THIRTHEENTH EUROPEAN ROTORCRAFT FORUM

Paper No. 22 12.4

TECHNOLOGICAL IMPROVEMENTS OF RIGS FOR STRUCTURAL TESTING OF COMPLEX EH 101 HELICOPTER COMPONENTS

A. Brivio
&
LPS Project & Development Team

A G U S T A - ITALY

September 8-11, 1987

ARLES, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

SUMMARY

THE PURPOSE OF THIS ABSTRACT IS TO PROVIDE A CONCISE DESCRIPTION OF THE ACTIVITY IMPLEMENTED IN RECENT PAST YEARS IN THE " STRUCTURAL TESTS LABORATORY " (L.P.S.) OF AGUSTA FOR THE IMPROVEMENT OF TEST RIGS EQUIPMENT. VARIOUS ASPECTS COVERING THE MECHANICAL/HYDRAULIC SEGMENT OF THE TEST RIGS WILL BE ELABORATED UPON, WHILST TWO IMPORTANT ASPECTS SUCH AS THE TEST RIGS' ELECTRONIC CONTROL SYSTEMS AND THE STRESS ANALYSIS INSTRUMENTATION WILL BE ONLY MARGINALLY HANDLED. WORTHS TO SAY THAT THEY ALSO KNEW IN RECENT PAST YEARS CONSIDERABLE DEVELOPMENT AND GREATER ATTENTION CONCERNING THE METHODOLOGICAL ASPECTS IN RESPECT OF BASIC FORMULATION, ACCURACY AND QUALITY ASSURANCE OF THE PRODUCT.

SUBJECTS HANDLED

SOME BASIC ENGINEERING CRITERIA WHICH LED TO THE DEFINITION OF NEW APPROACHES IN THE DESIGN OF THE TEST RIGS WILL BE HANDLED INITIALLY.
A SHORT DESCRIPTION OF HOW THESE BASIC CRITERIA HAVE PRACTICALLY MODIFIED THE TEST STAND CONFIGURATION, WITH THE ADOPTION OF CONCEPTS LIKE:
- MAJOR LOADS REACTION SYSTEM " FLOATING IN SPACE "
- "PIVOTING" TYPE HYDRAULIC "SERVO-ACTUATORS".
- "INTEGRATED" TYPE HYDRAULIC "SERVO-ACTUATORS".
- MODULARITY AND STANDARDIZATION OF TEST RIG COMPONENTS

WILL FOLLOW.
FINALLY TWO NEWLY-DESIGNED TEST RIGS WILL BE BRIEFLY ILLUSTRATED:
- EH 101 " MAIN ROTOR HUB " TEST RIG
- EH 101 " MAIN ROTOR TENSION LINK " TEST RIG

INTRODUCTION

THE REASONS WHICH REQUESTED A METHODOLOGICAL REFORMULATION OF THE DESIGN AND THE DEVELOPMENT OF TEST RIGS ARE TO BE SOUGHT IN A MORE IN-DEPT ANALYSIS OF THEIR WAY OF OPERATION AND OF THE LIMITS OF THE RESULTS THAT ARE ACHIEVED.
ALTHOUGH THIS SUBJECT IS APPLICABLE TO THE FORMULATION OF ANY KIND OF TEST RIG, THE REQUIREMENTS OF SOME EH 101 HELICOPTER CRITICAL COMPONENTS ARE EVIDENCED HEREINAFTER.
THESE REQUIREMENTS FEATURE HIGH STRESSES ABOUT ONE AXIS, WHICH CONSIDERABLY AFFECT THE LOADS IN THE OTHER AXES, BEING THE LATTER OF SMALLER AMPLITUDE RELATIVE TO THE FORMER.

DEFINITION OF BASIC REQUIREMENTS

IN RECENT PAST YEARS THE STRUCTURAL TESTS HAVE BEEN MORE AND MORE ENRICHED WITH IMPORTANT CONTENTS: BESIDES MANTAINING AND QUALITATIVELY IMPROVE THE PRODUCT'S INTEGRITY ASSURANCE UP TO THE CERTIFICATION, THESE HAVE INCREASINGLY STESSED THE ROLE OF SUPPORT TO DESIGN PROBLEMS IN A COMBINED EFFORT.
AS A RESULT THEREOF THE BASIC REQUIREMENTS FOR THE FORMULATION OF THE TEST RIGS HAVE RATHER RADICALLY CHANGED:
TODAY WE ARE FACED WITH THE INCREASING REQUIREMENT OF " AUSCULTATING " WITH THE APPROPRIATE MEANS THE SPECIMEN UNDER STESS, IN ORDER TO EVIDENCE ANY ABNORMAL BEHAVIOUR CONDITION AND TO COMPARE THE RESULTS WITH THE THEORETICAL PREDICTIONS OF EVEN THE MOST COMPLEX DESIGN'S ANALITIC MEANS.
IN ORDER TO ACHIEVE AN EXPERIMENTAL VERIFICATION HAVING AN ENGINEERING MEANING FROM EITHER THE QUANTITY AND QUALITY ASPECT, THE FOLLOWING OPERATIONAL CONDITIONS ARE REQUIRED:

- THE SPECIMEN SHALL BE CREARLY VISIBLE, ACCESSIBLE AND WITHIN EASY REACH.
- THE INDIVIDUAL LOADS SHALL BE KNOWN, EASILY COMPARABLE AND MODIFIABLE.
- NO INTERACTION SHALL EXIST BETWEEN THE DIFFERENT LOADS OR, IN ANY CASE, ALL INEVITABLE PARASITE LOADS SHALL BE CLEARLY ASSESSED.

