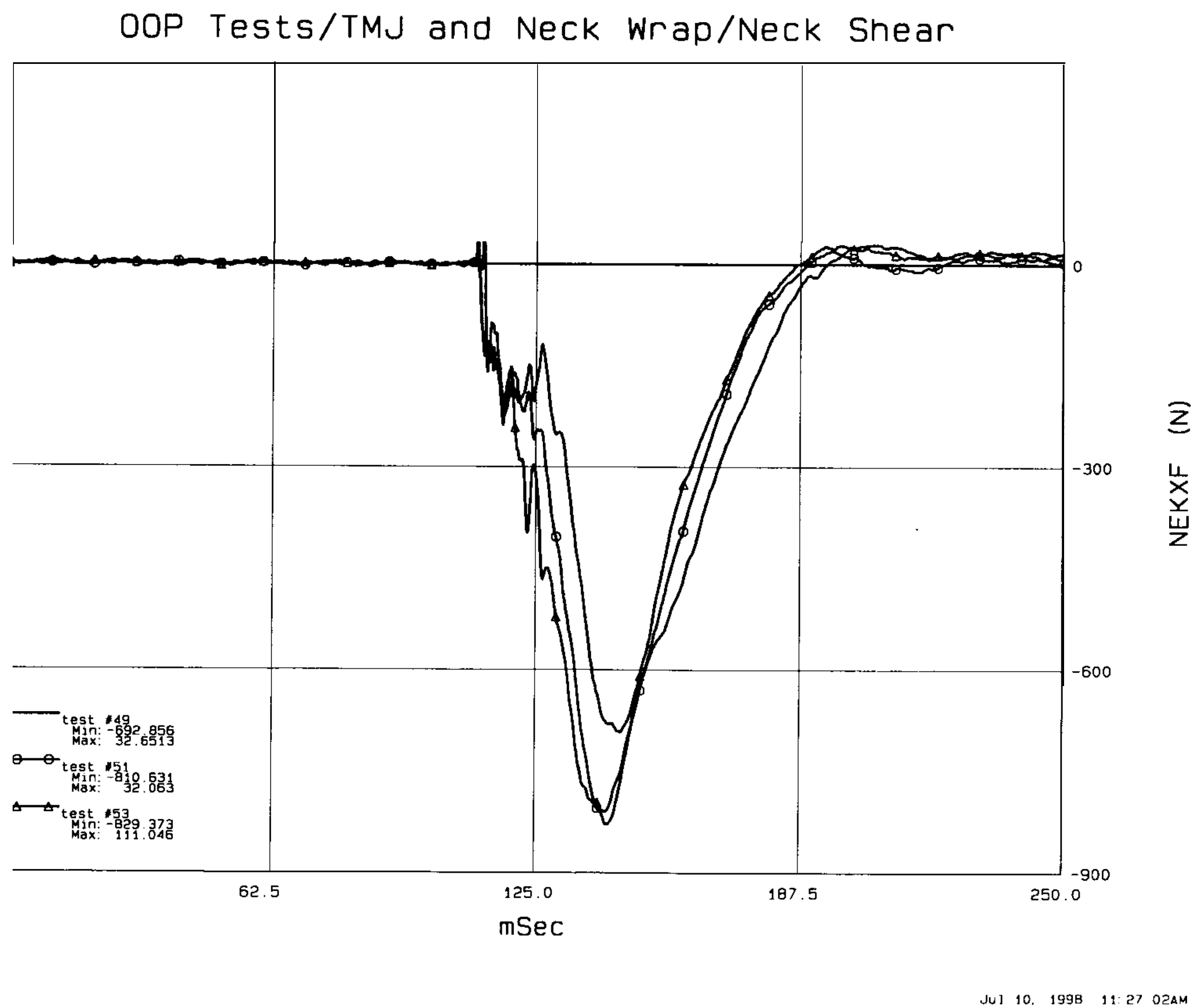
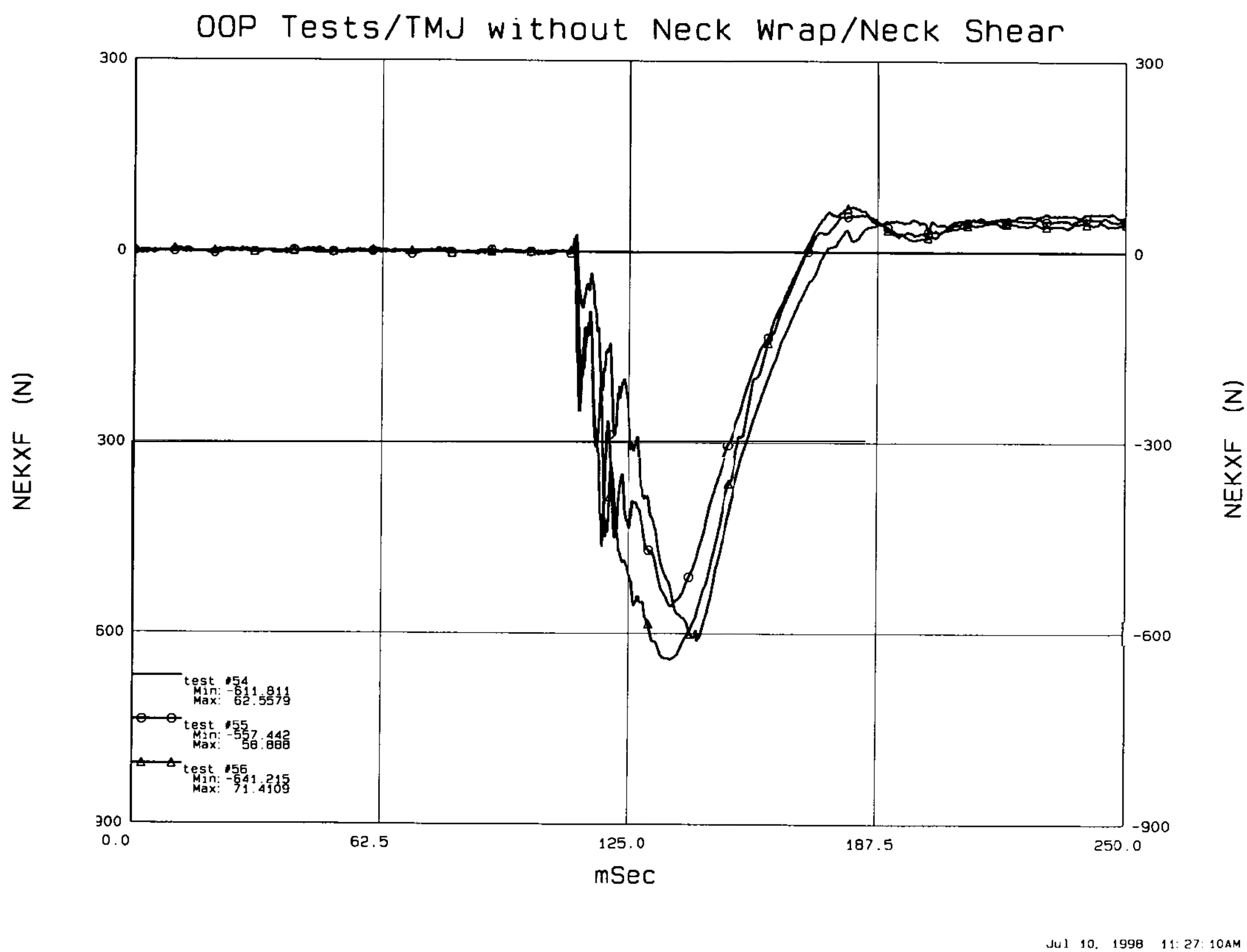

OOP Tests/Std. Head and Neck/Neck Shear
300
0
-300
-600
-900
0.0
62.5
125.0
187.5
250.0
mSec
NEKXF (N)
test #48
Min: -741.589
Max: 30.5217
test #50
Min: -599.906
Max: 44.0607
test #52
Min: -732.967
Max: 103.181
test #58
Min: -731.603
Max: 62.5257
Jul 10, 1998 11:26:54AM

Figure F.11



OOP Tests/TMJ and Neck Wrap/Neck Shear
test #49
Min: -692.856
Max: 32.6513
test #51
Min: -810.631
Max: 32.063
test #53
Min: -829.373
Max: 111.046
0
-300
-600
-900
NEKXF (N)
62.5
125.0
187.5
250.0
mSec
Jul 10, 1998 11:27 02AM

Figure F.12



OOP Tests/TMJ without Neck Wrap/Neck Shear
300
0
300
600
300
300
0
-300
-600
-900
NEKXF (N)
NEKXF (N)
0.0
62.5
125.0
187.5
250.0
mSec
test #54
Min: -611.811
Max: 62.5579
test #55
Min: -557.442
Max: 58.888
test #56
Min: -641.215
Max: 71.4109
Jul 10, 1998 11:27:10AM