

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**PART / DEVICE CERTIFICATION PROCESS IN AVIATION AND TEST
STAGES OF TSI BRAND ECONOMY CLASS AIRCRAFT SEATS WITH
EXPANDED SCREEN SIZE**



M.Sc. THESIS

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Department of Aeronautical and Astronautical Engineering

Aeronautical and Astronautical Engineering Programme

JULY 2020

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**HAVACILIKTA PARÇA / CİHAZ SERTİFİKASYONU VE EKCRAN BOYUTU
GENİŞLETİLEN TSI MARKA EKONOMİ KOLTUKLARIN TEST
AŞAMALARI**

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To my spouse and son,



FOREWORD

I am dedicating this thesis to my dear family who provided their all support to me during my lifetime.

I want to thank to Assis. Prof. Dr. Özge Özdemir who always supported and encouraged me with her guidance and criticises and kept my motivation at high level.

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ABBREVIATIONS

AC	: Advisory Circular
ADOA	: Alternative Design Organization Approval
APU	: Alternative Power Unit
ARP	: Aerospace Recommended Practice
ATD	: Antropomorphic Test Dummy
CCW	: Counter clockwise
CFR	: Code of Federal Regulation
CG	: Centre of Gravity
CoC	: Certificate of Conformity
CRP	: Cushion Reference Point
CS	: Certification Specification
CTR	: Centre
CW	: Clockwise
DDP	: Declaration of Design and Performance
DER	: Designated Engineering Representative
DGCA	: Directorate General of Civil Aviation
DOA	: Design Organization Approval
EASA	: European Union Aviation Safety Agency
E/C	: Economy Class
ENR	: Extra Narrow Seat
ETSO	: European Technical Standard Order
FAA	: Federal Aviation Administration
HIC	: Head Injury Criteria
IAT	: In-Arm Table
IAV	: In-Arm Video
IFE	: In Flight Entertainment
IOM	: Item of Mass
LH	: Left Hand
LOPA	: Layout of Passenger Accommodations
MIN	: Minimum

N/A	: Not Applicable
NR	: Narrow Seat
PAX	: Passenger
P/N	: Part Number
POA	: Production Organization Approval
RH	: Right Hand
SAE	: Society of Automotive Engineers
SHT	: Civil Aviation Instruction
SILAS	: Seat Interface Loads Analysis System
SRP	: Seat Reference Point
STC 1	: Supplemental Type Certificate
STC 2	: Stretcher Mechanism
STD	: Standard
TCDS	: Type Certificate Data Sheet
THY	: Turkish Airlines
TPL	: Triple
TSI	: Turkish Seat Industry
TSO	: Technical Standard Order
VHF	: Very High Frequency

SYMBOLS

g	: Acceleration Due to Gravity
lb	: Pound
m	: Meter
t	: Time





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PART / DEVICE CERTIFICATION PROCESS IN AVIATION AND TEST STAGES OF TSI BRAND ECONOMY CLASS AIRCRAFT SEATS WITH EXPANDED SCREEN SIZE

SUMMARY

With the spread of aviation day by day, the need for aircrafts and as a result, the parts and devices used in aircraft are increasing. In order to use part or device designed for an aircraft, “TSO / ETSO” (European) Technical Standard Order approval must be obtained from the authorized aviation authorities. This approval can be given by DGCA, EASA and FAA for the aircraft we use in our country. Authorities liable to ensure flight availability request some information and documents from the manufacturers, as proof, that airworthiness will be provided.

Standard parts are produced around the world in accordance with certain industrial standards. No special certification is required for these parts. It is sufficient to receive an acceptance only by the company that designed the aircraft for which the part will be used. However, if a part or device apart from standard parts will be used in an aircraft, either the manufacturer must obtain TSO / ETSO approval or be involved in the certification process with the aircraft manufacturer to which the part will be installed. Both methods have their own advantages and disadvantages.

The purpose of this thesis is to have information about part / device certification and to guide people or organizations that plan to manufacture for using in aircraft. In this context, in the introduction part of the thesis, information will be given how to make applications to DGCA, our authorized civil aviation authority, what documents will be used, and how to get involved as a subcontractor.

DGCA needs some test requirements as proof that the part or device to be used is suitable for airworthiness. For this reason, depending on the qualification of the part or device, durability test, flammability test, electrical tests and some tests that will not harm the environmental conditions will be requested by the civil aviation authorities. In this context, certification examinations will be made on TSI brand economy class seats of B787 aircraft that have recently begun to enter the inventory of Turkish Airlines. The economy seats, which currently have a screen size of 11.6 inches, will be expanded to have a 13-inch screen size. Thus, the scope of TSO / ETSO approval for 11.6 inch monitors will be extended.

When an approval application is made for the using of an aircraft passenger seat, it is requested that the seat can withstand 14G and 16G conditions. Within the scope of this thesis, the resistance of these seats to static and dynamic conditions will be tested. In normal conditions, if a new seat is to be fitted on an aircraft for the first time, it is expected that the nonflammability tests will also be successful. However, since the project of enlarging only the screens of the economy class seats of B787 is evaluated within the scope of the thesis, it is not necessary to perform the nonflammability tests again.

B787-9 aircraft, which are included in the Turkish Airlines fleet, have 270 economy class seats. When considering the cost and time issues, it is necessary to be able to verify all the seats with the minimum number of tests. For this, the seats will be divided into more than one seat families by taking into account certain features.

After the seat families are gathered under certain groups, one seat, which is thought to be exposed to the most critical load, will be selected from the seats in the families. For the selection of the critical seat, the interface load calculation program belonging to Boeing company and beam bending analysis program belonging to TSI company will be used. Boeing's interface load calculation program provides information on the highest loads on the rear legs of the seats, while TSI's program helps in comparing the loads that can reach certain points on the rear beams.

With the help of these two programs, one seat from each family was chosen since it was thought to be exposed to the highest loads. As a result, five seats were selected and the convenience of economy seats for the entire aircraft will be verified with these five seats. The seats selected here will be used in all static tests but they are dynamically suitable only for usage in 14.0g vertical tests and 16.0g longitudinal tests.

In static tests, force values are determined by multiplying the current weights of the seat and the passenger with certain load factors. When these forces are applied to the front, back, sides, lower and upper parts of the seat, deformations occur at various points on the seat. These deformation values are examined at 23 points for a double passenger seat and at 27 points for a triple seat. Deformations in the X and Z directions must be less than 3 inches, and deformations in the Y directions must be less than 1.5 inches. This evaluation also applies to dynamic tests.

Dynamic tests will also be evaluated in four separate groups. These are 14.0g vertical tests, 16.0g longitudinal tests, HIC (head injury criterion) tests and head path tests. For the 14.0g and 16.0g tests, the previously specified test seats are used. However, in HIC and head path tests, different seats are used. HIC tests are carried out under the conditions of 16.0g by using of two rows of seats. In these tests, the dummy placed on the second row seat hits the head to the front row seat and the situations that occur during the impact are examined. The 1000 value determined for HIC should not be exceeded. HIC tests are the most important tests due to the enlargement of the passenger seat screens. Because the passenger's head hits the front seat, the HIC value should be below 1000 to avoid any damage. There is a high probability of deaths occurring at values over 1000.

In HIC tests, the head of ATD is expected to hit the three different parts of the seat. The back of the seat is divided into groups: zone A, zone B and zone C. If the head does not touch these points during the test, some conditions are changed and the tests are repeated. The faces of the ATD are painted in different colors to determine where the impact occurred.

In dynamic tests where the head path is examined, only the front row seats are tested. In these tests, the passenger is expected not to hit the flat surface in front of his head.

Dynamic tests are also ideal tests for evaluating the loads that may come to points such as femur, pelvis and lumbar. The load on the lumbar and pelvis of the ATD should not exceed 1500 lb and the load on the femur should not exceed 2250 lb.

Absolute success has been achieved in static tests after the applied tests. A few undesirable situations were encountered in dynamic tests. However, since some of them did not exceed the allowable limits, the tests were considered successful. Other

problematic test seats have also been retested by using some new parts and the desired success has been achieved.

In order to obtain TSO / ETSO approval, the application has been submitted to the required authorities with these test results and is expected to be evaluated.





HAVACILIKTA PARA / CİHAZ SERTİFİKASYONU VE EKCRAN BOYUTU GENİŐLETİLEN TSI MARKA EKONOMİ KOLTUKLARIN TEST AŐAMALARI

ÖZET

Havacılıđın her geen gn yaygınlaŐmasıyla birlikte uaklara ve bunun sonucu olarak uaklarda kullanılan para ve cihazlara duyulan ihtiya giderek artmaktadır. Tasarlanan para veya cihazın bir hava aracında kullanılabilmesi iin yetkili havacılık otoritelerinden ‘‘TSO/ETSO’’ (European) Technical Standard Order onayı almak gerekir. Bu onay lkemizde kullandığımız uaklar iin SHGM, EASA ve FAA tarafından verilebilmektedir. UuŐa elveriŐliliđi sađlamakla ykml otoriteler bu onay karŐılıđında retici firmalardan uuŐa elveriŐliliđin sađlanacađına dair kanıt niteliđinde bazı bilgi ve belgeler talep ederler.

Standart paralar tm dnyada belirli endstriyel standartlara gre retilir. Bu paralar iin zel bir sertifikasyon gerekmez. Sadece paranın kullanılacađı aracın tasarımını yapan firma tarafından kabul edilmesi yeterlidir. Fakat standart paralar dıŐında bir para veya cihaz bir hava aracında kullanılacaksa ya reticinin TSO/ETSO onayı alması ya da paranın takılacađı hava aracı reticisi ile sertifikasyon srecine dahil olması gerekir. Her iki yntemin de kendi iinde avantaj ve dezavantajları mevcuttur.

Bu tezin amacı para/cihaz sertifikasyonu hakkında bilgi sahibi olmak, hava aracında kullanılmak zere retim yapmayı planlayan kiŐi veya kuruluŐlara yol gstermektir. Bu bađlamda tezin giriŐ kısmında kendi yetkili sivil havacılık otoritemiz olan SHGM’ye baŐvuruların nasıl yapılacađı, hangi dkmanların kullanılacađı, bir alt yklenici olarak srece nasıl dahil olunacađı hakkında bilgi verilecektir.

SHGM kullanılacak para veya cihazın uuŐa elveriŐliliđe uygun olduđunun kanıtı mahiyetinde bazı test gereksinimlerine ihtiya duyar. Bu sebeple para veya cihazın niteliđine gre dayanıklılık testi, yanmazlık testi, elektriksel testler ve evre koŐullarına zarar verilmeyeceđine dair birtakım testler sivil havacılık otoriteleri tarafından talep edilecektir. Bu kapsamda, Trk Hava Yolları’nın envanterine yakın zamanda girmeye baŐlayan B787 uaklarının TSI marka ekonomi sınıfı koltukları zerine sertifikasyon incelemeleri yapılacaktır. Mevcut durumda 11.6 in’lik ekran boyutuna sahip olan ekonomi koltukları geniŐletilerek 13 in ekran boyutuna sahip olacaktır. Bylece 11.6 in’lik monitorler iin sahip olunan TSO/ETSO onayının da kapsamı geniŐletilmiŐ olacaktır.

Bir uak yolcu koltuđunun uakta kullanımı iin onay baŐvurusu yapıldığında koltuđun 14G ve 16G koŐullarına dayanabilmesi talep edilmektedir. Bu tez kapsamında da sz konusu koltukların statik ve dinamik koŐullara dayanımı test edilecektir. Normal Őartlarda bir uađa yeni bir koltuk ilk defa takılacak ise mutlaka yanmazlık testlerinin de baŐarılı olması beklenmektedir. Fakat B787’lerin ekonomi sınıfı koltuklarının sadece ekranlarının bytlmesi projesi tez kapsamında deđerlendirildiđi iin yanmazlık testlerinin yeniden yapılmasına gerek duyulmamıŐtır.

Türk Hava Yolları filosuna dahil olan B787-9 uçaklarının 270 adet ekonomi sınıfı koltuğu bulunmaktadır. Maliyet ve zaman hususları göz önünde bulundurulduğunda mümkün olan en az sayıda test ile tüm koltukları tahkik edebilmek gerekmektedir. Bunun için koltuklar belirli özellikleri göz önünde bulundurularak birden fazla koltuk ailelerine ayrılacaktır.

Koltuk aileleri belirli gruplar altında toplandıktan sonra aileler içinde yer alan koltuklardan en kritik yüke maruz kalabileceği düşünülen birer adet koltuk test koltuğu olarak seçilecektir. Kritik koltuğun seçimi için Boeing firmasına ait olan arayüz yük hesaplama programı ve TSI firmasına ait olan giriş eğilme analizi programı kullanılacaktır. Boeing'in arayüz yük hesaplama programı koltukların arka ayakları üzerine gelebilecek en yüksek yükler hakkında bilgi verirken TSI firmasının programı arka girişler üzerindeki belirli noktalara gelebilecek yüklerin karşılaştırmasında yardımcı olmaktadır.

Bu iki program yardımıyla her bir aileden bir adet koltuk en fazla yüklere maruz kalabileceği düşünüldüğü için seçilmiştir. Sonuçta beş adet koltuk seçimi yapılmış ve bu beş adet koltuk ile tüm uçağın ekonomi koltuklarının elverişliliği doğrulanacaktır. Burada seçilen koltuklar statik testlerin tamamında, dinamik testlerin ise sadece 14.0g düşey testleriyle 16.0g boylamsal testlerinde kullanılacaktır.

Statik testlerde, koltuğun ve yolcunun mevcut ağırlıkları göz önünde bulundurularak belirli yük faktörleriyle çarpılarak kuvvet değerleri belirlenir. Bu kuvvetler koltuğun ön, arka, yan kısımlar, alt ve üst kısımlarına uygulandığında koltuk üzerinde çeşitli noktalarda deformasyonlar oluşur. Bu deformasyon değerleri ikili bir uçak yolcu koltuğu için 23 noktada, üçlü bir koltuk için 27 noktada incelenir. X ve Z yönündeki deformasyonların 3 inç'ten, Y yönündeki deformasyonların 1.5 inç'ten küçük olması gerekmektedir. Bu değerlendirme dinamik testler için de geçerlidir.

Dinamik testler de dört ayrı grupta değerlendirilecektir. Bunlar 14.0g düşey testleri, 16.0g boylamsal testleri, HIC (baş yaralanma kriteri) testleri ve baş yolu testleridir. 14.0g ve 16.0g testleri için daha önce belirlenen test koltukları kullanılmaktadır. Fakat HIC ve baş yolu testlerinde bunlardan farklı koltuklar kullanılır. HIC testleri birbiri ardına sıralan iki sıra koltuğun 16.0g koşulları altında değerlendirilmesi hususunu dikkate alır. Bu testlerde arka koltuğa yerleştirilen cansız mankenin darbe anında kafasını ön koltuğa çarpma durumu incelenir. HIC için belirlenen 1000 değerinin aşılmasına dikkat edilir. Yolcu koltuklarının ekranlarının büyütülmesi sebebiyle sonucu en çok merak edilen test HIC testleridir. Çünkü yolcunun başını ön koltuğa çarpması sonucu herhangi bir zarar görmemesi için HIC değerinin 1000 altında olması gerekmektedir. 1000'in üzerindeki değerlerde ölümlerin görülme olasılığı oldukça yüksektir.

HIC testlerinde mankenin başının koltuğun üçlü farklı bölgesine çarpması beklenir. Koltuk arkadası bölge A, bölge B ve bölge C olmak üzere gruba ayrılır. Baş test sırasında bu noktalara temas etmezse bazı şartlar değiştirilerek testler tekrarlanır. Mankenlerin yüzleri çarpmanın hangi noktada gerçekleştiğini tespit edebilmek için farklı renklere boyanmaktadır.

Baş yolunun incelendiği dinamik testlerde sadece ön sıra koltuklar teste tabi tutulur. Bu testlerde yolcunun başının önünde bulunan düz yüzeye çarpmaması beklenir.

Dinamik testler ayrıca bel, uyluk gibi noktalara gelebilecek yüklerin de değerlendirmesini yapmak için ideal testlerdir. Mankenin beline gelen yük 1500 lb'yi uyluğa gelen yük 2250 lb'yi geçmemelidir.

Uygulanan testler sonrası statik testlerde mutlak başarı sağlanmıştır. Dinamik testlerde ise birkaç istenmeyen durumla karşılaşmıştır. Fakat bunların bir kısmı izin verilen limitleri aşmadığı için testin başarılı olmasına engel değildir. Diğer sorunlu test koltukları da bazı yeni parçalar kullanılarak yeniden test edilmiştir ve istenen başarı sağlanmıştır.

TSO/ETSO onayı alabilmek için bu test sonuçlarıyla birlikte başvuru gerekli otoritelere yapılmıştır ve değerlendirilmesi beklenmektedir.





1. PART / DEVICE CERTIFICATION PROCESS IN AVIATION

Standard parts are manufactured as per international industrial standards and also do not require special aviation certification, but these parts must be approved by the device or product design organization that will be used. Except for standard parts, all parts / devices particular to aircraft must be certified either individually or together with the aircraft.

Two different methods can be followed for the certification of parts / devices:

- a) **ETSO approval received by parts / devices manufacturer:** Manufacturer makes an application to DGCA for ETSO approval. Concurrently, ADOA and POA applications are also required for design and production capability demonstrations and these approvals must be received before ETSO approval. If the manufacturer has already aforementioned approvals, an application is made for scope extension. The manufacturer manages these processes under the supervision of DGCA.

The advantages of this method;

- The manufacturer become certificate holder.
- The manufacturer can market the parts / devices directly.

The disadvantages of this method;

- Process and cost are relatively more difficult.
- The manufacturer can carry out certification without agreement with aircraft manufacturer.
- Additional activity is required for the part / device to use on aircraft.

- b) **ETSO approval received by aircraft manufacturer:** Aircraft type /supplemental type certificate holder manages the process of part / device designed to be integrated into the aircraft as part of own certification process and in this context, it reflects relevant requirements to the company. In this

case, the company does not need to receive ETSO, ADOA from authority. POA application can be made or followed the process without POA as a subcontractor of aircraft product organization. The aircraft design holder manages the process, the company participate in the process to provide support at necessary points.

The advantages of this method;

- Cost is relatively low.
- An agreement can be reached with aircraft type / supplemental type certificate holder without certification.

The disadvantages of this method;

- Part / device design and manufacturing difficulties without having full knowledge of aircraft certification process.
- Aircraft manufacturers prefer companies with experience in the aviation industry in their subcontractor selection.
- In this method, the designed part / device can just be marketed to the contracted aircraft type / supplemental type certificate holder. (SHGM Havacılıkta Parça ve Cihaz Sertifikasyonu Rehber Dökümanı, 2018).

1.1 Descriptons and Terms

Certification: Certification generally means approval and documentation of the suitability of users, processes, products, services. Certification term is used in many subjects. The certification term used in this thesis refers to airworthiness certification by DGCA.

Airworthiness: In accordance with national and international rules, airworthiness is the ability of an aircraft to start, maintain and terminate its flight safely within the approved usage conditions and restrictions without any danger to the flight crew, ground crew, passengers, the region where it flies and other aircraft flying.

Airworthiness Certification: It is a systematic process applied to determine the availability of an aircraft system under defined operating conditions and resulted in a decision documented by the authority. Within the scope of airworthiness certification

for products, parts and devices, type certificate, supplemental type certificate, ETSO approval is published.

Type Certificate: It is the document issued by DGCA that determines the compliance with the design criteria and airworthiness requirements for aviation products. The requirements for type certificates are described in detail in SHT-21 Subpart B. (SHGM SHT-21 Altbölüm B – Tip Sertifikaları ve Tahditli Tip Sertifikaları, 2018)

Supplemental Type Certificate: It is the document issued by DGCA when major design changes made to the type certified product are shown to comply with the relevant requirements. The requirements for type certificates are described in detail in SHT-21 Subpart E. (SHGM SHT-21 Altbölüm E – İlave Tip Sertifikası, 2018).

Design Organisation Approval (DOA): It is a prerequisite for the applications listed below by DGCA;

- Type / Limited Type Certificate
- Supplemental Type Certificate
- Major Repair Design
- ETSO application for auxiliary power unit (APU)
- Approval of aircraft minor changes and repair

As design organisation complies with SHT-21 requirements, approval is issued by DGCA. DOA requirements are defined in SHT-21 Subpart J. (SHGM SHT-21, Altbölüm J – Tasarım Organizasyon Onayı, 2018).

DOA is a prerequisite for obtaining and maintaining the Type Certificate and Supplemental Type Certificate. DOA provides certain privileges to design organisation to carry out activities such as desinging, approving design changes on behalf of DGCA. DOA privileges are given to legal entities.

Alternative Design Organisation Approval (ADOA): It is an approval given by DGCA to the company that designs the product, parts, devices and the changes / repairs to be made after compliance with the requirements of SHT-21; 21.A.14 (b,c); 21.A.112B (b,c); 21.A.432B (b,c) and 21.A.602B (a). (SHGM SHT-21, Altbölüm B – 21.A.14; Altbölüm E – 21.A.112B; Altbölüm M – 21.A.432B; Altbölüm O – 21.A.602B Kabiliyet Gösterimi, 2018).

The most important difference between DOA and ADOA is that privileges owned at DOA are not available in ADOA.

The activities required for ADOA are less than the requirements of DOA. ADOA is only used for products, parts / devices specified by DGCA.

ETSO and Its Requirements: ETSO describes the approval procedures of some parts / devices to be installed on the ETSO aircraft. ETSO approval demonstrates compliance of parts / devices with the specified minimum performance standards. (FAA TSO-C127B Technical Standard Order – Rotorcraft, Transport Airplane and normal & Utility Aeroplane Seating Systems, 2014), (EASA ETSO-C127B European Technical Standard Order – Rotorcraft, Transport Airplane and normal & Utility Aeroplane Seating Systems, 2016).

ETSO approval holder;

- will implement the alternative procedure for demonstration of capability under the DOA and,
- will have Product Organisation Approval (POA) as part of SHT-21 Subpart G, (SHGM SHT-21, Altbölüm G – Üretim Organizasyon Onayı, 2018) or,
- will contact with independent POA holder under an agreement, or,
- will perform the procedure under Subpart F. (SHGM SHT-21, Altbölüm F – Üretim Organizasyon Onayı Olmadan Üretim, 2018).

Production Organisation Approval (POA): It shows the compliance of the company having production responsibility with applicable requirements within the framework of SHT-21 Subpart G. (SHGM SHT-21, Altbölüm G – Üretim Organizasyon Onayı, 2018).

Within the scope of SHT-21; 21.A.139, the production organization must demonstrate that it has established and maintained a quality system. (SHGM SHT-21, Altbölüm G - 21.A.139 – Kalite Sistemi, 2018).

This quality system;

- must be documented,
- must ensure airworthiness,

- include independent quality assurance function to monitor compliance with written procedures and adequacy of procedures.

POA approval requirements detailed in SHT-21; 21.A.145 include the following topics. (SHGM SHT-21, Altbölüm G - 21.A.145 – Onay Gereksinimleri, 2018).

- Facilities and resources
- Organization
- Working conditions
- Design data
- Equipment and operations
- Administrative personnel
- Personnel
- Authorized personnel for approval

In accordance with the published approval requirements, within the scope of SHT-21; 21.A.163, POA holder;

- can carry out its production activities within the frame of SHT-21.
- In case of parts or device, it may issue approved output certificates (SHGM Form 1) without additional demonstration. (SHGM SHT-21, Altbölüm G - 21.A.163 – İmtiyazlar, 2018).

POA certificate holder responsibilities are explained in detail in SHT-21; 21.A.165. (SHGM SHT-21, Altbölüm G - 21.A.165 – Belge Sahibinin Yükümlülükleri, 2018).

1.2 Certification Process

The certification process is defined under two main titles as organisation approval and part / device certification.

1.2.1 Organization approval

Organisational structures that have the necessary powers for the execution and finalization of the certification process are described below. The contribution of the organisations whose details are presented in the previous section is mentioned.

- Design /Alternative Design Organisation Approval (DOA-SHT 21J)
- Production Organisation Approval (POA-SHT 21G)

1.2.1.1 Application process for design / alternative design organization approval

In order to become a design organisation, applications are made to DGCA with relevant application forms. During the audit process, the following informations is also provided to DGCA;

- SHGM Form 4 – Approval Form of the management personnel
- Design Organisation Handbook and Procedures.

1.2.1.2 Application process for production organization approval

In order to become a production organisation, applications are made to DGCA with relevant application forms. During the audit process, the following informations is also provided to DGCA;

- SHGM Form 4 – Approval Form of the management personnel
- Production Organisation Handbook and Procedures.

1.2.1.3 The relationship between design and production organizations

A production organization needs a design data from the design organization authorized by the same authority to be able to produce. The production organization is always obliged to comply with this data from the design organization. The whole relationship between the two organization is determined by an agreement between design organization and production organization within the frame of SHY-21 rules. Organizations clearly define their responsibilities by sharing their procedures with each other. The points highlighted in this agreement are as follows;

- **The responsibilities of design organization:** It provides approved design data with with a visible declaration, assuring that the approved design data will be updated and timely.
- **The responsibilities of production organization:** It provides support to the design department in terms of continuous airworthiness and certification compliance.
- **Shared responsibilities by design and production organization:** In production deviations and nonconformities, both organizations must act in accordance

with their procedures. They take the responsibility for the configuration control of the produced part / device and the production according to the design data.

- **Scope of the work to be done with this agreement:** The production organization has the authorization to produce only for the products specified under this agreement. It is usually determined on the basis of the part number.
- **Approved design data transfer:** Approved design data for production must be provided to the production organization in a controlled manner by the design organization. This method should be clearly stated in the procedures.
- **Direct delivery authorization:** The production organization must obtain this authorization from design organization in order to deliver the part it produce directly to the end user.