SIMILAR CONCEPTS OF COURSE ALSO APPLY TO INSTRUMENTATION AND MEASUREMENT EQUIPMENT, WHICH IS NOT HANDLED HEREIN.

IN SHORT WE CAN SAY THAT:
- TEST RIGS HAVE BEEN DESIGNED AND DEVELOPED IN THE PAST, WHICH HAD THE CAPACITY OF SUBJECTING THE SPECIMEN EVEN TO COMPLEX SYSTEM OF LOADS, BUT WITH A POOR CONTROL OVER ITS INTERNAL BEHAVIOUR, THEREBY ASSESSING ITS STRUCTURAL INTEGRITY MERELY FROM THE POINT OF VIEW OF THE EXTERNAL LOADS CAUSING FAILURE OR THE NUMBER OF CYCLES TO FAILURE OR TO DAMAGE.
- NOWDAYS, IN ADDITION TO THE FORMER, THE MAIN PURPOSE IS TO TRANSLATE INTO OPERATIONAL REALITY THE MATHEMATICAL AND PHISIC MODELS USED IN DESIGN CALCULATIONS, WITH THE FINAL AIM OF VALIDATING THEM AFTER HAVING EVIDENCED AND MODIFIED ALL APPLICATION INCONSISTENCIES.

IT CAN EASILY BE UNDERSTOOD THAT AN IMMEDIATE ADVANTAGE CAN BE DERIVED FROM THIS TYPE OF ACTIVITY IN TERMS OF OVERALL DESIGN RELIABILITY, WHICH CAN LEAD TO CONSIDERABLE COST AND TIME REDUCTION FOR FUTURE PROJECTS, COMBINED WITH A SENSIBLE INCREASE IN TERMS OF QUALITY.

MODIFICATIONS INCORPORATED IN TEST RIG CONFIGURATION

OF THE VARIOUS MODIFICATIONS INCORPORATED, HEREIN THE MAJOR ONES AFFECTING A LARGE NUMBER OF TEST RIGS WILL BE DESCRIBED.

SYSTEM OF REACTION OF THE APPLIED LOADS FLOATING IN SPACE

THIS TYPE OF SYSTEM WAS INTRODUCED RECENTLY AS A RESULT OF DIFFERENT EXPERIENCIES LOGGED UP IN PAST YEARS.
IT ENABLES TO ACHIEVE A CONSIDERABLE REDUCTION IN SIZE, COMPLEXITY, MAINTENANCE TIME AND COSTS, BESIDES A TECHNICAL IMPROVEMENT.

PHOTOS 1 AND 2, SHOWING EXAMPLES OF TEST RIGS, THE CONVENTIONAL AND THE NEW ONE, CAN BE USED TO EXPLAIN THE MAJOR DIFFERENCIES.

PHOTO 1 EVIDENCES THAT THE NEED TO MANTAIN IN TOLERABLE LIMITS THE PARASITE LOADS, WHICH INEVITABLY ARE GENERATED BY THE INPUT OF SEVERAL LOADS ACTING CUNCURRENTLY, IN A CONVENTIONAL RIG LEADS TO:
- CONSIDERABLE OVERALL DIMENSIONS, AT LEAST 10 TIMES THE SPEC. SIZE
- NEED TO DISCHARGE HEAVY FORCES (CENTRIGUGAL IN THIS CASE) ONTO ELASTIC ELEMENTS, WHICH CONSEQUENTLY STORE A GREAT ENERGY: THIS CONSTITUTE A HAZARD TO OPERATORS' SAFETY IN THE EVENT OF ANY FAILURES, WHICH ARE VERY LIKELY TO OCCOUR BEING THE TEST GENERALLY CONDUCTED CLOSE TO EXTREME STRENGHT LIMITS.
- DUE TO THE LARGE DIMENSIONS AND THEREFORE POOR ACCESSIBILITY, OBVIOUS DIFFICULTIES ARISE TO OBSERVE THE SPECIMEN AT A CLOSE RANGE TO VISUALLY EVALUATE THE PHENOMENA, SUCH AS DELAMINATIONS AND/OR FRETTING, TO BE INVESTIGATED AND TO MAKE PHOTOELASTIC ANALYSES.
- CONSIDERABLE DIFFICULTIES AND COMPLEXITIES TO SET-UP CONDITIONED CLIMATIC CHAMBERS.
- AMONG THE PARASITE LOADS INIRTIA FORCES MUST BE CONSIDERED; THESE ARE DUE TO THE SUSPENDED MASSES, HIGH IN THIS TYPE OF RIGS.
- CONSIDERABLE MANUFACTURING, ASSEMBLY AND MAINTENANCE COSTS.
- OPERATIONAL DIFFICULTIES HAVING TO HANDLE HEAVY WEIGHTS.

PHOTO 2 EVIDENCES THAT THE DIFFERENT LAYOUT ALLOWED BY THE NEW TYPE OF SYSTEM OF REATION OF THE LOADS CAN ALLOW:
- DRASTIC REDUCTION IN OVERALL DIMENSIONS, WITH THE COMPLETE TEST RIG'S SIZE EQUAL OR JUST EXCEEDING THE SPECIMEN'S.

- THE HIGH CENTRIFUGAL FORCES ARE GENERATED IN A WAY THAT CAN BE DEFINED "FLOATING" AND "SELF-BALANCED":
  . "FLOATING" BECAUSE THE SYSTEM IS FREE TO FLOAT IN SPACE, NOT REACTED TO THE GROUND, AND CAPABLE OF ADAPTING TO THE MOVEMENTS OF THE SPECIMEN UNDER STRESSES CAUSED BY OTHER LOADS AND MOMENTS.
  . "SELF-BALANCED" BECAUSE THE C.F. DISCHARGE CONCURRENTLY ON THE TOP OF EACH OTHER; THE ACCURACY OF THE APPLIED LOADS IN DIRECTY RELATED TO THE MANUFACTURING TOLERANCES, THAT CAN BE VERY HIGH AS THE ITEMS ARE OF SMALL SIZE.
- THERE IS NO NEED FOR HIGH ELASTIC COMPENSATION TO KEEP THE FORCES WITHIN THE REQUIRED TOLERANCE VALUES, BECAUSE ONLY VERY LITTLE IMPEDIMENTS EXIST TO SPECIMEN FREE DEFORMATION.
- THE SPECIMEN IS PLACED IN AN ERGONOMIC POSITION: THIS ALLOWS TO LOOK DIRECTLY, WITH A REASONABLE SAFETY MARGIN, AT ITS BEHAVIOUR DURING THE LOADING.
- POSSIBILITY TO PLACE THE SPECIMEN IN AN EASILY INSPECTABLE AND EASILY INSTALLABLE DEDICATED CONDITIONING CHAMBER.
- LOW AND ALMOST NEGLIGIBLE INERTIA FORCES, BEING THE ASSOCIATED MASSES VERY LOW: LESS THAN 1/1000 OF THE APPLIED LOADS.
- REDUCTION IN MANUFACTURING, INSTALLATION AND MAINTENANCE TIME: ALL THE COMPONENTS ARE OF SMALL SIZE AND THEREFORE EASY TO HANDLE
- IT IS POSSIBLE TO INSTRUMENT (WITH STRAIN-GAGES FOR INSTANCE) THE CRITICAL COMPONENTS OF THE TEST RIG, BEING SMALL AND PRECISION MACHINED: THIS ALLOWS THEIR PREVIOUS VERIFICATION AND A CONTINOUS MONITORING DURING THE TEST, IN ORDER TO EVIDENCE ANY MALFUNCTIONS (PARASITE LOAD MEASUREMENTS CAN BE CARRIED OUT).

PIVOTING SERVO- ACTUATORS

THESE REPRESENT AN IMPROVEMENT IN RELATION TO CONVENTIONAL LINEAR SERVO-ACTUATORS, WHICH, IN ORDER TO FOLLOW THE DEFORMATION MOVEMENT OF THE SPECIMEN UNDER LOAD, REQUIRE END ARTICULATED JOINTS.
DIFFERENT TYPES OF ARTICULATED JOINTS HAVE BEEN STUDIED TO TAKE UP THE ABOVE END MOVEMENTS:

- BALL-JOINTS AVAILABLE ON THE MARKET: THEY FEATURE COMPACTNESS, BUT HAVE A DRAWBACK OF FEATURING AN EVIDENT BACKLASH THAT CAN BE DECREASED WITH A PRELOAD, BUT THIS CAUSING HIGHER FRICTION MOMENTS THAT OPPOSES TO MOTION.
- IN ORDER TO RESOLVE THE BACKLASH PROBLEMS, WHICH RENDER TESTS VERY CRITICAL AND POORLY CONTROLLABLE, SPECIAL JOINTS INCORPORATING ELASTOMERIC COMPONENTS HAVE BEEN DEVELOPED: THESE SOLUTIONS HOWEVER FEATURE REACTION TO MOTION, WHERE PARASITE LOADS ARE GENERATED NO LONGER BY FRICTION BUT BY ELASTIC/PLASTIC REACTION.
- FLEXIBLE LAMINATION JOINTS HAVE BEEN DEVELOPED: THEY SHOW BETTER RESULTS, BEING THE PARASITE MOMENTS DUE MAINLY TO ELASTIC DEFORMATION, THAT CAN BE ACCURATELY ASSESSED.
- ALSO VARIOUS TYPES OF HYDRO-SUPPORTED BALL JOINTS HAVE BEEN DEVELOPED, FROM THE TYPE OPERATING IN ONE DIRECTION ONLY TO THE BI-DIRECTIONAL ONE: THESE HAVE RESULTED IN SUBSTANTIAL IMPROVEMENTS SUCH AS LACK OF BACKLASH AND FRICTION, BUT HIGHER COST AND SIZE.

THE "PIVOTING SERVO-ACTUATORS" HAVE PROVEN MUCH BETTER THAN ALL THE ABOVE SYSTEMS, MINIMIZING ALL THE PROBLEMS DESCRIBED: THEY CONSIST BASICALLY IN THE INTEGRATION INTO A SINGLE SYSTEM OF THE POSSIBILITIES TO PROVIDE ALTERNATIVE MOTIONS AND CONCURRENTLY TO PIVOT FREELY AROND THE POINTS REACHED DURING THE ACTUATOR'S STROKE.
PHOTO 3 SHOWS A TYPICAL "PIVOTING SERVO-ACTUATOR" AND ITS TEST RIG.
THE IMPROVEMENTS MENTIONED ABOVE AND THE EASE OF INSTALLATION RENDER THIS TYPE OF ACTUATORS GENERALLY PREFERABLE TO CONVENTIONAL TYPES, HAVING OPTIMIZED THE DEVELOPMENT PROCESS AND REDUCED THE RELEVANT COSTS, DESPITE THE HIGHER COMPLEXITY OF THE DESIGN.