The relationship (document delivery, production incompatibilities etc.) between these two organizations should be recorded. In this context, the procedures and forms specified in the agreement of both organizations must be used signed by authorized persons and archived.

1.2.2 Part / device certification

As per DGCA rules, any part /device that does not have the necessary certification can not be installed to aircraft. Some examples for part /device that require certification are presented below;

- Main monuments such as seat, galley, lavatory, stowage bins.
- IFE server, VHF transceiver radio,
- Cabin lights,
- Galley equipments (Standard Unit, oven, hot cup etc.)
- Textile parts (Carpet, curtain, seat covers etc.)
- Metal and plastic parts
- Harness (Wiring)
- Ventilation system components

Parts / devices to be installed to the aircraft are produced by the authorized production organization (or produced by appropriate subcontractors of production organization) and DGCA Form 1 is published for these parts / devices.

DGCA Form 1 is not required for standard parts. When it comes to parts certification, just requirement to publish Form 1 should not be understood.

DGCA Form 1 means “authorised release certificate”. It is a document showing that the part has been produced in accordance with the approved design data. Just having the DGCA Form 1 certificate of the produced part or device is not enough to be installed to the aircraft. An integration project approved by the Design Organization is required for a part /device to be installed to the aircraft. While the certification process of ETSO parts /device does not require an integration project, certification for non-ETSO parts /devices must be completed within a project. Figure 1.1 shows a sample of SHGM Form 1.

1. Approving Competent Authority / Country Turkish DGCA / Turkey		AUTHORISED RELEASE CERTIFICATE SHGM FORM 1			3. Form Tracking Number 852016000723
4. Organisation Name and Address: TURKISH TECHNIC TURKISH TECHNIC INC. Ataturk Airport Gate B 34149 Yesilkoy / ISTANBUL / TURKEY				5. Work Order/Contract/Invoice 1470249	
6. Item	7. Description	8. Part No.	9. Qty.	10. Serial No.	11. Status/Work
1	MICROWAVE OVEN HARNESS MANUFACTURING	TPO-TT-2531001-11	1	N/A	New
12. Remarks Manufactured as per design data: CL-2531001-DG08 Rev.00 (ref. design approval no: CL-2531001-DA01-00)					
13a. Certifies that the items identified above were manufactured in conformity to: <input checked="" type="checkbox"/> approved design data and are in a condition for safe operation <input type="checkbox"/> non-approved design data specified in block 12			14a. <input type="checkbox"/> Part-145.A.50 Release to Service <input type="checkbox"/> Other regulation specified in block 12 Certifies that unless otherwise specified in block 12, the work identified in block 11 and described in block 12, was accomplished in accordance with SHY-145 and in respect to that work the items are considered ready for release to service		
13b. Authorised Signature  		13c. Approval/Authorisation Number TR.21G.001	14b. Authorised Signature		14c. Certificate/Approval Ref. No
13d. Name ALI KULAÖGLU		13e. Date (dd/mm/yyyy) 08Apr2016	14d. Name		14e. Date (dd/mm/yyyy)
USER/INSTALLER RESPONSIBILITIES					
This Certificate does not automatically constitute authority to install. Where the user/installer performs work in accordance with regulations of an airworthiness authority different than the airworthiness authority specified in block 1, it is essential that the user/installer ensures that his/her airworthiness authority accepts items from the airworthiness authority specified in block 1. Statements in block(s) 13a and 14a do not constitute installation certification. In all cases aircraft maintenance records must contain an installation certification issued in accordance with the national regulations by the user/installer before the aircraft may be flown.					

Figure 1.1 : SHGM Form 1 Sample.

The Certificate of Conformity (CoC) prepared by organization that owns a POA within the scope of SHT-21 or has an adequate quality system is a document that shows the

compliance of the product, part or device with the minimum regulation, technical and safety requirements. Figure 1.2 shows a sample of CoC.

Certificate No :					
<i>_____ hereby certifies that the System herein delivered has been inspected and is in compliance with all applicable implied or included requirements of Contract:_____ .</i>					
<i>_____ further certifies that the new installed/integrated avionics sub-systems for which relevant <u>COC's</u> are attached hereto, are of the quality specified, produced of new parts, and conform to all Contract requirements, including specifications, drawings, preservation, packaging, packing, marking requirements and physical item identification .</i>					
SIGNATURE(S)	:	<u>Part No</u>	<u>Description</u>	<u>Quantity</u>	<u>Serial No.</u>
NAME(S)	:	.....	.....	.....	.....
TITLE(S)	:	.....	.....	.....	.....
DATE	:	.....	.....	.....	.....

Figure 1.2 : Certificate of Conformity Sample.

The following items must be provided in summary in order to publish DGCA Form 1 to a part / device;

- The equipment must be designed by the design organization (or by its subcontractor)
- The equipment must be produced by production organization (or by its subcontractor)
- The history of the sub-parts of the part / device must be traceable and comply with aviation standards.

1.2.2.1 Requirements for installation of parts / devices to aircraft

- Integration design must be made by Design Organization.
- The part / device to be installed must have DGCA Form 1.
- Devices to be installed must be tested according to the applicable categories of RTCA DO-160 (Environmental Conditions and Test Procedures for Flying Devices)
- It must be shown that integration of the parts / devices to be installed by Design Organization does not reduce the safety of aircraft. For this reason, the part / device to be installed is subjected to many evaluations. For example;

- Evaluation of whether the part / device meets the airworthiness requirements (seat that can withstand 9G / 16G, other functions of the aircraft are not impaired while the device is operating).
- Evaluation of the nonflammability of the part /device
- Comparison of the environmental and electrical certification levels of the part / device with the section which part / device will be installed in the aircraft.
- Evaluation of whether there are suitable parts / devices to install to an aircraft (eg: voltage drop in cables is acceptable, circuit breaker trip curves meet requirements, etc.)

After determining the aircraft to be implemented, the part / device to be integrated and its location, the requirements from the aircraft are revealed and the minimum conditions that the part / device must perform are determined. Necessary certification tests, acceptance tests, structural analysis, reliability analysis, etc. should be completed.

1.2.2.2 Required process for part / device certification and roadmap

Part / device certification can be performed under one of the three main items;

- As part / device with ETSO approval
- With application under type certificate (with aircraft design organization authorization)
- With supplemental type certificate (STC-major change) or minor change by a design organization.

As seen in Figure 1.3, Part Certification Roadmap describes the basic process and alternatives for the certification of a part. The subject of which the parts / devices whose certification is completed and DGCA Form 1 released will be applied to which aircraft is related to the operator (aircraft owner, airline, etc.) who wants to use this part in the aircraft and design organization that will make the integration project.

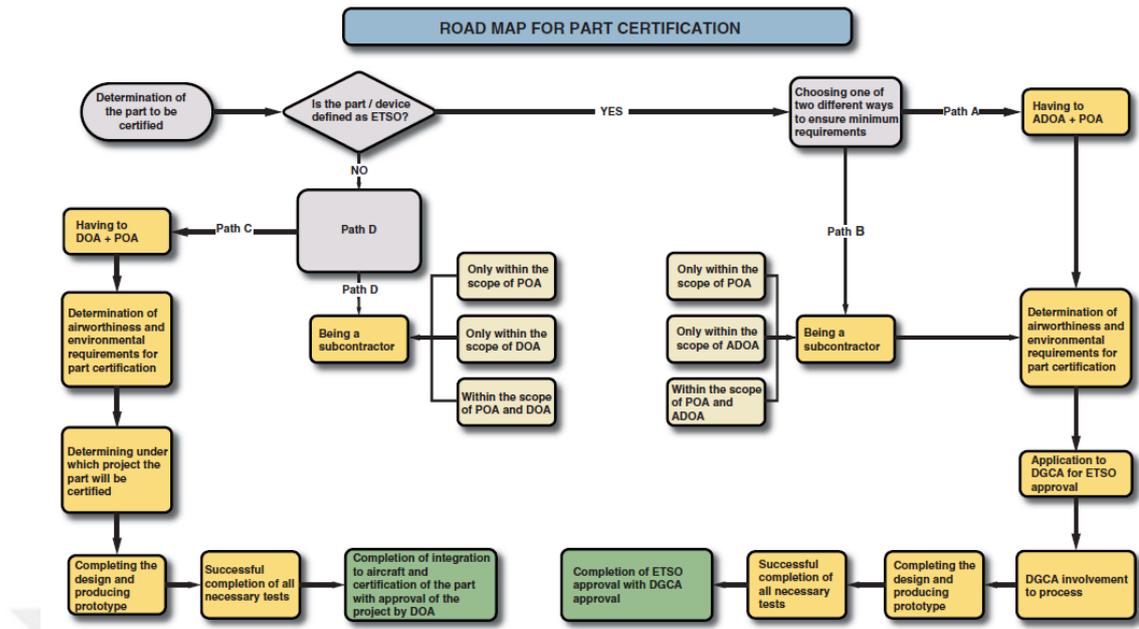


Figure 1.3 : Part / Device Certification Roadmap.

Path A: When this path is selected, the part / device to certified must be in the ETSO category. The company that will do the certification already has ADOA and POA. After all ETSO requirements (there may also be additional requirements) related to the part are determined, an application is made to DGCA to start the relevant ETSO approval process. DGCA is involved in the process. The design is completed and the prototype is produced. Necessary test processes are completed. After the successful completion of the test processes, all necessary results and reports for ETSO approval are provided to DGCA. With the approval of DGCA, it completes the part / device certification process and gets ETSO approval. Now production can be made for this part / device and SHGM Form 1 can be published.

Path B: When this path is selected, the part / device to be certified must be defined as ETSO. Most of the process is the same as Path A. The only difference is that the company that wants to do this job does not have ADOA and/or POA. In this case, under the roof companies with these power, this can do job. The method for this to be subcontractor of the approved companies. Issues related to the design and sales rights of the part / device should be discussed with company that has the approval.

Path C: When this path is selected, the part / device to be certified is not defined as ETSO. ETSO application can not be made because the part is not covered by ETSO.

In this case, the relevant company must have DOA and POA. Although the part / device has not ETSO approval, there are defined requirements for airworthiness and environmental conditions that must be met. In accordance with these requirements, the design is made by design organization. Design organization designs the part or device and carries out the integration process to the aircraft. Production organization produces prototypes, the necessary tests are carried out by design organization and the part is certified with approval of the project. Mass production can be done through production organization.

Path D: When this path is selected, the part / device to be certified is not defined as ETSO. Most of the process is the same as Path C, but the company that wants to do the job does not have design and production organization approvals. In this case, it can perform this work under the roof of companies with these powers. The method for this is to be the subcontractor of the approved companies. Issues related to the design and sales rights of the part / device should be discussed with the company that has the approval.

1.3 ETSO Process

The company, which is preparing to produce ETSO approved material, should apply to DGCA by showing its capability for the part / device to be produced. The applicant must submit documents containing the following information and documents to DGCA for ETSO authorization.

- Declaration of conformity showing that it meets the requirements.
- Declaration of Design and Performance (DDP)
- Technical data file
- Handbook in accordance with SHT-21 Subpart-F or POA handbook in accordance with Subpart-G.
- Detailed procedures referenced in the handbook.

The company that has ETSO authorization should have a procedure to classify the design changes as major and minor and should apply to DGCA to authorize a new ETSO for the major design changes.

ETSO Applicant's obligations are as follows;

- Compliance with design data and securing product safety,
- Archiving product technical data and records and securing production according to current data,
- Preparation and updating of all manuals required by airworthiness specifications,
- Preparation and updating of the manuals required for the usage and maintenance of ETSO approved material, ready and easily accessible to DGCA in case of user and demand,
- Marking of ETSO approved material,
- Reporting any incident, malfunction, defect or error to DGCA that may adversely affect or possibly affect airworthiness
- Ensuring the airworthiness
- Coordination between design and production
- Meeting requirements for capability demonstration.

After the completion of the ETSO application process, the owner of the ETSO will have the right to produce with proper marking.

1.3.1 Authorization period and validity

ETSO authorization is published indefinitely by DGCA and remains valid unless the following issues are met;

- Loss of the conditions owned when ETSO authorization is obtained,
- The authority holder can not fulfill its obligations,
- ETSO approved material endangers airworthiness and flight safety,
- Suspension or cancellation of authority by DGCA,

ETSO authority can not be transferred under any circumstances (except ownership change).

1.3.2 Declaration of design and performance

Declaration of Design and Performance (DDP) must be submitted to DGCA prior to receiving ETSO. DDP is submitted to DGCA approval by specifying the date with the signature of the ETSO authority holder or its representative. DDP should contain the following information;

- Design and testing standard information of the part / device,
- If appropriate, calculated performance information of ETSO approved material,
- Declaration of conformity to ETSO requirements,
- Related test reports,
- Related maintenance and repair manuals,
- Compliance level information
- Deviation list

1.4 The Process of Being A Subcontractor

1.4.1 The process of being a subcontractor for POA

Subcontractor: It refers to the persons or institutions that will produce any part, device, system under the authority and supervision of another POA holder. The company that wants to manufacture any aircraft part must either have its own production organization authority or be a subcontractor of an authorized production organization. Although there is no universal consent requirement set out in the legislation to become a production organization subcontractor, each DOA holder determines, documents and imposes it to the authority. Companies that will be subcontractors are expected to have a quality management system. Although minimum ISO9001 certificate is requested, it is recommended and encouraged to obtain AS9100 Aviation and Space Industry Quality Management System certificate customized for aviation industry. Moreover, it has been obligatory to obtain the AS9100 certificate by some POA holder (e.g. Airbus, Boeing, TAI etc.)

Regardless of the AS9100 requirement, every subcontractor candidate must have a system within its business scope to secure the following process:

- Publishing, approval and amendment of documents
- Supplier and subcontractor evaluation, audit and control
- Verification of incoming products, parts, material and devices
- Part identification and traceability
- Identification of production processes
- Inspection and acceptance tests
- Management of calibrated tools and devices
- Inappropriate product control
- Control of production records
- Personnel competence
- Transport, storage and packaging
- Internal quality audits and corrective actions

The subcontractor will be audited by the POA holder under the above terms. The detected nonconformities are eliminated by the company and presented to the POA holder. So, the approved company is authorized as a subcontractor and included in the approved subcontractor list of the POA holder. The POA holder is responsible for the realization of the production carried out in the subcontractor company in accordance with all requirements. The subcontractor company performs its production activities under the authority of POA holder.

Due to this situation, the subcontractor company is obliged to permit the audit if a request is made by POA holder and DGCA to perform planned or unplanned audits.

1.4.2 The process of being a subcontractor for DOA

In case of need, DOA holder can identify the companies that will carry out their design and testing activities on their behalf and authorize them as subcontractor. The subcontractor of DOA can perform the following activities according to its capability and scope of authority;

- Preparation of part / device or system design data to be approved within the scope of TC, STC or the amendment to TC.

- Performing of the activities to be carried out in order to demonstrate compliance with the certification requirements and preparation of relevant documents (Analysis report, test programs etc.)
- Providing support to DOA for continuous airworthiness management and preparation of necessary technical documents (service bulletin, maintenance guide etc.)

The DOA subcontractor candidate should have a system within its scope of work to secure the following processes:

- Project management
- Reporting errors, faults and defects (incident reporting)
- Coordination between design and production
- Management of nonconformity
- Management of inspection and tests
- Keeping records
- Configuration management
- Personnel competence and signature rules management
- Suitability and performance of technical and airworthiness outputs
- Management of subcontractor
- Continuous airworthiness management
- Internal audit and finding management

Considering the result of the evaluation, DOA holder forms the supervision and inspection plans by shaping the business relationship with subcontractor company. (SHGM Havacılıkta Parça ve Cihaz Sertifikasyonu Rehber Dökümanı, 2018).

2. QUALIFICATION TESTS FOR AIRCRAFT PASSENGER SEATS

In order to receive TSO / ETSO, a guarantee should be given that the monument to be installed to aircraft will not create an obstacle to airworthiness in no way. The relevant test reports must be submitted to the authorities within the scope of design performance declaration of monument with the application made in this process. Before starting the tests, it is necessary to know the minimum performance standards, qualification requirements and minimum documentation requirements of aircraft seats. The main purpose here is to provide durability, passenger protection and comfort under operational loads and define test and evaluation criteria to demonstrate passenger protection when a seat system is subjected to statically applied ultimate loads and dynamic impact test conditions stated in the applicable Federal Regulations 14 CFR 25. In addition, relevant flammability test reports should be submitted to the authority with these test reports. The purpose of this thesis is to publicize uniform techniques for seat certification and create a guideline for interpretation of test procedures, measurements, equipment and results to obtain acceptable data. It is very important to know the test procedures exactly, to make the measurements accordingly and to interpret the test results in order to keep the minimum number of tests and obtain acceptable data. The responsibility of the seat manufacturer comprises of meeting all performance requirements of the seat system and providing all data to the relevant civil aviation authority and aircraft manufacturer.

TSI company carries out these tests in three different locations. Asım Kibar Organized Industrial Zone in Kocaeli city of Turkey, NIAR and MGA Research Corporation in America are test facilities for this purpose.

The test set-up is verified by FAA DER and their designees. They witness all tests.

2.1 Deformation Criteria

Allowable permanent deformations experienced by a seat that is subjected to ultimate static tests or dynamic impact tests must be measured properly and met the test fail criteria. Measuring points on the test seat should be defined and labelled. Their location measured in the lateral, vertical and longitudinal directions relative to fixed points on the test fixture should be determined. Such measurements should be recorded before and after the tests. The distance between the pre-test and post-test measurements should be reported as permanent deformations. In dynamic tests, floor deformations should be examined according to pre-test and post-test measurements.

2.1.1 Longitudinal direction

The longitudinal measurement for the forward direction shall be carried out at the forward most hard point(s) of the seat at a height up to and including the armrest. If the seat has not an armrest, this measurement should be done for seats at 25 inches (635 mm) above the floor. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

2.1.2 Downward direction

There is no restriction on permanent deformation downward if it can be shown that the passengers' feet or legs will not be injured or entangled by the deformation, seat design can ensure sufficient clearance for that deformation, taking account of the possible existence of under-seat baggage or stowed objects.

2.1.3 Seat rotation

The rotational permanent deformation of the seat bottom shall not result in an angle that exceeds 20 degrees pitch down or 35 degrees pitch up from the horizontal plane. This rotational deformation shall be determined at the centerline of each seat bottom between the front and back extremities of the seat pan. Figure 2.1 reflects this situation visually. Rotation of the seat pan shall not cause trapping of the passenger. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

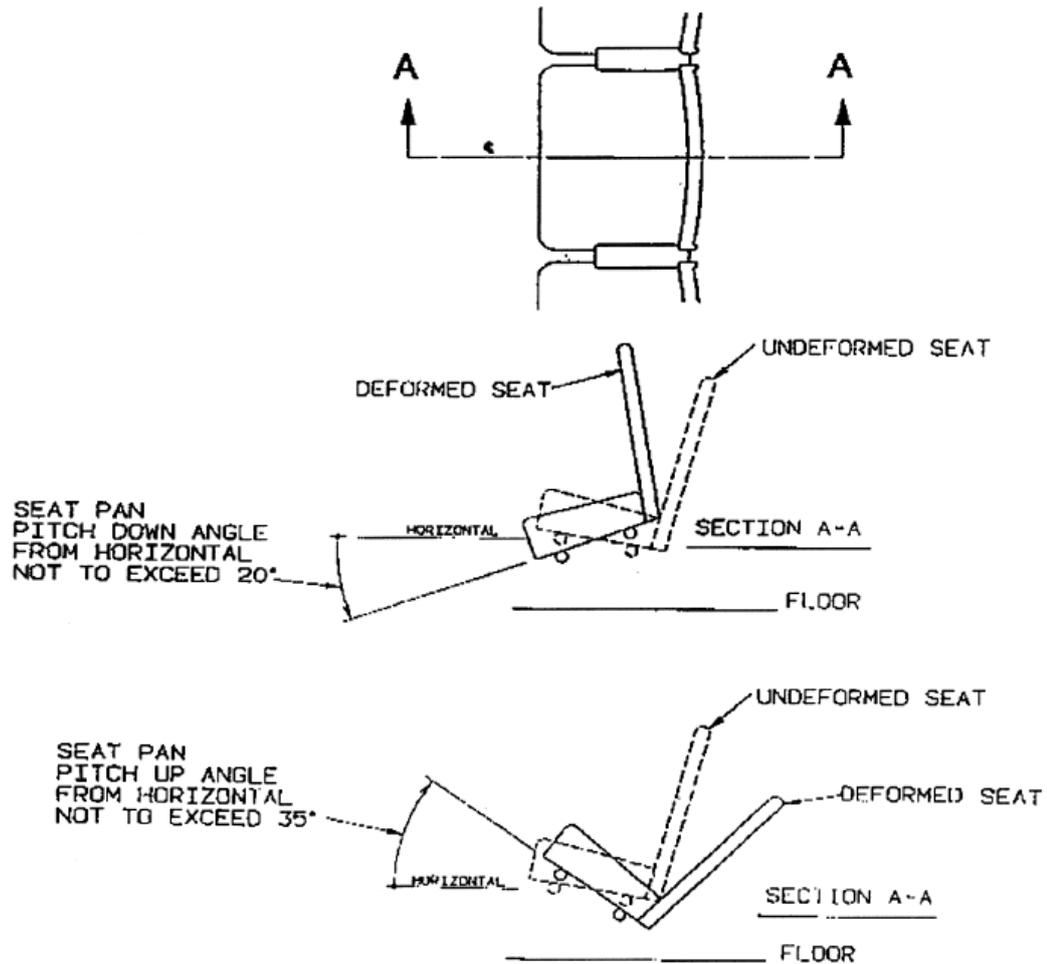


Figure 2.1 : Seat pan rotation.

2.1.4 Sideward direction

The maximum lateral permanent deformations towards an corridor should be measured at heights below 25 inches (635 mm) above the floor and at heights 25 inches (635 mm) or more above the floor. Determining of which parts of the seat are at what heights is done before the test and prior to applying floor deformation. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

2.1.5 Other deformation limits

In line with the information received from SAE 8049 Rev.C (2015), “The most forward surface of a seat back centerline must not bend to a point greater than one half the original point to the forward-most hard structure on the seat that supports the seat

bottom cushion.” (p. 9). This situation is indicated visually in Figure 2.2. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

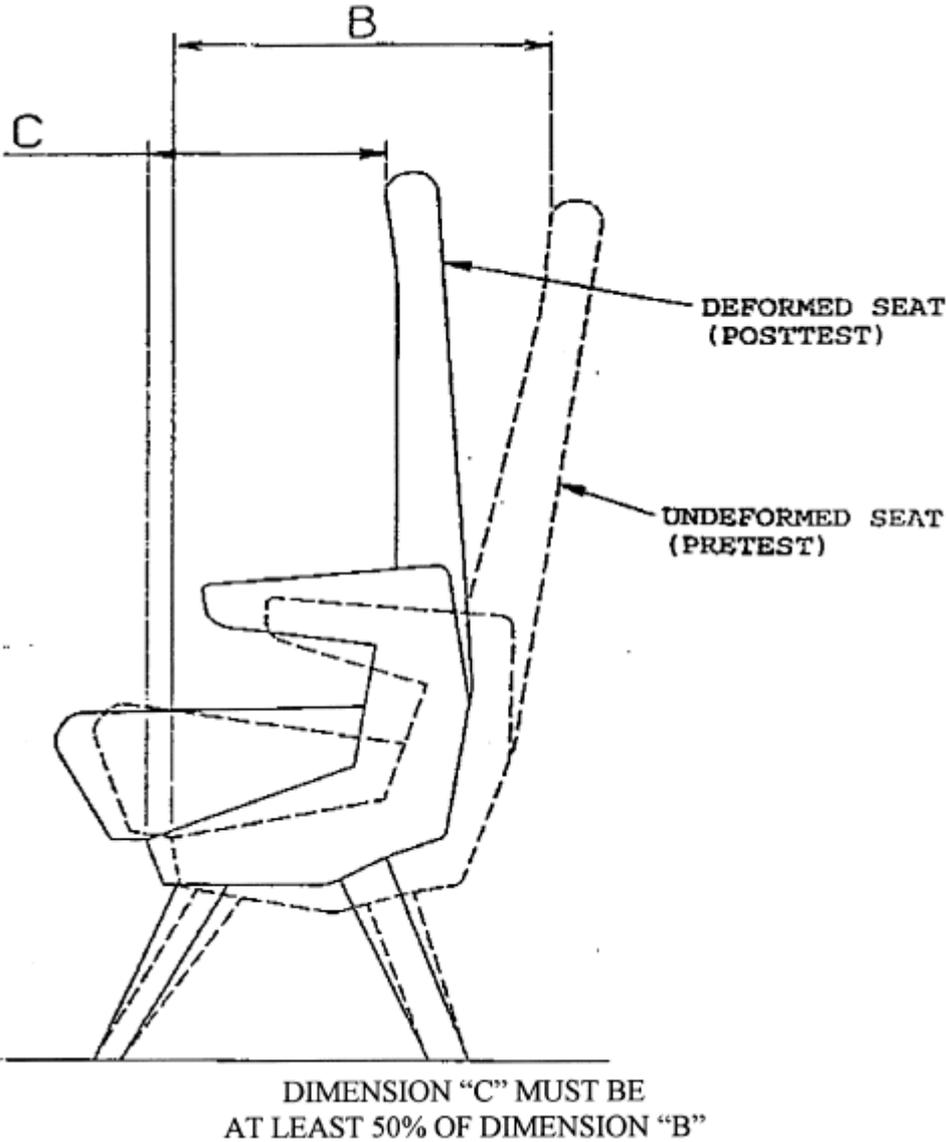


Figure 2.2 : Maximum seat back permanent deformation (Applicable for forward facing seats only).