INTEGRATED SERVO- ACTUATORS

THEIR NAME IS DERIVED BY THE FACT THAT THEY ARE PLACED INTO THE GENERATED LOADS' REACTION STRUCTURE,WHICH SERVES AS THEIR SUPPORT AND OF WHICH THEY ARE AN INTEGRAL PART.
TIPICALLY THEY ARE PLACED INSIDE THE "FLAOTING GROUND" SYSTEMS, ACTING AS ACTUATORS TO GENERATE THE DESIDERED FORCES.
THEY CONSTITUTE A FURTHER EVOLUTION OF THE "PIVOTING-ACTUATOR" CONCEPT AND RELATIVE TO THE LATTER THEY DIFFER UNDER THE FOLLOWING ASPECTS:

- THEY ARE SINGLE-EFFECT ACTUATORS, GENERATING ONLY THRUSTS.
- THEY CAN BE USED IN DIFFERENT LOADING STRUCTURES, WHICH CAN VARY IN RELATION TO INSTALLATION.
- THEY GENERATE VERY STRONG THRUSTS, ALTHOUGH FEATURING MASSES MUCH LOWER THAN OTHER TYPES OF ACTUATORS.

MODULARITY AND STANDARDIZATION OF SYSTEMS AND TEST-RIGS.

THIS IS A BASIC CHARACTERISTIC OF THE SYSTEMS PROJECTED IN THE LABORATORY FROM SOME YEARS NOW IN ALL ITS SECTORS:
IN THE MECHANIC AND HYDRAULIC, THAT ARE DESCRIBED HERE, AS IN THE ELECTRONIC AND THE MEASURING SYSTEMS: THEY ALSO WERE DEEPLY STUDIED AND EXPERIMENTED, BUT ARE NOT SHOWN HERE.
IT WORTHS TO STRESS THAT THESE MODIFICATIONS HAD A SUBSTANTIAL IMPACT ALSO ON THE GRAPHIC FORMULATION OF THE PROJECTS, WHICH TODAY IS ALMOST TOTALLY MANAGED WITH THE AID OF CAD SYSTEMS:
ALL THE STANDARDS AND THE MODULAR ELEMENTS DEVELOPED, STARTING FROM UNIVERSAL BENCHES TO THE SMALLEST COMPONENT, HAVE BEEN STORED IN; CONSEQUENTLY THE TIME DEVOTED TO THE PROJECT AND GRAPHIC SEGMENT HAS BEEN DRASTICALLY DIMINISHED, THEREBY IMPROVING THE ON-TIME AND ACCURACY ASPECTS.

DESCRIPTION OF TWO TEST RIGS FOR EH 101

MAIN ROTOR HUB TEST RIG

THE SPECIMEN, M.R. HUB, IS A HYBRID, COMPOSITE PLUS METAL, COMPONENT; IT IS PROVIDED WITH ELASTOMERIC JOINTS FOR THE CONNECTION TO THE 5 BLADES THROUGH TENSION LINKS.
THE COMPOSITE PORTION REACTS TO THE CENTRIFUGAL FORCE GENERATED BY THE BADE' ROTATION DURING FLIGHT AND TO THE BLADE GENERATED LOADS WHEN THE HELICOPTER IS ON THE GROUND.
THE METAL CENTRAL PORTION TAKES UP THE LIFT AND THE DRAG LOADS IN FLIGHT AND SIMILAR LOADS WHEN THE HELICOPTER IS ON THE GROUND.
THE TEST RIG ASSY (PHOTO N. 4) CONSIST OF A STURDY PENTAGONAL BENCH AT THE CENTER OF WHICH THE HUB IS ANCHORED.
THE SCHEME OF THE ACTING LOADS IS AS FOLLOWS:

- 5 VERTICAL FORCES, 135.000 KG F.S., ARE APPLIED TO THE COMPOSITE: THESE ARE GENERATED BY ACTUATORS INTEGRATED INTO THE SELF-BALANCED, FLOATING IN SPACE, REACTION SYSTEM. (PHOTO N. 5)
- 5 VERTICAL AND 5 ORIZONTAL FORCES CONVERGE TO THE SAME APPLICATION POINTS OF THE C.F. AND SIMULATE THE LOADS DUE TO THE PRE-CONE ANGLE AND THE OFFSET OF THE CENTRIFUGAL FORCES WITH RESPECT TO THE HUB CENTER: THESE LOADS ARE GENERATED BY INTEGRATED PUSHERS.
- 5 FORCES APPLY A VERTICAL BENDING LOAD TO THE COMPOSITE, SIMULATING GROUND LOADS: THESE ARE GENERATED BY PIVOTING SERVO-ACTUATORS, 25.000 KG F.S.
- 5 FORCES APPLY THE LIFT LOADS TO THE CENTRAL METALLIC PART: THEY ARE GENERATED BY PIVOTING SERVO-ACTUATORS, 20.000 KG F.S.+ LEVER.
- 5 FORCES APPLY THE DRAG LOADS TO THE CENTRAL METALLIC PART: THEY ARE GENERATED BY PIVOTING SERVO-ACTUATORS, 20.000 KG F.S.+ LEVER.

THE TEST RIG CAN SUBJECT THE HUB TO VERY HIGH STATIC LOADS AS WELL AS TO FATIGUE TESTS SIMULATING THE GROUND AND/OR FLIGHT LOADS; IT IS FURTHER USED FOR EXPERIMENTAL STRESS ANALYSIS PURPOSES.

TENSION LINK TEST RIG

THE SPECIMEN, TENSION LINK, IS A HYBRID, COMPOSITE PLUS METAL, COMPONENT WHICH PROVIDES CONNECTION BETWEEN THE HUB AND THE BLADE. THE INTEGRAL COMPOSITE AND METAL PORTIONS REACT TO THE LIFT, DRAG, TORQUE AND CENTRIFUGAL FORCES GENERATED BY THE BLADE IN FLIGHT, IN ADDITION TO THE GROUND LOADS DUE TO BLADE, FOLDING SYSTEM AND WIND. THE TEST RIG ASSY (PHOTO N. 6) CONSIST OF A TYPICAL UNIVERSAL MODULAR BENCH TO WHICH THE TENSION LINK IS FIRMLY SECURED.
THE SCHEME OF THE ACTING LOADS IS AS FOLLOWS:

- THE CENTRIFUGAL FORCE IS GENERATED BY TWO INTEGRATED ACTUATORS: THEY CAN WORK WITH THE SAME LOADS OR WITH DIFFERENT LOADS AS WELL, THEREBY GENERATING ALSO STATIC AND DYNAMIC LOADS IN THE CHORD PLANE; F.S. LOAD IS 40.000 KG.
- THE LIFT AND DRAG FORCE, WHICH CONVERGE AT THE SAME POINT, ARE GENERATED BY TWO LINEAR SERVO-ACTUATORS, INDEPENDENT EACH OTHER AND PROVIDED WITH BALL JOINTS ONE SIDE AND ELASTOMERIC ROD ENDS THE OTHER SIDE.
- TORQUE IS GENERATED BY AN ACTUATOR CONNECTED IN A POSITION WHICH IS GEOMETRICALLY SIMILAR TO THE HELICOPTER PITCH CONTROL.

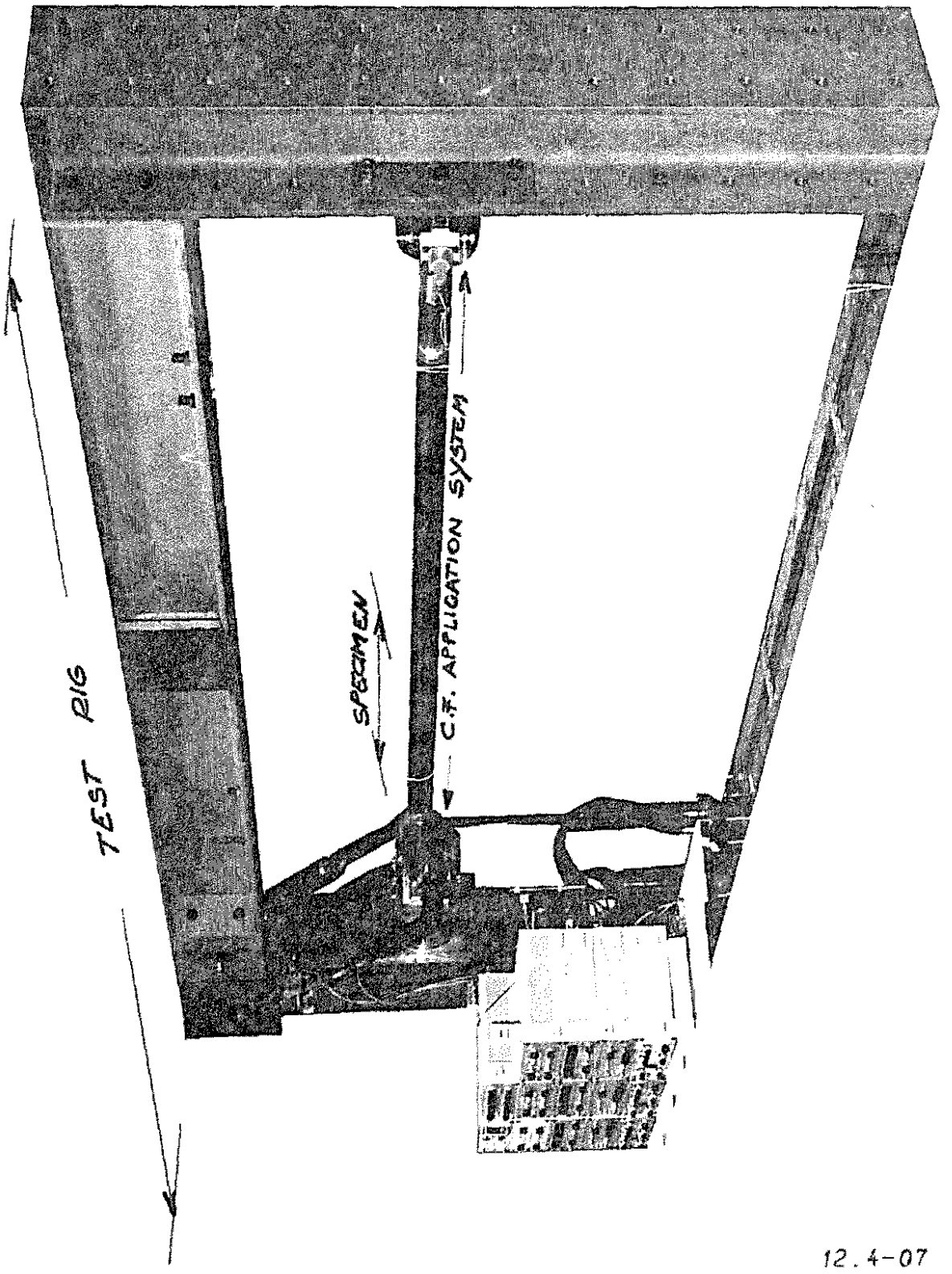
THE TEST RIG CAN SUBJECT THE TENSION LINK TO VERY HIGH STATIC LOADS AND TO FATIGUE TESTS AS WELL, WHICH SIMULATE GROUND AND/OR IN FLIGHT LOADS. IT IS FURTHER USED FOR EXPERIMENTAL STRESS ANALYSIS TESTS AND FOR CALIBRATION OF INSTRUMENTED ITEMS FOR FLIGHT TESTING THE TENSION LINK ON THE PROTOTIPES.