The components that make up the seat family and specified in Figure 2.3 are located on the seat primary load path. In the event that these components are damaged after the tests, they must be performed again by using a new type of component. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, 2015).

Primary Load Path Elements

Other Primary Load Path Elements (not pictured):
Seat Back
row to row HIC
Primary load path for a ft facing seats
Attach Fittings
e.g., between spreaders and beams
Bottom Cushion
Seat Pan

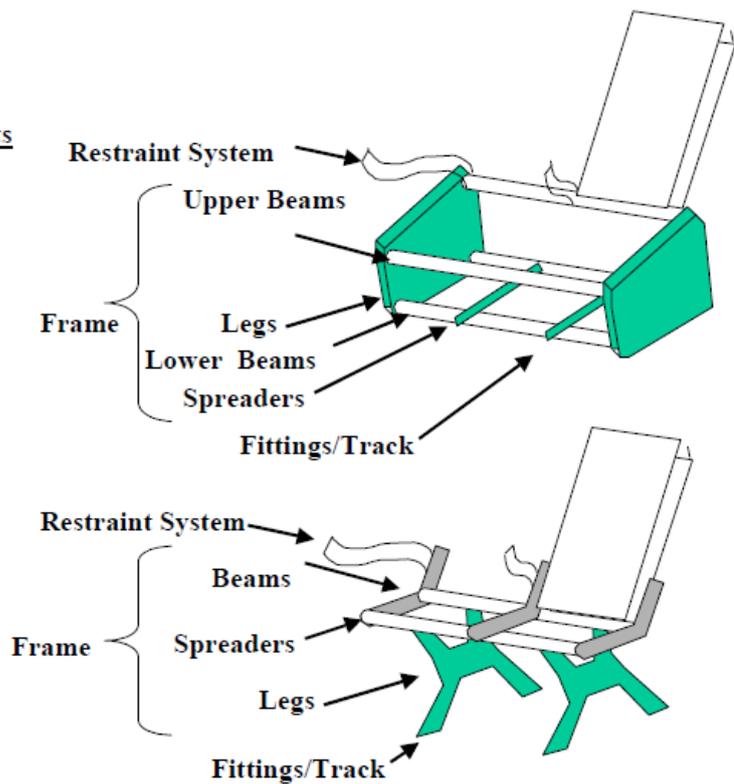


Figure 2.3 : Primary load path elements.

2.1.6 Deployable Items

Some items on the seat, such as legrest, food tray tables, arm caps over in-arm tray tables, etc., are used by passengers in flight and are required to be stowed for taxi, takeoff and landing. Deployment of these items should be accepted as permanent deformation if the item is deployed to an area that several passengers are expected to use for evacuation. The position of the measurement point used to assess the deformation of the deployed item shall be either at the point complete deployment or at the actual deployment point if a partially deployed item resists further deployment when a static load of 10 pounds (45 N) is applied along the inertial load path direction. These deployments can be considered acceptable, if they are easily pushed out of the way by normal movement of passenger, and remain in a position which does not affect exit (i.e., when moved out of the way it stays in that point). Regular movement of passenger is the act of the seated occupant getting up out of the seat and going to leave the aircraft. It does not include any additional movements for lifting or stowing items, or latching an item in place. Any items that remain in an egress-affected position shall be reported as permanent deformation.

If the food tray table is deployed during a row-to-row HIC check as a result of being hit by the ATD head and the food tray table is easily pushed out of the way, the deployment is appropriate and does not need to be treated as permanent deformation. If the food tray table is deployed during the check as a consequence of being hit by the ATD head and the food tray table is not easily moved out of the way, the deployment shall be accepted as permanent deformation. Where the food tray table is deployed, but not as a result of ATD head hit, the deployment shall be treated as permanent deformation. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

2.2 Strength

Aircrafts can be seriously damaged during an emergency landing to land or water, but cabin interior equipments must be designed to protect the passengers from any potential hazard under these conditions. For this reason, structures such as seats should be able to give an opportunity to passengers to avoid serious injuries in landing which minor collisions can occur. (EASA CS-25 Certification and Specifications and Acceptable Means of Compliance for Large Aeroplanes, CS 25.561 Emergency Landing Conditions-General, 2012).

All seats must be withstand both statically and dynamically applied loading operation within the criteria specified below.

2.2.1 Static load requirements

This section will determine the load conditions that FU12 model seats must withstand. Seats should be designed by testing or appropriate analysis to withstand the final loads determined using the load factors specified in Table 2.1 quoted from SAE AS8049 Rev.C (2015). In addition to sum of each passenger weight specified in this table, the total weight of the seat (including all equipment and accessories) and total weight of any item of mass restrained by the seat (e.g., under-seat baggage, stowage compartment weight plus the weight of contents, literature pocket content weight, etc.), all of them multiplied by the appropriate load factor in Table 2.1 should be applied to the seat. The column for type A-T seats which shows transport airplane category will be considered within the scope of this thesis. (SAE AS8049 Rev.C

Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

Table 2.1 : Ultimate load factors and passenger weight.

		Type A-T Seat Airplane (Transport Category)
Load Direction	Forward	9.0
	Sideward	4.0
	Upward	3.0
	Downward	6.0
	Aftward	1.5
Passenger weight		170 pounds (77 kg)

The strength of fittings (a part or terminal used to connect one structural component to another) in the seat and occupant restraint for ultimate load conditions shall be 1.15 (where proven by analysis) or 1.0 (if demonstrated by test) times the ultimate load factors shown in Table 2.1. This situation is valid for the strength of seat attachments to the aircraft structure and passenger restraint attachments to the seat or aircraft structure. In such case, load factors should be 1.33 times of specified loads. However, 1.33 fitting factor stated in Table 2.1 is already involved in the 4.0 g sideward load factor for type A-T seats subject to this thesis. All other special factor such as 1.15 fitting factor, bearing, casting, etc. should be included in ultimate 4.0 g sideward load factor and all other load factors stated in Table 2.1.

Where a part needs more than one special factor, the maximum applicable factor shall be used and not a combination of the applicable factors. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

The load factors, which have been reported so far, are specified in a standard way for the general of standard aircraft. However, these loads may vary depending on aircraft type and model.

Boeing/FAA present the static load factors in a more comprehensive manner in Table 2.2 considering the frame ranges for B787 aircraft.

Table 2.2 : Static load factors.

	FWD	AFT	UP	DOWN	SIDE	SIDE + 1.5G DOWN	UP + 1.5G LONG	UP + 0.8G FWD	UP + 1.0G AFT	DOWN +1.5G LONG	DOWN +1.6G AFT	DOWN +1.7G AFT	DOWN +1.7G FWD
14 CFR 25.561 AMDT 25-91	9.0	1.5	3.0	6.0	3.0								
787-8 Galleys, Seats and other furnishings (STA240-STA296)	9.0	1.5	3.0	6.0	3.0	1.7	1.8			5.5			
787-8 Galleys, Seats and other furnishings (STA296-STA802)	9.0	1.5	3.0	6.0	3.0	1.5	1.7			5.9			
787-8 Galleys, Seats and other furnishings (STA802-STA1769)	9.0	1.6	3.0	6.0	3.0	2.0	2.4			6.0			
787-8 Galleys, Seats and other furnishings (STA1769-STA1785)	9.0	1.6	3.0	6.0	3.0	2.0	2.4			5.2	3.0		
787-8 Galleys, Seats and other furnishings (STA1785-STA1880)	9.0	1.6	3.0	6.4	3.0	2.3	2.7			6.6	3.0		
787-9 Galleys, Seats and other furnishings (STA234-STA327.5)	9.0	1.7	3.0	6.0	3.0	1.6	1.0	1.5	1.5	6.4		4.0	3.5
787-9 Galleys, Seats and other furnishings (STA327.5-STA821)	9.0	1.5	3.0	6.0	3.0	1.3	1.3	1.5	1.5	6.6			3.0
787-9 Galleys, Seats and other furnishings (STA821-STA1785)	9.0	1.5	3.0	6.1	3.0	1.7	1.4	2.4	2.4	6.5			
787-9 Galleys, Seats and other furnishings (STA1785-STA1880)	9.0	1.5	3.1	6.4	3.0	2.0	0.8	2.8	2.8	6.5			
787-10 Galleys, Seats and other furnishings (STA234-STA327.5)	9.0	1.7	3.0	6.0	3.0	1.7	1.3	1.5	1.5	6.4		4.0	3.5
787-10 Galleys, Seats and other furnishings (STA327.5-STA1061)	9.0	1.5	3.0	6.0	3.0	1.4	1.3	1.5	1.5	6.6			3.0
787-10 Galleys, Seats and other furnishings (STA1061-STA2241)	9.0	1.5	3.1	6.4	3.0	1.7	2.7	2.3	2.3	6.5			
787-10 Galleys, Seats and other furnishings (STA2241-STA2345)	9.0	1.5	3.7	6.8	3.0	1.9	0.9	2.7	2.7	6.6			
787-8 Galleys, Seats and other furnishings (STA240-STA296)	1.5	1.5	1.8	4.8		1.7		1.5	1.5	3.9			
787-8 Galleys, Seats and other furnishings (STA296-STA802)	1.5	1.5	1.7	4.7		1.5		1.5	1.5	3.8			
787-8 Galleys, Seats and other furnishings (STA802-STA1785)	1.5	1.5	2.4	5.4		2.0		1.8	1.8	4.6			
787-8 Galleys, Seats and other furnishings (STA1785-STA1880)	1.5	1.5	2.8	5.7		2.3		2.1	2.2	4.6			
787-9 Galleys, Seats and other furnishings (STA234-STA327.5)	1.5	1.5	1.6	4.6		1.6	1.0	1.5	1.5	6.0			
787-9 Galleys, Seats and other furnishings (STA327.5-STA821)	1.5	1.5	1.4	4.4		1.3	1.3	1.5	1.5	5.6			
787-9 Galleys, Seats and other furnishings (STA821-STA1785)	1.5	1.5	2.6	6.1		1.7	1.4	2.4	2.4	4.8			
787-9 Galleys, Seats and other furnishings (STA1785-STA1880)	1.5	1.5	3.1	6.4		2.0	0.9	2.8	2.8	5.0			
787-10 Galleys, Seats and other furnishings (STA234-STA327.5)	1.5	1.5	2.7	5.3		1.7	1.3	1.5	1.5	6.0			
787-10 Galleys, Seats and other furnishings (STA327.5-STA1061)	1.5	1.5	2.2	4.8		1.4	1.3	1.5	1.5	5.6			
787-10 Galleys, Seats and other furnishings (STA1061-STA2241)	1.5	1.5	3.1	6.4		1.7	2.7	2.3	2.3	4.9			
787-10 Galleys, Seats and other furnishings (STA2241-STA2345)	1.5	1.5	3.7	6.8		1.9	0.9	2.7	2.7	5.0			

In order to make the tests more reliable, the maximum load factors in all directions specified in table 2.2 can be summarized and applied to the total weight as specified in Table 2.3.

Table 2.3 : Summary of the ultimate load factors.

	FWD	AFT	UP	DOWN	SIDE	SIDE + 1.5G DOWN	UP + 1.5G LONG	UP + 0.8G FWD	UP + 1.0G AFT	DOWN + 1.5G LONG	DOWN + 1.6G AFT	DOWN + 1.7G AFT	DOWN + 1.7G FWD
Ultimate load factors	9.0	1.7	3.7	6.8	3.0	2.3	2.7	2.8	2.8	6.6	-	4.0	3.5

The 3.0 value specified for the side loads in Table 2.3 will be considered as 4.0 for the seats. Up load factors will also be taken into account as 6.0 due to special factor.

Symbolic masses simulating the baggage load should be 9.1 kg (20 pounds) per passenger.

Loads in all directions (forward, side, down, up and aft loads) should be applied separately for at least 3 seconds without any failure.

There are some structure called item of mass (IOM) on the seat. If these structures does not remain on the seat after test, it requires a design change on the seat. The structure which is accepted as item of mass is armrest, food tray (seat back and in arm position), headrest, HPS-DC box, backrest cushion and bottom cushion with dress cover, spreader cover and kick panel, life vest and its box, video monitor, handset. If any part which exceed 3% of the empty weight of the seat (without passenger, life vest, literature pocket, baggage etc.) is detached before the seat achieves peak reaction loads, the test should be repeated.

Some parts such as handset, seat back and bottom cushion, life vest, RJU, IAT housing and mechanism, headrest etc. can be used from tested article to other test article to be tested after the compliance check.

The following notation in Table 2.4 will conform to the forces and coordinates used in this thesis.

Table 2.4 : Sign and coordinate system.

Coordinate	Direction
+X	Aft
-X	Forward
+Y	Right
-Y	Left
+Z	Up
-Z	Down

2.2.2 Dynamic load requirements

As a system, the seat structure, cushions and passenger restraint system should be designed and shown to withstand the dynamic impact test conditions and pass / fail criteria with test or appropriate analysis.

The tests will be carried out by applying 14G and 16G force to the selected seats within the scope of this thesis.

Mass objects below 0.33 lb are considered light weight and should not be taken into consideration. 0.15 kg (0.33 pounds) or greater items that affect the injury and exit of passenger together with the dynamic performance of the seat should be on the test article during the tests. However, if such items do not affect the dynamic performance, representative masses can be used. Items less than this weight does not need to be on the seat in tests.

Regardless of weight, symbolic masses can be used instead of wiring harness. The life vests should be on the test article. But they do not need to be the own life vest of seat. After the tests, the cover of the life vest should not be jammed. Even if the seat is damaged, the life vest should be accessible.

During dynamic tests, literature pockets should have 1.36 kg (3 pounds) weigh and taped to the seat. Using of literature pocket is not required for both rows during HIC tests.

As specified in the static load requirements, IOM criteria are also valid for this test. If these structures does not remain on the seat after test, it requires a design change on the seat. Similarly, if any part which exceed 3% of the empty weight of the seat (without passenger, life vest, literature pocket, baggage etc.) is detached before the seat achieves peak reaction loads, the test should be repeated.

Some parts such as handset, seat back and bottom cushion, life vest, RJU, IAT housing and mechanism, headrest etc. can be used from tested article to other test article to be tested after the compliance check.

2.3 Qualification Tests

Seat qualification tests consist of static and dynamic tests. Dynamic tests will also be evaluated as 14G, 16G, HIC and head path tests. With the enlargement of the screen size of the economy class seats in B787 aircraft of Turkish Airlines, qualification tests have to be made again. The results obtained from HIC tests, which is one of the dynamic tests, will provide clear information about suitability of the screen size. If HIC tests fail, the screen sizes in these seats can not be enlarged. The subject seat is the Epianka series FU12 model economy seats of TSI company. Currently the screen sizes are 11.6 inches and intended to be 13 inches.

2.3.1 Static qualification tests

The critical seats determined in static qualification tests are exposed to ultimate loads from the forward, aft, sides, up and down directions. Seat parts which are not part of the seat primary structure and whose presence will not change the pass / fail criteria of test may not be considered as test substance, but their weight should be added to static loads. The body blocks are used during the test on behalf of passengers and ATD. They are restrained with seat belts. In case of forward and side loads, a nonrigid foam block can be used representative of bottom cushion and backrest cushions. While applying forward and side loads, the body block is positioned either on actual bottom cushion or non-rigid foam substituted for bottom cushion. During side load application, a backrest cushion or a non-rigid foam must be available. It is essential to apply the down loads as distributed loading of seat pan.

Load application points for static tests are shown in Table 2.5 obtained from SAE AS8049 Rev.C (2015). In this thesis, the economy class seats belonging to TSI company should be considered as the front-facing seat. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

Table 2.5 : Static resultant load application points.

Load	Forward-Facing Seat	Sideward-Facing Seat	Rearward-Facing Seat
Down	Evenly over seat bottom	Evenly over seat bottom	Evenly over seat bottom
Side	10.5 inches (270mm) up from SRP 8.5 inches (215mm) forward of SRP	10.5 inches (270mm) up from SRP	10.5 inches (270mm) up from SRP 8.5 inches (215mm) forward of SRP
Up	8.5 inches (215mm) forward of SRP	8.5 inches (215mm) forward of SRP	8.5 inches (215mm) forward of SRP
Forward	10.5 inches (270mm) up from SRP	10.5 inches (270mm) up from SRP 8.5 inches (215mm) forward of SRP	10.5 inches (270mm) up from SRP
Rearward	10.5 inches (270mm) up from SRP	10.5 inches (270mm) up from SRP 8.5 inches (215mm) forward of SRP	10.5 inches (270mm) up from SRP

2.3.2 Pass/Fail criteria for static tests

The static tests should provide the following;

- All test seats has to withstand the ultimate loads at least 3 seconds and remain attached to the seat track.
- Failure of primary structure parts is not acceptable. Deformations in other structures of the seat are acceptable, as long as they do not prevent the emergency evacuation of the passengers
- If item of mass remain on the seat structure in dynamic tests, no additional test is required for forward and down static conditions. But retention demonstration is still required for all other directions in static conditions.
- Seat belts has to remains attached to all points of attachments.
- After ultimate loads are applied and released, permanent deformations at previously determined points are examined. In the light of the experience of the seat manufacturers in this field, the points that may have high deformation are determined. TSI Seat company has determined 23 points in double seats and 27 points in triple seats for qualification tests. Since all of the seats to be examined in this thesis are triple, deformations of 27 points will be considered. These points should not be deformed more than 3 inches at forward and back directions, more than 1.5 inches in side directions. ($X \leq 3$ inch, $Y \leq 1.5$ inch, $Z \leq 3$ inch). Relevant points are shown in Figure 2.4 as side and top view. (TSI – Static Test Plan for TSI Epianka Series FU12 Model Economy Class Seats issue 01, 2019).

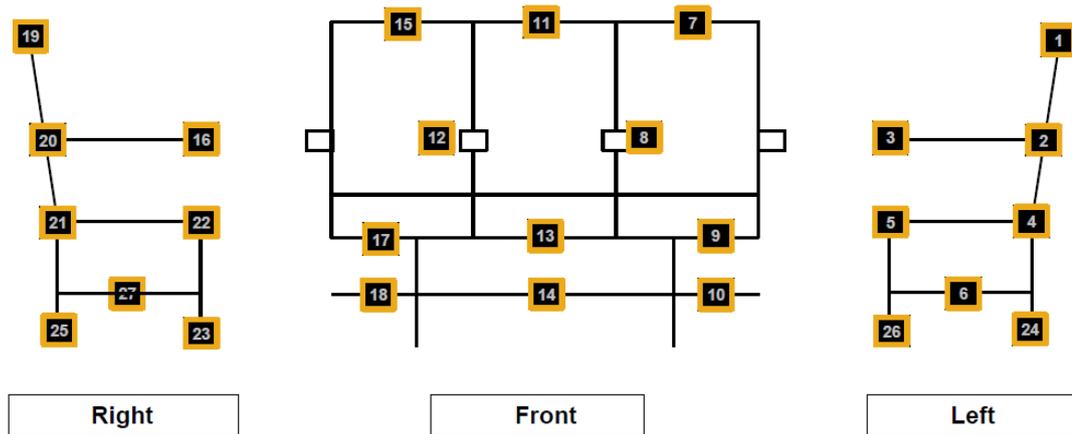


Figure 2.4 : Target marker locations and deformation points for triple seats.

2.3.3 Dynamic qualification tests

In structural dynamic qualification tests, the seats try to withstand ultimate load conditions, so passenger seats and restraint system are expected to be damaged and stretched. These damages must be within acceptable limits. The dynamic qualification tests will be examined in 4 main sections. These are 14G, 16G, HIC and head path tests.

The seat structure, cushions and restraint of passenger will be considered as a total system. Any replacement of these elements will only be made on the basis of further testing or rational analysis depending on the test. In other words, the seat structure, the cushion and dress cover combination and seat belts are part of the certification. These are part of the seat approval for dynamically certified seats. In case of manufacturer or material change for these items, additional testing and certification are necessary. (TSI Component Maintenance Manual 25-20-14 with Illustrated Part List Economy Class Epianka Series, 2019).

In addition to preventing injuries of passengers sitting and moving, the seat elements should not prevent rapid evacuation in emergency situations.

During dynamic tests, the 50th percentile male ATD will be used as defined in 49 CFR Part 572, Subpart B. This ATD gives reliable results for repetitive tests. ATD body parts are remarked in Figure 2.5. (49 CFR Part 572 Anthropomorphic Test Devices Subpart B - 50th Percentile Male, 2011).

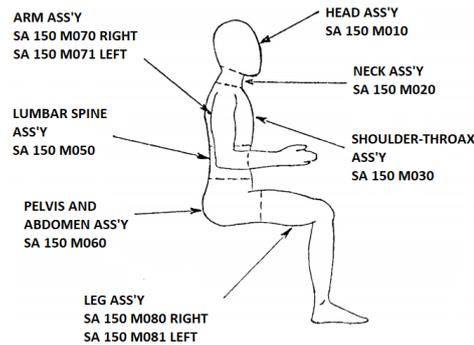


Figure 2.5 : 50th percentile male ATD.

In general, load cell are centered below the seat attachment points. Where load cells can not be physically centered below these points, load cells should be centered below critical areas which will be loaded highest during dynamic tests. Load cells calculate the forces synchronously in three perpendicular directions, thus force direction and magnitude are dependably determined. Load cells with single axis may not give reliable results.

Overhead camera and high speed camera will be used to record data for dynamic seats as electronic and photographic equipments. This instrumentation will measure and record data needed to compare output of pass/fail criteria. Electronic and photographic instrumentations will be carried out according to SAE J211 Instrumentation for Impact Test (2014). Part 1 of this document describes electronic properties and part 2 describes the photographic properties for impact tests. The set-up requirements and general analysis procedures of equipment such as overhead camera and high speed camera used to track the trajectory of head and knee path with high-speed film or digital video should be met a certain standard. (SAE ARP5482A Photometric Data Acquisition Procedures for Impact Test, 2011.)

High speed cameras which supply the necessary information to calculate displacement and velocity are capable of taking 500 frames per second. The photographs should show that the seat is attached to the test fixture at all attachment points.

Within the scope of dynamic qualification tests, all seats will be validated with 14G and 16G structural, lumbar, first row head path and row-to-row HIC tests. At least two dynamic tests are required to evaluate the performance of an aircraft seats. The seat, seat belt and cushions liaise as a system to protect the passenger during concussion or crash. The tests will be carried out by applying 14G and 16G force to

the selected seats within the scope of this thesis. 14G and 16G tests are hereinafter referred as test 1 and test 2 respectively.

2.3.3.1 14G and 16G tests

Test 1 and test 2 give information about system performance. They evaluate the structural qualification of the seat, lumbar/pelvic column force, loads on the seat leg affected on seat tracks and fittings, permanent deformation of parts on the test seats under forward and downward combined load and gives information on Anthropomorphic Test Dummy (ATD) for displacement of head, acceleration time and velocity history. As part of dynamic test, Figure 2.6 shows which conditions the test seat will be subjected to and how they will be positioned. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

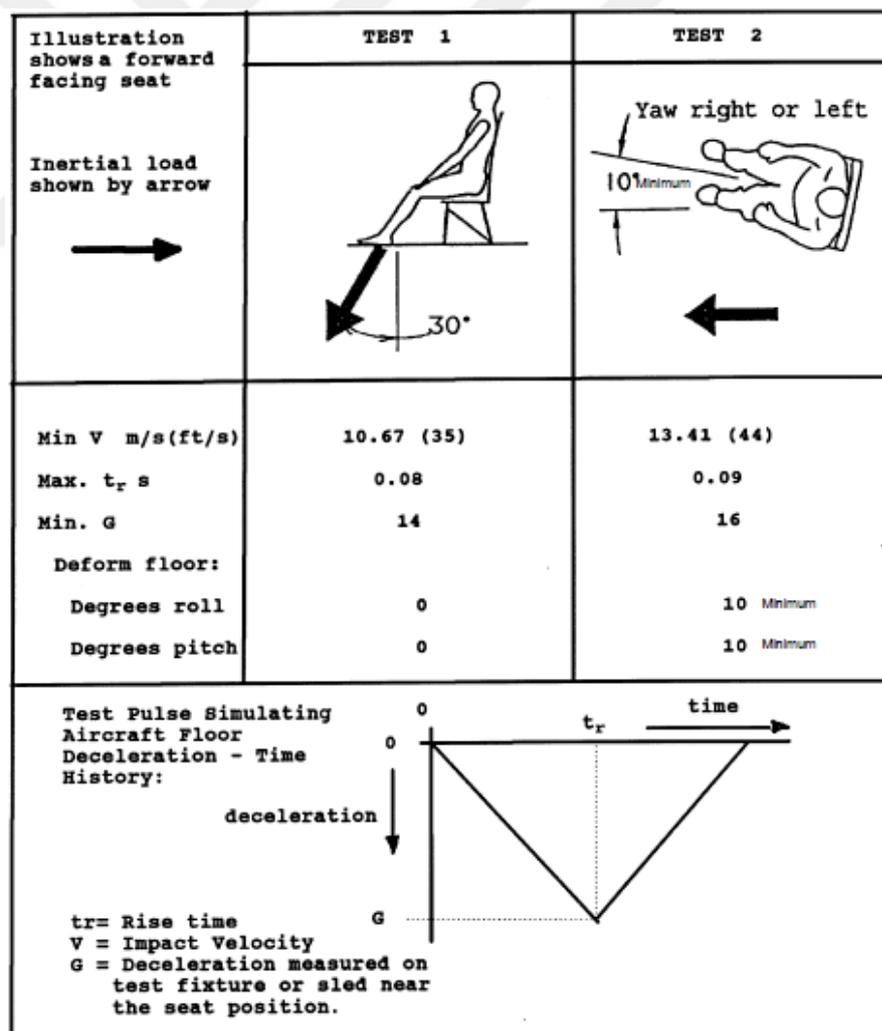


Figure 2.6 : Dynamic test conditions.

According to Figure 2.6, vertical velocity change in the direction shown for test 1 must be minimum 10.67 m/s (35 ft/s). Peak of floor deceleration must occur within no more than 0.08 seconds of impact and it must reach a minimum 14g. The longitudinal velocity change in the forward direction for test 2 must be minimum 13.41 m/s (44 ft/s). Peak of floor deceleration must occur within no more than 0.09 seconds of impact and it must reach a minimum 16g. (EASA CS-25 Certification and Specifications and Acceptable Means of Compliance for Large Aeroplanes, CS 25.562 Emergency Landing Dynamic Conditions, 2012).

During the test 1, all of three ATDs will be placed on the seats to create the maximum pressure load. There is no such requirements for test 2.

An analysis to be mentioned later will be used to determine the seat yaw in the dynamic test 2 of the most critical seat, along with the number and ATD location. They should be chosen to increase the load on the highest loaded seat leg.

2.3.3.2 HIC and head path tests

Under these circumstances, each passenger should be protected from serious head injury. Head impact should not exceed a 1000 unit Head Injury Criterion (HIC) at front row seats or at monuments, where head contact may occur, such as dividers, galleys, lavatory, and also appropriate precautions should be taken. The HIC value is calculated by the following equation (2.1)

$$\text{HIC} = \left\{ (t_2 - t_1) \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} \right\}_{max} \quad (2.1)$$

Where t_1 and t_2 are initial and final integration time at any two points in time (in seconds) during the head strike and $a(t)$ is resultant head acceleration during head contact. a is in units of gravity.

HIC value is method used to specify an acceptable limit. HIC is always calculated by data analysis system. Three perpendicularly mounted accelerometers are used at the head of ATD to calculate the HIC value.

In HIC tests for the front row seats, a symbolic impact target is placed in front row seat. Monuments to represent this target should be rigid enough to match the rigidity of structure on the aircraft. HIC value should not exceed 1000 in case of any contact.

To assess head injury data during multiple row tests of HIC, the seat pitch should be chosen so that the head is likely to contact with a rigid structure on the forward seat. In HIC tests, the front row seat can be unoccupied. These tests can also be used to assess femur injury criteria.

In tests where the ATD's head is expected to hit another seat or structure such as partition, galley, lavatory, the head and face of the ATD will paint with different colors to see which areas of the head touch. The paints to be used should be chosen so as not to decrease the HIC values.

Still pictures are used to show that aircraft seats do not prevent rapid evacuation of passengers. For still pictures used for this purpose, ATD should be removed from the seat. In tests such as HIC (Head injury criteria) and head path data, if ATD's head touches a bulkhead or the another seat back, photographs showing the touch point of the head should be taken.

During these tests, it is considered that the ATD head forms a zone between 20.5 inch arc and 35 inch arc. It should be paid attention that there are no sharp and extreme points in the head strike zone during seat design and after HIC tests. This zone, where there are no problems up to 18 inch from the floor, is shown Figure 2.7. (FAA Advisory Circular (AC) 25-17A, Transport Airplane Cabin Interiors Crashworthiness Handbook, Change 1, 2016).

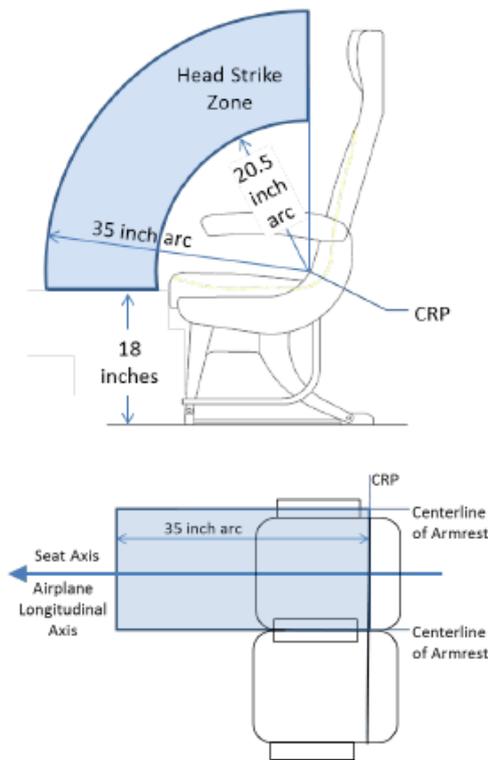


Figure 2.7 : Head strike zone.

Row-to-row HIC tests are carried out in three different ways, taking into account the three zones located behind the seat. The relevant three zones is shown in Figure 2.8 as Zone A, Zone B and Zone C. It should be ensured that ATD heads hit the specific zones in each test. If the ATD head does not hit the desired area, the seat pitches should be changed and tests should be repeated. Especially the Zone C area has been determined quantitatively. The 6” to 12” rectangular area where the latch of food tray table is considered the center is called Zone C. This latch is assumed to be hitting point. The yaw angle of the seat is turned 10 degrees to right or left so that the ATD head hits Zone A and Zone B. Zone A and B tests are carried out a seat pitch of 33 inches, while Zone C test is carried out a seat pitch of 30 inches.

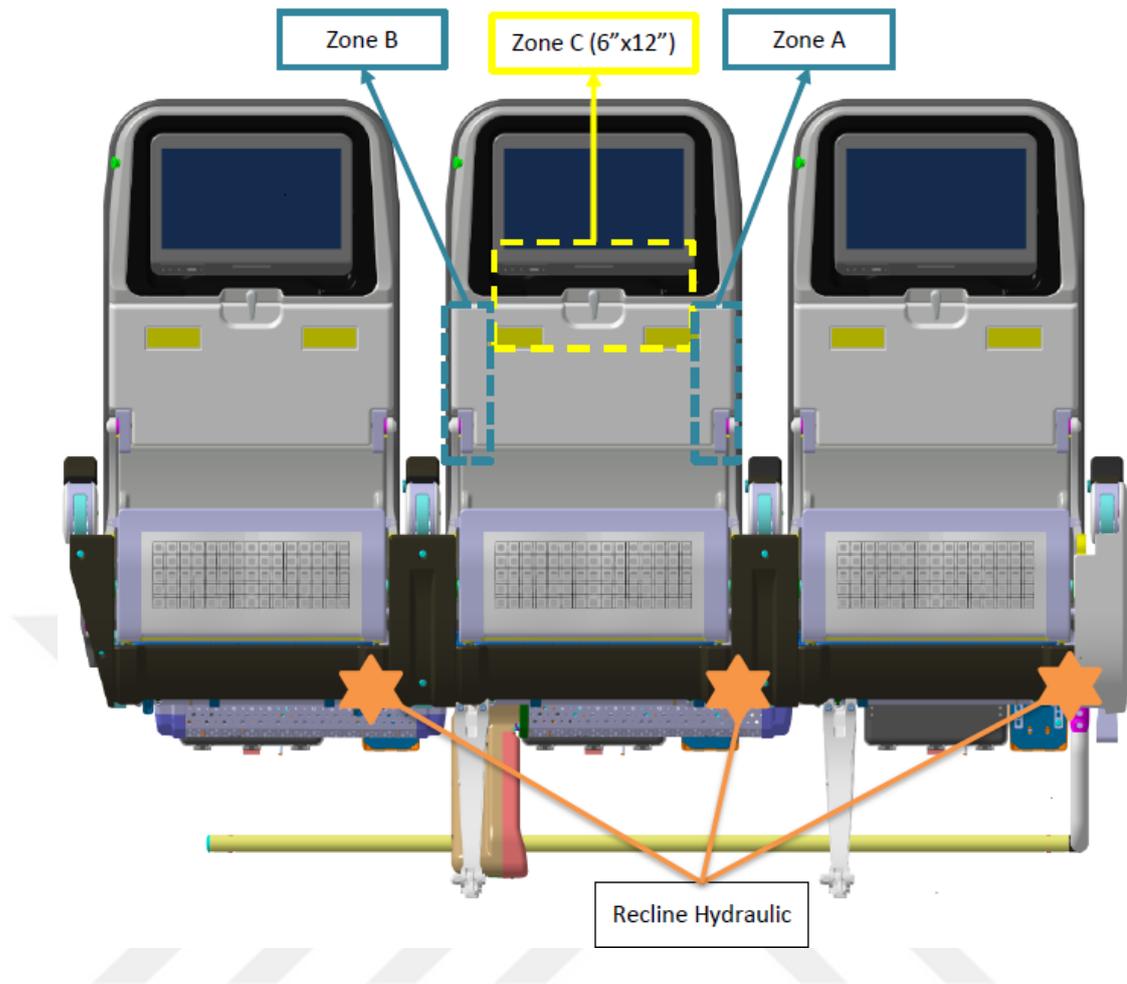


Figure 2.8 : Zone definition of seat backrest.

Except the first row, the relevant seats are planned to be installed with 31" pitch ranges on the aircraft. The tests will be carried out to cover the range of 30"-33" inches, by taking into consideration future seat placement programs.

In these tests, different seats are selected from the seats that will be used in static and dynamic tests. FU12-3L002A001 seat will be evaluated for row-to-row tests and first row seats (FU12-3L001A001, FU12-3C001A001, FU12-3R001A001) will be used for head path tests to substantiate all seats. LH seat can be used since RH seats are symmetrically identical with LH seats. Knee path data can be provided with the head path test of first row seats.

2.3.4 Pass/Fail criteria for dynamic impact tests

The dynamic impact tests should provide the following;

- The seat structure must remain attached to all attachment points and the primary load path must remain intact.

- Since the tests are carried out under ultimate load conditions, damage of seat and its restraint systems are expected. Bending and tension deformation, shear buckling are among the acceptable deformation groups for structural elements carrying load. Cracking of structural members, minor delamination of the composite panels, shearing or separation of rivets are allowed as long as there is a constant load path between the passenger and seat attachments.
- Passenger restraint system must remain attached at all points of attachment. As long as there are no cuts or tears on the seat belt, there is no problem in damage such as breakage of the fiber, friction, wear.
- If ATD's head is exposed to impact with the seat in front during HIC tests, the HIC value must not exceed 1000.
- Between ATD's pelvis and lumbar column, the maximum compressive load must not be more than 1500 pounds (6,67 kN). Pelvic seat belt must remain on the ATD's pelvis during impact.
- The axial compressive load in each femur must not exceed 2250 pound (10.0 kN) when legs contact with seat or another construction.
- As stated in 2.1.5, dimension "C" must be at least %50 of dimension "B".
- Similar to the static test, the values of 27 deformation points should be checked.
- Item of mass must be retained.
- Sharp edges or projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, should not occur.
- All deployable parts such as food tray table, legrest must not prevent emergency exit, must not cause serious injury, must be kept in a stowed position. (SAE AS8049 Rev.C Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft, 2015).

2.3.5 Seat families and test article selection

Although many aircraft seats have the same basic structural design, they have the details that separate them. For instance, different seat leg location, spreader diversity, beam structure is some of them. Such differences that separate the seat cause them to be evaluated under different seat family during tests. Each test to be applied creates a

serious burden on the companies in terms of cost and time. For this reason, the seats to be tested should be kept as minimum as possible and these seats should be selected as the seats that will be exposed to maximum loads.

While choosing the seat families and determining the most critical seats, two important factors should be considered. The first step is the comparison of the basic parts such as beam assy, spreader, seat legs and fittings of the seat. The second step is to use tools for selection of the most critical seats. What is accepted as a tool here is the using of analysis programs that can perform interface load calculations. For this purpose, TSI company uses both the seat load analysis program from Boeing and its own beam bending moment analysis program for the selection of test article prior to tests. Civil aviation authorities and aircraft manufacturers demand precise interface load calculations to avoid overloading the fuselage structure during flight. If a product is placed to be mounted on a redesigned body, such analysis is often required. TSI company uses Boeing seat loads analysis program to calculate the interface loads and meet requirements for installing TSO/ETSO approved passenger seats on Boeing model aircrafts. A list of the static interface loads will be sent for approval to Boeing. Boeing will review the report to ensure that structural capability of the aircraft is not exceeded. Interface loads should be calculated according to all static load conditions. All test plans will be submitted to Boeing for approval prior to tests. After satisfactory completion of all tests, each test report will be submitted to Boeing for approval.

For tests that have same criteria and previously approved by Boeing, similarity forms of dynamic test reports are created and submitted to Boeing to avoid additional testing.

Boeing describes the method of standard interface loads required for analysis of floor-mounted seats in document D6-36238 Rev.E. The purpose of Boeing is to explain the method in sufficient detail to ensure that all suppliers have acceptable and consistent analysis results. There are many applications that can do this, but Boeing offers its suppliers to use the Boeing SeatLoads Excel template optionally. Apart from this, suppliers such as TSI company using this excel can send their interface loads directly to Boeing with the web-based tool called SILAS. The same calculation method is used in both applications. SILAS application can not be used in non-standard seats, only Boeing seat load excel is used. To calculate seat interface loads in these applications, the dimensions shown in Figure 2.9 should be entered. (Boeing D6-36238 Rev.E Passenger Seat Structural Design and Interface Criteria, 2016).

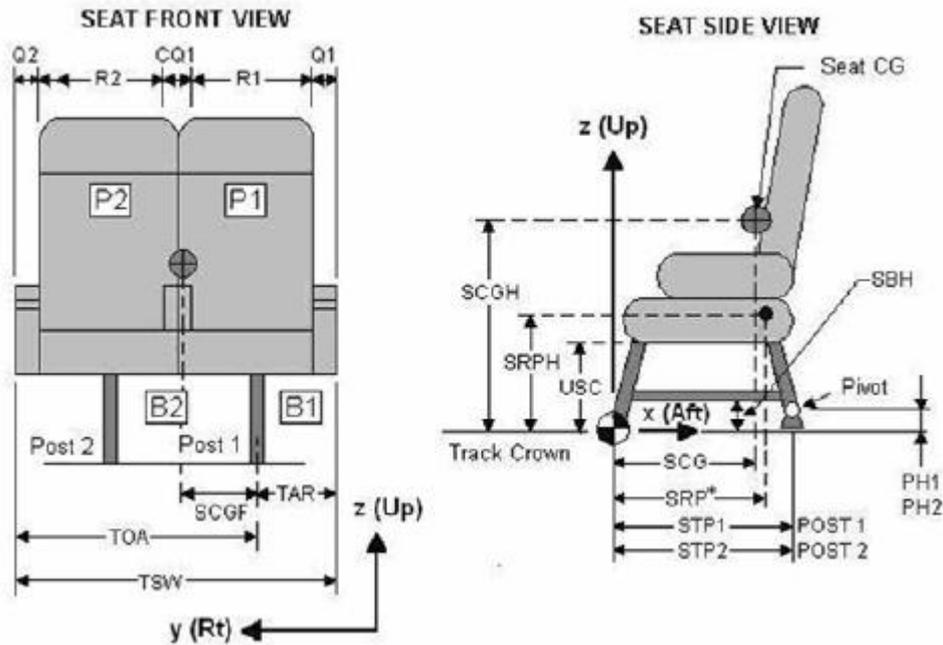


Figure 2.9 : Required dimensions for SILAS.

Economy class seats of B787 aircraft are designed in 13 different types. Economy group consists of 90 triple seats and total passenger capacity is 270. The part number and quantities of each seat is given in table 2.6.

Table 2.6 : Seat identification.

Item No	Part Number	Seat Description	Quantity
1	FU12-3L001A001	SEAT TPL, LH, IAT, IAV	2
2	FU12-3C001A001	SEAT TPL, CTR, IAT, IAV	2
3	FU12-3R001A001	SEAT TPL, RH, IAT, IAV	2
4	FU12-3L002A001	SEAT TPL, LH, STD, STC	25
5	FU12-3C002A001	SEAT TPL, CTR, STD	26
6	FU12-3R002A001	SEAT TPL, RH, STD, STC	25
7	FU12-3L003A001	SEAT TPL, LH, LAST ROW, STC	1
8	FU12-3C003A001	SEAT TPL, CTR, LAST ROW	2
9	FU12-3R003A001	SEAT TPL, RH, LAST ROW, STC	1
10	FU12-3L004A001	SEAT TPL, LH, NR, STC	1
11	FU12-3R004A001	SEAT TPL, RH, NR, STC	1
12	FU12-3L005A001	SEAT TPL, LH, ENR, LAST ROW, STC	1
13	FU12-3R005A001	SEAT TPL, RH, ENR, LAST ROW, STC	1
SUM			90

LOPA showing the layout of the 13 different types of relevant seats on the aircraft is indicated in Figure 2.10. (TSI – THY B787-9 FU12 LOPA Drawing Rev.P05, 2019).

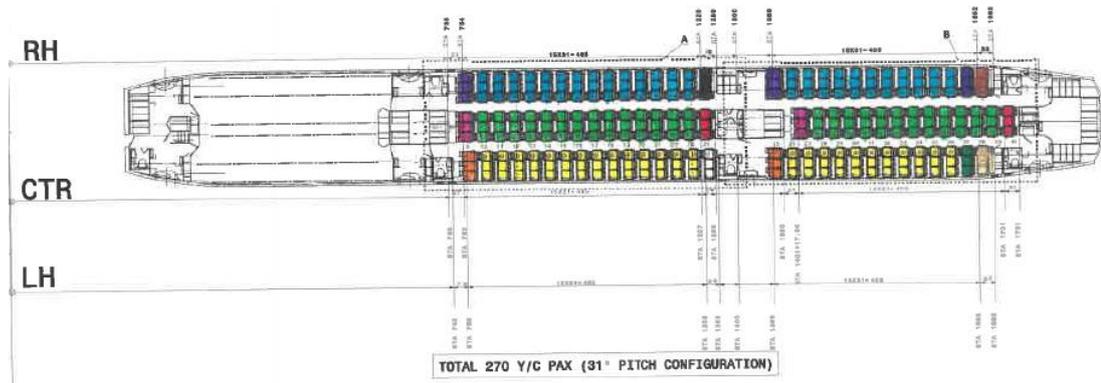


Figure 2.10 : LOPA for B787 economy class passenger seats.

As a first step, it is necessary to select the seat families for the relevant seat and then select the most critical test articles. The chart in Figure 2.11 gives information about the path to be followed while choosing a seat family. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, 2015).

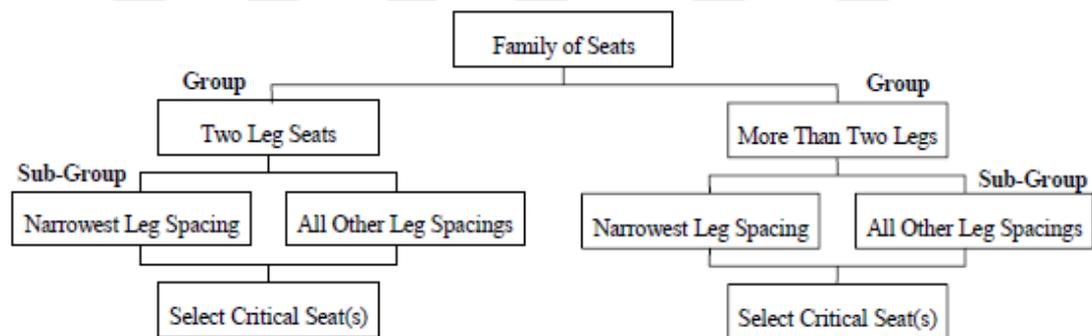


Figure 2.11 : Decision chart for selection of seat family.

While choosing seat families, the number of seat leg should be taken into consideration firstly. Since all economy class seats on this aircraft are triple, each has two legs. Then, if each of these families differs in terms of seat leg location and seat leg space, they are included in different families. If the similarity between these structures continues, important structures such as restraint system, beam and spreaders are compared. The presence of standard, first and last row seat in different families will give more realistic results to determine the critical seats. In this direction, economy seats on the aircraft are divided into groups as shown in Table 2.7.

Table 2.7 : Seat families.

FU12 Seat Families					
	Family 1	Family 2	Family 3	Family 4	Family 5
	First Row LH-RH Seats with IAV and Y-belt	Standard Seats (36.5" Leg spacing)	Last row seats (20.5" Leg spacing)	First Row center Seat with IAV and Y-belt	Standard Center Seats
Seat PNs	FU12-3L001A001 FU12-3R001A001	FU12-3L002A001 FU12-3R002A001 FU12-3L003A001 FU12-3R003A001 FU12-3L004A001 FU12-3R004A001	FU12-3L005A001 FU12-3R005A001	FU12-3C001A001	FU12-3C002A001 FU12-3C003A001

According to this comparison, seats in family 1 and family 4 are first row seat but they have different spreader due to seat belts. Also seats in family 2, family 3 and family 5 are similar but leg pitch and seat width make them different. After creating the seat families in this way, one seat will be selected from each family to be tested. For selection, the most critical seat, which is supposed to be subjected to the highest load by getting support from the previously mentioned analyzes, will be determined. While using these applications, the design data of the seats is required. Some dimensions shown in Figure 2.12 are the inputs that should be used during load calculations. (TSI – Static Test Plan for TSI Epianka Series FU12 Model Economy Class Seats issue 01, 2019).

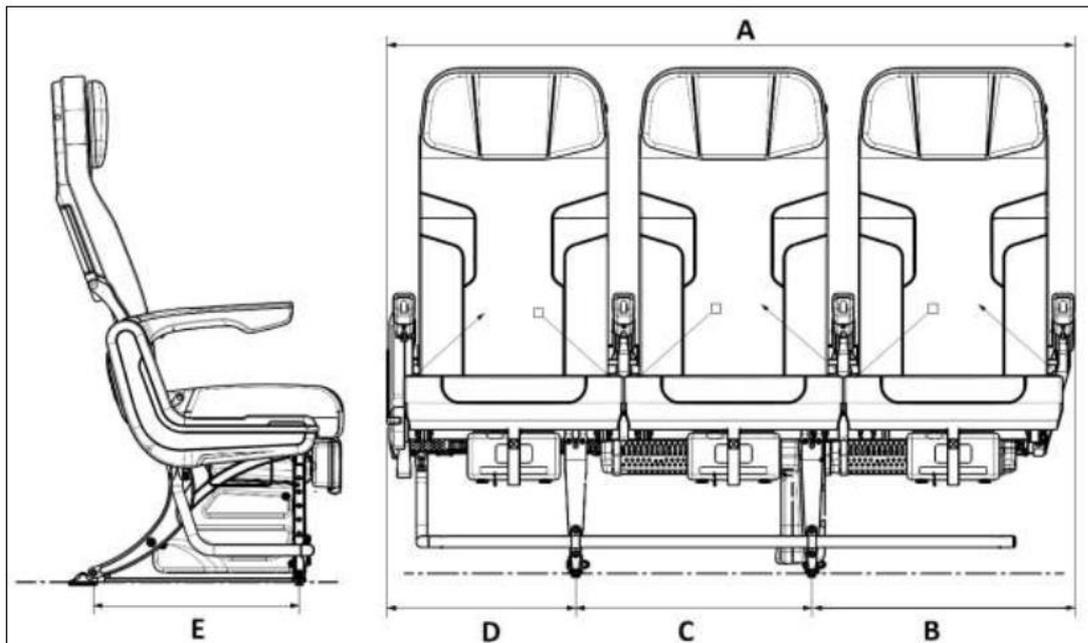


Figure 2.12 : Seat dimensions.

The seat base assembly, which holds all the parts on the seat, consists of legs, spreaders, front and rear beams. Also it is the primary load path for the seats and other assembly to which all other seat parts are attached. These parts are made of aluminium. Different types of seat base assembly and design differences between parts affect the selection of test article. Figure 2.13 shows the seat base assembly for FU12 model seat. (TSI – Static Test Plan for TSI Epianka Series FU12 Model Economy Class Seats issue 01, 2019).

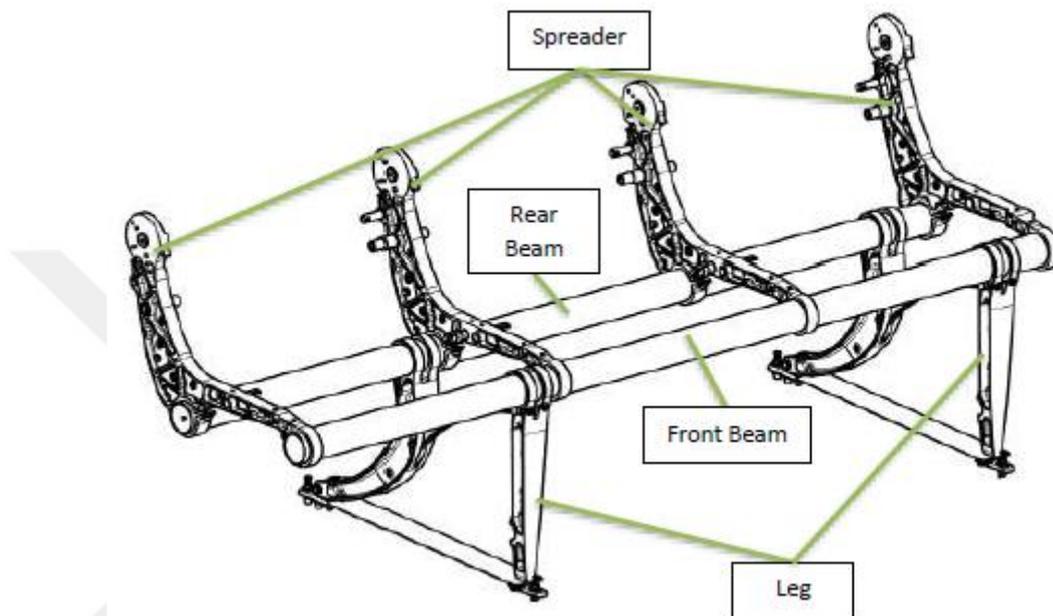


Figure 2.13 : Seat base assembly.