ACKNOWLEDGEMENT

THE STUDY, SETTING-UP AND DEVELOPMENT OF THE VARIOUS MECHANICAL AND HIDRAULIC SYSTEMS DESCRIBED HAVE BEEN CARRIED OUT IN THE STRUCTURAL TEST LABORATORY IN A SYSTEMATIC WAY IN THE PAST TWO YEARS, MAINLY DURING THE EXPERIMENTATION ACTIVITY OF THE EH 101 HELICOPTER.
I'D LIKE TO THANK THE FOLLOWING GENTLEMEN AND COLLABORATORS FOR THEIR VALUABLE CONTRIBUTIONS:

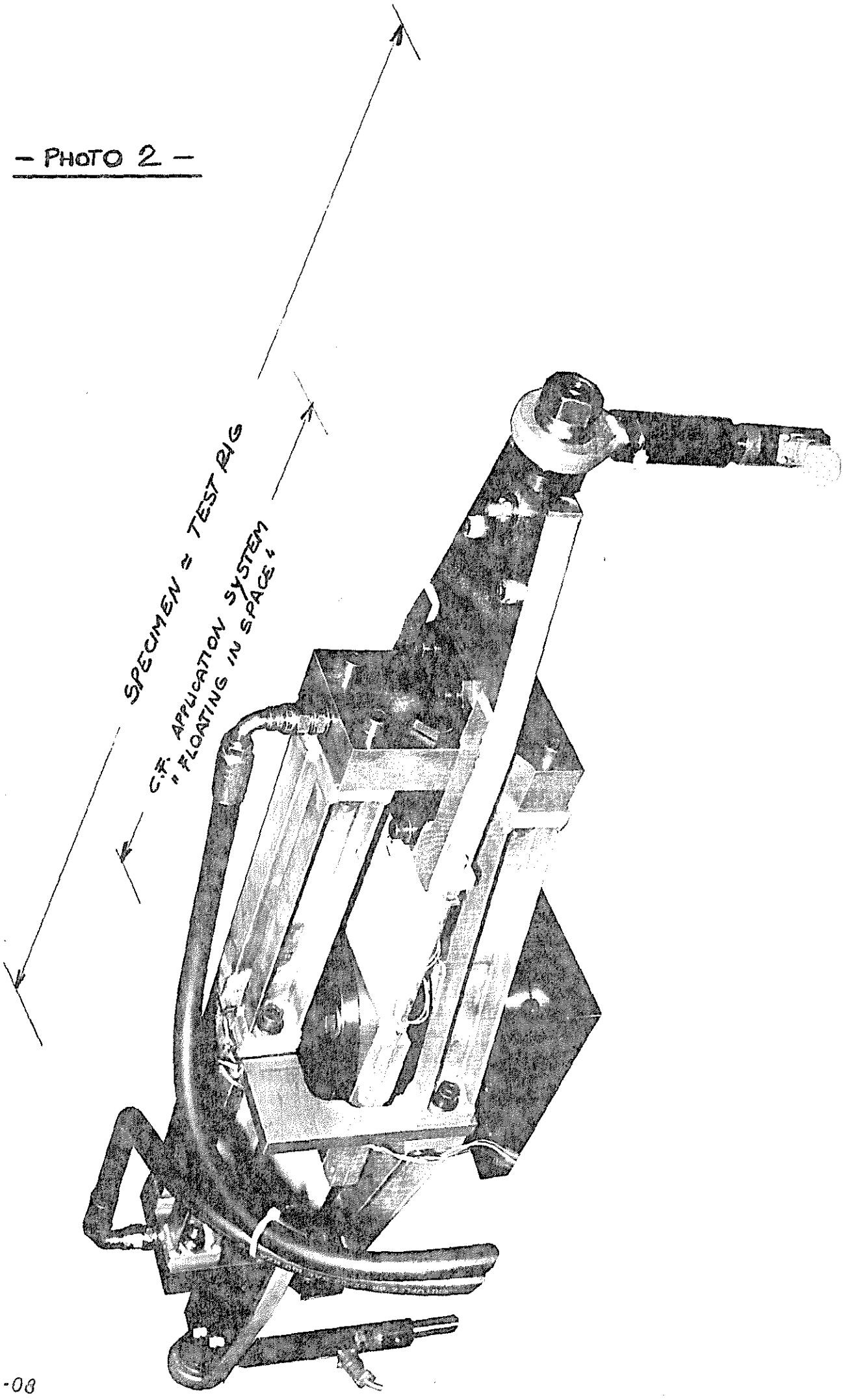
- MR. F. BRIVIO- MR. F. NAGGI, FOR THE SETTING UP OF THE TEST RIGS AND THE EXPERIMENTATION PHASES.
- MR. A. RAMUNDO, FOR THE DESIGN ACTIVITY.
- MR. C. FERRARIO, FOR THE DESIGN ENGINEERING DEVELOPMENT AND SETTING UP.

— PHOTO 1 —

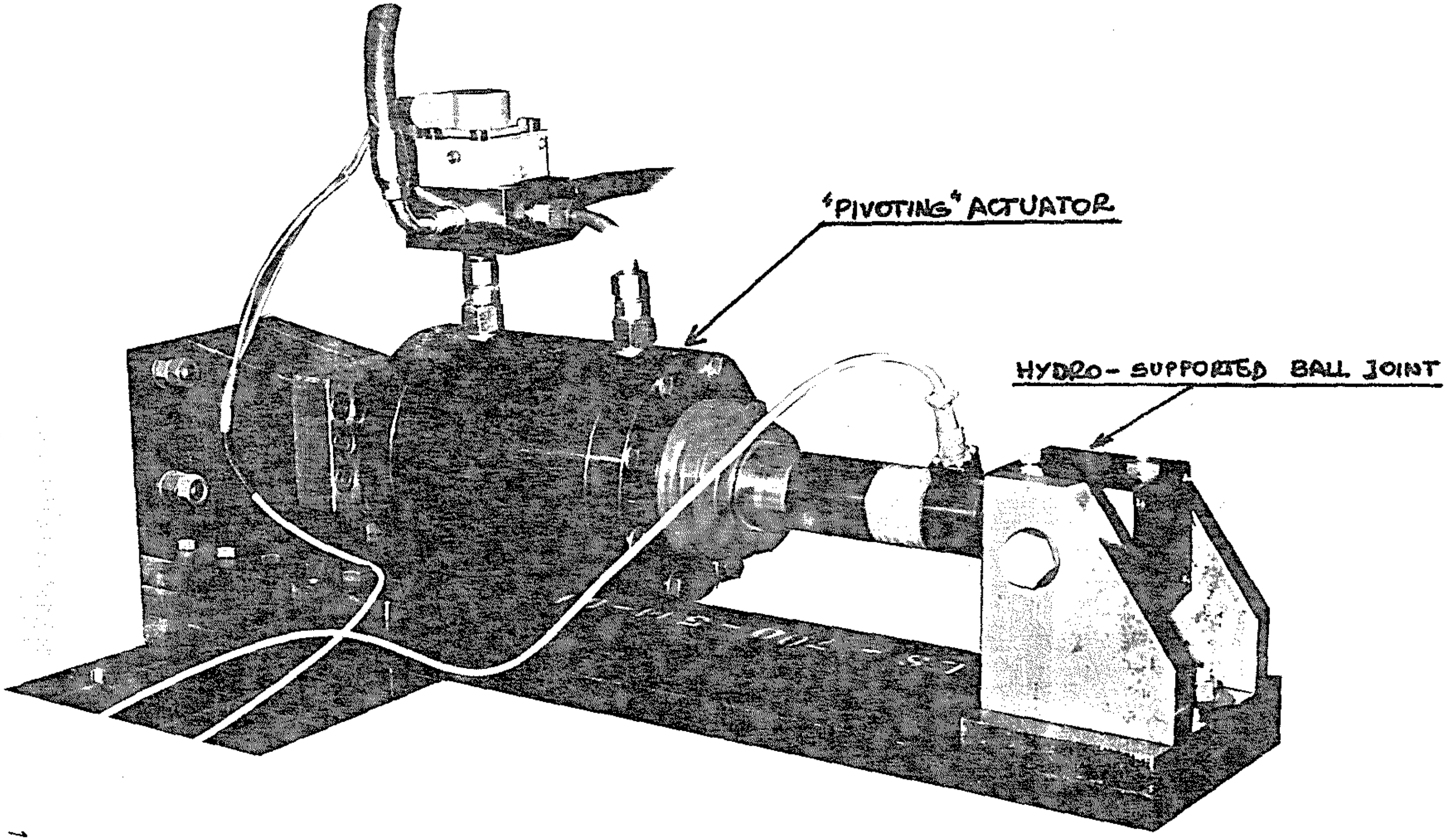


12.4-07

– PHOTO 2 –

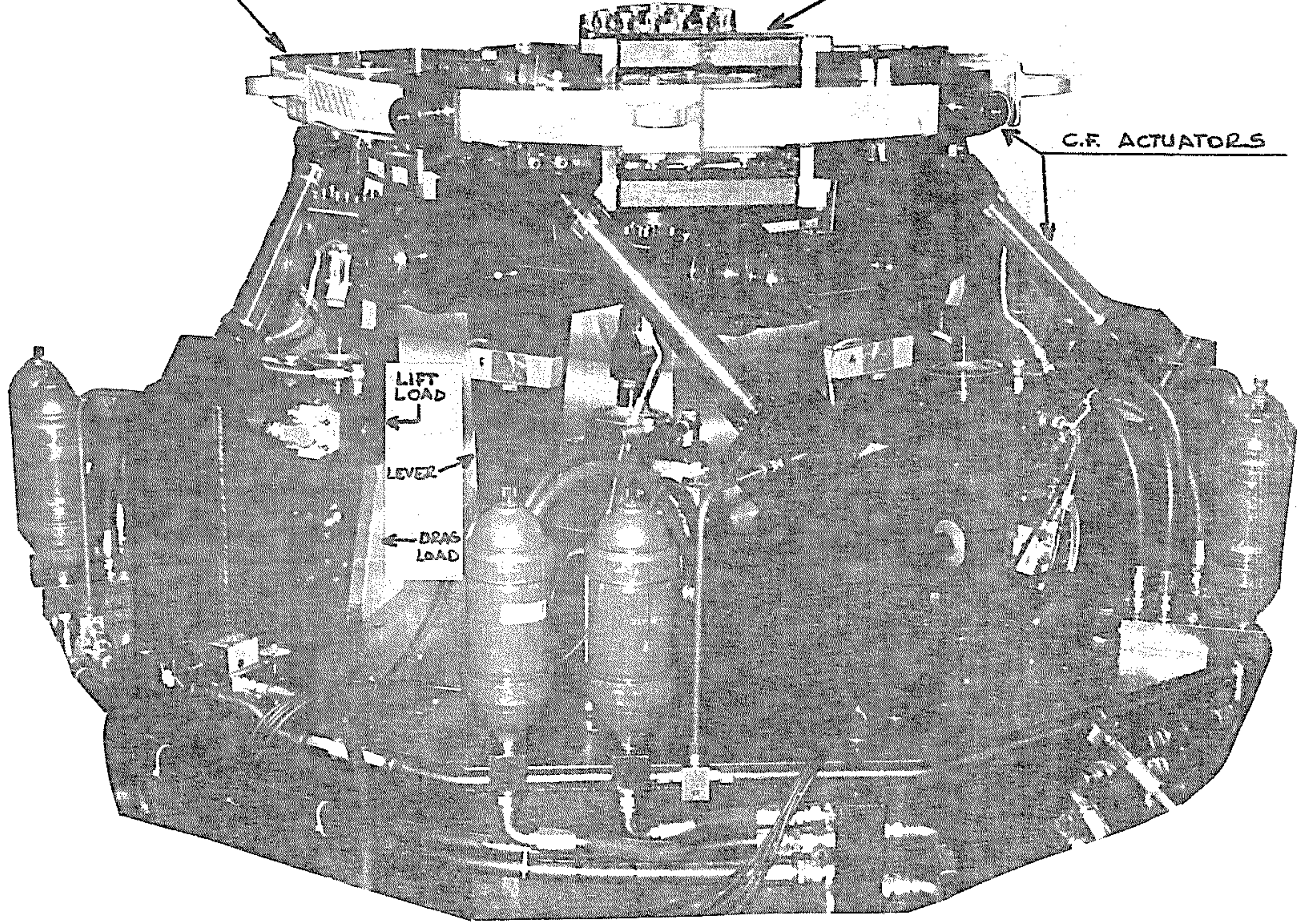


12.4-08



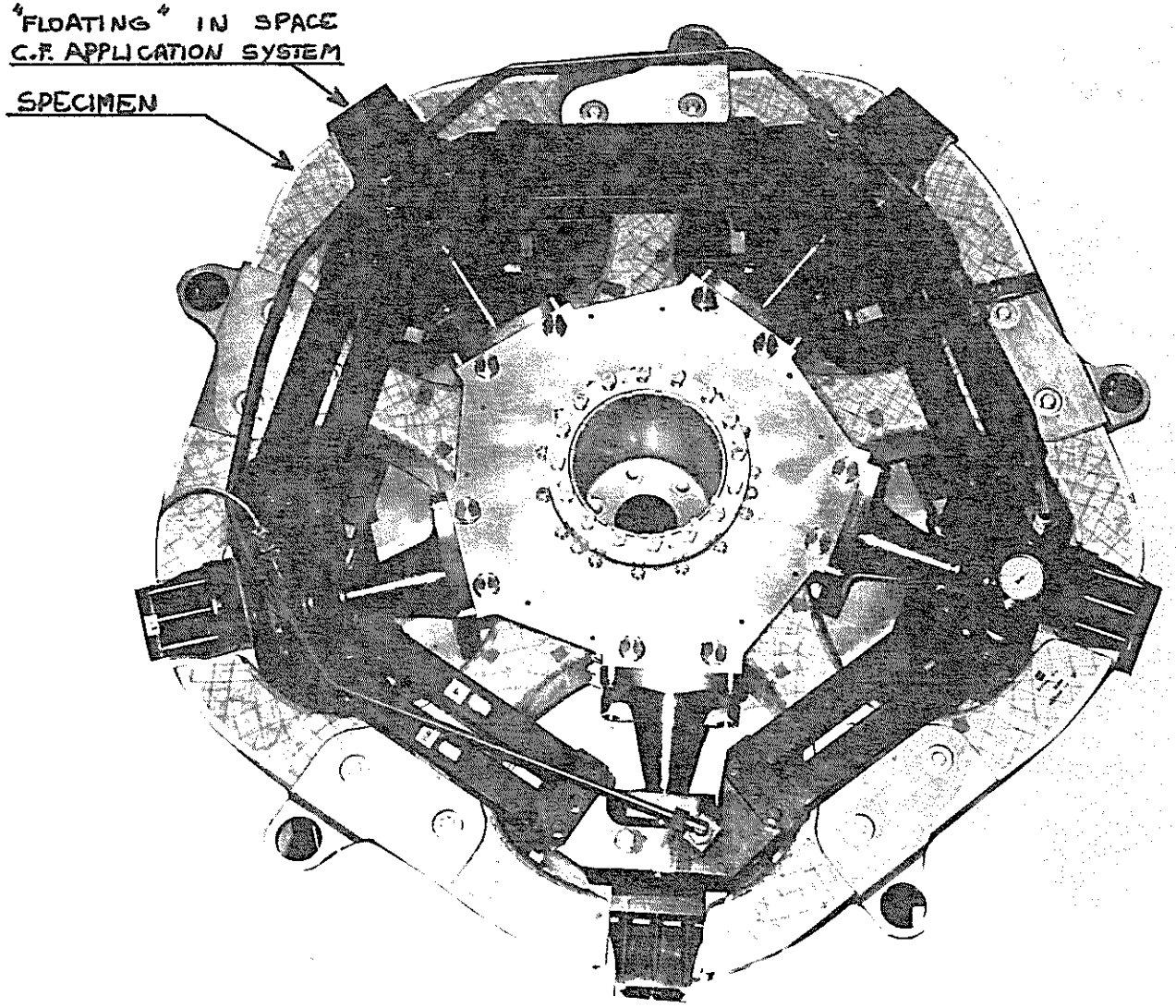
— ENDURANCE TEST RIG —

— PHOTO 3 —



— PHOTO 4 —

— EH 101 — MAIN RC HEAD TEST RIG — Front vi —



- EH 101 - MAIN ROTOR HEAD TESTRIG — Top view -

- PHOTO 5 -

- PHOTO 6 -

- EH 101 — TENSION LINK TEST RIG -