In order to detect critical seats before qualification tests, beam bending moment analysis belonging to TSI company will be used for the loads likely to be exposed on the beams and interface load analysis application belonging to Boeing for the forces on the legs.

The aft legs and the spreaders are installed to the rear beam. The beam bending moment of the rear beam is calculated with a unit load per passenger. Some seats have one inner beam, some have two inner beams on the front and rear beams. Therefore, each seat will be evaluated in two different ways by taking this into consideration. Due to the confidentiality decision made with the TSI company, the beam bending moment of each seat will not be shared. Only the results of the seats with the highest moment value will be mentioned as a summary table. The summary table formed after two analyses is given in Table 2.8. In these calculations, only LH seats were evaluated, since RH seats are symmetrical with LH seats. For seat occupancy, 1 and 0 indicate

full and empty respectively. (TSI – Static Test Plan for TSI Epianka Series FU12 Model Economy Class Seats issue 01, 2019).

Table 2.8 : Summary table of maximum bending moments.

Item No	Part Number	Occupancy	Max. Beam Bending Moment (N.mm)
1	FU12-3L001A001	Full (111)	1336.6
3	FU12-3R001A001	Full (111)	1336.6
4	FU12-3L002A001	Full (111)	1336.6
6	FU12-3R002A001	Full (111)	1336.6
7	FU12-3L003A001	Full (111)	1336.6
9	FU12-3R003A001	Full (111)	1336.6
10	FU12-3L004A001	Center + Right (011)	1266.6
11	FU12-3R004A001	Center + Right (011)	1266.6
12	FU12-3L005A001	Left + Center (110)	1123.8
13	FU12-3R005A001	Left + Center (110)	1123.8
2	FU12-3C001A001	Left + Center (110)	1155.9
5	FU12-3C002A001	Left + Center (110)	1155.9
8	FU12-3C003A001	Left + Center (110)	1155.9

The data obtained here will be evaluated together with the data from the interface load analysis. Interface load analysis is similarly applied to detect the critical seat from each seat family under 9G forward load condition. Leg 1 and Leg 2 always indicate the inboard leg and outboard leg respectively. Similarly, no calculations will be made for the seats in RH side due to symmetry. Due to the confidentiality decision made with the TSI company, the interface load analysis of each seat will not be shared. Only the results of the seats with the highest interface load value will be mentioned as a summary table. The summary table formed after these results is given in Table 2.9. (TSI – Static Test Plan for TSI Epianka Series FU12 Model Economy Class Seats issue 01, 2019).

Table 2.9 : Critical rear leg load summary.

TSO P/N	Leg	Occupancy	Critical Rear Leg Loads (lb)			
			x	y	z	Resultant
FU12-3L001A001	1	Full (111)	-4767.2	0.0	5689.2	7422.5
FU12-3C001A001	2	LH+CTR (110)	-4176.2	0.0	5041.5	6546.6
FU12-3L002A001	1	Full (111)	-4338.9	0.0	5349.1	6887.6
FU12-3C002A001	2	LH+CTR (110)	-3773.4	0.0	4728.9	6049.9
FU12-3L003A001	1	Full (111)	-4162.9	0.0	5096.6	6580.7
FU12-3C003A001	2	LH+CTR (110)	-3564.5	0.0	4467.7	5715.4
FU12-3L004A001	1	Full (111)	-4450.7	0.0	5485.9	7064.3
FU12-3L005A001	2	LH+CTR (110)	-3542.7	0.0	4454.1	5691.2

In the light of information in Table 2.8 and Table 2.9, critical seats selected for the tests are formed as in Table 2.10.

Table 2.10 : Test article selection.

FU12 Families	Item No	Part Number	Selection Criteria
Family 1	1	FU12-3L001A001	Highest interface load & Highest beam bending moment in family 1
	3	FU12-3R001A001	Symmetrical with item 1
Family 2	4	FU12-3L002A001	Lower interface loads than item 10
	6	FU12-3R002A001	Symmetrical with item 4
	7	FU12-3L003A001	Lower interface loads than item 10
	9	FU12-3R003A001	Symmetrical with item 7
	10	FU12-3L004A001	Highest interface load in family 2
Family 3	11	FU12-3R004A001	Symmetrical with item 10
	12	FU12-3L005A001	Highest interface load in family 3
Family 4	13	FU12-3R005A001	Symmetrical with item 12
	2	FU12-3C001A001	Highest interface load in family 4
Family 5	5	FU12-3C002A001	Highest interface load in family 5
	8	FU12-3C003A001	Lower interface loads than item 5

The selected test articles will substantiate all economy class seats in the aircraft. Some technical specifications of the relevant test seats are given in Table 2.11.

Table 2.11 : Technical specifications for test articles.

Part Number	Location	Total Seat Width (in)	Leg Pitch (in)	Critical Overhang (outboard)	Leg Spacing (in)	Maximum Certified Seat Weight	Maximum Installed Seat Weight
FU12-3L001A001	Left	60.35	20.0	18.8	36.5	179.1	194.1
FU12-3L004A001	Left	59.17	20.0	18.8	36.5	122.1	137.1
FU12-3L005A001	Left	57.99	20.0	19.21	20.5	88.7	103.7
FU12-3C001A001	Center	60.82	20.0	19.41	22.0	176.9	191.9
FU12-3C002A001	Center	60.82	20.0	19.41	22.0	128.8	143.8

In the next process, the test set-up will be made by using the critical seats and their technical features and tests will be performed under the given conditions

3. RESULTS OF QUALIFICATION TESTS

In this section, information about the results of qualification tests carried out in the light of the data obtained in the previous sections will be given.

3.1 Static Test Results

The first positions of the 27 deformation points determined before tests were marked on the test articles. The minimum load required to be applied to the seats is calculated as given in the equations 3.1 to 3.3.

$$\text{Total Load For Body} = (\text{Load Factor}(g)) \times (\text{Occupancy} \times \text{Pax Weight} + \text{Seat Weight}) \quad (3.1)$$

$$\text{Load for Baggage Bar} = \text{Load Factor}(g) \times (\text{Occupancy} \times \text{Baggage Weight}) \quad (3.2)$$

$$\text{MIN. REQUIRED LOAD} = (\text{Total Load for Body} + \text{Load for Baggage Bar}) \quad (3.3)$$

In accordance with the information obtained in section 2.3.5, static tests were applied to test articles under load conditions given in Table 3.1.

Table 3.1 : Static test cases.

Test Article P/N	Test Type	Minimum Required Occupancy Load (lb)			Minimum Required Baggage Bar Load (lb)	Minimum Required Total Load (lb)
		LH	CTR	RH		
FU12-3L001A001	9.0g FWD	2112.3	2112.3	2112.3	540.0	6876.9
	1.7g Aft	399.0	399.0	399.0	N/A	1197.0
	6.0g Up	1528.2	1528.2	1528.2	Added to seat load	4584.6
	6.8g Down	1596.0	1596.0	1596.0	N/A	4787.9
	4.0g Side	938.8	938.8	938.8	240.0	3056.4
	6.6g dDown + 1.5g Aft	1549.1Down+ 352.1 Aft	1549.1Down+ 352.1 Aft	1549.1Down+ 352.1 Aft	N/A	4647.1 Down 1056.2 Aft
	12.0g FWD	2816.4	2816.4	2816.4	720.0	9169.2
FU12-3L004A001	9.0g FWD	1941.5	1941.5	1941.5	540.0	6364.4
	1.7g Aft	366.7	366.7	366.7	N/A	1100.2
	6.0g Up	1414.3	1414.3	1414.3	Added to seat load	4242.9
	6.8g Down	1466.9	1466.9	1466.9	N/A	4400.7
	4.0g Side	862.9	862.9	862.9	240.0	2828.6
	6.6g dDown + 1.5g Aft	1423,7 Down 323.6 Aft	1423,7 Down 323.6 Aft	1423,7 Down 323.6 Aft	N/A	4271.2 Down 970.7
FU12-3L005A001	9.0g FWD	1996.4	1996.4	0.0	540.0	4533.3
	1.7g Aft	377.1	377.1	0.0	N/A	754.3
	6.0g Up	1510.9	1510.9	0.0	Added to seat load	3021.8
	6.8g Down	1508.6	1508.6	0.0	N/A	3016.8
	4.0g Side	818.3	818.3	818.3	240.0	2694.8
	6.6g dDown + 1.5g Aft	1464.0 Down 332.8 Aft	1464.0 Down 332.8 Aft	0.0	N/A	2928.0 Down 665.5 Aft
FU12-3C001A001	9.0g FWD	0.0	2393.6	2393.6	540.0	5327.1
	1.7g Aft	0.0	452.1	452.1	N/A	904.2
	6.0g Up	0.0	1775.7	1775.7	Added to seat load	3551.4
	6.8g Down	0.0	1808.5	1808.5	N/A	3616.9
	4.0g Side	935.9	935.9	935.9	240.0	3047.6
	6.6g dDown + 1.5g Aft	0.0	1755.3 Down 398.9 Aft	1755.3 Down 398.9 Aft	N/A	3510.5 Down 797.8 Aft
FU12-3C002A001	9.0g FWD	2177.1	2177.1	0.0	540.0	4894.2
	1.7g Aft	411.2	411.2	0.0	N/A	822.5
	6.0g Up	1631.4	1631.4	0.0	Added to seat load	3262.8
	6.8g Down	1644.9	1644.9	0.0	N/A	3289.8
	4.0g Side	871.7	871.7	871.7	240.0	2855.2
	6.6g dDown + 1.5g Aft	1596.5 Down 362.9 Aft	1596.5 Down 362.9 Aft	0.0	N/A	3193.0 Down 725.8 Aft

The relevant loads were applied to the test articles and the loads were increased at a nominally constant speed until the ultimate test load was reached. The final load was maintained for a minimum of 3.0 seconds. Then the loads were removed. The deformation points of the structures were measured after the tests.

Test articles were subjected to tensile testing as shown in Figure 3.1 to Figure 3.5.

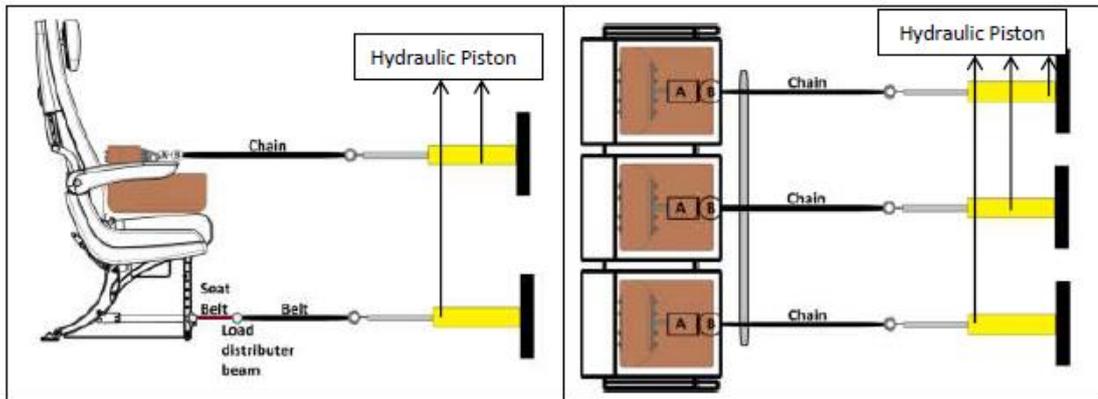


Figure 3.1 : Forward test installation.

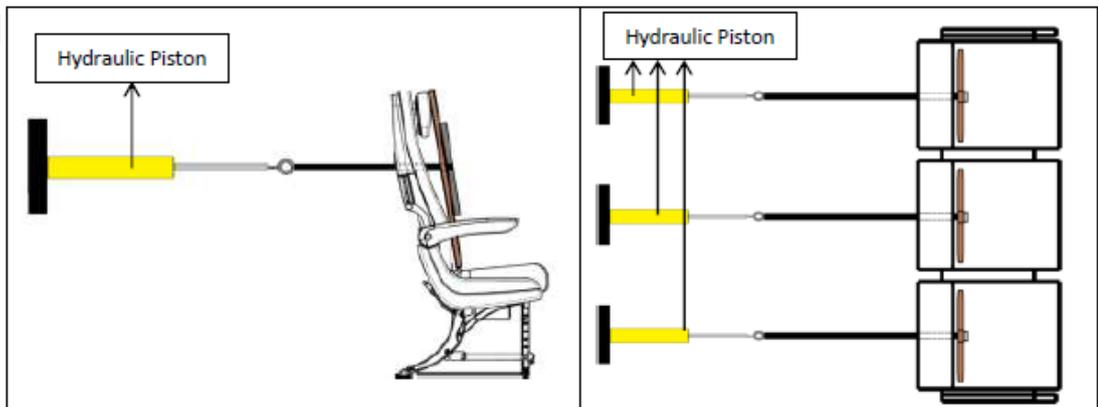


Figure 3.2 : Aft test installation.

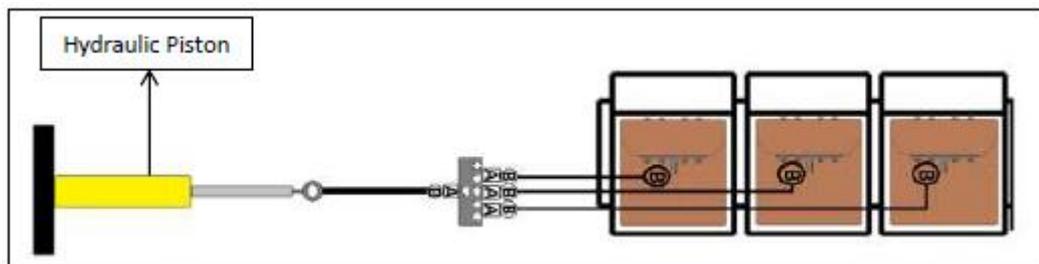


Figure 3.3 : Side test installation.

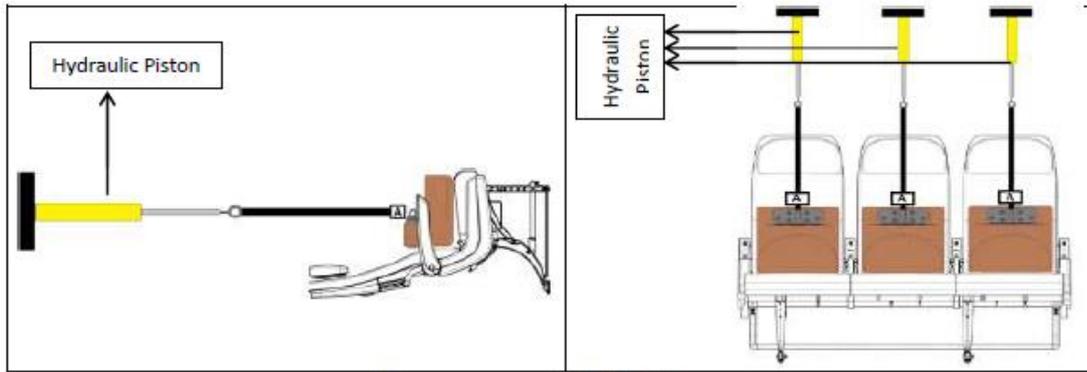


Figure 3.4 : Up test installation.

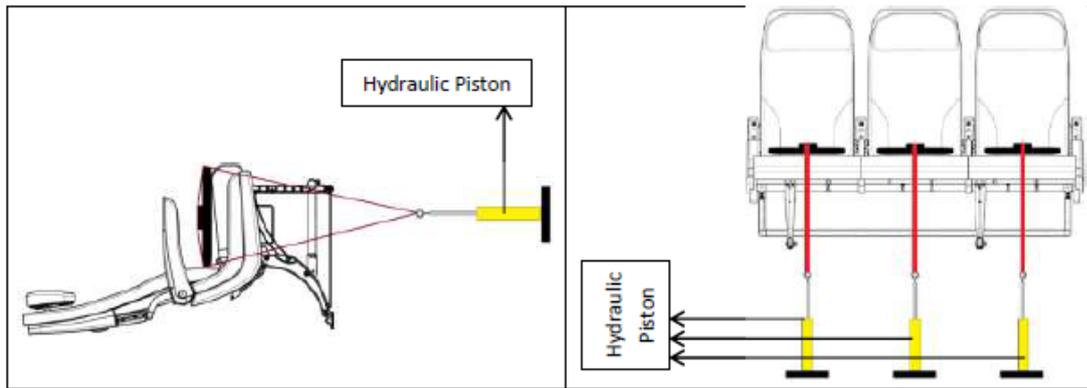


Figure 3.5 : Down test installation.

After performing the static tests, C/B ratio stated in section 2.1.5 occurs as given in Table 3.2. It is sufficient that this value is over 50 %. All values obtained meet these conditions.

Table 3.2 : C/B ratio.

Part Number	C/B Ratio		
	Left	Center	Right
FU12-3L001A001	0,92	0,91	0,94
FU12-3L004A001	0,97	0,97	0,98
FU12-3L005A001	0,94	0,95	0,93
FU12-3C001A001	0,92	0,91	0,92
FU12-3C002A001	0,95	0,94	0,96

After applying the static tests, the deformation values of the determined 27 points of FU12-3L001A001 seat were formed as in Table 3.3. The deformation results of the other four test seats are also given collectively in Table 3.4.

Table 3.3 : Deformation data for FU12-3L001A001.

Point	Pre-Test			Post-Test			Deformations		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	-39.63	71.08	47.71	-40.58	70.56	47.71	-0.95	-0.52	-0.36
2	-33.58	74.25	26.32	-33.57	74.00	26.32	0.01	-0.25	-0.02
3	-18.99	74.02	29.75	-18.86	73.87	29.75	0.13	-0.15	-0.44
4	-29.14	73.52	16.52	-29.09	73.45	16.52	0.05	-0.07	-0.01
5	-18.61	73.58	17.70	-18.58	73.58	17.70	0.03	0.00	-0.01
6	-19.14	72.78	8.34	-19.10	72.72	8.34	0.04	-0.06	-0.03
7	-39.52	63.81	49.39	-40.54	63.30	49.39	-1.02	-0.51	-0.49
8	-19.06	55.14	29.39	-18.99	55.12	29.39	0.07	-0.02	-0.50
9	-17.66	63.32	18.16	-17.49	63.28	18.16	0.17	-0.04	-0.02
10	-18.65	62.51	8.61	-18.65	62.48	8.61	0.00	-0.03	0.02
11	-39.79	44.44	49.35	-41.27	43.86	49.35	-1.48	-0.58	-0.94
12	-19.00	34.68	29.19	-18.96	34.66	29.19	0.04	-0.02	-0.33
13	-17.64	44.71	18.14	-17.28	44.70	18.14	0.36	-0.01	0.00
14	-18.63	44.41	8.47	-18.63	44.39	8.47	0.00	-0.02	0.17
15	-39.60	25.84	49.41	-41.33	25.25	49.41	-1.73	-0.59	-1.28
16	-19.09	15.69	29.41	-19.09	15.60	29.41	0.00	-0.09	-0.24
17	-17.61	25.46	18.07	-17.04	25.50	18.08	0.57	-0.04	0.01
18	-18.60	26.20	8.44	-18.20	26.18	8.44	0.40	-0.02	-0.12
19	-39.22	18.77	47.93	-40.84	18.20	47.93	-1.62	-0.57	-1.34
20	-33.50	15.33	26.64	-33.38	15.12	26.64	0.12	-0.21	-0.90
21	-29.11	15.41	16.23	-28.32	15.35	16.23	0.79	-0.06	-0.59
22	-18.54	15.35	17.73	-17.89	15.35	17.73	0.65	0.00	0.13
23	-18.29	33.51	6.02	-18.22	33.49	6.02	0.07	-0.02	0.02
24	-36.57	71.80	5.83	-36.56	71.78	5.83	0.01	-0.02	0.04
25	-36.65	33.08	5.88	-36.59	33.05	5.88	0.06	-0.03	0.01
26	-18.26	70.86	5.87	-18.24	70.82	5.87	0.02	-0.04	-0.01
27	-24.14	17.62	8.5	-23.45	17.60	8.5	0.69	-0.02	-0.40

Table 3.4 : Deformation data for other test seats.

Point	Deformations for FU12-3L004A001 seat			Deformations for FU12-3L005A001 seat			Deformations for FU12-3C001A001 seat			Deformations for FU12-3C002A001 seat		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	-0.86	-0.45	-0.26	-0.99	-0.82	-0.41	-0.25	-0.33	-0.26	-1.91	-0.67	-0.39
2	0.07	-0.29	-0.08	0.04	-0.33	-0.01	-0.07	-0.46	-0.07	0.14	-0.45	-0.05
3	0.09	-0.18	-0.37	0.21	-0.12	-0.49	0.57	-0.30	-0.41	0.25	-0.35	-0.48
4	0.01	-0.02	-0.05	0.15	-0.04	-0.08	0.08	-0.15	-0.04	0.07	-0.26	-0.07
5	0.06	0.04	-0.04	0.06	0.09	-0.02	0.06	0.12	-0.06	0.14	0.15	-0.02
6	0.11	-0.09	-0.02	0.09	-0.12	-0.05	0.14	-0.03	-0.14	0.16	-0.03	-0.05
7	-0.09	-0.48	-0.41	-1.26	-0.88	-0.53	-1.17	-0.41	-0.24	-1.42	-0.55	-0.60
8	0.12	-0.09	-0.47	0.17	-0.13	-0.87	0.06	-0.07	-0.65	0.06	-0.09	-0.56
9	0.21	-0.07	-0.06	0.19	-0.21	-0.17	0.15	-0.08	-0.17	0.19	-0.04	-0.07
10	0.03	-0.11	0.08	0.12	-0.01	0.09	0.06	-0.05	0.16	0.23	-0.06	0.03
11	-1.23	-0.51	-0.76	-1.02	-0.81	-1.24	-1.32	-0.61	-0.92	-1.36	-0.25	-0.84
12	0.00	0.05	-0.63	0.01	-0.13	-0.37	0.05	-0.05	-0.25	0.14	-0.14	-0.38
13	0.62	-0.08	0.04	0.31	-0.04	0.06	0.23	-0.17	0.05	0.32	-0.11	0.16
14	0.07	-0.04	0.27	0.03	-0.03	0.13	0.01	-0.03	0.14	0.05	-0.04	0.37
15	-1.31	-0.71	-1.35	-1.97	-0.76	-1.26	-1.07	-0.50	-1.13	-1.56	-0.79	-1.44
16	0.09	-0.15	-0.27	0.05	-0.17	-0.60	0.06	-0.03	-0.74	0.00	-0.12	-0.36
17	0.43	-0.08	0.07	0.77	-0.08	0.05	0.27	-0.06	0.08	0.57	-0.24	0.03
18	0.25	-0.03	-0.18	0.27	-0.11	-0.16	0.43	-0.01	-0.19	0.48	-0.03	-0.18
19	-1.47	-0.66	-1.45	-1.56	-1.04	-0.29	-1.34	-0.54	-1.45	-1.65	-0.57	-1.36
20	0.19	-0.26	-1.17	0.09	-0.61	-0.75	0.77	-0.22	-1.67	0.13	-0.22	-0.95
21	0.66	-0.04	-0.34	0.89	-0.09	-0.43	0.75	-0.04	-0.53	0.76	-0.16	-0.76
22	0.68	0.02	0.43	0.73	0.01	0.17	0.34	0.13	0.23	0.54	0.22	0.25
23	0.04	-0.06	0.08	0.09	-0.09	0.05	0.12	-0.05	0.44	0.19	-0.12	0.00
24	0.00	-0.08	0.04	0.05	-0.07	0.07	0.23	-0.02	0.03	0.22	-0.07	0.08
25	0.08	-0.13	0.00	0.05	-0.08	0.08	0.08	-0.01	0.09	0.16	-0.05	0.12
26	0.13	-0.07	-0.03	0.00	-0.02	-0.03	0.13	-0.04	-0.08	0.22	-0.03	-0.03
27	0.54	-0.04	-0.37	0.54	-0.03	-0.24	0.35	-0.03	-0.49	0.96	-0.10	-0.54

- When the static test results in these two tables are examined, it is determined that deformations in X, Y and Z directions for 27 points did not exceed the required boundary conditions. (X<=3 inch, Y<=1.5 inch, Z<=3 inch)
- The seats does not have enough deformation to prevent the rapid evacuation of passengers.
- All seats succeed to remain attached to seat tracks.
- No failure was observed on the primary structures.

- Also, there was no damage in the other seat structures, all equipment could remain on the seats.
- It has been determined that the seat belts did not separate from attachment points.

With all these, since the deformation values are acceptable, static tests have been successful.

3.2 Dynamic Impact Test Results

The summary of dynamic tests to be performed in the light of the data obtained from the interface load analysis is formed as in Table 3.5.

Table 3.5 : Dynamic impact test summary.

Test Article P/N	Test Type	Pitch	Roll	Yaw
FU12-3L001A001	16.0g	10° down LH leg	10° CW RH leg	10° CW
FU12-3L004A001	16.0g	10° down LH leg	10° CW RH leg	10° CW
FU12-3L005A001	16.0g	10° down RH leg	10° CCW LH leg	10° CCW
FU12-3C001A001	16.0g	10° down LH leg	10° CW RH leg	10° CW
FU12-3C002A001	16.0g	10° down LH leg	10° CW RH leg	10° CW
FU12-3L001A001	14.0g	0°	0°	0°
FU12-3L004A001	14.0g	0°	0°	0°
FU12-3L005A001	14.0g	0°	0°	0°
FU12-3C001A001	14.0g	0°	0°	0°
FU12-3C002A001	14.0g	0°	0°	0°
FU12-3L002A001	16.0g row to row 30" Zone C	0°	0°	0°
FU12-3L002A001				
FU12-3L002A001	16.0g row to row 33" Zone B	0°	0°	10° CW
FU12-3L002A001				
FU12-3L002A001	16.0g row to row 33" Zone A	0°	0°	10° CCW
FU12-3L002A001				
FU12-3L001A001	16.0g front row head path with bulkhead	0°	0°	0°
FU12-3C001A001	16.0g front row head path	0°	0°	0°
FU12-3L001A001	16.0g front row head path without bulkhead	0°	0°	0°

In these tests, the pitch, roll and yaw direction are selected to increase the criticality of critical aft leg. The program, which helps in the selection of critical seat with the interface load calculation, also provides the determination of these directions. These angles are applied to the seats at a minimum of 10 degrees when necessary.

3.2.1 16.0g FWD structural dynamic test results

In this section, information about the test set-up and results of 16.0g structural dynamic tests will be given.

3.2.1.1 16.0g FWD structural dynamic test for FU12-3L001A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.6 and Figure 3.6.

Table 3.6 : Test setup information for FU12-3L001A001.

Test setup		Remarks
Yaw	10° CW	
Pitch	10° Down	LH Leg
Roll	10° CW	RH Leg
ATD number	3	Full occupied
Seat weight	179.1 lb	It does not include life vest and literature
Min. Balast Weight	194.1 lb	Weight value with life vest and literature
Baggage	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

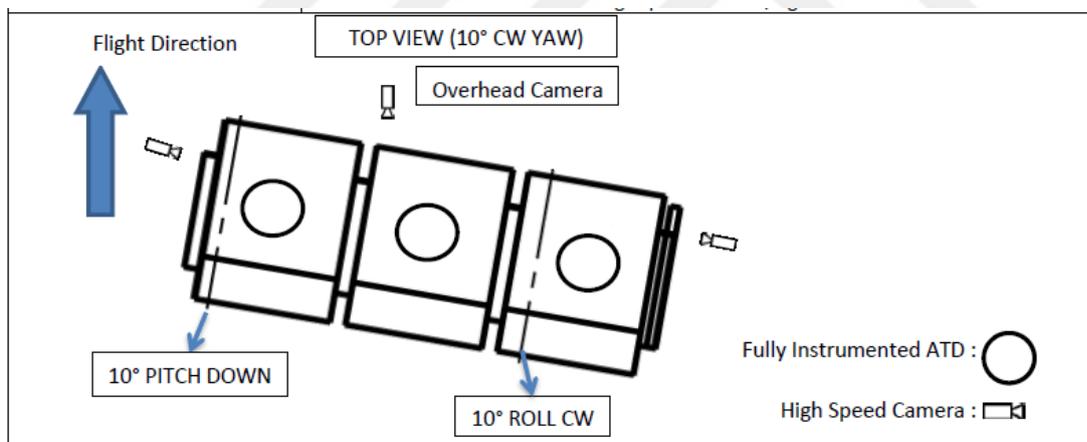


Figure 3.6 : Test drawing for FU12-3L001A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.

- All deployable parts retained on their positions.
- The results indicating other numerical values are given collectively in Table 3.11 and 3.12. The deformations are within the allowable limits.
- The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.1.2 16.0g FWD structural dynamic test for FU12-3L004A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.7 and Figure 3.7.

Table 3.7 : Test setup information for FU12-3L004A001.

Test setup		Remarks
Yaw	10° CW	
Pitch	10° Down	LH Leg
Roll	10° CW	RH Leg
ATD number	3	Full occupied
Seat weight	122.1 lb	It does not include life vest and literature
Min.Balast Weight	137.1 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

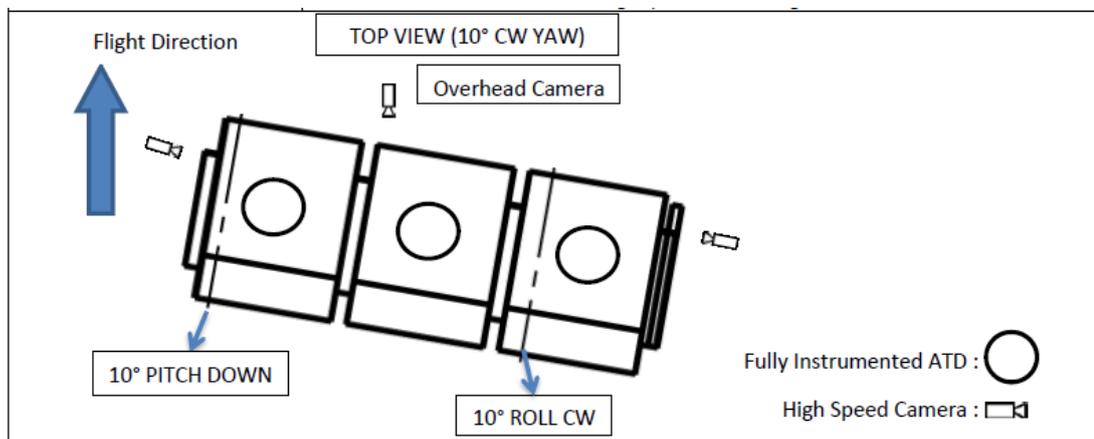


Figure 3.7 : Test drawing for FU12-3L004A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.

- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- During the inspection performed after the test, it was detected that there is a crack at front edge of RH seat pan and there are small broken part on other seats because of leg pressure of ATD. But it was considered that it has no appreciable effect both sharp, injury object and preventing rapid evacuation of passengers. The photos of damaged parts are shown in Figure 3.8.



Figure 3.8 : Craked and broken seatpan.

The weight of the broken seat pan part is shown in Figure 3.9. Due to the fact that their weighing is less than 0.33 pound, they are considered to be within the acceptable limits. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 5, 1(e) 2015).



Figure 3.9 : Weight of the broken seatpan parts.

- The results indicating other numerical values are given collectively in Table 3.11 and 3.12. The deformations are within the allowable limits.
- The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.1.3 16.0g FWD structural dynamic test for FU12-3L005A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.8 and Figure 3.10.

Table 3.8 : Test setup information for FU12-3L005A001.

Test setup		Remarks
Yaw	10° CCW	
Pitch	10° Down	RH Leg
Roll	10° CCW	LH Leg
ATD number	2	LH and Center Occupied
Seat weight	88.7 lb	It does not include life vest and literature
Min. Balast Weight	103.7 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

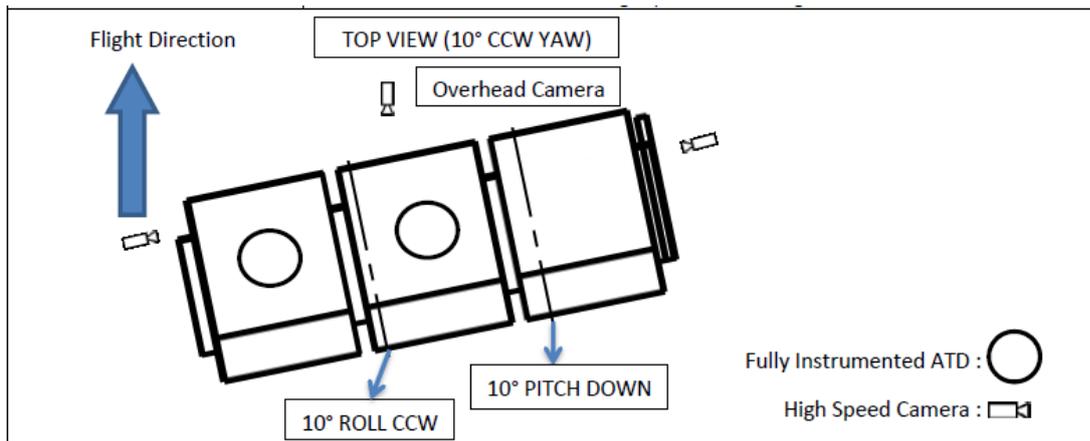


Figure 3.10 : Test drawing for FU12-3L005A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- During the inspection performed after the test, it was detected that there is a crack at front edges of seat pans and there are small broken parts because of leg pressure of ATD. But it was considered that it has no appreciable effect both sharp, injury object and preventing rapid evacuation of passengers. The photos of damaged parts and their weight are shown in Figure 3.11.

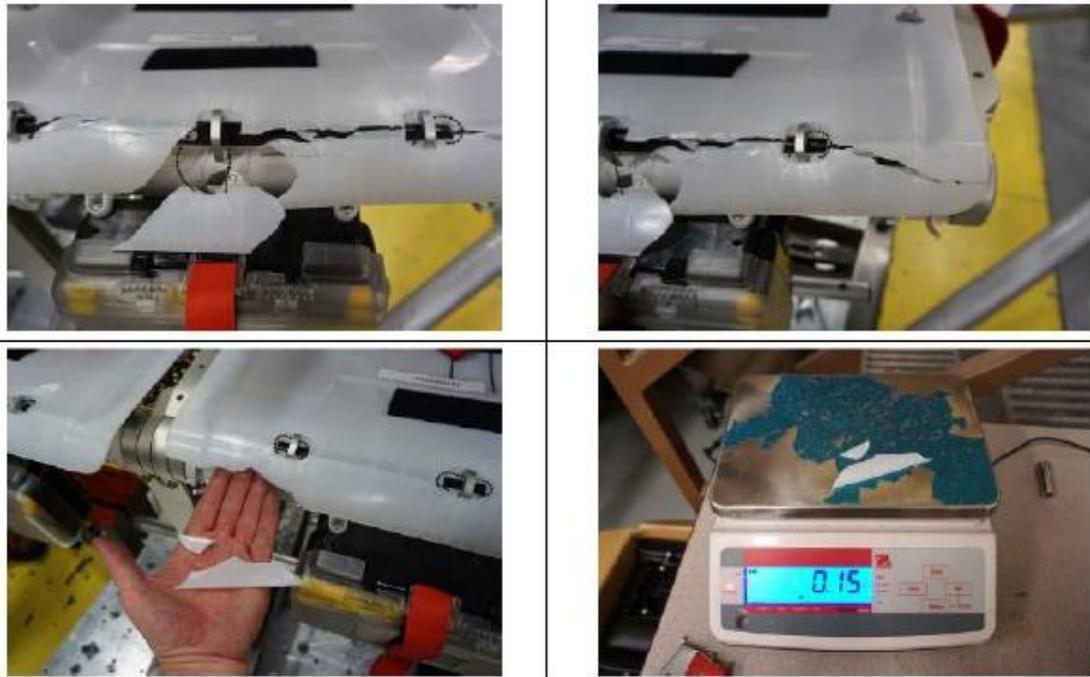


Figure 3.11 : Cracked/broken seatpan and their weight.

Due to the fact that their weighing is less than 0.33 pound, they are considered to be within the acceptable limits. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 5, 1(e) 2015).

- The results indicating other numerical values are given collectively in Table 3.11 and 3.12. The deformations are within the allowable limits.
- The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.1.4 16.0g FWD structural dynamic test for FU12-3C001A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.9 and Figure 3.12.

Table 3.9 : Test setup information for FU12-3C001A001.

Test setup		Remarks
Yaw	10° CW	
Pitch	10° Down	LH Leg
Roll	10° CW	RH Leg
ATD number	2	LH and Center Occupied
Seat weight	176.9 lb	It does not include life vest and literature
Min. Balast Weight	191.9 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

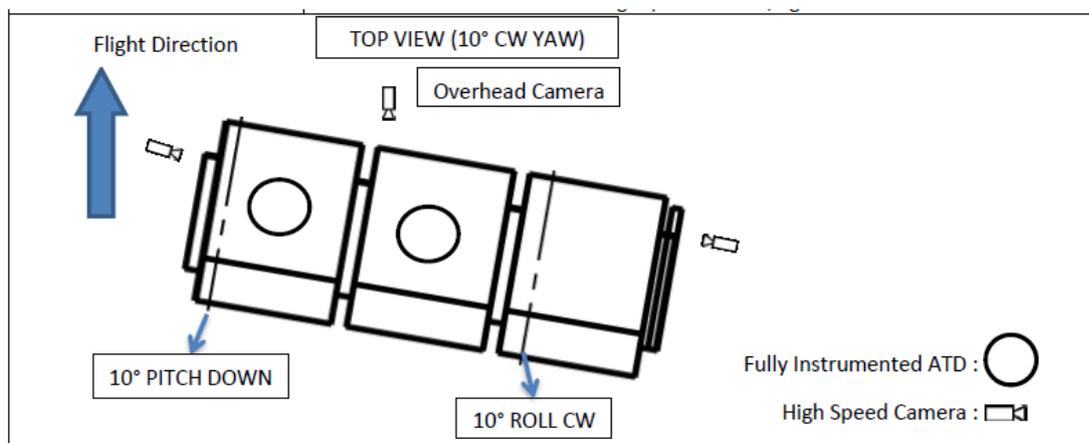


Figure 3.12 : Test drawing for FU12-3C001A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- During the inspection performed after the test, it was observed that armrest was broken. The photos of broken armrest is shown in Figure 3.13.



Figure 3.13 : Broken armrest.

The weight of the broken armrest is shown in Figure 3.14. Due to the fact that their weighing is less than 0.33 pound, they are considered to be within the acceptable limits. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 5, 1(e) 2015).



Figure 3.14 : Weight of the broken armrest.

As shown in Figure 3.15, with measurement performed, it can be also concluded that the broken armrest is not in the head strike zone. In other words, the test can be considered successful since the head of ATD will not contact with the broken armrest. It has no appreciable effect both sharp, injury object and preventing rapid evacuation of passengers. (FAA Advisory Circular (AC) 25.17-A, Transport Airplane Cabin Interiors Crashworthiness Handbook, Change 1, Section 25-785, 2016).

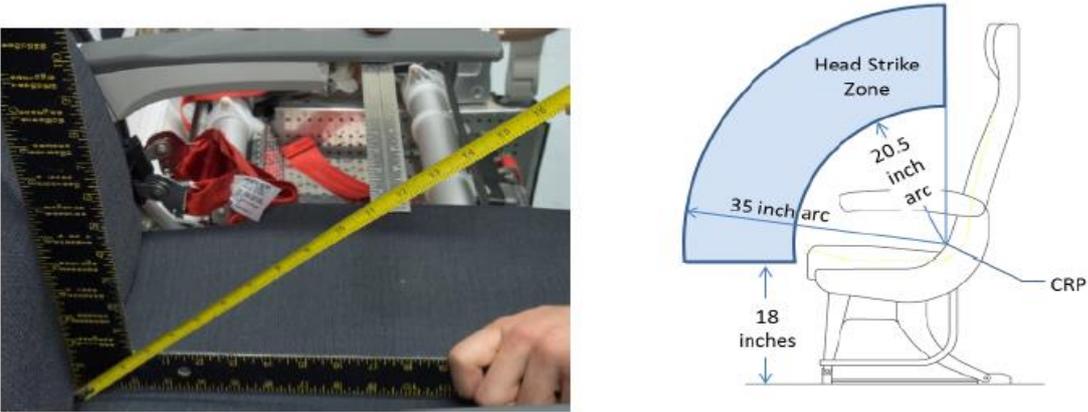


Figure 3.15 : Head strike zone.

- The results indicating other numerical values are given collectively in Table 3.11 and 3.12. The deformations are within the allowable limits.
- The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.1.5 16.0g FWD structural dynamic test for FU12-3C002A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.10 and Figure 3.16.

Table 3.10 : Test setup information for FU12-3C002A001.

Test setup		Remarks
Yaw	10° CW	
Pitch	10° Down	LH Leg
Roll	10° CW	RH Leg
ATD number	2	LH and Center Occupied
Seat weight	128.8 lb	It does not include life vest and literature
Min.Balast Weight	143.8 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

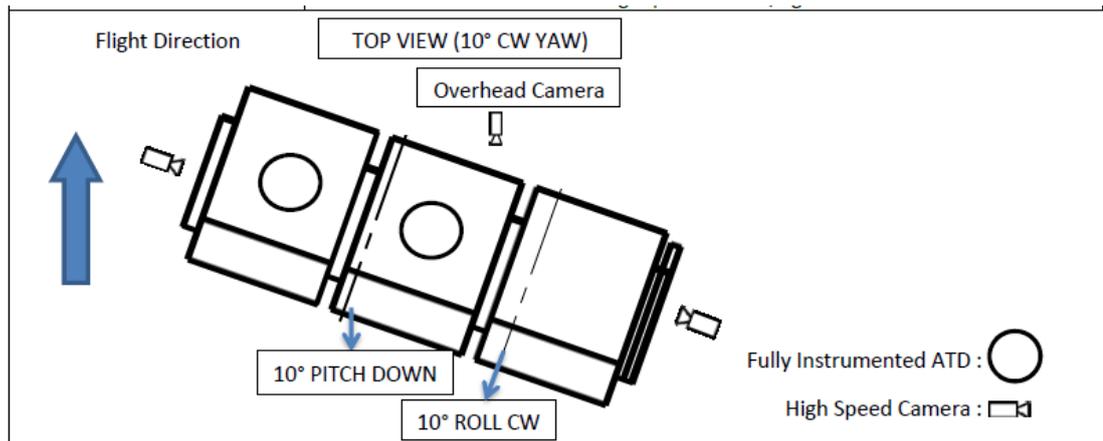


Figure 3.16 : Test drawing for FU12-3C002A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- The results indicating other numerical values are given collectively in Table 3.11 and 3.12. The deformations are within the allowable limits.
- The test result is PASS because this test satisfies the pass/fail criteria successfully.

The values of the 27 deformation points in these 16.0g FWD structural dynamic tests are given in Table 3.11. When the dynamic test results in this table are examined, it is determined that deformations in X, Y and Z directions for 27 points did not exceed the required boundary conditions. ($X \leq 3$ inch, $Y \leq 1.5$ inch, $Z \leq 3$ inch).

Table 3.11 : Deformation values for 16.0g tests.

Point	Deformations for FU12-3L001A001 seat			Deformations for FU12-3L004A001 seat			Deformations for FU12-3L005A001 seat			Deformations for FU12-3C001A001 seat			Deformations for FU12-3C002A001 seat		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	2.04	-1.02	-0.50	1.18	-0.45	-0.50	0.66	0.12	-0.25	2.50	-0.26	-0.62	1.21	0.06	-0.37
2	0.02	-0.24	-0.01	0.08	-0.14	-0.19	0.49	0.01	-0.30	0.64	-0.28	-0.17	0.28	-0.09	-0.13
3	0.04	-0.40	0.02	0.08	-0.28	0.02	0.53	0.21	-0.09	0.71	-0.27	0.22	0.30	-0.10	0.08
4	0.03	-0.11	0.05	-0.08	-0.05	-0.14	0.41	0.00	-0.23	0.46	-0.21	-0.06	0.09	-0.05	-0.05
5	-0.01	-0.24	0.01	-0.07	-0.13	0.00	0.41	0.11	-0.15	0.46	-0.19	0.13	0.11	0.03	0.11
6	0.06	-0.14	-0.01	0.03	0.01	0.05	0.63	-0.04	-0.17	0.32	-0.09	0.15	0.16	0.04	-0.10
7	2.46	-1.10	-0.74	1.52	-0.55	-0.65	0.61	0.13	-0.21	2.61	-0.21	-0.60	1.22	0.09	-0.31
8	0.93	-0.37	0.38	0.54	-0.17	0.05	0.23	0.14	-0.06	0.55	0.17	0.70	0.04	0.06	0.08
9	0.15	-0.22	0.07	0.01	-0.12	0.09	0.30	0.17	-0.05	0.35	-0.16	0.13	0.01	0.00	0.13
10	-0.08	-0.11	-0.01	0.13	-0.04	-0.03	0.33	0.01	-0.14	0.21	-0.07	-0.03	0.09	0.06	-0.04
11	3.17	-0.57	-1.17	1.84	-0.19	-0.87	0.22	-0.01	-0.09	0.66	-0.39	-0.23	0.04	0.11	0.00
12	1.15	-0.56	0.3	0.68	-0.14	0.16	0.4	0.17	-0.01	0.15	-0.19	-0.09	-0.18	0.09	0.06
13	0.36	-0.22	0.17	0.10	-0.11	0.14	0.09	0.17	0.06	0.19	-0.17	0.04	-0.09	0.03	0.06
14	0.18	-0.2	0.35	-0.14	0.05	-0.35	0.04	-0.06	0.00	0.10	-0.08	-0.09	-0.07	0.03	-0.01
15	2.39	-0.87	-1.69	2.12	-0.51	-1.06	1.15	-0.06	-0.28	0.27	-0.30	-0.21	1.15	0.42	-0.07
16	1.57	-0.52	0.04	0.86	-0.33	-0.09	0.03	0.17	0.13	-0.08	-0.14	-0.32	-0.59	0.12	0.32
17	0.59	-0.28	-0.08	0.24	-0.13	0.08	-0.07	0.14	0.09	0.08	-0.16	-0.07	-0.17	0.04	0.07
18	0.10	-0.6	-0.27	-0.03	-0.01	-0.11	-0.05	-0.06	-0.05	0.09	-0.07	-0.20	-0.07	0.04	-0.04
19	2.24	-0.82	-1.89	1.87	-0.42	-1.17	1.00	-0.03	-0.25	0.19	-0.31	-0.19	0.95	0.40	0.07
20	1.40	-0.33	-1.38	0.77	-0.19	-0.94	0.01	0.01	-0.12	-0.07	-0.23	-0.14	-0.58	0.09	0.46
21	0.70	-0.12	-1.06	0.22	-0.06	-0.73	-0.16	0.05	-0.06	0.02	-0.18	-0.17	-0.19	0.00	0.25
22	0.75	-0.22	-0.3	0.21	-0.11	-0.04	-0.15	0.14	0.11	0.00	-0.15	-0.24	-0.23	0.00	-0.15
23	0.11	0.01	-0.03	0.06	0.02	0.02	-0.02	0.00	0.01	0.08	-0.08	-0.08	-0.06	0.06	0.01
24	0.03	-0.01	-0.06	0.11	-0.03	-0.07	0.06	0.02	0.03	0.07	0.03	-0.06	-0.03	0.04	0.02
25	0.09	0.02	-0.02	0.03	0.02	0.02	-0.02	0.01	-0.03	0.07	-0.06	-0.17	-0.08	0.03	0.11
26	0.01	-0.07	-0.04	0.10	0.00	-0.02	0.07	0.00	-0.05	0.11	-0.03	-0.04	-0.01	0.06	0.06
27	0.01	-0.06	-0.47	-0.10	-0.01	-0.47	-0.11	-0.09	-0.04	0.12	-0.12	-0.26	-0.06	0.02	0.15

Also, some numerical data indicating that the necessary conditions of tests are met are given together with C/B ratio, the angle of seat pan in Table 3.12. According to this table, the C/B ratio calculated with first and last conditions of the backrest did not exceed 50%. The pitch down angles of the seat pan also did not exceed 20%.

With all these results, it can be said that the 16.0g dynamic tests have been successfully completed.

Table 3.12 : The table of output performance for 16.0g tests.

		UNIT	REQUIR ED 16.0g	TEST RESULTS			
Test article part number			FU12-3L001A001	FU12-3L004A001	FU12-3L005A001	FU12-3C001A001	FU12-3C002A001
Test description			16.0g FWD Structural	16.0g FWD Structural	16.0g FWD Structural	16.0g FWD Structural	16.0g FWD Structural
Setup Yaw	[°]		10° CW	10° CW	10° CCW	10° CW	10° CW
Setup Occupancy			Full occupancy	Full occupancy	Left + center	Left + center	Left + center
Lifevest Retrieval			ok	ok	ok	ok	ok
Acceleration G	[g]	>16	16.19	16.14	16.52	16.28	16.60
Rise time Tr	[ms]	<90	83.65	85.95	81.75	86.85	84.55
Impact velocity V	[ft/sec]	>44.00	44.5	44.41	44.4	45.33	44.93
C/B ratio (Left)	[%]	>50.00	89.6	93.2	98.6	89.8	94.4
C/B ratio (Center)	[%]	>50.00	87.4	92.1	99.4	97.9	99.4
C/B ratio (Right)	[%]	>50.00	78.3	91.5	94.3	99.1	94.0
Seat pan pitch down	[°]	<20.00	4	4.4	0.7	2.9	2.1
Seat pan pitch up	[°]	<35.00	N/A	N/A	N/A	N/A	N/A
Comments			PASS	PASS	PASS	PASS	PASS

3.2.2 14.0g vertical structural dynamic test results

In this section, information about the test set-up and results of 14.0g vertical structural dynamic tests will be given.

3.2.2.1 14.0g vertical structural dynamic test for FU12-3L001A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.13 and Figure 3.17.

Table 3.13 : 14.0g test setup information for FU12-3L001A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	179.1 lb	It does not include life vest and literature
Min.Balast Weight	194.1 lb	Weight value with life vest and literature
Baggage weight	N/A	
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

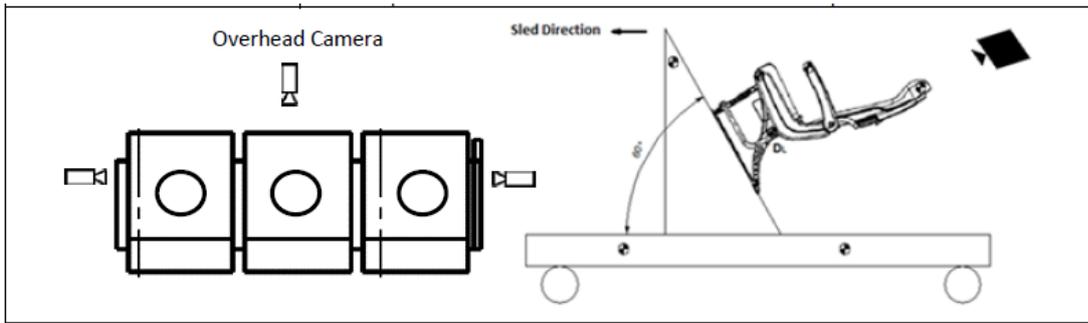


Figure 3.17 : 14.0g test drawing for FU12-3L001A001.

After the test is applied, it was found that the seat pan was damaged as seen in Figure 3.18. The weight of the broken parts of seat pans are also shown in Figure 3.18. Even though all other criteria such as deformation limits, weight of broken seat pan parts, maximum lumbar load of ATD have acceptable limitations, since seat pan is accepted as one of the primary load path elements, the test result was recorded as FAIL. The same test will be repeated by using a new seat pan. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 3, 2015).



Figure 3.18 : Damaged seat pan and their weight of broken parts.

3.2.2.2 Repeated 14.0g vertical structural dynamic test for FU12-3L001A001

The test was repeated by using new seat pan under the conditions specified in Table 3.13 and Figure 3.17.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- Lumbar loads did not exceed the 1500 lb. This result will be given collectively in Table 3.19 together with results indicating other numerical values such as seat pan angle, C/B ratio.
- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.18.

The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.2.3 14.0g vertical structural dynamic test for FU12-3L004A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.14 and Figure 3.19.

Table 3.14 : 14.0g test setup information for FU12-3L004A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	122.1 lb	It does not include life vest and literature
Min.Balast Weight	137.1 lb	Weight value with life vest and literature
Baggage weight	N/A	
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

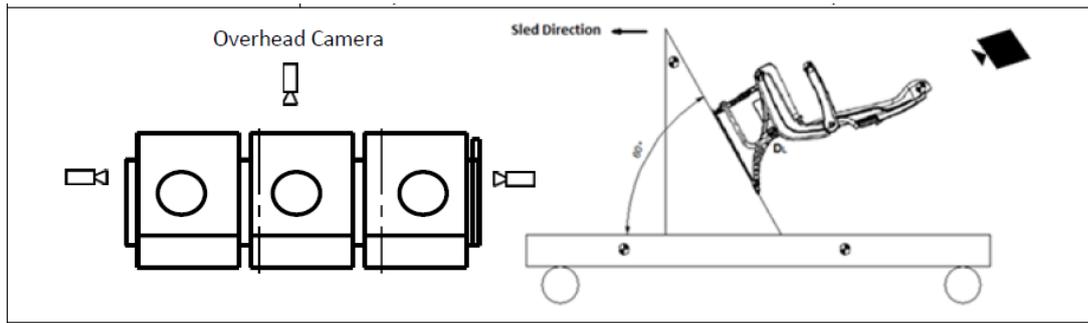


Figure 3.19 : 14.0g test drawing for FU12-3L004A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- Lumbar loads did not exceed the 1500 lb. This result will be given collectively in Table 3.19 together with results indicating other numerical values such as seat pan angle, C/B ratio.
- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.18.

The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.2.4 14.0g vertical structural dynamic test for FU12-3L005A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.15 and Figure 3.20.

Table 3.15 : 14.0g test setup information for FU12-3L005A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	88.7 lb	It does not include life vest and literature
Min.Balast Weight	103.7 lb	Weight value with life vest and literature
Baggage weight	N/A	
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

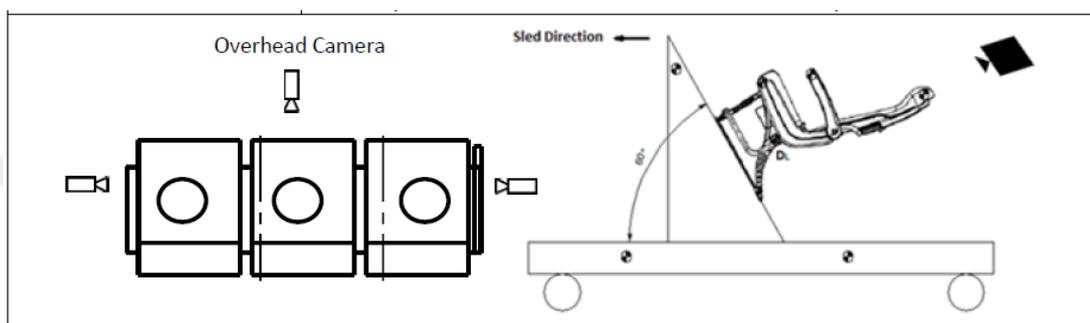


Figure 3.20 : 14.0g test drawing for FU12-3L005A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- Lumbar loads did not exceed the 1500 lb. This result will be given collectively in Table 3.19 together with results indicating other numerical values such as seat pan angle, C/B ratio.
- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.18.

The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.2.5 14.0g vertical structural dynamic test for FU12-3C001A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.16 and Figure 3.21.

Table 3.16 : 14.0g test setup information for FU12-3C001A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	176.9 lb	It does not include life vest and literature
Min.Balast Weight	191.9 lb	Weight value with life vest and literature
Baggage weight	N/A	
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

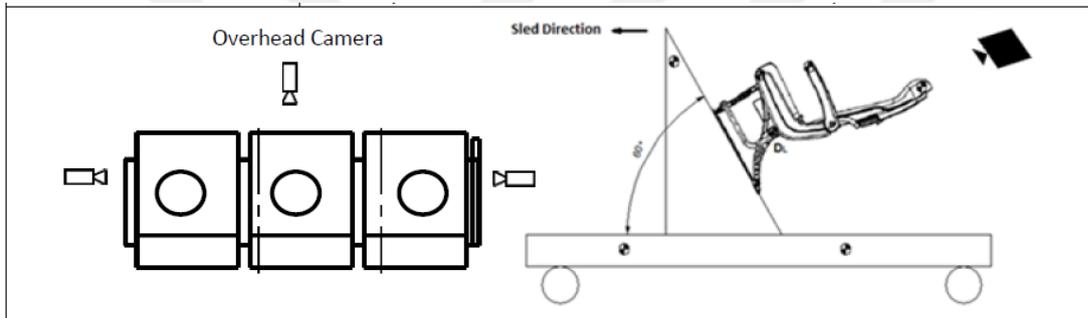


Figure 3.21 : 14.0g test drawing for FU12-3C001A001.

After the test is applied, it was found that the seat pan was damaged as seen in Figure 3.22.

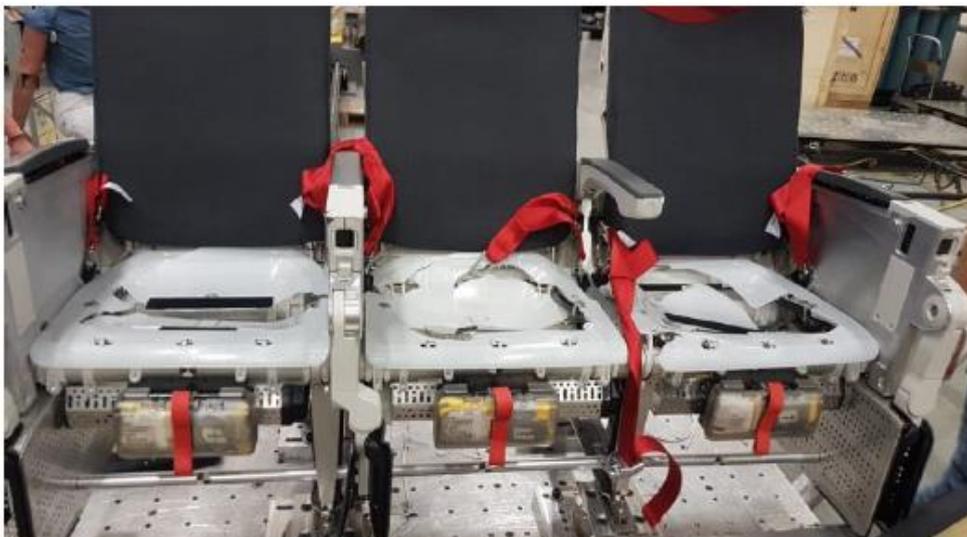


Figure 3.22 : Damaged seat pan.

The weight of the broken parts of seat pans are also shown in Figure 3.23. Even though all other criteria such as deformation limits, weight of broken seat pan parts, maximum lumbar load of ATD have acceptable limitations, since seat pan is accepted as one of the primary load path elements, the test result was recorded as FAIL. The same test will be repeated by using a new seat pan. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 3, 2015).



Figure 3.23 : The weight of broken seat pan parts.

3.2.2.6 Repeated 14.0g vertical structural dynamic test for FU12-3001A001

The test was repeated by using new seat pan under the conditions specified in Table 3.16 and Figure 3.21.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.
- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.

- Lumbar loads did not exceed the 1500 lb. This result will be given collectively in Table 3.19 together with results indicating other numerical values such as seat pan angle, C/B ratio.
- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.18.

The test result is PASS because this test satisfies the pass/fail criteria successfully.

3.2.2.7 14.0g vertical structural dynamic test for FU12-3C002A001

The test article is prepared for setup in the light of the information and drawing given in Table 3.17 and Figure 3.24.

Table 3.17 : 14.0g test setup information for FU12-3C002A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	176.9 lb	It does not include life vest and literature
Min. Balast Weight	191.9 lb	Weight value with life vest and literature
Baggage weight	N/A	
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

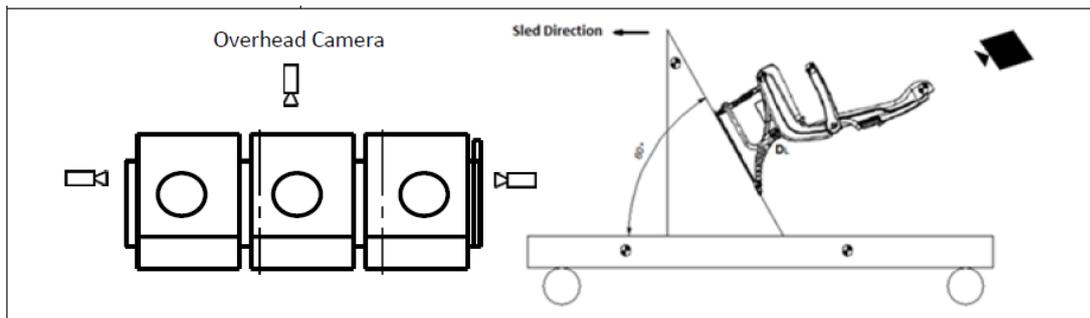


Figure 3.24 : 14.0g test drawing for FU12-3C002A001.

After the test is applied, when considering the pass/fail criteria in section 2.3.4;

- The attachments of seat structure and the primary load path were not damaged.
- The seat restraint system was not separated from the attachment points.
- Item of mass remained on the seat.

- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.
- All deployable parts retained on their positions.
- Lumbar loads did not exceed the 1500 lb. This result will be given collectively in Table 3.19 together with results indicating other numerical values such as seat pan angle, C/B ratio.
- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.18.

The test result is PASS because this test satisfies the pass/fail criteria successfully.

The values of the 27 deformation points in these 14.0g vertical structural dynamic tests are given in Table 3.18. When the dynamic test results in this table are examined, it is determined that deformations in X, Y and Z directions for 27 points did not exceed the required boundary conditions. ($X \leq 3$ inch, $Y \leq 1.5$ inch, $Z \leq 3$ inch).

Table 3.18 : Deformation values for 14.0g tests.

Point	Deformations for FU12-3L001A001 seat			Deformations for FU12-3L004A001 seat			Deformations for FU12-3L005A001 seat			Deformations for FU12-3C001A001 seat			Deformations for FU12-3C002A001 seat		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	-1.17	-0.36	-0.31	-0.95	-0.52	-0.36	-0.76	0.09	-0.55	-1.31	0.43	-0.86	-1.56	0.53	-1.07
2	-0.03	-0.10	0.06	0.01	-0.25	-0.02	-0.15	0.09	-0.31	-0.14	0.12	-0.49	-0.17	0.21	-0.68
3	-0.04	-0.05	-0.14	0.13	-0.15	-0.44	-0.15	0.18	-0.40	-0.23	0.03	0.26	-0.18	0.22	-0.26
4	0.02	0.01	0.01	0.05	-0.07	-0.01	0.12	0.06	-0.28	0.25	0.05	-0.25	0.31	0.06	-0.42
5	-0.05	0.08	0.01	0.03	0.00	-0.01	0.08	0.06	-0.04	0.22	0.03	0.18	0.20	0.06	0.09
6	0.01	-0.01	0.06	0.04	-0.06	-0.03	0.00	0.02	-0.05	0.57	0.08	-0.01	0.26	-0.01	-0.33
7	-1.66	-0.52	-0.57	-1.02	-0.51	-0.49	-1.06	0.16	-0.53	-1.68	0.54	-0.76	-1.75	0.57	-0.92
8	-0.07	-0.01	0.21	0.07	-0.02	-0.50	-0.02	0.21	-0.46	0.21	0.16	-0.82	0.10	0.17	-0.53
9	0.10	0.08	0.06	0.17	-0.04	-0.02	0.06	0.02	-0.01	0.20	0.00	0.08	0.22	0.06	-0.02
10	0.18	0.05	0.10	0.00	-0.03	0.02	0.02	0.06	-0.03	0.24	0.03	0.03	0.15	-0.02	-0.12
11	-1.17	-0.44	-0.71	-1.48	-0.58	-0.94	-1.03	0.00	-0.51	-0.74	0.00	-0.34	-1.26	-0.09	-0.64
12	0.00	-0.03	0.19	0.04	-0.02	-0.33	-0.07	0.13	-0.42	0.05	0.00	0.05	-0.10	-0.03	0.01
13	0.29	0.08	0.11	0.36	-0.01	0.00	0.12	0.03	-0.03	0.18	0.03	0.01	0.22	0.04	0.04
14	0.53	0.17	0.04	0.00	-0.02	0.17	0.03	-0.06	0.02	0.07	0.07	0.05	0.02	-0.04	0.17
15	-1.64	-0.47	-1.14	-1.73	-0.59	-1.28	-1.84	-0.22	-0.87	-1.57	-0.41	-0.73	-2.43	-0.45	-1.12
16	-0.05	-0.02	0.23	0.00	-0.09	-0.24	-0.27	0.09	-0.09	-0.32	-0.03	-0.21	-0.59	-0.09	0.12
17	0.48	0.02	0.07	0.57	0.04	0.01	0.14	0.07	0.07	0.16	0.04	0.04	0.17	0.05	0.22
18	0.56	0.06	0.00	0.40	-0.02	-0.12	0.17	0.00	-0.02	0.26	0.08	0.06	0.20	-0.02	0.05
19	-1.01	-0.36	-1.19	-1.62	-0.57	-1.34	-1.20	-0.19	-0.80	-1.37	-0.29	-0.85	-2.10	-0.39	-1.23
20	0.18	-0.14	-0.74	0.12	-0.21	-0.90	-0.17	-0.02	-0.47	-0.25	-0.06	-0.54	-0.45	-0.02	-0.68
21	0.74	0.01	-0.51	0.79	-0.06	-0.59	0.17	0.05	-0.24	0.17	0.05	-0.37	0.21	0.08	-0.39
22	0.67	0.05	0.06	0.65	0.00	0.13	0.16	0.06	0.20	0.14	0.00	0.11	0.14	0.06	0.37
23	0.01	0.05	0.09	0.07	-0.02	0.02	0.07	0.04	0.04	0.07	0.00	0.01	0.02	-0.02	0.13
24	0.00	0.01	0.01	0.01	-0.02	0.04	0.03	0.03	-0.03	0.02	0.02	0.03	0.03	-0.01	0.02
25	0.10	0.02	0.11	0.06	-0.03	0.01	0.07	0.05	-0.09	0.03	0.07	0.04	0.01	0.06	0.03
26	0.05	0.02	0.00	0.02	-0.04	-0.01	0.04	-0.02	0.04	0.09	0.05	0.04	0.04	-0.02	0.03
27	1.16	0.02	0.07	0.69	-0.02	-0.40	0.29	0.03	-0.13	0.53	-0.02	0.07	0.36	0.02	-0.23

Also, some numerical data indicating that the necessary conditions of tests are met are given together with C/B ratio, the angle of seat pan, maximum lumbar load in Table 3.19. According to this table, the C/B ratio calculated with first and last conditions of the backrest did not exceed 50%. The pitch down angles of the seat pan also did not exceed 20%. The maximum lumbar loads of the ATD on the lumbar area did not exceed 1500 lb. With all these results, it can be said that the 14.0g dynamic tests have been successfully completed.

Table 3.19 : The table of output performance for 14.0g tests.

UNIT	REQUIR ED 14.0g	REQUIR ED 16.0g	TEST RESULTS							
			FU12- 3L001A0 01 14.0g Structural	FU12- 3L001A0 01 14.0g Structural	FU12- 3L004A0 01 14.0g Structural	FU12- 3L005A0 01 14.0g Structural	FU12- 3C001A0 01 14.0g Structural	FU12- 3C001A0 01 14.0g Structural	FU12- 3C002A0 01 14.0g Structural	
Test article part number										
Test description										
Setup Yaw [°]			0°	0°	0°	0°	0°	0°	0°	0°
Setup Occupancy			Full occupancy	Full occupancy	Full occupancy	Full occupancy	Full occupancy	Full occupancy	Full occupancy	Full occupancy
Lifevest Retrieval			ok	ok	ok	ok	ok	ok	ok	ok
Acceleration G [g]	>14	<16	14.25	14.60	14.60	14.30	14.36	14.40	14.40	14.40
Rise time Tr [ms]	<80	<90	73.65	70.8	69.8	69.9	78.15	71.1	70.3	70.3
Impact velocity V [ft/se c]	>35.00	<44.00	35.98	36.7	36.7	36.9	36.85	36.6	36.5	36.5
C/B ratio (Left) [%]	>50.00	>50.00	83.4	108	105	105	105.2	109	109	109
C/B ratio (Center) [%]	>50.00	>50.00	85.3	107	108	106	102.1	104	107	107
C/B ratio (Right) [%]	>50.00	>50.00	79.9	110	110	109	104.5	108	112	112
Seat pan pitch down [°]	<20.00		N/A	3.3	3.0	0.6	N/A	0.6	4.3	4.3
Seat pan pitch up [°]	<35.00		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Max.Lumbar Load [lb]	<1500		809.3	776.8	1038	976.7	892.5	953.6	1047.8	1047.8
Comments			FAIL	PASS	PASS	PASS	FAIL	PASS	PASS	PASS

3.2.3 HIC (Head Injury Criteria) test results

In this section, information about the test set-up and results of 16.0g FWD row to row HIC tests will be given. As mentioned before, HIC tests will be carried out in three different situations. These are Zone A, Zone B, Zone C row to row tests. While Zone A and B tests perform with 33 inches distance, Zone C test performs with 30 inches distance. During the tests, P/N FU12-3L002A001 seats will be used in two rows. One of them will be target seat, the other will be launch seat. In this tests, HIC value will be examined and femur loads will also be evaluated.

Before the tests, the head of ATD is painted in different colors as seen in Figure 3.25. The purpose of painting is to identify which area the seat hits during the impact. Special paints produced for this purpose are used because HIC value may be affected by the type of paint used. The knees and hand fingers are painted for similar purpose.



Figure 3.25 : 16.0g HIC zone C test drawing.

3.2.3.1 16.0g FWD row to row 30” zone C test

The test articles are prepared for setup in the light of the information and drawing given in Table 3.20 and Figure 3.26.

Table 3.20 : 16.0g row to row 30” zone C test setup information.

Test setup		Remarks
Yaw	0°	Zone C
Pitch	0°	
Roll	0°	
ATD number	1	Centre
Seat weight	124.5 lb	Target Seat
Seat weight	124.5 lb	Launch Seat
Baggage weight	N/A	
Life vest weight	N/A	
Literature weight	N/A	

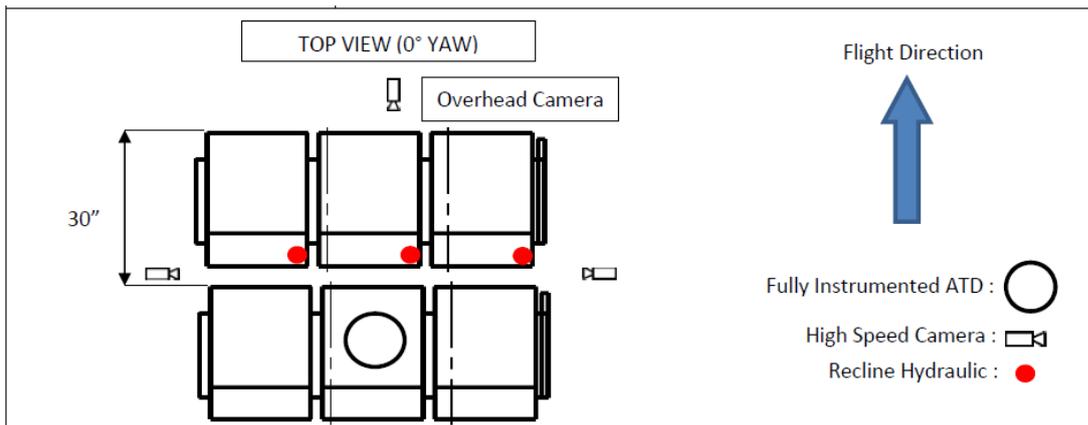


Figure 3.26 : 16.0g HIC zone C test drawing.

According to the test performed;

- Sharp edges and projections, which could cause injury or significantly prevent passengers from leaving the seat or aircraft, did not occur.

- As seen in Figure 3.27, the head of ATD struck the rectangular area mentioned before.



Figure 3.27 : Contact point of ATD and Zone C.

- The deformations are within the allowable limits. The deformation values of all tests are given Table 3.23.
- Also, some numerical data indicating that the necessary conditions of tests are met are given together with C/B ratio, the angle of seat pan, maximum femur load and HIC value in Table 3.24. According to this table, the C/B ratio calculated with first and last conditions of the backrest did not exceed 50%. The pitch down and up angles of the seat pan also did not exceed 20% and 35% respectively. The maximum femur loads of the ATD did not exceed 2250 lb. With all these results, it can be said that the Zone C HIC dynamic test has been successfully completed.

3.2.3.2 16.0g FWD row to row 33” zone B test

The test articles are prepared for setup in the light of the information and drawing given in Table 3.21 and Figure 3.28.

Table 3.21 : 16.0g row to row 33” zone B test setup information.

Test setup		Remarks
Yaw	10° CW	Zone B
Pitch	0°	
Roll	0°	
ATD number	1	Centre
Seat weight	124.5 lb	Target Seat
Seat weight	124.5 lb	Launch Seat
Baggage weight	N/A	
Life vest weight	N/A	
Literature weight	N/A	

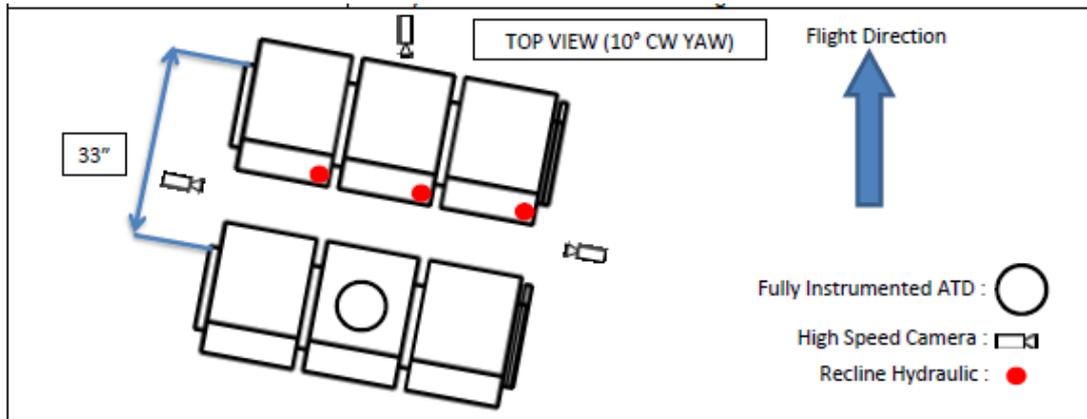


Figure 3.28 : 16.0g HIC zone B test drawing.

According to the test performed;

- As can be seen in Figure 3.29, ATD head hit a point below Zone B. In such a case (glancing blow) HIC evaluation can not be made properly. Although HIC values, femur load values, deformation values are sufficient and there are no sharp edges on the test article, the test is NULL. So the test must be repeated with reduced seat pitch. The distance will be reduced to 30 inches.



Figure 3.29 : Contact point of ATD for Zone B test.

3.2.3.3 Repeated 16.0g FWD row to row zone B test (with 30")

The test set-up was adjusted by reducing the seat pitch from 33" to 30" and the test performed again. The contact of ATD with zone B is shown in Figure 3.30.



Figure 3.30 : Correct contact point of ATD for Zone B test.

According to the test performed;

- Any sharp edge or object that could harm the passengers were not seen.
- Deformations are within the acceptable limits. The deformation results are shown Table 3.23 together with all other HIC test deformations.
- Maximum HIC and femur load values did not exceed 1000 and 2250 lb respectively. They are shown in Table 3.24 together with results of all other HIC tests.

With all these results, it can be said that the Zone B HIC dynamic test has been successfully completed.

3.2.3.4 16.0g FWD row to row 33” zone A test

The test articles are prepared for setup in the light of the information and drawing given in Table 3.22 and Figure 3.31.

Table 3.22 : 16.0g row to row 33” zone A test setup information.

Test setup		Remarks
Yaw	10° CCW	Zone A
Pitch	0°	
Roll	0°	
ATD number	1	Centre
Seat weight	124.5 lb	Target Seat
Seat weight	124.5 lb	Launch Seat
Baggage weight	N/A	
Life vest weight	N/A	
Literature weight	N/A	

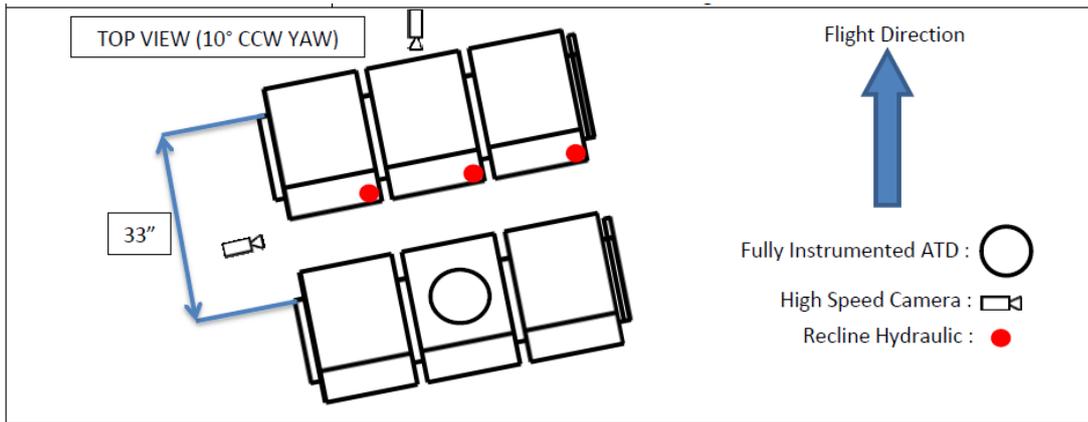


Figure 3.31 : 16.0g HIC zone A test drawing.

According to the test performed;

- As can be seen in Figure 3.32, ATD head hit a point below Zone A. In such a case (glancing blow) HIC evaluation can not be made properly. Although HIC values, femur load values, deformation values are sufficient and there are no sharp edges on the test article, the test is NULL. So the test must be repeated with reduced seat pitch. The distance will be reduced to 30 inches.

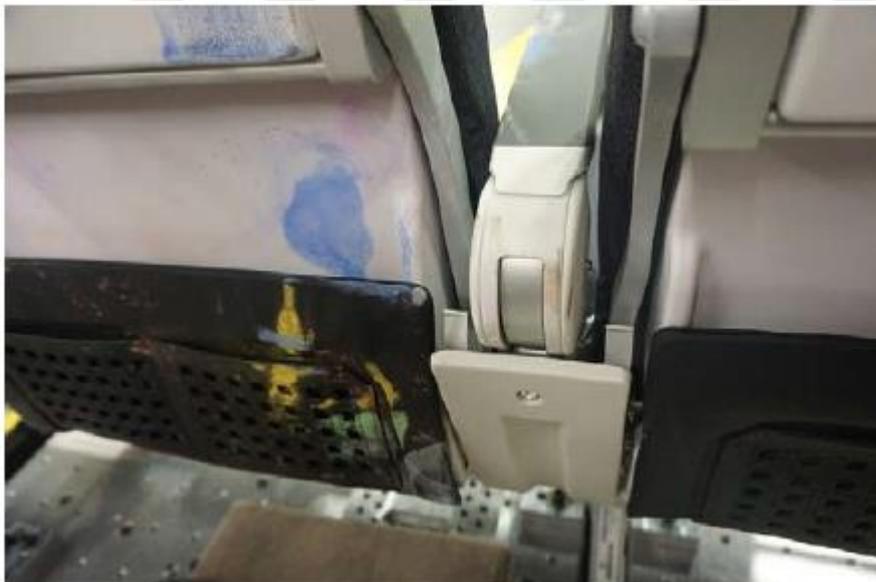


Figure 3.32 : Contact point of ATD for Zone A test.

3.2.3.5 Repeated 16.0g FWD row to row zone A test (with 30")

The test set-up was adjusted by reducing the seat pitch from 33" to 30" and the test performed again. The contact of ATD with zone A is shown in Figure 3.33.



Figure 3.33 : Correct contact point of ATD for Zone A test.

According to the test performed;

- Any sharp edge or object that could harm the passengers were not seen.
- Deformations are within the acceptable limits. The deformation results are shown Table 3.23 together with all other HIC test deformations.
- Maximum HIC and femur load values did not exceed 1000 and 2250 lb respectively. They are shown in Table 3.24 together with results of all other HIC tests.

With all these results, it can be said that the Zone A HIC dynamic test has been successfully completed.

The values of the 27 deformation points in these 16.0g row to row HIC tests are given in Table 3.23. When the dynamic test results in this table are examined, it is determined that deformations in X, Y and Z directions for 27 points did not exceed the required boundary conditions. ($X \leq 3$ inch, $Y \leq 1.5$ inch, $Z \leq 3$ inch). The deformation values are available for both target seat and launch seat.

Table 3.23 : Deformation values for HIC tests.

Point	Zone C (Target/Lauch)			Zone B (Target/Lauch)			Zone A (Target/Lauch)		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	0.09/0.65	-0.09/-0.05	0.00/-0.17	0.22/0.64	-0.14/-0.10	-0.02/-0.16	0.05/0.39	0.02/0.12	-0.03/-0.10
2	0.00/0.07	-0.03/-0.02	0.01/0.03	-0.07/0.05	-0.02/-0.02	0.04/0.05	-0.01/0.08	0.01/0.00	0.01/-0.03
3	0.02/0.09	0.02/-0.03	0.02/0.05	-0.11/0.05	-0.05/-0.07	-0.11/0.01	0.00/0.06	-0.10/0.08	0.02/0.00
4	0.01/-0.01	-0.02/-0.03	0.06/-0.02	0.02/0.04	-0.02/-0.01	0.03/-0.01	0.01/0.06	0.02/0.00	0.00/-0.02
5	0.01/0.03	-0.03/-0.01	0.04/0.00	-0.02/0.05	-0.01/-0.02	-0.02/0.01	0.02/0.08	0.00/0.01	0.01/0.02
6	-0.02/0.01	0.00/-0.01	0.05/0.02	0.04/0.05	-0.01/0.01	-0.01/-0.03	0.02/0.08	0.03/0.02	0.05/0.01
7	0.07/0.73	-0.14/-0.07	0.00/-0.18	0.19/0.69	-0.18/-0.11	-0.01/-0.17	0.07/0.42	0.00/0.13	-0.01/-0.08
8	0.00/0.14	-0.02/0.11	-0.02/0.00	0.01/0.14	-0.07/0.03	0.19/-0.08	0.03/0.04	-0.01/0.06	-0.01/-0.06
9	0.00/0.04	-0.02/0.02	0.01/0.05	-0.03/0.02	-0.08/-0.02	-0.02/-0.02	0.02/0.05	0.01/-0.02	-0.03/-0.01
10	0.11/0.02	-0.09/0.01	-0.09/0.06	0.01/0.04	-0.03/0.02	0.05/0.07	0.14/0.04	0.00/-0.02	-0.10/0.03
11	2.53/0.22	-0.06/0.03	-0.76/-0.03	1.54/0.50	-0.13/0.09	-0.33/-0.11	1.71/0.00	0.02/0.02	-0.34/0.05
12	0.17/0.08	0.03/0.01	0.11/-0.05	0.00/0.14	0.05/-0.09	0.16/0.00	0.19/0.07	0.12/-0.07	0.72/0.17
13	0.01/0.06	-0.02/-0.04	0.02/0.03	-0.01/0.12	-0.04/0.02	0.04/-0.10	0.08/0.06	0.02/0.01	0.04/0.01
14	0.29/0.06	-0.02/-0.05	-0.29/0.11	0.01/0.05	-0.02/0.01	0.03/0.00	0.32/0.05	0.04/0.04	-0.034/0.02
15	0.13/0.22	0.06/-0.01	-0.01/-0.01	0.33/1.37	0.03/0.12	-0.09/-0.23	0.91/0.06	0.09/0.06	-0.18/0.02
16	-0.09/0.01	0.08/0.01	0.02/-0.02	0.00/0.15	0.04/0.01	-0.05/0.02	0.05/0.03	0.06/0.01	-0.04/0.02
17	0.03/0.06	-0.02/0.02	0.00/-0.01	-0.02/0.14	-0.01/0.02	0.01/0.00	0.05/0.07	0.02/0.00	0.00/0.03
18	-0.17/0.07	-0.01/-0.01	0.24/0.04	-0.06/0.14	-0.01/0.01	0.06/0.02	-0.09/0.08	0.03/0.02	0.13/-0.01
19	0.10/0.11	0.08/0.05	0.04/0.04	0.32/1.36	0.01/0.11	-0.10/-0.21	0.86/0.08	0.07/0.02	-0.14/0.03
20	-0.03/-0.03	0.00/0.00	0.08/0.05	0.01/0.05	0.00/0.02	-0.03/0.08	0.08/0.01	0.04/0.01	-0.02/0.02
21	0.03/0.10	-0.02/-0.02	0.08/0.06	-0.03/0.14	-0.03/-0.01	-0.04/0.09	0.08/0.05	0.02/0.01	-0.04/0.04
22	0.02/0.03	-0.02/-0.01	-0.03/0.00	-0.03/0.17	-0.02/0.00	0.00/0.01	0.11/0.01	0.01/0.02	0.00/-0.02
23	0.01/0.05	0.03/0.03	0.06/0.04	-0.05/0.10	0.01/0.02	0.02/0.02	0.04/0.07	-0.06/0.05	0.01/-0.01
24	0.03/0.03	-0.01/0.01	-0.01/-0.03	-0.02/-0.01	-0.02/0.00	0.05/0.00	0.01/0.03	0.00/0.01	0.04/-0.02
25	0.06/0.08	-0.02/-0.01	-0.03/0.01	-0.02/0.10	-0.03/-0.04	0.00/-0.09	0.07/0.07	0.04/-0.01	-0.01/0.01
26	-0.01/0.00	-0.04/-0.04	0.05/0.05	0.00/0.04	-0.01/-0.04	0.01/0.09	0.03/0.00	0.01/0.02	0.02/0.05
27	-0.34/0.07	-0.07/-0.02	0.25/0.05	-0.24/0.15	-0.07/0.00	0.35/0.05	-0.24/0.12	0.00/0.05	0.21/-0.02

Also, some numerical data indicating that the necessary conditions of tests are met are given together with C/B ratio, the angle of seat pan, maximum femur load in Table 3.24. According to this table, the C/B ratio calculated with first and last conditions of the backrest did not exceed 50%. The pitch down and up angles of the seat pan also did not exceed 20% and 35% respectively. The maximum femur loads of the ATD on the femur area did not exceed 2250 lb. With all these results, it can be said that the 16.0g row to row HIC tests have been successfully completed.

Table 3.24 : The table of output performance for 16.0g row to row HIC tests.

	UNIT	REQUI	TEST RESULTS				
		RED 16.0g					
Test article P/N (launch)		FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	
Test article P/N (target)		FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	FU12-3L002A001	
Test description		16.0g row to row 30" Zone C	16.0g row to row 33" Zone B	16.0g row to row 30" Zone B	16.0g row to row 33" Zone A	16.0g row to row 30" Zone A	
Setup Yaw	[°]	0°	10° CW	10° CW	10° CCW	10° CCW	
Setup Occupancy		Centre	Centre	Centre	Centre	Centre	
Lifevest Retrieval		N/A	N/A	N/A	N/A	N/A	
Acceleration G	[g]	>16	16.39	16.34	16.42	16.27	16.28
Rise time Tr	[ms]	<90	84.05	82.45	88.45	88.5	89.05
Impact velocity V	[ft/sec]	>44.00	45.51	45.03	45.3	45.47	44.91
C/B ratio (Left)	[%]	>50.00	96.9	94.1	97	99.1	98.3
C/B ratio (Center)	[%]	>50.00	99.3	90.6	98.3	99.7	100.3
C/B ratio (Right)	[%]	>50.00	99.2	97.7	94.3	99.8	100
Seat pan pitch down	[°]	<20.00	0	0	0.4	0.1	1.9
Seat pan pitch up	[°]	<35.00	0.1	0.8	0.6	0.6	1.7
Max.HIC		1000	575.2	548.9	446.8	519.2	419.7
Max.Femur Load	[lb]	<2250	177.6	191.7	178.6	48.9	195.6
Comments		PASS	NULL	PASS	NULL	PASS	PASS

3.2.4 Head path test results

In this section, information about the test set-up and results of 16.0g FWD head path tests will be given. Head path tests carry out in three different situations. These tests will be performed to the first row seats. Since the RH and LH row is symmetrically identical, two front row LH seats and one center row seat will be used in the tests. While bulkhead is placed in front of the seats in two test, no obstacle will be placed in one. During the tests, two each P/N FU12-3L001A001 seats and one each P/N FU12-3C001A001 seats will be used. In these tests, it is undesirable to contact the head of ATD with the bulkhead. If it hits, the HIC value should be examined. With these tests, both head path and knee path of ATD will be investigated.

Before the tests, the head of ATD is painted in different colors as seen in Figure 3.25. The purpose of painting is to identify which area the seat hits during the impact. Special paints produced for this purpose are used because HIC value may be affected by the type of paint used. The knees and hand fingers are painted for similar purpose.

3.2.4.1 16.0g FWD head path test for FU12-3L001A001 with bulkhead

The test articles are prepared for setup in the light of the information and drawing given in Table 3.25 and Figure 3.34.

Table 3.25 : 16.0g FWD head path test setup information for fu12-3L001A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	179.1 lb	It does not include life vest and literature
Min.Balast Weight	191.1 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

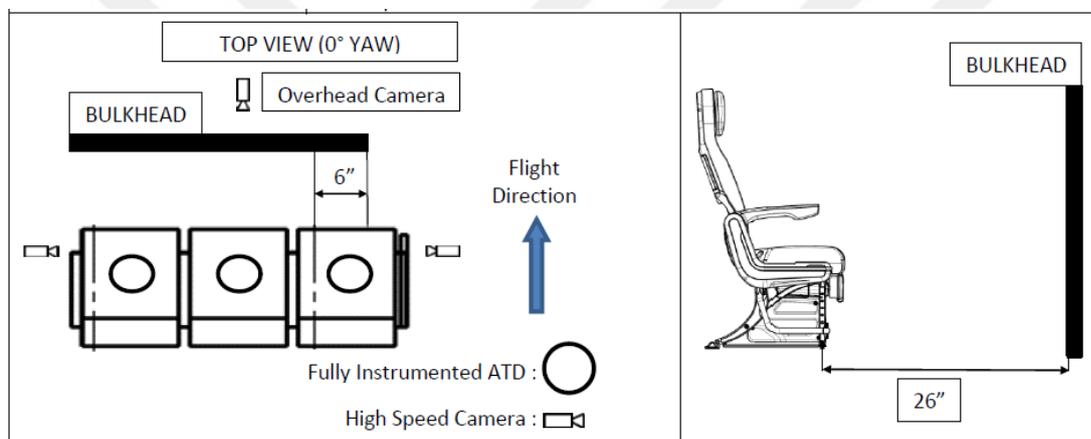


Figure 3.34 : 16.0g FWD head path test drawing for FU1-3L001A001.

According to the test performed;

- Any sharp edge or object that could harm the passengers were not seen.
- The head of ATD did not contact with the bulkhead. As can be seen Figure 3.35, there was only contact between the hand finger of ATD and bulkhead.
- Deformations are within the acceptable limits. The deformation results are shown Table 3.28 together with all other head path test deformations.
- Other results to be provided are given in Table 3.29.

With all these results, it can be said that the head path with bulkhead dynamic test for FU12-3L001A001 seat has been successfully completed.



Figure 3.35 : Contact with ATD finger and bulkhead.

3.2.4.2 16.0g FWD head path test for FU12-3C001A001 with bulkhead

The test articles are prepared for setup in the light of the information and drawing given in Table 3.26 and Figure 3.36.

Table 3.26 : 16.0g FWD head path test setup information for FU12-3C001A001.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	176.9 lb	It does not include life vest and literature
Min.Balast Weight	191.9 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

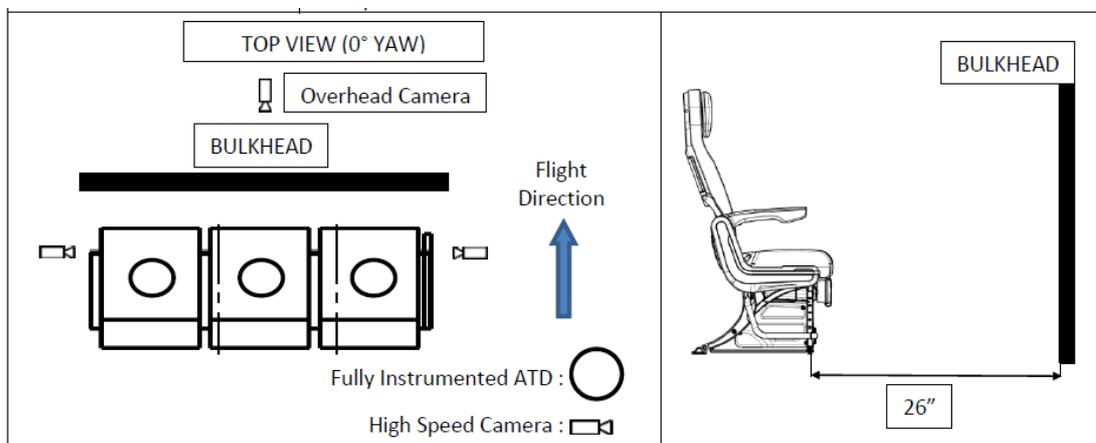


Figure 3.36 : 16.0g FWD head path test drawing for FU12-3C001A001.

According to the test performed;

- Any sharp edge or object that could harm the passengers were not seen.
- The head of ATD did not contact with the bulkhead. There was only contact between the hand finger of ATD and bulkhead.
- Deformations are within the acceptable limits. The deformation results are shown Table 3.28 together with all other head path test deformations.
- Other results to be provided are given in Table 3.29.

With all these results, it can be said that the head path with bulkhead dynamic test for FU12-3C001A001 seat has been successfully completed.

3.2.4.3 16.0g FWD head path test for FU12-3L001A001 without bulkhead

The test articles are prepared for setup in the light of the information and drawing given in Table 3.27 and Figure 3.37.

Table 3.27 : 16.0g FWD head path test setup information without bulkhead.

Test setup		Remarks
Yaw	0°	
Pitch	0°	
Roll	0°	
ATD number	3	Full occupied
Seat weight	179.1 lb	It does not include life vest and literature
Min.Balast Weight	194.1 lb	Weight value with life vest and literature
Baggage weight	60 lb	20 lb per PAX
Life vest weight	6 lb	2 lb per PAX
Literature weight	9 lb	3 lb per PAX

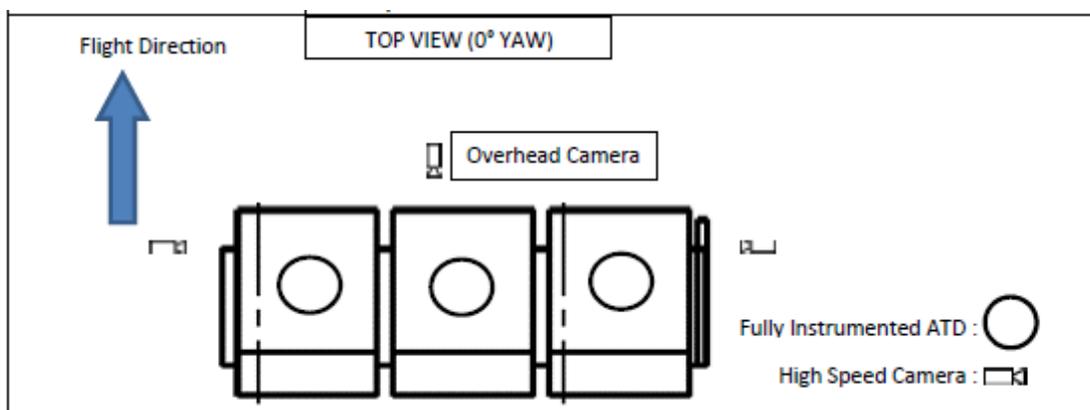


Figure 3.37 : 16.0g FWD head path test drawing without bulkhead.

According to the test performed;

- Any sharp edge or object that could harm the passengers were not seen.
- During the inspection, RH seat pan found cracked and a small part was detected due to pressure of ATD legs. The cracking seat pan is shown in Figure 3.38.



Figure 3.38 : Damaged seat pan.

As can be seen in Figure 3.39, weighing of broken part is less than 0.33 pound, it is considered to be within the acceptable limits. (FAA Advisory Circular (AC) 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, Change 1, Appendix 5, 1(e) 2015).



Figure 3.39 : The weight of broken part.

- Deformations are within the acceptable limits. The deformation results are shown Table 3.28 together with all other head path test deformations.
- Other results to be provided are given in Table 3.29.

With all these results, it can be said that the head path without bulkhead dynamic test for FU12-3L001A001 seat has been successfully completed.

The values of the 27 deformation points in these 16.0g head path tests are given in Table 3.28. When the dynamic test results in this table are examined, it is determined that deformations in X, Y and Z directions for 27 points did not exceed the required boundary conditions. ($X \leq 3$ inch, $Y \leq 1.5$ inch, $Z \leq 3$ inch). The deformation values are available for both target seat and launch seat.

Table 3.28 : Deformation values for head path tests.

Point	Head path with bulkhead for FU12-3L001A001			Head path with bulkhead for FU12-3C001A001			Head path without bulkhead for FU12-3L001A001		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	1.26	-0.29	-0.29	0.00	-0.23	0.13	1.00	-0.65	0.22
2	0.06	0.01	0.02	0.08	0.00	0.08	-0.11	-0.18	0.06
3	-0.05	-0.07	-0.27	0.09	0.00	0.02	-0.13	-0.23	0.03
4	0.06	0.05	0.01	0.12	0.00	0.09	-0.04	-0.08	0.06
5	0.06	0.01	0.07	0.12	0.01	-0.05	-0.06	-0.11	-0.02
6	0.08	0.02	0.06	0.15	0.00	0.03	0.07	-0.09	-0.03
7	1.45	-0.28	-0.42	-0.05	-0.32	0.07	1.20	-0.71	-0.38
8	0.43	0.10	0.19	0.13	0.07	0.11	0.42	-0.06	0.29
9	0.10	0.01	0.07	0.08	-0.02	-0.02	-0.03	-0.11	0.11
10	0.00	0.03	0.04	0.00	0.03	0.04	-0.15	-0.07	0.05
11	0.74	0.15	-0.36	0.74	0.15	-0.36	2.51	-0.36	-0.88
12	0.32	0.01	0.12	0.32	0.01	0.12	0.41	-0.06	0.20
13	0.16	0.02	0.11	0.16	0.02	0.11	-0.03	-0.05	0.23
14	0.00	-0.04	-0.05	0.00	-0.04	-0.05	2.37	-0.66	-1.04
15	0.17	0.08	-0.47	0.17	0.08	-0.47	0.63	-0.19	0.22
16	0.44	-0.03	0.12	0.44	-0.03	0.12	-0.06	-0.09	0.00
17	0.23	-0.06	0.07	0.23	-0.06	0.07	-0.35	-0.06	-0.15
18	0.4	0.01	0.1	0.4	0.01	0.1	2.28	-0.58	-1.18
19	1.16	-0.01	-0.53	1.16	-0.01	-0.53	0.46	-0.23	-0.87
20	0.36	0.02	-0.31	0.36	0.02	-0.31	-0.07	-0.08	-0.65
21	0.19	0.04	-0.20	0.19	0.04	-0.20	-0.05	-0.08	-0.07
22	0.18	0.00	-0.01	0.18	0.00	-0.01	-0.08	-0.04	0.01
23	0.04	0.02	0.06	0.04	0.02	0.06	-0.01	-0.08	0.05
24	0.11	0.05	0.02	0.11	0.05	0.02	-0.13	-0.09	0.00
25	0.02	0.05	0.05	0.02	0.05	0.05	-0.01	-0.07	0.03
26	0.05	0.04	0.00	0.05	0.04	0.00	-0.17	-0.05	0.14
27	0.03	0.06	0.05	0.03	0.06	0.05	-0.58	-0.06	-0.21

Also, some numerical data indicating that the necessary conditions of tests are met are given together with C/B ratio, the angle of seat pan in Table 3.29. According to this table, the C/B ratio calculated with first and last conditions of the backrest did not exceed 50%. The pitch down angles of the seat pan also did not exceed 20%. With all these results, it can be said that the 16.0g head path tests have been successfully completed.

Table 3.29 : The table of output performance for 16.0g head path tests.

	UNIT	REQUIRED 16.0g	TEST RESULTS		
Test article P/N			FU12-3L001A001	FU12-3C002A001	FU12-3L001A001
Test description			16.0g head path with bulkhead	16.0g head path with bulkhead	16.0g head path without bulkhead
Setup Yaw	[°]		0°	0°	0°
Setup Occupancy			Full occupancy	Full occupancy	Full occupancy
Lifevest Retrieval			ok	ok	ok
Acceleration G	[g]	>16	16.16	16.18	16.32
Rise time Tr	[ms]	<90	82.85	86.6	85.75
Impact velocity V	[ft/sec]	>44.00	44.55	44.88	44.52
C/B ratio (Left)	[%]	>50.00	94	N/A	94.5
C/B ratio (Center)	[%]	>50.00	97.4	N/A	88.4
C/B ratio (Right)	[%]	>50.00	95.7	N/A	88.7
Seat pan pitch down	[°]	<20.00	1.3	N/A	3
Seat pan pitch up	[°]	<35.00	N/A	N/A	N/A
Comments			PASS	PASS	PASS



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